The Cost-Effectiveness of Commissioning

A summary of a major study of 224 new and existing commercial buildings of various types

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Building-performance problems are pervasive. Deficiencies, such as design flaws, construction defects, malfunctioning equipment, and deferred maintenance, have a host of ramifications, ranging from equipment failure to compromised indoor-air quality and comfort to unnecessarily elevated energy use or the underperformance of energy-efficiency strategies. Fortunately, an emerging form of quality assurance—building commissioning—can detect and remedy most deficiencies.

Scattered case studies and anecdotal information form the basis of the conventional wisdom among energy-management professionals that commissioning is highly cost-effective. However, given the lack of standardized information on costs and benefits of detecting and correcting deficiencies, it is not surprising that the most frequently cited barrier to widespread use of commissioning is a decision-maker's uncertainty about its cost-effectiveness.

This article summarizes a major study[1] compiling and synthesizing extensive published and unpublished data from building-commissioning projects undertaken across the United States over the past two decades, establishing the largest available collection of standardized information on commissioning experience.

SAMPLE

The authors' data-collection efforts yielded 224 buildings (175 projects) spanning 21 states and representing 30.4 million sq ft of floor area (73 percent in existing buildings and 27 percent in new construction). These projects collectively embodied $17 million (2003 dollars) of commissioning investment.

The information represented the work of 18 known commissioning providers. The provider was unknown for 16 percent of the existing-building projects' floor area and for 62 percent of the new-construction projects' floor area.

Among the existing-building projects analyzed, the most common locations were Texas and California, while for new-construction projects, the most common locations were Washington, Oregon, and Montana. The median building size was 151,000 (95,101 to 271,650) sq ft for existing buildings and 69,500 (32,268 to 151,000) sq ft for

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	All		Existing buildings			New construction		
	Total	Sample size	Total	Median per project	Sample size	Total	Median per project	Sample size
Number of projects	175	175	106		106	69		69
Number of buildings[1]	224	175	150	**1.4**	106	74	**1.1**	69
Number of states	21	175	15		106	15		69
Total project floor area, million square feet	30.4	175	22.2	**0.151**	106	8.2	**0.07**	69
Year built				**1978**	78		**1996**	59
Total new-building construction costs, millions of dollars[2]						1,514	**10.2**	58
Number of deficiencies identified	6,805	120	3,500	**11**	85	3,305	**26**	35
Commissioning cost as a fraction of total building-construction cost (excluding non-energy benefits), percent							**0.6**	65
Total commissioning costs (excluding non-energy impacts[3]) Thousands of dollars Dollars per square foot	16,984	171	5,223	**34** **0.27**	102 102	11,760	**74** **1.00**	69 69
Total savings[3] Thousands of dollars per year[4] Dollars per square foot per year[4]	8,840	133	8,022	**45** **0.27**	100 100	818	**3** **0.05**	33 33
Whole-building energy-cost savings, percent[5]				**15**	74			
Simple payback time, local energy prices, years				**1.0**	99		**5.6**	38
Simple payback time, standardized U.S. energy prices, including some cases with non-energy impacts, years[6]				**0.7**	59		**4.8**	35

Notes:
[1]Actual values likely higher. For the many data sources that did not specify number of buildings, the authors stipulated one.
[2]All costs in this table are in inflation-corrected 2003 dollars.
[3]Payback time should not be inferred from these two rows, as sample sizes are different.
[4]Total based on inflation-corrected local energy prices. Median based on inflation-corrected standardized national-average energy prices of 7.86 cents per kilowatt-hour for electricity, $8 per million British thermal units (MMBtu) for fuel, and $9 per MMBtu for hot water, chilled water, and steam.
[5]Percentage savings generally are not available for new construction.
[6]In a number of cases, commissioning costs were partly or fully offset by resultant first-cost savings.

TABLE 1. Summary of results.

new construction. (Ranges represent the interquartile range of the sample [i.e., 25th to 75th percentile].) With the exception of "religious worship" and "vacant," the sample covered all major building types identified in the U.S. Energy Information Administration's periodic Commercial Buildings Energy Consumption Survey. All data elements were not available for all projects.

