

Non-Energy Benefits (NEBs) from Commissioning in Schools, Prisons, and Other Public Buildings

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ABSTRACT

As part of a broader study to examine the cost-effectiveness of commissioning public buildings, the authors examined the non-energy benefits (NEBs) (or non-energy impacts) from commissioning efforts in a sample of public buildings, including schools, offices, prisons, and other buildings. Phone surveys were used to gather data to measure “hard to measure” NEBs (both positive and negative), and values were computed based on multiple measurement methods. Results showed the highest-valued (positive and negative) NEBs for key stakeholders, included:

- For occupants: changes in comfort, indoor air quality, productivity, light quality, safety,.
- For facility operations: changes in tenant complaints, operational deficiencies, system documentation, knowledge for O&M staff, equipment lifetime, equipment O&M,
- During design and construction: changes in contractor callbacks, change orders or warranty claims, time to optimize systems, project schedule, coordination between team members.

While interviewees were generally pleased with the commissioning process and results, we found patterns based on interviewee roles, building and business type, systems commissioned, new vs. retrofit commissioning, and other subgroups.

The analysis showed that non-energy benefits can be measured and attributed for commissioning projects, and priority benefits for decision-makers, building staff, and occupants can be used for program promotion, targeting, and design. The results showed indirect non-energy benefits add significant value above and beyond the direct benefits (e.g. energy savings or other cost savings), and often more than offset the costs of the commissioning work. Coupled with energy savings, the non-energy benefits lead to strong computed benefit cost ratios for commissioning projects. Incorporating NEB values into case studies on commissioning may improve outreach materials and attract additional buildings to commissioning programs because they speak to participants in terms they value most highly.

Introduction

This analysis of non-energy benefits (NEBs) was a small part of a much larger study designed to examine the cost-effectiveness of a program that provided assistance in commissioning public buildings. The program buildings included libraries, schools, offices / courthouses, and prisons. These facilities varied in size from 18,000 square feet to more than 350,000 square feet in size. To conduct the NEB analysis, we conducted detailed interviews with facility managers; facility and maintenance staff; construction managers; design-related staff (A&E, mechanical engineers, etc.), and directors of operations. The project was sponsored

by the Northwest Energy Efficiency Alliance and the NEB analysis was conducted by Skumatz Economic Research Associates (SERA) under subcontract to SBW Consulting.

Background on NEB Valuation

The objective of this study was to quantify the occupants' value perception of energy technologies, requiring use of survey, rather than metering, techniques. Over the past decade, SERA has conducted extensive research to develop and test alternative valuation methods for commercial and residential NEBs (Skumatz 2002, Skumatz and Gardner 2006). This project provided an opportunity to quantify the array of NEBs that have been associated with commissioning and retro-commissioning– and develop information that serves a number of purposes:

- **Marketing:** NEBs inform efficiency-related marketing, targeting, design, and outreach efforts. Previous research demonstrates that reliable methods can be used to derive quantitative estimates (Skumatz 2002, Skumatz and Gardner 2006) of NEBs, and these estimates identify which NEBs are especially valuable to participants – both in dollar terms and relative to direct benefits from energy savings from the program. These results point out which benefits are most important to various groups, providing opportunities to design program interventions and outreach activities to target groups such as builders, decision-makers, and other sub-groups. It will permit them to address those energy technologies which show the greatest NEB benefits, using terms and benefits that the end users value and respond to. Highly valued NEBs are likely easier to “sell” than energy efficiency, and more importantly, they are likely to appeal to owners or decision-makers. Tailoring the program message to the high scoring NEBs for the audience of interest is potentially more fruitful than continuing to push energy efficiency on efficiency or bill savings grounds.
- **Benefit-Cost:** The NEB information provides data for improved program benefit-cost analyses. The quantitative values for program- or intervention-related NEBs provide more complete information for assessing benefits and costs associated with programs – for the agency / utility, for societal or regulatory tests, and for participants deciding whether to install efficient measures or undertake commissioning efforts.¹ The NEB values provide information for the benefit/cost analysis from participant point of view, and may be useful as inputs for scenario analysis around regulatory tests as well.
- **Analysis of Program Barriers:** Negative benefits are indications of program barriers that remain – either perceived or real (or both) depending on which actors report the negative NEB. If non-participants or vendors report a negative NEB but the participants do not, then the program may benefit by providing greater education or data on that factor. The program would likely obtain more applicants, and the vendors may be able to make a

