Measuring the Success Rate of ECMs in New Construction

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ABSTRACT

The effectiveness of a third-party review and feedback process during the construction phase in achieving implementation of energy conservation measures (ECMs) is addressed in this study. The process consists of construction document review and field verification. A data set of 105 new buildings that participated in MidAmerican Energy's Commercial New Construction program is analyzed. The final incentive from the utility is based on modeled energy savings of the ECMs observed during the final field verification.

Implementation rate, defined as the ratio of modeled energy savings (on a kWh basis) for a particular review phase compared to modeled energy savings initially predicted at the end of the design phase, is analyzed with respect to various factors. Overall, the projects achieved a yearly average final implementation rate of 94%-101% in 2003-2005, which equate to final modeled energy cost savings of 7%-66% (compared to the local energy code, a variant of ASHRAE 90.1-1989). A subset of 24 projects showed an average implementation rate of 80% on a kWh basis for the initial review of construction documents that improved to 91% after feedback. At the initial site visit, the implementation rate dropped to 88% and improved to 92% after feedback. The results from this preliminary study demonstrate the value of ongoing construction-phase assistance, particularly at the stage of initial review of construction documents. Other results include higher implementation rates for repeat program participants and for schools compared to other building types. Of the technology groups, daylighting controls are implemented the least, suggesting a need for further assistance.

Introduction

True success for energy conservation lies not in the *intent* to undertake conservation, but in the ability of the building owners and designers to *incorporate* the energy conservation measures (ECM) in the building, thereby enabling conservation to be realized. Using data from 105 completed new building projects in MidAmerican Energy's Commercial New Construction (CNC) program in Iowa, this research traces the implementation rates for energy conservation measures throughout the construction phase. The purpose of this study is to determine how and where ongoing assistance in the form of construction document (CD) reviews and site verification, together called the *verification process*, help improve implementation rates.

This study tests two hypotheses. The first is that the verification process, consisting of review and feedback, helps improve implementation of ECMs as selected by design teams and owners. The verification process was originally intended to calculate the incentive to be paid to the owner for implementing ECMs. Over a period of time, the verification process was modified to play an assistance role in helping design teams catch omissions and provide technical guidance when needed. The first hypothesis is motivated by the desire to understand how well the process is serving to ensure final implementation of ECMs. The second hypothesis is that the final implementation rate of ECMs is related to project size (as measured in kWh of savings), technology type (e.g., daylighting), building type (e.g., school), and experience with implementation (i.e., repeat participants). This second hypothesis is motivated by the desire to differentiate the effectiveness of the verification process according to the factors identified and to see what lessons may be learned from each category.

The study provides insights that will help improve program efforts to achieve implementation of ECMs, and thus energy conservation. Results will help determine the value of the ongoing assistance provided by the program, in the form of CD review and site verification, by estimating the energy savings that would be lost in the absence of this activity. Results will guide efforts to refocus the review and verification process on ECMs, building types, and design firms where success rates are low. Similarly, it will provide guidance in areas where effort might be reduced (i.e., for technologies that see high implementation even before review). Where the review process does not significantly improve ECM implementation, educational efforts may need to be developed to assist designers and contractors.

The paper is organized as follows. First background information on MidAmerican Energy Company's Commercial New Construction program, the Energy Design Assistance Process, the Verification Process, and literature review is given. Second, the methodology is described, including the design of the database, the available data, and the research questions addressed. Third, results are presented and discussed, followed by conclusions.

Background – The Verification Process

The projects in this study all participated in the Commercial New Construction program sponsored by MidAmerican Energy Company. The utility paid for Energy Design Assistance (EDA) consulting and provided construction incentives when efficiency levels, determined with a DOE2 model, exceeded the local energy code (based on ASHRAE 90.1-1989) by 15%. MidAmerican also paid design teams for their time in attending EDA meetings and providing documentation. MidAmerican makes the final incentive payment to owners upon final verification of ECMs in the building. Some summary statistics of MidAmerican's CNC program are shown in Table 1.

Table 1. MidAmerican Energy Company CNC Program Summary

Number of Participating buildings	203
Total area in SF in program	22,740,480
Average annual energy cost savings compared to code	31%
Maximum annual energy $ savings compared to code	66%
Average annual kWh savings compared to code	32%
Maximum annual kWh savings compared to code	65%
Average annual gas savings compared to code	30%
Maximum annual gas savings compared to code	72%

The Energy Design Assistance process, illustrated in Figure 1, uses a whole building consulting approach, where conservation measures that impact all energy end-uses are analyzed. The process encourages integrated design by providing information to owners and design teams early in the design process. This information is primarily in the form of results from DOE-2 computer simulations of ECMs. The designers, owners and energy consultants together evaluate the energy performance and incremental costs of the ECMs in a series of meetings. The first meeting explores the range of ECMs to be studied, where the energy consultants broaden the scope based on their knowledge of success in other buildings. The design teams refine the list based on their particular project circumstances. In a second meeting the group evaluates the energy performance and cost implications of the measures and identifies bundles of strategies that form a range of possible solutions. In a third meeting, the group evaluates the performance of the strategy bundles and reviews incentive amounts and resultant paybacks. All meetings are facilitated by the consultant and the utility representatives in a style that puts no pressure on the design team or owner to implement any technologies of which they are not confident. After the third meeting, the owner and design team agree to implement a bundle of strategies that fit the construction budget, that they feel confident of, and that show a promise for energy conservation. MidAmerican promises an incentive amount for the mix of selected ECMs based on their annual electric and gas consumption savings. This sets the expectations of the owner in terms of the building energy performance. The design team is then responsible for incorporating the ECMs with the appropriate performance parameters in design documents.