FINDINGS

The top-level results are shown in Table 1. For existing buildings, median commissioning costs of 27 cents (13 cents to 45 cents) per square foot, median whole-building energy savings of 15 percent (7 percent to 29 percent), and a median payback of 0.7 year (0.2 year to 1.7 years) were found. For new construction, median commissioning costs were $1 (49 cents to $1.64) per square foot (a median of 0.6 [0.3 to 0.9] percent of total construction costs), yielding a median payback time of 4.8 years (1.2 to 16.6 years). These values

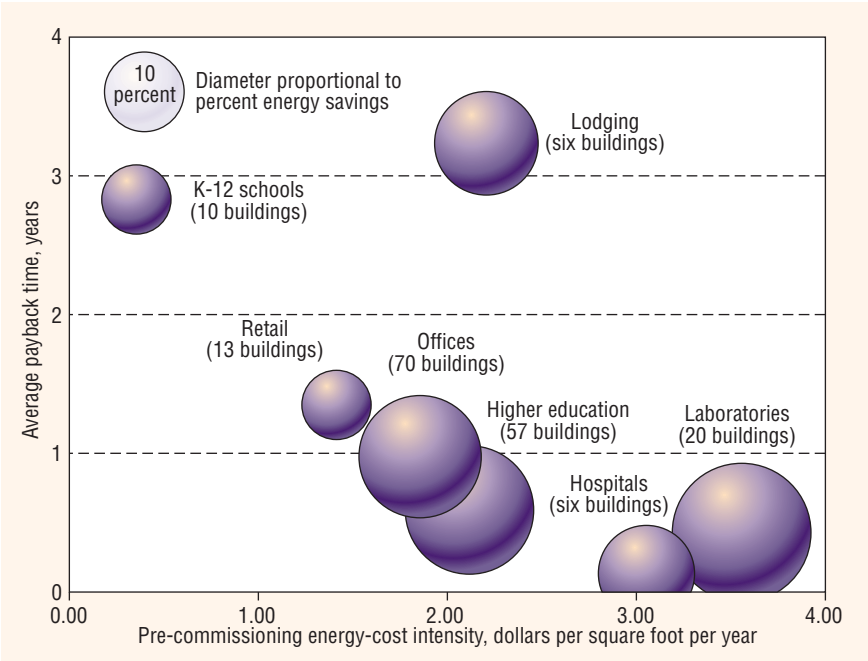

FIGURE 1. Existing-building average payback time, pre-commissioning energy-cost intensity, and energy savings.

exclude non-energy impacts, which are discussed in greater depth below. The values are based on corrections for inflation and standardized assumptions for energy prices. While, on average, these normalizations did not have a large absolute effect, adjusted values varied by up to a factor of four in individual cases. Pre-commissioning energy intensities, savings, and payback times varied among building types, as shown in Figure 1.

The findings are conservative insofar

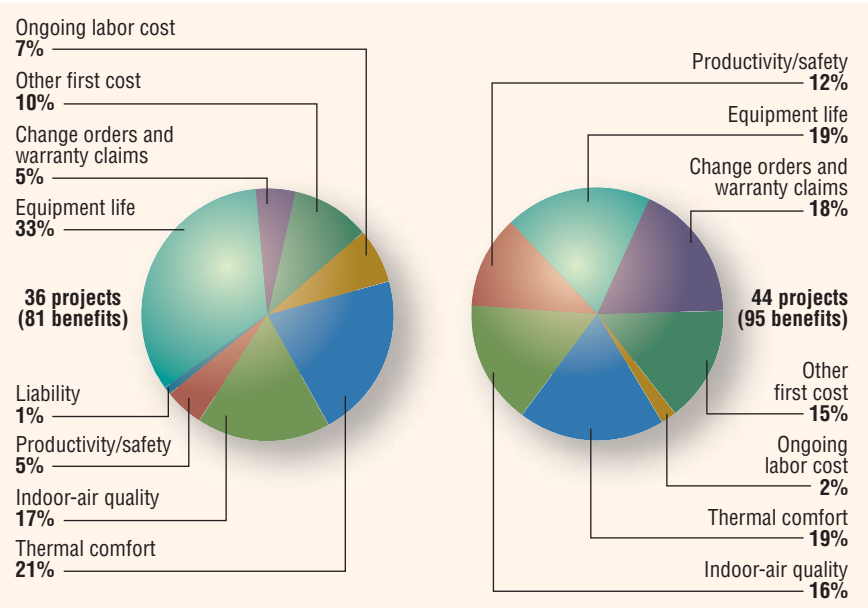

FIGURE 2. Reported non-energy impacts for existing buildings (left) and new construction (right).

as the scope of commissioning in practice rarely spans all fuels and building systems in which savings may be found—not all recommendations are implemented, and significant first-cost and ongoing non-energy benefits rarely are quantified, but are important drivers for undertaking commissioning and important among the perceived benefits (Figure 2). Examples included reduced change orders thanks to early detection of problems during design and construction, rather than after the fact, and correcting causes of premature equipment breakdown.