¹ Dollar-related NEB benefits (“net” including positive and negative NEBs) can be added to direct cost and benefit information, enhancing program-related cost/benefit computations. The user may choose to include all NEBs or only a subset of the overall NEBs in the cost/benefit computations – or there may be different cost/benefit computations depending on the perspective upon which the test is based. One specific application for quantified non-energy-benefits may include programs in which post-evaluation shows that the projected energy savings have not been achieved. Rather than considering these programs as failures, the financial valuation of non-energy-benefits can demonstrate a quantifiable positive outcome nevertheless – albeit not the originally intended one.

stronger case for the energy efficient equipment. If, however, the barrier represents a real cost – if participants or others (A&E, contractors) notice the problem as well – the NEB results provide an estimate of the cost of the rebate, refund, warranty buy-down or other interventions that may help participants become indifferent to the barrier – and spur participation and adoption of new measures. Tracking these negative values over time provides useful information feedback to let program staff check whether the program is decreasing these barriers over time.² The dollar value provides information on the level of investment that may be needed to overcome the barrier.

- **Analysis of differences in decision-maker perceptions:** The authors have demonstrated in other work that gathering NEB information from multiple actors and decision-makers involved in a program can provide an even more robust analysis. These results allow an examination of differences in positive and negative perceptions about NEBs as well as differences in associated values (“disconnects”). Using this approach, the literature (Skumatz, et. al, 2003, Skumatz and Gardner 2005) has been able to identify situations in which architects / engineers / contractors assign more “negatives” to NEBs than do owners – potentially leading to underinvestment in energy efficiency. The implication is that in some cases, builders may be including less energy efficiency than owners might be willing to “buy”. In some cases, these analyses may highlight where additional education, incentives, or other program interventions targeted at those with more skepticism may aid the program.

Most of the previous NEB work has assessed benefits associated with measure-based programs or audits that lead to measure changes. This project was experimental in the sense that it was attempting to identify whether commissioning led to similarly-recognized benefits. This phase of the project was designed to see if benefits were recognized and attributed to commissioning, and to see if actual dollar values – or ranges – could be associated.

NEB Measurement Approaches

The research difficulty is valuing these “hard-to-measure” positive and negative benefits. The authors have conducted extensive research to develop several measurement methods to quantify and “value” a wide range of participant and other NEBs. The authors have explored and applied more than a dozen measurement approaches to estimate participant NEBs, representing variations on several core methodologies (Skumatz and Gardner 2006):

- Willingness to pay (WTP) / willingness to accept (WTA) / contingent valuation (CV)
- Alternative methods of comparative, scaling, or relative valuations
- Direct computations of value to owner,
- Discrete choices or ordered logit, and
- Other revealed and stated preference and other approaches.

These measurement methods can be complex to implement, and the authors have worked hard to refine the techniques. They have been applied to more than 50 programs across the US

² This feedback is potentially more useful than tracking barrier “scores”, which provide less information on the importance of the barrier before or after.

and internationally, and have worked very successfully. Our research over 10 years of performing these analyses has found that generally, comparative or relative valuations³ perform substantially better than other methods. Willingness to pay (WTP) can often provide very volatile numbers and respondents have an extremely difficult time understanding the concept of stating a dollar amount they would be willing to pay for these benefits. We have incorporated multiple measurement methods into the same studies, and have found that on average, WTP is volatile (and less conservative), and that scaling, discrete choice, and other measurement methods we have adapted perform more reliably; our research incorporates these approaches.⁴

In most of our previous projects we have used at least two of these approaches – allowing a “check” on the computation of values. Given the findings on the performance of various approaches, we selected the two options we believed were best suited to this project. For this project, we used two methods: willingness to pay and scaled valuations⁵ valuation methods.

Purpose

Our purpose is to measure and develop quantitative (dollar) estimates of the important positive and negative NEBs associated with commissioning efforts, as realized and recognized by building stakeholders. The information is provided on a building-by-building basis, as well as “averages” and analysis by a variety of strata (e.g. business/building subgroups, etc.). The data collection work was designed to mesh with and make maximum use of the work and interviews previously conducted in other parts of the project.