The energy consultants continue to stay involved with the project with the verification process, which includes reviewing construction documents (CDs), conducting on-site verification, and providing feedback to the design team at each stage. Both the CD review and the on-site verification are done in two stages, a draft and final, with separate reports issued at those stages. The CD review focuses on ensuring that the ECMs are incorporated in the construction documents. Field verification of the strategies consists of a combination of approaches that include review of contractor submittals, visual inspection of installed equipment and short term monitoring using data loggers to observe performance of selected strategies. ECMs that are static in nature, such as window glazing, fixed shading devices, insulation levels and equipment efficiencies, are verified through contractor submittals and on-site visual inspection. Dynamic ECMs, such as daylighting controls, variable frequency drives, or equipment efficiencies that vary with part loads, are monitored for up to two weeks to observe their performance over time.

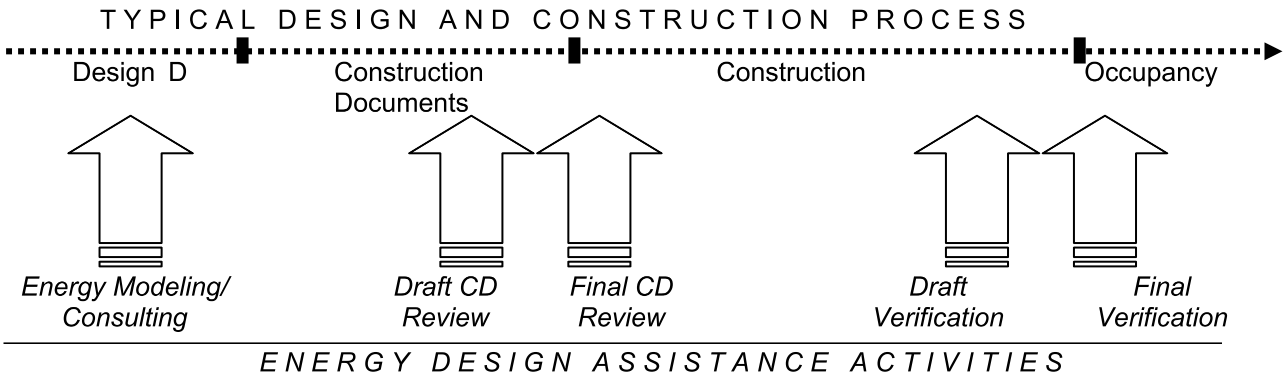
Each report identifies the shortcomings in the implementation of the ECMs, gives pointers towards improvement, and summarizes the savings and incentives achieved as a result of the level of implementation. Draft CD review[1] results (DCD) capture the intent of the construction documents that would likely have gone to the contractor had there not been any review or feedback. The summary of the impact on the savings and incentive amount in the reports draws the attention of the owner and design team to individual ECM performance.

Coordination meetings between the design team members and phone discussions with the reviewers are often held to further understand the shortcomings or clarify design intent. Typically, design teams improve, modify or add to their construction documents as a result of the feedback given at the DCD stage; in these cases the energy consultants modify the review results into a final CD review report. On-site verification, conducted once the building is constructed, is done similarly to arrive at Draft Verification results (DV) and final Verification results (V). Between the Draft Verification feedback and the final Verification results, design teams provide

[1] The DCD review is a draft report of the review of CDs provided as feedback to design teams so that they may make modifications before the final report is issued; it is not a review of draft CDs.

additional contractor submittals to the energy consultants as evidence of compliance with performance parameters. In some cases design teams go back to the contractor and insist on improvement of ECMs that were not implemented as intended, thus improving the overall implementation rate.

Figure 1. Energy Design Assistance Process Followed in the Program



Architect and engineers convey their design intent to the contractor through drawings and specifications. Everything about a building that is not to be assumed is documented and specified. For a commercial building with complex systems, the design teams hold coordination sessions to discuss how systems may interact or conflict with each other. A commissioning authority, employed on a growing number of projects, also checks documents to verify the design intent and coordination issues. The design team and commissioning authority inspect the construction site to verify installation. Despite all these checks in a typical process, ECMs are still too often poorly specified and implemented. Some of the reasons include the following:

- ECMs whose primary purpose is to save energy as opposed to serve another functional requirement in the building are considered add-ons. Unless energy performance of an individual system is part of a designer's conscious intent, the ECMs are likely to be an after-thought.
- The design team may lack the expertise to specify and execute certain measures (e.g. daylighting controls) but may not be aware of their shortcoming or may not be willing to disclose it to their client.
- The design team member who attends the EDA meetings may not be the same person who eventually prepares the documentation, and the ECM performance requirement agreed to in the EDA meeting does not reach the final specifier.
- When construction is expected to go over budget, design teams conduct *value engineering* sessions. These sessions are focused on eliminating items that are not directly related to the building's function. Unless energy performance is a primary goal for the design, ECMs can fall into this category.

