Assessing Energy Savings from Building Commissioning

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ABSTRACT

Commissioning a building is an important step in ensuring that its systems are working and operating according to "design intent." Building commissioning is necessary because, in the real world, buildings (both new and old) often do not operate as designed. Old buildings (for which the term retro-commissioning is often used) tend to drift over time and use, and often need to be brought back to their original design intent. Older buildings are also often used differently today than the original design intent – in which case not only does the building's operation need to be assessed, but its design intent needs to be re-evaluated. New buildings require commissioning to ensure that all equipment is installed as specified, and is operating/ calibrated to design intent. Energy efficiency objectives are increasingly being integrated into the new building design process. This is made easier as energy efficiency modeling tools are becoming more sophisticated, user friendly, and accessible to engineering design teams. Modeling tools like eQuest and EnergyPlus are often used to estimate ex ante savings for whole building performance incentives. Additional savings are often incentivized for building commissioning - these savings are usually quantified using general engineering "rules-of-thumb." This paper will discuss two major challenges energy impact evaluators face when assessing energy savings for building commissioning measures, and offer solutions to overcome those challenges. The first challenge is identification of what constitutes commissioning as opposed to building maintenance. Since the building commissioning process includes everything from replacing malfunctioning sensors to optimizing chiller sequencing, there is often a gray line in establishing actions required for building maintenance from actions which go beyond building maintenance requirements. Many building maintenance items are coupled with the building's energy performance, further complicating delineation. The second challenge is in delineation between the realized energy savings associated with whole building performance and the realized energy savings associated with building commissioning. Programs like eQuest and EnergyPlus assume fully operational building systems when simulating building energy performance. Simulation results therefore already include most of the energy savings gained by the commissioning process. However, whole building performance is often incentivized separately from commissioning, and sometimes during separate program years. The authors analyze case studies of previously evaluated incentivized commissioning projects to propose ways in which these challenges can be overcome while ensuring that building commissioning remain recognized as a crucial step to realizing energy savings.

Introduction

Many independent case studies have been performed which have established the cost and energy savings benefits associated with building commissioning activities. One well known Meta-analysis compiles the results from 224 building commissioning projects to illustrate both the energy and non-energy impacts realized by commissioning activities (Mills et al. 2004). It is interesting to note that the perceived non-energy benefits are often times the main catalyst for commissioning activities. Until recently there has been a lack of public awareness regarding the energy efficiency benefits in building commissioning. However, building owners and designers seem to be slowly incorporating it into the design process (Mills 2011). For over a decade now utility DSM Programs designed to target commissioning in existing buildings have been well established in utility portfolios throughout the United States[1], but new building commissioning activities have historically represented a minority of DSM program activity. New building commissioning projects have been seen with increasing frequency in recent program evaluations throughout the country. Furthermore, commissioning of new buildings is likely to continue gaining importance in utility DSM programs as the construction industry begins to recover from the 2007 U.S. economic recession. One study indicated that while the total amount of commercial new construction (measured by square feet of new building) had slowed significantly, the relative percentage of new construction receiving commissioning was increasing (Navigant Consulting, Inc. 2012).[2] Program evaluators have had time to develop EM&V best practices for evaluating retrocommissioning programs and their peculiarities (Heinemeier, Friedman & Welker 2005), but new building commissioning has not received as much attention. This paper identifies difficulties facing evaluators as new building commissioning projects gain momentum in DSM programs, and uses lessons learned from several case studies to inform recommendations for best practices in evaluating new building commissioning projects. Many of these difficulties expand on those encountered in any new construction program evaluation. Some are unique to commissioning given its focus on operations and maintenance measures (O&M). All represent unique challenges that require an innovated response from program evaluation industry. Before any project specifics can be discussed, we will first take a closer look at new building commissioning and what difficulties it represents.

Commissioning vs. Retrocommissioning

In this paper the term *commissioning* (Cx) is used to describe the systematic process by which new buildings and their systems are critically inspected to ensure that each system is operating according to design intent. Cx ideally participates in the design, construction, and initial operations of the building process (ASHRAE 2003). *Retrocommissioning* (Rx) is used to refer to a similar process applied to existing buildings. The two are similar in that they both target operations and maintenance type improvements. Rx differs from Cx in that it can include a mix of capitol expense measures (i.e. equipment replacement) in addition to O&M improvements. The new construction element to commissioning further separates the two and makes its evaluation more difficult.