Approach

The basic approach involved telephone interviews with several⁶ key building actors – including potential building operators and owners/occupants – to ask about specific NEBs (positive and negative) associated with specific commissioning efforts. The authors developed questionnaires and conducted interviews to ask about the presence and values of associated NEBs. Preliminary work suggested some NEBs associated with commissioning, including:

- *For occupants:* improved comfort, improved indoor air quality, improved productivity, improved light quality, safety, and other benefits.
- *For facility operations:* fewer tenant complaints, fewer operational deficiencies, better system documentation, improved knowledge for O&M staff, increased equipment lifetime, lower equipment O&M, and other NEBs

³ Methods pioneered by the authors, based on the academic literature; see descriptions in Skumatz (2002) and Skumatz and Gardner (2006).

⁴ For an analysis of comparative, willingness to pay, and labeled magnitude scaling methods, see Skumatz (2002) and Skumatz and Gardner (2006).

⁵ Our “scaling” or comparison approaches to measuring NEBs requires a value against which to compare the value of benefits. Rather than energy savings, as we use in many other projects, we identified a more suitable comparison factor for this project, and it worked very successfully.

⁶ Usually one or two per building, depending on the actors involved and likely to be knowledgeable about the commissioning and impacts.

- *During design and construction:* fewer contractor callbacks, fewer change orders or warranty claims, less time to optimize systems, project delays, coordination difficulties, or increased conflicts between team members, and other NEBs.

On previous projects, we have asked sets of questions to support different derivations of valuation – and to “bracket” estimates. In this project, we assessed the total benefits two ways – WTP and comparison methods. Although there were differences between the different metrics, the feedback and valuations from the respondents make it clear that there are NEBs deriving from commissioning work and it is highly valued. The results are presented in the following sections.

Results – NEB Survey

The interviews for this project were conducted with facility managers; facility and maintenance staff; construction managers; design-related staff (A&E, mechanical engineers, etc.) , and directors of operations . Libraries, prisons, schools, offices / courthouses, and prisons were the buildings included in the interviews, and they varied in size from 18,000 square feet to more than 350,000 square feet in size. The projects were completed in 2000 – 2003, and commissioning costs varied from \$12K to \$225K. Rebates for the projects varied from \$6K to \$90K.

Most of the benefits could be separately identified with the exception of “coordination” and “team member relationships”. In many cases, these were jointly addressed. In addition, a subset of respondents noted some overlap or difficulties in separating indoor air quality and sick days.

We analyzed several key types of results:

- The share of respondents that recognized positive or negative NEB impacts from commissioning,
- The total value of the non-energy benefits (NEBs),
- The percentage of value deriving from each of the NEB categories, and
- Ratios of benefits compared to commissioning cost.

We analyzed the results in overall terms, on a building-by-building basis, and for key subgroups, including respondent type, type of commissioning conducted, etc. The results are presented below.