When the review process has been able to improve the expected performance of the building compared to that specified in the initial construction document set, it has done so by drawing attention to the shortcomings and providing a succint summary of the impact on energy savings and incentive amounts. Once energy performance becomes a focus during the CD or construction phase, further discussions are possible or warranted.

Literature Review

The literature review provides motivation for studying the effectiveness of a third-party review and feedback process for design teams and owners during the construction document and construction phases. Review and feedback are essential to good management of any process, but are too often missing as a building transitions through its various life phases (i.e., design, construction, occupancy, retrofit, and demolition). Direct feedback from performance of real buildings is one way to help improve definition of client requirements, professional standards, and regulations (Bordass, 2001). Direct feedback from all stages of a building's life will help design teams and contractors improve their knowledge base of how to achieve successful implementation of technologies related to energy conservation.

Review and feedback during the period from construction document development to initial occupancy has not been widely addressed in the literature. Bordass and Leaman (2005) present a portfolio of feedback techniques, including audits, discussions, questionnaires, software packages, and process change methodologies, that have been developed and put into practice in the UK. Each category applies to various stages of building conception; however, very few apply specifically to the construction document, construction, and/or construction completion stages. Thus, assessment of the review and feedback methodology described in this paper fills a void in the literature.

Review and feedback are increasingly recognized as important processes for design firms and contractors to achieve learning and continuous improvement, yet this section of the building industry rarely obtains routine feedback on achieved performance. As noted by Bordass (2001), even where energy efficiency was the aim, there can often be large discrepancies between intentions and achieved results. Thus, the review process used in the Energy Design Assistance process to verify the incentive amount serves a greater purpose of supporting learning and improvement. A long-term purpose of this study is to assess the extent to which learning is supported by the review and feedback process during the construction phase.

The review process described in this paper is distinct from an overall commissioning process in that the review process occurs only during the construction phase and does not do functional testing of the systems. The review process is similar to that prescribed by LEED's 'Additional Commissioning' Credit, which requires that a third party conduct a document review and conduct a selective review of contractor submittals of commissioned equipment, among other things; recently, LEED® version 2.2 also modified the commissioning requirements so that they only address the energy related systems (USGBC, 2005). The benefit of the review process having occurred before calibration of equipment is that it helps to ensure that the expected systems are in place. The earlier a provider is designated for a project where design review is required, the easier and less expensive it will be to rectify design problems before they are implemented in the field (Baxter *et. al*., 2002).

Methodology

The analysis methodology consisted of three stages. The first step was to design and build a database of project data that enabled sorting by time, firm type, building type, and technology type. The second step was to populate the database with information that currently resides in project working documents (i.e., Excel spreadsheets). For each project, there are files that detail the technologies and associated energy savings at each stage of the review process:

- DCD (draft review of construction documents);
- CD (final review of construction documents);
- DV (draft review of as-built verification); and
- V (final verification).

The third step was to conduct statistical analysis, calculating averages, ranges, and trends. This step included rejecting projects with incomplete data. The overall methodology is designed to facilitate ongoing assessment of the research questions beyond the projects available for analysis in this study.

Database Design

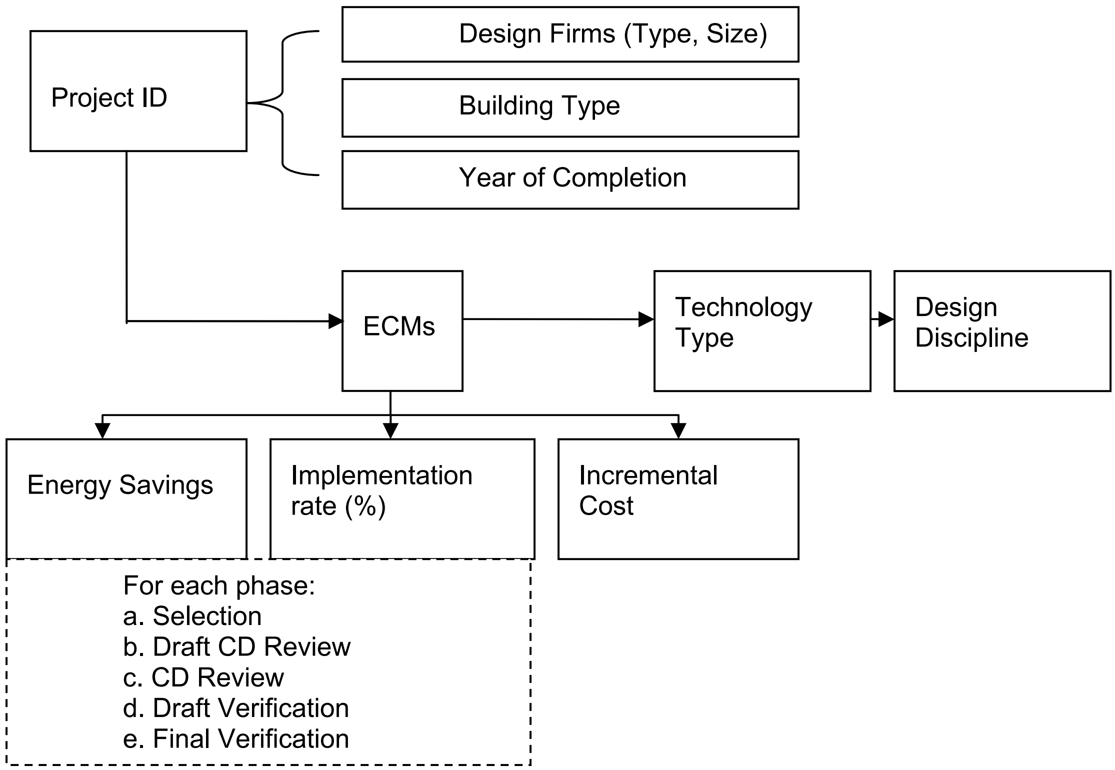
The database design is pictured in Figure 2. The database fields include a project identifier, design firm information (e.g., discipline, size, and business model), building type, year of completion, and the ECMs. For each ECM, there is a field for energy savings (kWh, therms, kW, and cost), implementation rate at each of the five phases (selection, DCD, CD, DV, and V), and incremental costs.