Where quantified, non-energy impacts had a material positive impact on cost-effectiveness. In four cases, non-energy impacts represented a cost increase, rather than savings.

For the 36 existing-building projects providing information, information on 81 non-energy benefits was reported. Median one-time non-energy benefits were 18 cents per square foot for existing buildings (10 cases) and $1.24 per square foot for new construction (22 cases), comparable to the entire cost of commissioning.

For 44 new-construction projects in this compilation, information on 95 non-energy benefits was reported. For this cohort, the median commissioning-cost ratio declined to 0.2 percent of total construction costs (average value 0.0 percent), while seven cases out of 22 reported having negative net costs. In one case, first-cost savings achieved through commissioning resulted in a 5-percent overall reduction in construction cost. Improved equipment lifetime was the most commonly reported benefit (19 percent of the cases).

Deeper analysis of the results shows cost-effective outcomes for existing buildings and new construction alike across a range of building types, sizes, and pre-commissioning energy intensities (figures 3 and 4). The most cost-effective results—both in terms of depth of savings and payback times—occurred among energy-intensive facilities, such as hospitals and laboratories. Less cost-effective results were most frequent in smaller buildings. Energy savings tended to rise with the comprehensiveness of commissioning.

The projects identified 3,500 deficiencies (11 per building, 85 projects reporting) among existing buildings and 3,305 (28 per building, 34 projects reporting) among new construction. HVAC systems presented the most problems, particularly within air-distribution systems.

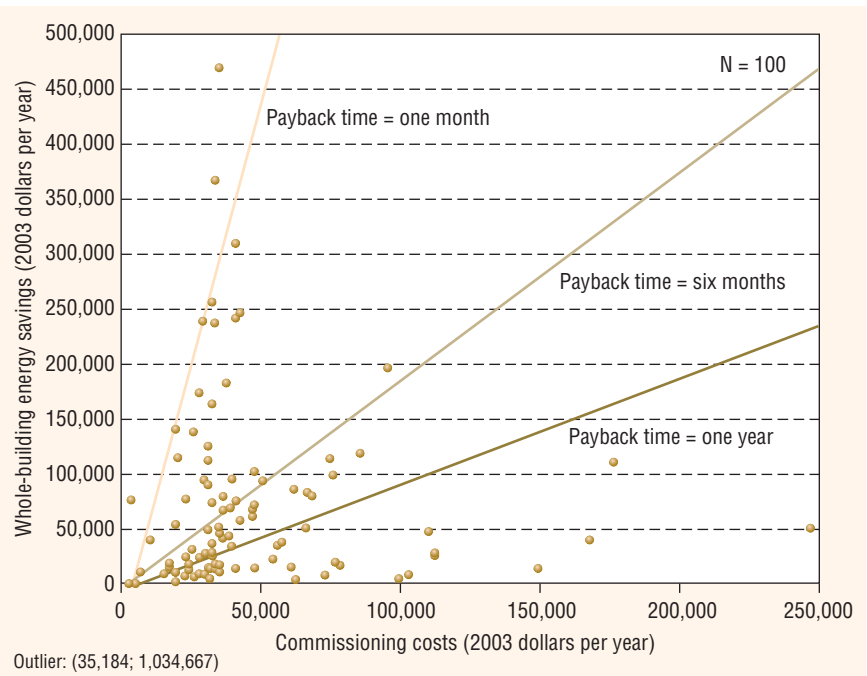

FIGURE 3. Costs, savings, and payback times of existing-building commissioning.