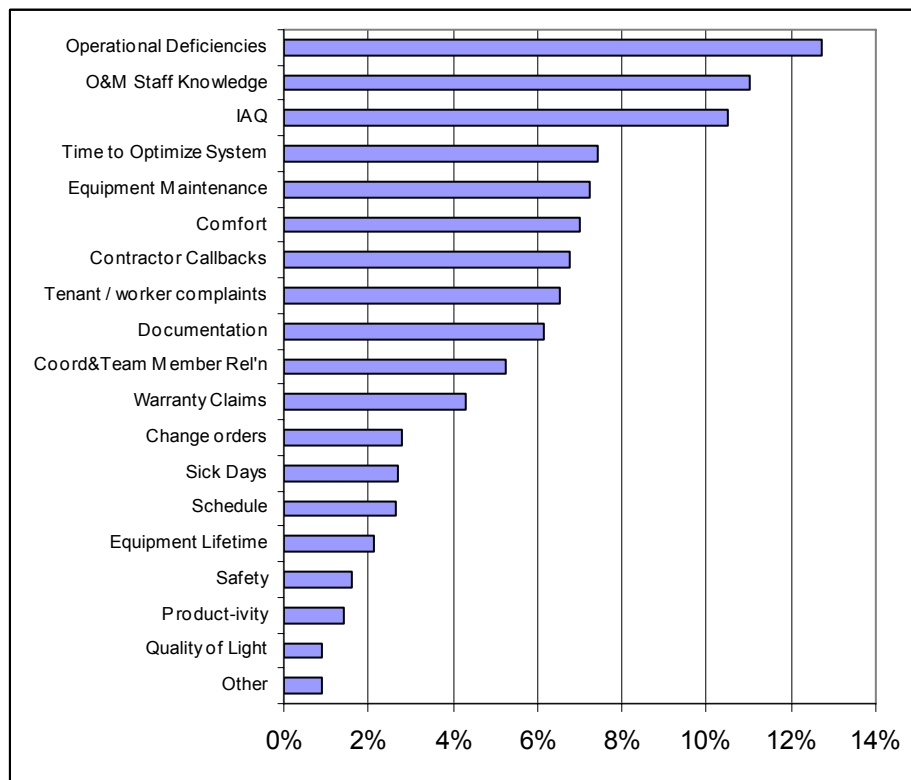
Attributions of NEBs to the Commissioning Work

The survey asked participants about the positive and negative non-energy outcomes from the project. We found that the most common negative effects included: negative impact on project schedule (15%), difficulties with coordination and team member relationships (12%), and increased time to optimize the system (8%). The NEB factors with overwhelmingly reports of positive NEBs included: correcting operational deficiencies, knowledge for O&M staff, equipment maintenance, and comfort improvements. They also ranked reductions in contractor call backs and improved system documentation as positive.

Although reports of positive effects are important, we also examined two other indicators of NEB value. We examined the “importance” of particular NEBs, and found high scores for operational deficiencies, knowledge for O&M staff, equipment maintenance, comfort, and IAQ.

Finally, we computed NEB values. Figure 1 shows the percent of the total average NEBs that derive from each of the NEBs categories asked about. The results show that the commissioning NEBs of greatest value well-reflected the key services provided by commissioning: correction of operational deficiencies, increased knowledge and improved maintenance, and IAQ and comfort advantages. In many cases, the primary driver for having commissioning done is not energy savings, but operational and maintenance concerns.

Figure 1. Overall NEB Valuation Results: Percent of Total NEBs by Category



We examined the non-energy benefits, grouped into three main categories of benefits:

- Design/ construction benefits, including: reduced contractor callbacks, change orders, warranty claims, time to optimize the system, project schedule, and coordination and team member relationships. In total, these categories of benefits combined accounted for just over 31% of the average reported NEBs.
- The “operational” benefits included: correcting operational deficiencies, improved system documentation, knowledge for O&M staff, equipment maintenance and equipment lifetime benefits. These benefits accounted for 44% of the benefits reported by the respondents.
- The “occupant” benefits included: comfort, indoor air quality, fewer illnesses/sick days, tenant or worker complaints, and other benefits mentioned by respondents. The combination of these benefits represents 25% of the reported NEBs.

Overall, the individual benefits reported to have greatest perceived value to the respondents include:

- Correcting operational deficiencies, representing almost 18% of the total NEBs. This, in many cases, was reported to be the real purpose of the commissioning work – not energy conservation.
- Increased knowledge gained by the O&M staff, representing 13% of total value. They readily reported that they became better educated, were better able to manage building settings, and they were more efficient at fixing building problems.

These two benefits account for almost one-third of the total NEB value. Other relatively high individual benefit categories included reducing time to optimize the system and indoor air quality benefits, each representing more than 8% of the benefits.

NEB Valuation Results by Subgroups

We investigated the patterns in which benefits were most valuable based on groupings of:

- Job titles / responsibilities;
- Building types;
- Business types;
- Whether only HVAC was commissioned, or additional systems were also commissioned; and
- New vs. retrofit / recommissioning efforts.

We conducted a detailed analysis of the NEB results by category for each of these subgroups. Our results are summarized below.