Data Available

The 105 projects in the overall data set are all greater than 50,000 sf; are new construction or addition and major renovation; and all but one was owner occupied. The population was reduced to 83 projects after filtering out projects with incomplete data. The 83 projects had data for, at minimum, the first and final stages (Selection and final Verification). From that set of 83 projects, three other subsets were derived for the purposes of answering questions that had stricter data needs. To analyze implementation rate according to building type, those building types with at least 5 projects were selected; therefore, the data set was narrowed to 57 projects. To analyze the implementation success of technology groups, the set of 83 projects was narrowed to 38 projects that had energy savings results for each ECM at a minimum of *either* the draft CD review or CD review stages in addition to final Verification. To analyze the variation in overall implementation success at each of the four review stages, the set of 38 was further narrowed to 24 projects that had data at all four stages.

The data for energy savings for a project is derived from DOE-2 energy models of the building. The savings amount attributed to a particular strategy is determined by comparing the results of the strategy run with those of the code base run. ASHRAE 90.1-1989 served as Iowa's State Energy Code for the time period studied (2000-2005). The code will be raised to the 2004 version of ASHRAE 90.1 in 2006.

Figure 2. Database Fields for Capturing Energy Conservation Measure (ECM) Data Implemented in Projects



Implementation rate is defined as the energy savings of the ECM at a particular phase relative to the energy savings predicted at the Selection phase, as follows

$$I_{s,p} = \frac{E_{s,p}}{E_{s,selection}}$$

where $I_{s,p}$ is the implementation rate of energy conservation measure *s* at phase *p*, $E_{s,p}$ is the energy savings of *s* at phase *p*, and $E_{s,selection}$ is the energy savings of *s* at the Selection phase. Implementation rate can be greater than 100% if more ECMs, or a higher level of an ECM, are implemented than stated at the selection phase. For example, the final building may have a lighting system with lower watts/square foot or daylighting controls in more areas than originally planned at the selection phase.

Research Questions

With the selected sets of project data, the research questions listed in Table 2 are addressed. The questions are answered by calculating averages and looking for trends. In the future, with more projects and data, correlations and statistically significant differences amongst data groups will be evaluated. In the interim period, observations of trends elucidate the impact of a review and feedback process on implementing energy conservation.

Table 2. Research Questions Addressed and Applicable Data Sets

Research question	Data set
What is the average implementation rate at the final verification stage?	83 projects
How does the final implementation rate vary by the size of the project?	83 projects
How does the implementation rate vary at each stage?	24 projects
Does implementation rate vary depending on whether members of the design team are repeat participants in the EDA program?	24 projects
Does implementation rate vary by the building type?	57 projects
Are some technology groups implemented more than others?	38 projects

Results

First, overall program results are presented and discussed. Next, results are presented for how implementation rate varies by stage of the review and feedback process. Third, the impact of building type and repeat firms are presented, followed by technology group results.

Overall Program Results

Averages of the overall, final (verification) implementation rate for the program in years 2001-2005 are shown in Figure 3. Implementation rate is the percent of electricity (kWh) savings achieved as compared to that which design teams were aiming for at the selection phase. An implementation rate of greater than 100 percent means that the project implemented more energy savings strategies than planned at the selection phase. Over 2001-2005, final implementation rates averaged 92 to 104% for projects completed in that year.

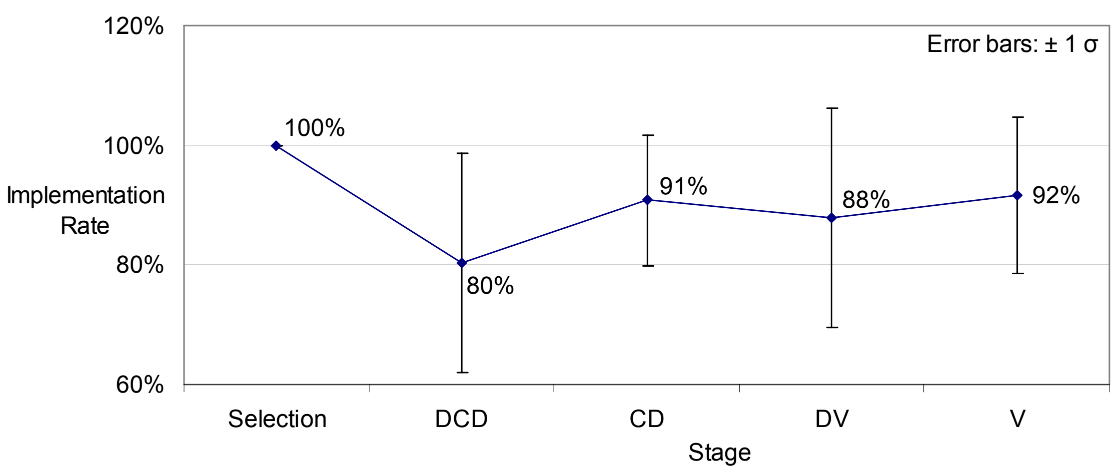
Figure 4 shows the average implementation rate at each of the four post-selection phases: Draft CD review (DCD); final CD review (CD); Draft Verification (DV); and final Verification (V) for 24 projects completed in 2003-2005. Implementation rate improves, on average, with successive review and feedback stages, with a low initial start at Draft CD and a slight drop at Draft Verification. The lowest point in the implementation rate occurs before any review or feedback has reached the design team – at the draft CD review phase (80% implementation rate). This is the most important feedback point. At the final CD review, implementation is improved to 91%, where it more or less stays throughout the remaining three phases, on average.