Cx measures are implemented at the design and start-up phases of the construction process. This increases the time lag between which commissioning activities and evaluation activities are performed. Similar to new construction projects, many Cx improvements do not have a physical baseline that can be measured. Commissioning findings during building start-up may be quantified (for example sensor miscalibration), but they are remedied before the building operates at its expected capacity. Thus, the impact at the system level cannot be verified through measurement alone. This is compounded by the often subtle nature of the measures which can make it difficult to identify the mechanisms by which energy is being saved. This makes it very important for a successful evaluation to not only have access to detailed commissioning documentation, but also to work with program implementers and local commissioning authorities (CxA) to educate all parties on what information is required by the evaluation to reasonably quantify and report the energy impacts. Within the same commissioning project one finding can result in considerable energy savings, while another can increase energy use. These swings in energy impacts have been identified in several studies of commissioning and retrocommissioning

[1] Examples of successful programs are plentiful. Some of the programs reviewed while studying industry literature for this paper include the San Diego Retrocommissioning Program (Heinemeier, Friedman & Welker 2005), and NEEA's Building Operator Certification (BOC) and Commissioning in Public Buildings Projects (Navigant Consulting, Inc. 2012).

[2] While some of this increase can be attributed to the increasing rigor of state building code requirements, there are still few states which require commissioning for new construction. Also, general market awareness regarding commissioning and its benefits will vary significantly throughout the country.

projects, (Tso et al. 2007) and (Mills 2011), and exemplify the importance for evaluators develop an in depth understanding of each implemented finding, its impact on building systems, and against what baseline its impacts will be assessed. It will be demonstrated by the case studies that proper baseline assessment represents the single most difficult (and influential) factor in establishing energy impacts from commissioning activities.

Commissioning impacts are further obfuscated when Cx is coupled with above code building improvements whose savings may have already been quantified under a separate incentive. Current modeling practice assumes "properly working" systems. This creates an "accounting" problem that must be considered by the evaluation if a building receives incentives separately for above code construction and commissioning services. Additionally, some building energy rating certifications require commissioning as part of the certification.[3] This can add further complication to an already complicated baseline assessment process.

Case Studies

In this section two commissioning projects from a recent evaluation are discussed. They are used to demonstrate some of the evaluation difficulties discussed above. Their results and the "lessons learned" will be used to propose best practices for evaluating new building commissioning projects. Both of the projects below recently participated in a commercial new construction program evaluated by the authors.

Case Study # 1 – New University Campus Building (Classrooms)

The first case study presents the evaluation results for a new university classroom facility which received incentives for both above code improvements and building commissioning services. The above code improvements were wide-ranging and incorporated envelope improvements, lighting power density reductions, mechanical system improvements, and extensive building controls upgrades. The building did not participate in any efficient building certification programs.

Often with new construction, it is impossible to acquire enough data to fully characterize a building's operation. This is primarily due to two factors: 1) the building is rarely fully occupied within the first few years of its construction, and 2) at the time of the evaluation it is common for there to be less than one year of available utility billing history for the building. Thus, the evaluation must rely on building simulation models to extrapolate the on-site findings to typical annual results. Furthermore, additional on-site data collection is necessary to inform building calibration. For this facility, the evaluation developed building simulation models in eQuest and simulated the savings for each of the above code improvements. Due to the building's extensive Direct Digital Controls (DDC) system, the evaluation was able to collect a significant amount of building operation trending to inform the modeling.

In addition to the above code measures, this facility received incentives for building commissioning. The project documentation included a detailed commissioning report – which contained a detailed list of each Cx finding and whether or not it had been addressed. The evaluation reviewed this document in order to identify Cx actions that may have impacted the building energy use. In this review the evaluation noted the following:

1) For this site, a large number of Cx activities surrounded the DDC system to verify that it was working appropriately.

[3] The U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) program requires building commissioning for example.

2) The majority of action items were focused on issues related to building code violations, occupant health and safety, occupant comfort, and ensuring installed equipment met specifications.
3) Only (3) actions were identified that specifically targeted energy improvements – one of which was ignored and characterized as "out of scope" by the general contractor. However, many of the actions reviewed indirectly impacted system energy use.
4) Many of the action items surrounding the DDC system were caused by the commissioning authority (CxA) when addressing other issues in the system programming.
5) The CxA adjusted design temperatures and flow rates for several systems. These changes were not reflected in the construction documents provided to the evaluation.

Ultimately it was determined that the implemented Cx activities, as they related to energy impacts, were already being modeled by the eQuest simulation used for the above code measures and that the only changes needing to be incorporated were the adjusted design points referenced above. Thus, the Cx energy impacts were already included and being reported in the results for the above code measures. This illustrates two important considerations. The first is that commissioning activities rarely stand alone as energy efficiency or occupant comfort improvements. However, they can indirectly impact the performance of stand-alone energy efficiency improvements through adjustments to building set-points, or equipment specifications. Secondly, the current industry standard practice when simulating new construction energy impacts is to assume a fully functioning (and typically optimized) system.[4] Thus, many of the potential Cx findings are already assumed present in the as-built simulation. As will be discussed in our conclusions this results in a conservative estimate when commissioning is performed. However, it likely also results in optimistic savings estimates for buildings whose systems are not commissioned.