- **Roles:** The bulk of NEBs for construction staff are concentrated in the design and construction phases. Design staff (including architects and mechanical engineers, etc.) recognized benefits in the areas of reduced time to optimize the system, and operational / documentation benefits. Facility managers showed higher levels of concern about occupant-related benefits, especially in indoor-air-quality (IAQ), and tenant / worker complaints. Facility and maintenance staff placed especially high relative value on correcting operational deficiencies and improved knowledge for O&M staff.
- **Building types:** Those involved in commissioning projects for office buildings ranked three benefit categories most highly – correcting operational deficiencies; occupant comfort; and knowledge for O&M staff. University building staff ranked operational deficiencies and knowledge for O&M staff highly, but comfort, was not highly ranked. These three categories represented a large percent of overall benefits. A set of “other” buildings, including recreation centers, museums, and others ranked operational deficiencies, time to optimize system, and reducing contractor callbacks most highly.
- **Business types:** The largest difference between state and university buildings was that the attributed benefits in reduction in time to optimize the system was rated much more highly for state buildings (12.5% of reported benefits, vs. 3.8% for universities).
- **Systems commissioned:** Those buildings with more than just HVAC commissioned showed roughly the same relative rankings for key benefits categories, with the exception

of equipment maintenance (higher for HVAC only buildings), and greater concern with operational deficiencies. Other systems commissioned included fire alarms, lighting, plumbing, electrical, and other systems.

- **New vs. Retrofit Commissioning:** As expected, the benefits for the design/ construction phases of new commissioning projects were much higher than for retrofit / recommissioning efforts. Most notably, however, operational deficiencies and IAQ, and to some degree, comfort, were ranked very highly for retrofit commissioning projects. Correcting these types of problems may have been the particular drivers for undertaking the commissioning work in the first place.

Overall NEB Indicators by Subgroup

The average NEB benefit per building provided a return of \$1 dollar of NEB benefits per \$1 spent on commissioning costs (gross), and \$2.30 dollars per every \$1 spent on the rebates. The benefit per square foot was 50 cents.

The results are shown in Table 1; note, however, that there are small sample sizes for some subgroups (specifically, the prison group).

Table 1. NEB Results for Commissioning Project

| | NEB Value per dollar of Cx cost | NEB Value per dollar Cx rebate provided | Benefit per "net" Cx cost | Benefit per building square foot | Score for Cx (0-100) |
|------------------------------|---------------------------------|---|---------------------------|----------------------------------|----------------------|
| Overall | 1.0 | 2.3 | 3.1 | 0.5 | 70.5 |
| Respondent Role | | | | | |
| Facility Mgrs | 1.2 | 2.8 | 4.3 | 0.7 | 79.1 |
| Construction related | 0.9 | 1.2 | 2.0 | 0.4 | 68.8 |
| A&E | 0.6 | 2.9 | 0.8 | 0.8 | 62.5 |
| Facil / maint | 0.5 | 1.2 | 1.1 | 0.2 | 46.7 |
| Building Type | | | | | |
| Office | 2.0 | 4.9 | 3.4 | 1.0 | 91.3 |
| University | 0.9 | 2.0 | 4.9 | 0.6 | 70.5 |
| Prison | -0.4 | -0.8 | -0.6 | | 50.0 |
| Other | 0.9 | 2.0 | 1.7 | 0.5 | 58.0 |
| Business Type | | | | | |
| Government | 1.1 | 2.6 | 3.9 | 0.6 | 67.5 |
| University | 0.8 | 1.8 | 1.7 | 0.4 | 75.0 |
| Systems Commissioned | | | | | |
| HVAC only | 1.4 | 3.0 | 10.5 | 1.2 | 79.0 |
| More than HVAC | 0.9 | 2.2 | 1.8 | 0.4 | 67.7 |
| Type of Commissioning | | | | | |
| New | 0.7 | 1.6 | 2.9 | 0.5 | 62.1 |
| Retrofit | 1.9 | 4.7 | 3.7 | 0.7 | 90.0 |

Table 1 shows the results for computations of total benefits and ratios by subgroup. The table shows that:

- The “score” for the commissioning work (0-100) was highest for office buildings, and for facility managers, and for retrofit work. This factor reflected the importance of the expenditures for commissioning compared to the overall building construction and operation cost. Respondents took it as the general usefulness of the commissioning work.
- Facility managers were the source of the highest discrepancies between the “sum” of the individual benefits and their reported values for net total benefits.
- The highest NEB value per dollar spent for commissioning work derives from work on office buildings (2 dollars of value per dollar spent on commissioning, and 4.9 dollars per rebate dollar spent).
- HVAC-only work tended to have higher NEB returns per dollar spent than broader commissioning work.
- Retrofit work also showed higher value per dollar spent than new building commissioning.