Authors' observations suggest two explanations for the low implementation rate at the Draft CD review followed by improvement. The first is that incomplete construction documents are submitted to the third-party reviewer at the draft stage, and that the design team has further developed the documents by the final CD review (not necessarily with the aid of feedback, but still under the influence of knowing that a third-party reviewer will inspect the documents). The second is that the third party review catches omissions, as intended, and aids the design team in producing complete construction documents. Most often, a combination of the two explanations applies. The goal of review is to help see that incomplete construction documents are not passed onto contractors, as that could mean that instead of seeing final implementation rates of around

90% (similar to the final CD review rate), the program would be seeing rates of around 80% (similar to those found in the Draft CD review) and thereby loosing 20% instead of 10% of energy conservation potential as measured against selected, design phase savings estimates.

Figure 3. Average Implementation Rate at the Final Verification Stage of Projects Completed in 2001 through 2005 (83 Projects)

Figure 4. Program Average Implementation Rates at Each of the Four Post Selection Phases for Years 2003-2005 (24 Projects)



The difference in implementation rate between the final CD and Verification stages is shown in Figure 5 by the size of energy savings for each project. The highlighted areas in the figure indicate there is a split in the variability of this metric at a savings level of 750,000 kWh (calculated at the selection phase). The projects with less than 750,000 kWh of total savings tend to improve more between the CD and Verification reviews, while those that are greater than 750,000 kWh of total savings improve less, albeit they still improve on average. Projects right around the 750,000 kWh level appear to be the most likely to decrease in implementation of ECMs between the CD and Verification stages. One field observation is that smaller projects tend to have a less formalized design and construction process. These project may not have the benefit of starting from a formal template of construction specifications and likely lack the design fees to hold periodic coordination meetings between the architects and engineers. The absence of a formal process would allow a greater variability in the results.

Figure 5. Difference in Implementation Rate between Final CD and Verification Stages (38 Projects)

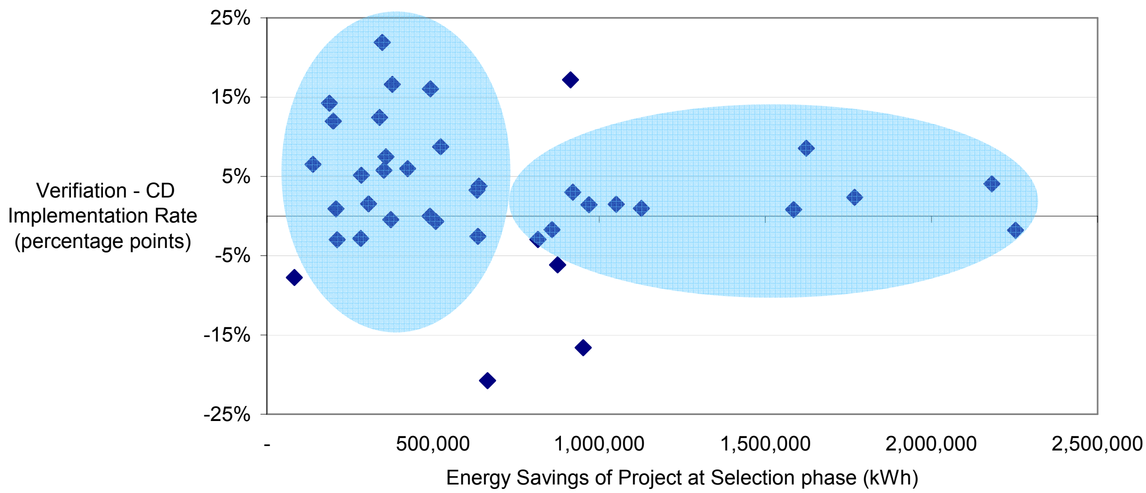


Figure 6 shows the implementation rate for all four stages for grouping of projects by size (kWh savings greater than and less than 750,000 kWh). The larger savings projects are more consistent in the implementation rates at the CD and Verification stages, as compared to the smaller savings projects that have much more variability. The variability is also illustrated in the frequency distribution shown in Figure 7 for the final Verification stage.