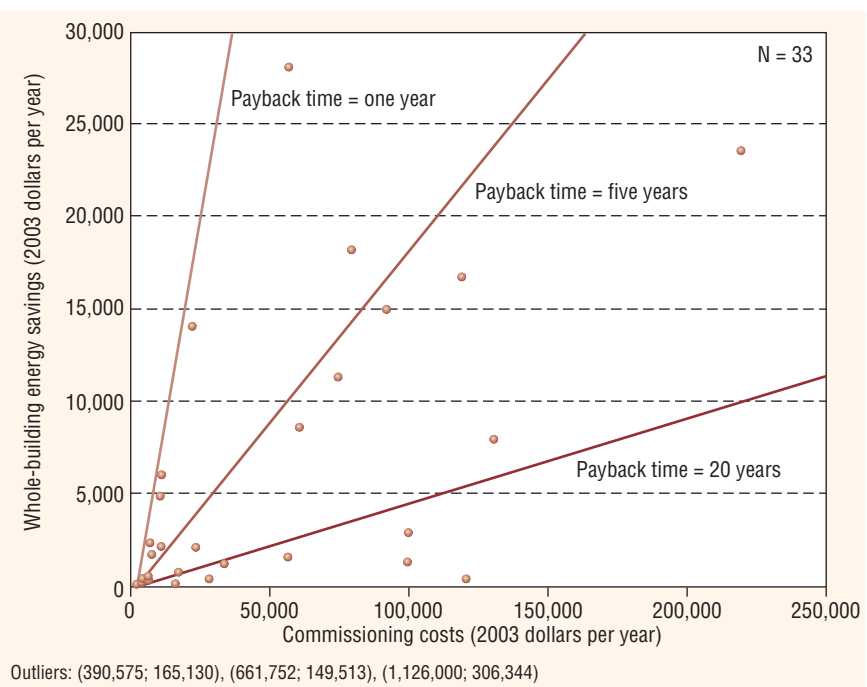

FIGURE 4. Costs, savings, and payback times of new-construction commissioning.

The most common correctional measures focused on operations and control.

Considerable differences between the results for existing buildings and new construction were found. Commissioning costs were higher in new construction, especially for larger buildings. This was reflected in the "bottom-line" results per unit of floor area—sixfold-greater energy savings and fourfold-lower commissioning costs for existing buildings. It should be noted, however, that median payback times were attractive in both cases, especially when non-energy impacts were accounted for. Larger median building floor areas in the existing-buildings sample (151,000 sq ft) tended to result in lower floor-area-normalized costs compared with the new-construction cases (69,500 sq ft). New-construction commissioning was more strongly driven by non-energy objectives, such as overall building performance, thermal comfort, and indoor-air quality, whereas existing-building commissioning was more strongly driven by energy-savings objectives. The need for commissioning in new construction was indicated by the observation that the number of deficiencies identified in new-construction exceed that for existing buildings by a factor of three.

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CONCLUSIONS

Some view commissioning as a luxury and "added" cost, yet it is only a barometer of the cost of errors promulgated by other parties previously involved in the design, construction, or operation of buildings. Commissioning agents are just the "messengers"; they are only revealing and identifying the means of addressing pre-existing problems.

Commissioning is one of the most cost-effective means of improving energy efficiency in commercial buildings. While not a panacea, it can play a major and strategically important role in achieving national energy-savings goals. If the results observed across the sample in this study are representative of the practice and potential of commissioning more broadly, significant energy savings could be achieved nationally. Specifically, if the median project performance were to be achieved over the entire commercial-buildings stock (essentially, an economic potential, not adjusted for partial penetration rates), the full cost-effective potential would amount to 15 percent of the $120 billion annual energy bill for the sector (as of 2002). This translates into savings of $18 billion annually among existing commercial buildings. In practice, the fraction of the full stock ultimately reached will depend on the effectiveness of public and private efforts to build the market for this emerging service.

As noted, the median-savings numbers certainly were less than would be achieved if all of the buildings had been comprehensively commissioned and all recommended measures implemented. The upper-quartile existing-building-commissioning savings of 29 percent was twice the median, which may be closer to a best-practice level of savings.

As buildings become more complex and utilize more advanced technologies, the incidence of problems and need for commissioning will only increase, hence, amplifying the need for and value of commissioning.

Commissioning is underutilized in public-interest deployment programs and research-and-development activities. As technologies, controls, and their applications change and/or become more complex in an effort to capture greater energy savings, the risk of underperformance will rise, as will the value of commissioning. Indeed, innovation driven by the desire for increased energy efficiency may itself inadvertently create energy waste if those systems are not designed, implemented, and operated properly. The ultimate impact of energy-efficiency research-and-development portfolios, deployment programs, and in-house energy-management initiatives lies in no small part in the extent to which they are coupled with cost-effective quality assurance (i.e., commissioning).

Commissioning is one of the most cost-effective means of improving energy efficiency in commercial buildings and can play a major role in achieving national energy goals.

REFERENCE

1) Mills, E., et al. (2004). *The cost-effectiveness of commercial-buildings commissioning: A meta-analysis of energy and non-energy impacts in existing buildings and new construction in the United States* (LBNL-56637). Available at http://eetd.lbl.gov/emills/PUBS/Cx-Costs-Benefits.html

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