Case Study #2 – Casino Hotel

The second case study presented is a new casino hotel which received a rebate for above code new construction in one program year and then another for commissioning in the next. The above code improvements were extensive with upgrades to the building envelope, controls systems, and space conditioning equipment. The building also had reduced internal lighting power densities. Like the first case study, this building did not participate in any green building certification programs. The energy impacts from the above code improvements were verified using calibrated eQuest simulations. The main difference between this building and the one presented in the first case study is the time lag between the new construction and building commissioning incentives.

The commissioning documentation for this project was extensive and included a seven thousand page commissioning report containing a complete issues and resolutions log. The commissioning report was reviewed to determine what Cx activities resulted in energy impacts on the building's systems. The following summarizes our findings for this site:

1) The issues and resolutions log for this project was presented as a dialog between the CxA and building contractors. Many of the listed issues were questions which when answered resulted in no actionable impacts.
2) Many of the findings represented required maintenance in order for the systems to work at all (for example backwards plumbing or failed equipment).

[4] This assumption is implicit in any simulation performed using building modeling software unless specific in-efficiencies are "built" into the simulations. Furthermore, many of the inefficiencies identified by the Cx process are beyond the scope of most software packages to simulate and would thus require a "derating factor" to be accounted for.

3) Stand-alone energy efficiency improvements were identified which had been reported and received rebates under the previous new construction rebate
4) Several actionable energy efficiency improvements, not already accounted for in the previous rebate, were identified. However, only two were reported with sufficient detail for reasonable energy impacts to be assessed.

While some energy savings were identified as a result from the commissioning process, several measures were found to have been included in the simulations and energy savings estimates for the rebate received in the previous program year. The reason for the time lag between rebates was rooted in the timing of the commissioning process compared to the rebate program's annual cycle. This building was one of several evaluated which received incentives for new construction and building commissioning in separate years. Also, while the provided documentation was very detailed regarding the list of commissioning findings and actions – these findings were not recorded with evaluation activities in mind. This led to insufficient documentation for the evaluation to assess energy impacts for several actions.

Evaluation Considerations for Cx Projects

For both of the above case studies the *ex ante* energy impacts were estimated using a deemed (per square foot) energy savings values. This is a common approach used to estimate savings for building commissioning – particularly for *ex ante* savings estimation. This is understandable given historically low presence of such measures in DSM programs coupled with the time and engineering rigor required to reasonably assess energy impacts for Cx. With the additional literature review and subtle nature of the implemented measures the resources required to accurately evaluate Cx can often exceed that required for custom projects. However, the magnitude of realized energy savings for Cx projects has historically not justified the additional resources to do so. As the standard battery of energy efficiency measures saturate the market more innovative (and typically more complicated to evaluate) energy efficiency opportunities take their place. Cx continues to gain public awareness as an energy efficiency opportunity and like retrocommissioning before it will become an important component to DSM. The case studies presented in this paper illustrate some of the unique evaluation challenges exhibited by Cx measures and are used to discuss best practices in measuring their impacts.

One of the more apparent difficulties identified in the case studies was the need to appropriately capture the real world benefits from Cx when many of its benefits may already be accounted for in the models used to evaluate above code improvements. As discussed in the case studies, current standard modeling practice does not derate building systems or purposely incorporate inefficiencies into a model to account for a "non-commissioned" building. In both of the projects discussed, zero credit was given to those commissioning activities as they would otherwise be double-counted. This is illustrated in Figure 1 where the simulated savings for an example new construction project are compared to the real world energy impacts.