Figure 6 also demonstrates the possible trends of any individual project:

1. W-shape - sharp drops in implementation rate are seen at the Draft CD and Draft Verification stages.
2. Flat shape – implementation rate does not vary much between stages.
3. Drop at draft CD then improve to a flat level at the remaining stages.
4. Improve at draft CD then stays flat or decreases slightly at remaining stages.

The sharp W-shape may indicate incomplete information reviewed by the third-party at the Draft CD and Draft Verification stages, but it may also mean the same incomplete information would represent the final implementation.

Figure 6. Implementation Rate for Projects with Greater than 750,000 kWh of Savings (Left) and Less than 750,000 kWh of Savings (Right) at all Four Stages (24 Projects Total)

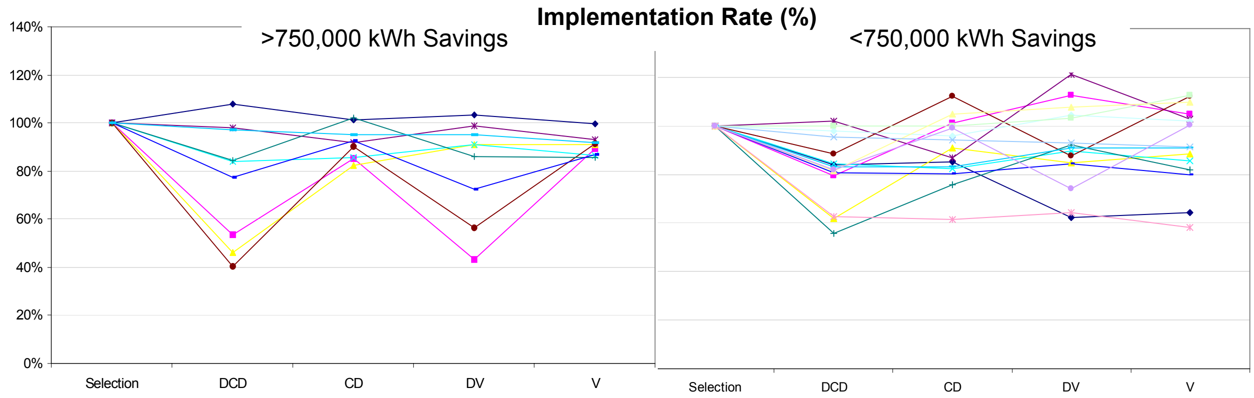
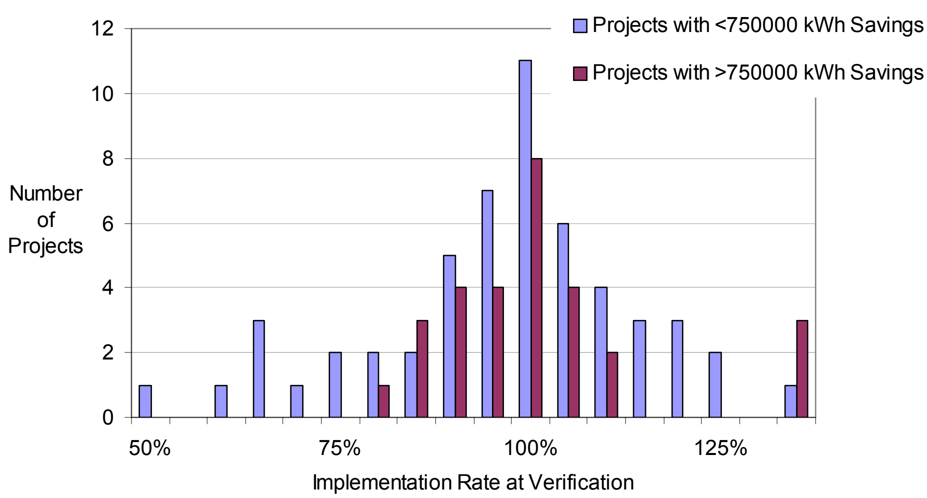


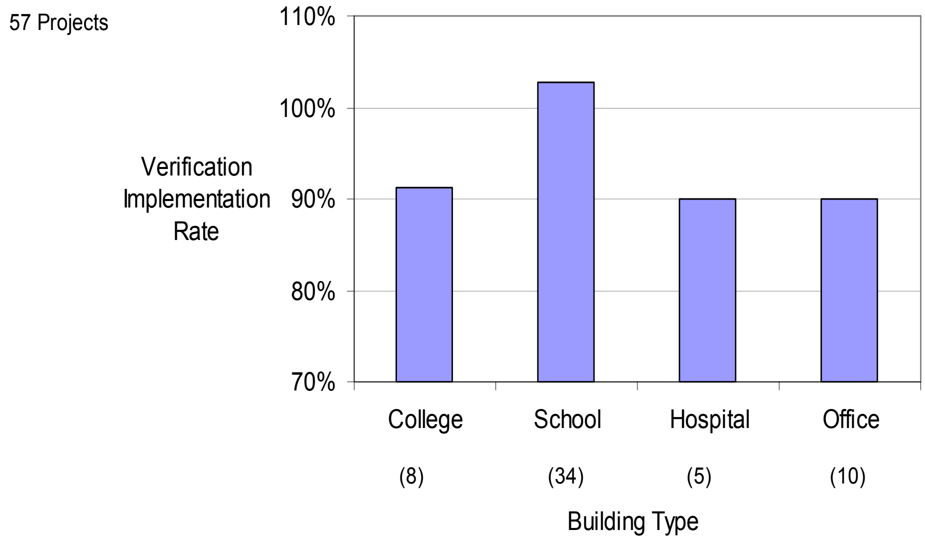
Figure 7. Implementation Rate at the Final Verification Stage for Projects by Amount of Savings (Greater and Less Than 750,000 kWh Savings) (38 Projects)