Positive and Negative Comments about Commissioning

Respondents made a number of comments about commissioning work. Positive effects they noted from the commissioning work included:

- The commissioning was worth the cost.
- The building now works – and this includes many aspects including control, comfort, and other systems.
- They got things fixed up front.
- The commissioning agent was a valuable inspector and arbitrator.
- The commissioning will help improve maintenance over time.

The major categories of negative benefits included:

- No negative impacts.
- The cost.
- Commissioning agents should be brought in early in the process to avoid problems.
- There were complaints from the contractors and others that were being “checked” by the commissioning agent (and this needs to be worked into their contracts up front).

Other comments generally covered the following areas:

- I would do it again – it turned out well.
- Bring in commissioning agents at the beginning of the process.
- It is important to get this work done up-front so occupants don’t get an initial negative impression of the building that is very difficult to ever get them to lose.
- It is cheaper to commission up front than to constantly tweak and fix (and “jerry-rig”) the system(s) over time.

Conclusions

The study demonstrates that NEBs from commissioning can be estimated – and the responses also indicate that there are strong benefits from commissioning above and beyond the direct benefits. These benefits are recognized by an array of stakeholders – stakeholders that can be targeted for commissioning information, rebates, and other programs. In addition, the NEBs are probably also strongly recognized by occupants, who may not know the source of their improved comfort.

Overall, the results suggest that there are strong benefits that appeal to the types of stakeholders that were interviewed in this project. The overall experience – with very few exceptions – has been positive, and most plan to commission in the future if the budget can be raised.

The major findings from the work attributing, assessing, and valuing the NEBs from commissioning include:

- NEBs are valuable and easily / well recognized and appreciated by (a variety of) stakeholders associated with the building.
- There appears to be a strong return on investment (ROI) for the stakeholders. The respondents we interviewed valued the NEBs from commissioning as at least making up for the cost of the commissioning work – without adding in energy savings and other direct benefits.
- From a program perspective, the return on investment in terms of NEBs from rebates is strong. However, the program costs accrue to the states and programs, while the NEBs accrue to the building stakeholders and occupants. The ROI to the program expenditures will depend on the energy savings or other direct benefits. However, the NEBs provide a way to improve the cost-effectiveness of the programs because NEBs encourage program participation, presumably reducing the marketing and outreach expenditures – and potentially reducing the level of rebate needed to achieve participation.
- The benefits that make up the majority of the value are: correcting operational deficiencies, increasing knowledge for O&M staff, reducing time to optimize the system, and indoor air quality benefits. The first two represent 31% of all attributed benefits, and the latter two add another 16%. Improvements in comfort, contractor callbacks, and equipment maintenance were also highly rated (adding another 19%) and this list represents potentially effective benefits to recommend commissioning.
- Facility managers appreciate this work and they should be a key target for marketing efforts. They value the benefits highly. A&E staff also value the NEBs highly, and represent another target. The two groups value different categories of benefits, which supports tailoring of the design, outreach, and program materials. Offices recognized especially high benefits and may represent a useful focus for future marketing.

There are benefits from both new and retrofit commissioning, although they tend to accrue to different categories of benefits. Commissioning work on retrofits often seems directed to address issues we have categorized as NEBs rather than direct impacts – particularly operational deficiencies, IAQ issues, and comfort.

Using tested measurement approaches, we were able to value the non-energy benefits associated with commissioning and retro-commissioning work in public buildings. The work

confirmed that correcting operational deficiencies and addressing O&M (and IAQ) issues are among the most highly prized outcomes of commissioning / retro-commissioning work. We also collected open-ended information and comments about the benefits, negative, and suggestions regarding commissioning. These comments and valuations can be used to update benefit cost and payback assessments, address barriers, allay fears, and reconfirm the clearly positive overall conclusions about commissioning that are held by this sample of participant stakeholders.

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