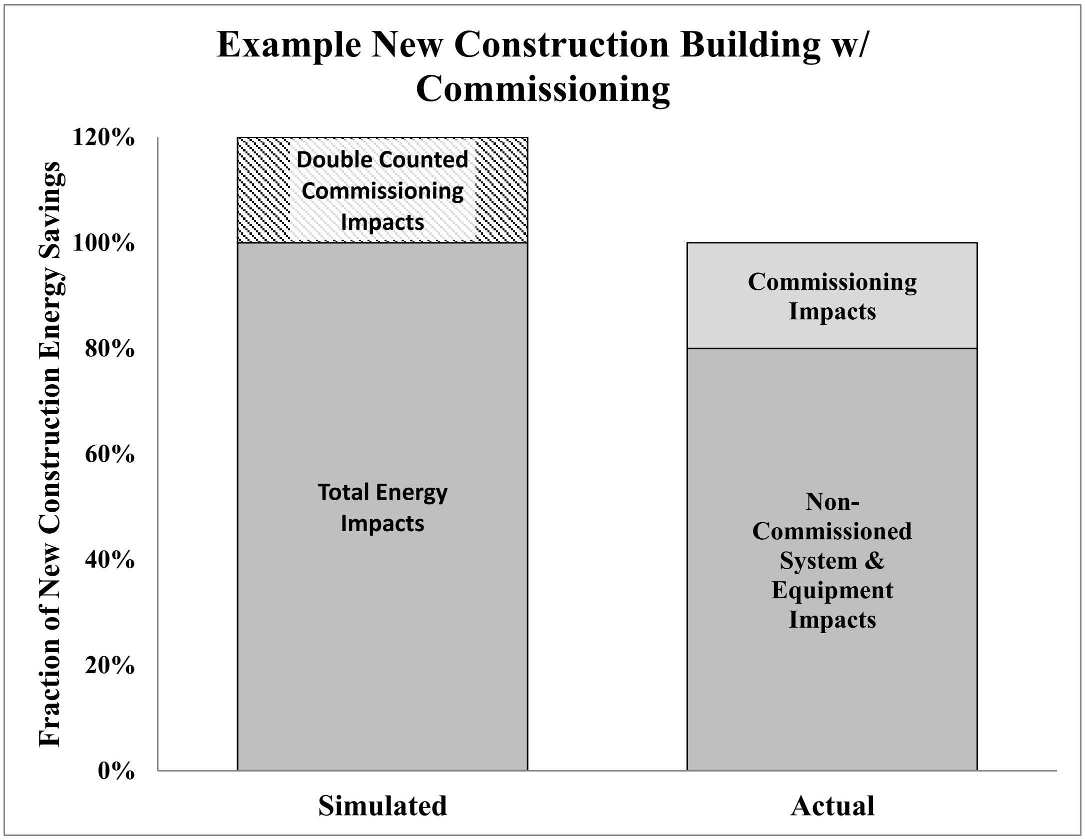

Figure 1. Example New Construction Building with Commissioning Savings

While assigning zero credit was appropriate for these projects (as the impacts had already been accounted for elsewhere), it creates a disincentive for commissioning as a DSM opportunity in general. One way around this is to require any building participating in a commercial new construction program to receive commissioning (Cx is for example a requirement for LEED certification). However, such a provision may prove to inhibit participation in some markets. A more rigorus approach to Cx and New Construction building energy modeling practices represents a better solution. Building energy simulation (for Cx projects only) should apply a building *derating* factor to the baseline energy use. Energy impacts for new construction projects would then be calculated as follows:

$$Project\ Energy\ Impacts = Baseline\ Use * Derate - As\ built\ Use$$

Notice that the derate factor is applied only to the baseline energy use in the above equation because it is assumed that the as built building received building commissioning. If the energy impacts need to be reported separate for commissioning, or the building never received commissioning services, then the derate factor would need to be applied to as-built energy use as well. This derating factor is equal to the relative energy impacts identified for the as-built building through its commissioning process – essentially discounting the energy impacts for non-commissioned systems and equipment.

The major challenge in implementing this practice will be in establishing an appropriate value for the derate factor. The magnitude of the energy impacts from Cx are tied to the size and complexity of a building and its systems. Thus separate factors would likely need to be developed for overarching building types, controls systems, and distribution equipment. Meta-analysis of the current research available on building commission will be important in helping to estimate reasonable factors. However;

focused research will need to be conducted in order to measure the real-world impacts of commissioning across building types and sectors.

Conclusions

While additional focused research will be paramount, in order to facilitate the proposed approach evaluators also need to move away from an "arms-length" paradigm and actively engage with implementation staff, local building designers, and commissioning authorities in order to educate all parties regarding what documentation is required for the evaluation. This will have an instant impact in identifying energy impacts that likely would not have been verified without. Furthermore, evaluators need to capitalize on the industry's shift to concurrent evaluation by working with the implementation staff to identify projects which evaluation personnel can shadow throughout the commissioning process. This would enable a more thorough baseline assessment (while providing the opportunity for baseline monitoring) which feeds directly into the simulation models used to estimate the final energy impacts.

As public awareness grows regarding commissioning and its benefits utilities have the opportunity to help make building commissioning the norm as opposed to the exception. As evaluators we must evaluate our own tools and paradigm to ensure that we are well equipped to promote and substantiate the energy efficiency and environmental benefits of new building commissioning.

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