Impact of Building Type and Repeat Firms

Analysis by building type, given in Figure 8, shows that schools on average have a final Verification implementation rate of over 100 percent (average of 34 projects, range 62-167%). About half of these 34 school projects have ground source heat pumps which contribute to a large percentage of their savings. The greater than 100% implementation rate was sometimes due to installing heat pumps with higher efficiencies than those stated at the selection phase. The high implementation rate of schools is also explained by government mandates to implement energy conservation measures. Additionally, owner and facility manager involvement from the beginning of the energy design process often results in the exclusion of more ambitious measures for which they are not confident. The other building types (college, hospital, and office) had average final verification implementation rates of at least 90%. The building types shown in Figure 8 have at least five projects each.

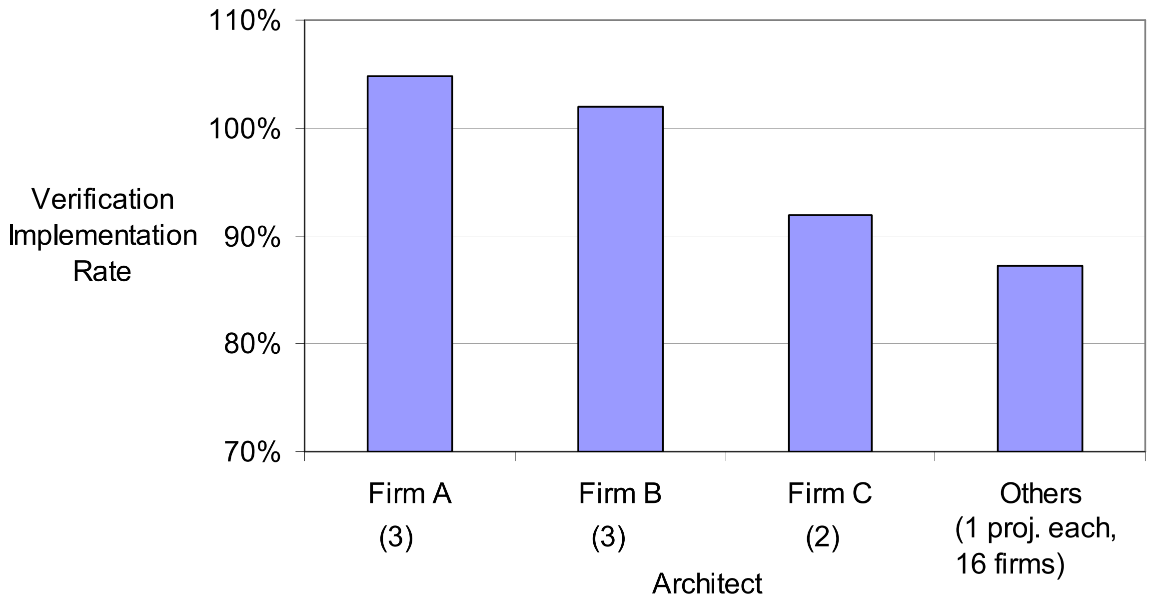
Figure 8. Final Verification Implementation Rates for Building Types That Had at Least 5 Projects in the Database (57 Projects)



Analysis for relationship between repeat participation and final Verification implementation rate is limited because of a small set of data. Thus, the analysis presented herein on repeat participation is preliminary and addresses repetition as opposed to time trends. Figure 9 shows the results for architecture firms for the subset of 24 projects that had complete data. Two firms had three projects each, one firm had two projects, and sixteen had only one project each. The firms with three projects had greater than 100 percent implementation on average, while the one with two projects had a final Verification implementation rate of 90 percent. The firms with a single project achieved 87 percent implementation on average, with a range of 58 to 110 percent. Similar relationships are exhibited for electrical and mechanical engineering firms; those with two or more projects achieved implementation of at least 90 percent on average, while those with one project achieved approximately 85 percent implementation on average. Reed and Oh (2002) have demonstrated through network analysis that small cliques of firms tend to collaborate over the long run in the construction industry. The repeat architectural firms in this study were more likely to have the entire design team, including mechanical and electrical engineers, repeating the process.

The data suggests that firms need to participate in the program and go through the review process more than twice before they gain the expertise of executing ECMs successfully in the absence of any third-party review. Further research is needed to better understand the number of repeats at which the review and feedback process provides diminishing returns.

Figure 9. Relationship between Implementation Rate at Verification and the Number of Projects Undertaken by the Architecture Firm (24 Projects)



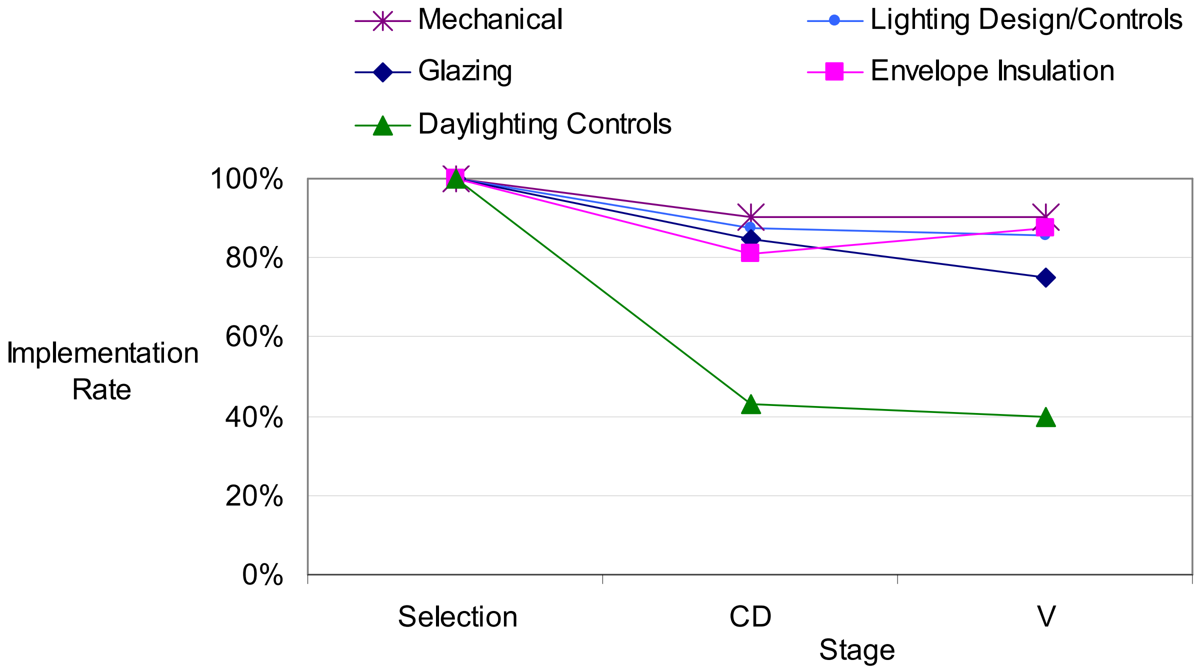
Technology Group Results

Implementation rate by technology group at the CD and Verification stages is shown in Figure 10. The technology groups are mechanical systems, lighting design and controls, daylighting controls, envelope insulation, and glazing. The data set is 38 projects. Within the dataset, incomplete data was discarded for each project's technology group only; the remainder of the project's data was preserved. (Thus, an overall project average cannot be calculated). None of the technology groups are implemented 100 percent on average. The averages range from 75-90 percent, except for daylighting which is at 40 percent average.

The results clearly show daylighting has the lowest implementation rate. Most cases for daylighting controls involved sidelighting and the poor performance is likely to be the result of lack of knowledge for implementing daylighting controls properly, as also pointed out in studies by Vaidya *et. al.* (2004 and 2005) and the Heschong Mahone Group (2005). The implementation rates for daylighting controls stay relatively flat between CD and Verification, which points to poor definition of the technology in the construction documents.

Envelope strategies benefit the most from the review process—implementation improves by 10 percent between CD review and Verification. In contrast, glazing does not seem to benefit from the review process—installed is even lower than specified in CDs. Mechanical, lighting design and controls, and daylighting are constructed more or less as specified in CDs, on average. (Note that some projects actually improve and some projects are much worse.)

Figure 10. Implementation Rate by Technology Group at the CD and Verification Stages (38 Projects)



Conclusion

The results demonstrate that the review and feedback process helps improve the implementation rate of energy conservation measures. Implementation rates are especially improved between the draft review of CDs and the final review of CDs, as the largest drop in implementation rate is seen at the first review of construction documents. The feedback provided between draft and final phases helps design teams and owners make corrections, make change-orders, and ask contractors to see the changes through to implementation. The results demonstrate the overall importance of not only CD review, but also the opportunity afforded by the Draft CD and Draft Verification stages to make corrections. The process provides a platform for communication amongst the designers and contractors during the construction phase.

One major conclusion from this study is that the best chance to improve implementation rate is to affect the inclusion of an ECM in construction documents. This may be achieved by greater assistance and education in the period during which construction documents are developed. Participating design teams could also make the utility program's CD review a formal milestone that needs to be completed before final CDs can be issued for bids or for construction. While all ECM technologies still have room for improved implementation, daylighting is the category that is least implemented, yet has a significant opportunity to provide energy savings and other benefits to building owners and occupants. The results also demonstrate that repeat participants in the program achieve higher implementation rates on average. As for building type, schools had the highest success rate of implementation, at over 100 percent on average. Factors that play a role in the high implementation rate for school projects include a) early and sustained involvement by owners and facilities managers and b) multiple building projects, and thus experience, in a school district.

A long-term goal of this research is to support large scale investments in energy conservation technologies for buildings through rebate programs, code improvements and education. As more projects are entered into the database, calculations may be made of the overall confidence in the various ECMs. Such data will allow the calculation of risk-reward indicators of the various energy savings technologies. The data should address the needs of design teams undertaking integrated design with new technologies as well as commissioning agents to help with prioritization. Overall, continuous learning and action through the design, construction, and occupancy phases will help move the energy design assistance processes towards areas of greatest impact for energy conservation in new construction.

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