Metrics for Reporting Benefits of Commissioning in New School Facilities

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Synopsis

There is ample anecdotal evidence that commissioning benefits exceed the costs, although there is a shortage of concrete documentation of the costs and benefits, or even information as to where the costs and benefits lie. Without this kind of evidence, it is very difficult to communicate to potential customers what value the commissioning service will provide, which is one of the key barriers to establishing commissioning as standard practice. The State of Texas has funded a study of the costs and benefits of commissioning of new school facilities. This study, which is ongoing, involves close investigation of two schools: one school that is being commissioned, and a similar school that was recently built without benefit of commissioning. This paper reports on the findings of the first phase of the study, which includes analysis of the performance of the baseline building and definition of metrics for reporting performance.

About the Authors

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Introduction

Commissioning

Commissioning is defined as "a quality oriented process for achieving, verifying, and documenting that the performance of facilities, systems, and assemblies meets defined objectives and criteria." It has many similarities to quality assurance efforts in other industries, although the fact that each new building is unique makes quality assurance both more important and more difficult. The Commissioning process ideally begins in the early planning stages of a building, and continues through the turnover and early occupancy. In commissioning, a Commissioning Authority (CA) coordinates, communicates, and documents efforts by others in the design and construction teams, and is a champion for quality for the owner. While commissioning, as a clearly defined process, has been available for some time, it is still far from being business-as-usual. One of the difficulties in promoting this technology is the difficulty to estimate the potential savings from commissioning, and even to estimate the cost for commissioning. It is difficult to convince an owner to spend an uncertain amount of money to purchase an unknown service with unknown savings. Any effort to rigorously document the costs or benefits of commissioning will be helpful in making this technology business-as-usual.

Interestingly, it turns out that a key to understanding the benefits of commissioning is understanding where costs are incurred in a *conventional* building. The design process, communication and management in the construction process, changes made throughout the process, and ongoing maintenance are important contributors to the cost of delivering a building. These are the kind of costs that will be affected by commissioning, so it is instructive to describe these costs in a conventional building and a commissioned building.

Approach to Investigation

This study was funded by the Texas State Energy Conservation Office (SECO), because of their interest in promoting energy efficiency technologies in buildings throughout the state, as well as their desire to ensure the appropriateness of any technologies they promote. They provided funding directly to the Northside Independent School District to pay for both the commissioning and the study. The school District, then, with money from the state as well as some of their own cofunding, contracted with the Brooks Energy and Sustainability Laboratory, who conducted the study and engaged the services of Testing Specialties, Inc., as a Commissioning Authority (CA).

The overall approach to investigating the benefits of commissioning was to commission the Mechanical, Electrical, and Plumbing systems (MEP) in a building and evaluate its performance, and to also evaluate the performance of a similar "baseline" building. Rather than conduct a statistically significant and controlled experiment, we attempted to design a more qualitative study: to identify and document the nature of the costs and the benefits in great detail, rather than to expect to prove them quantitatively. Metrics have been defined that will help in the comparison, but with a sample size of two, any generalizations will have to be drawn carefully. Table 1 describes the types of information that was collected and analyzed for this evaluation.

Table 1: Information Sources from Baseline and Commissioned Schools

Construction Documents	Specifications, as-built drawings, initial and final project schedules, change orders, requests for information, design review minutes, and construction meeting minutes. These were all used to establish a narrative description of the construction process in the baseline school, and to identify the cost and schedule impacts of issues that were encountered.
Construction Process Interviews	Interviews with key actors were conducted to interpret the documents and to provide other information as to what took place and the impacts. Interviews included the architect, NISD Construction Director, Engineering Director, Maintenance Director, and the Energy Manager.
Lessons Learned Workshop	Part of the process we are recommending for commissioning is to hold a Lessons-Learned workshop for a previously constructed facility, if applicable. Therefore, as a part of the commissioning for the new school, are holding a Lessons Learned Workshop for the baseline school. This serves a dual-purpose: to provide valuable lessons to improve the commissioned school, and to provide information for the study of benefits that would have been gained at the baseline school. We will also hold a workshop for the commissioned school (for the study, and also as input for the next commissioned school, if applicable).
Occupant Satisfaction Interviews	We conducted in-depth interviews of key personnel halfway into the first year of occupancy. These interviews helped us to identify some of the issues that occurred with the building during the "shake-out" period, while the issues were still fresh in the informants' minds. These interviews covered topics such as thermal, lighting, and indoor environment acceptability. The interviews were conducted with the school principal, several representatives of the teachers or administrative staff, and the head custodian.
Occupant Satisfaction Survey	In addition to the in-depth interviews, a quick survey was conducted of the entire school staff, covering the same topics, in order to obtain more comprehensive response. This was done at about the same time as the occupant satisfaction survey.
Work Orders	Work Order data was a source of quantitative information regarding the amount, nature, and cost of maintenance required. It will also used to evaluate and document any reduction in operating costs due to reduced maintenance. These data were obtained halfway through the first school year of occupancy, and will be reviewed again at the end of the year, and at the end of the study.
Utility Bills	Gas and electricity bills are collected by the district, and tracked in an energy accounting system. Reports were generated from this system for our analysis. These data will be used to evaluate the difference in energy intensity and costs. Data were collected after the first six months of occupancy, and on an on-going basis thereafter. They will be reviewed for the first school year of occupancy for the both schools, and for the first three school years of occupancy for the baseline school. For analysis, the energy use data were normalized for the number of days in the reading, square footage, weather, occupancy, and schedule differences.
Metered Data	Evaluating reductions in energy costs requires more detailed energy consumption data than monthly utility bills can provide. We are collecting 15-minute data for the utility meters for both schools.
Building Walk-thru	We toured the school about halfway through its first year of occupancy, with an eye towards any deficiencies in the design, installation, operation, or other factors that could affect building operation.
Observation	In addition to the qualitative and quantitative data described above, many of the benefits were documented through direct observation. The observations of the study and commissioning team were logged using a database to collect information regarding the nature of the observation, the area in which it was observed, and the expected implications of the observation. These observations were "mined" to identify the most repeated or significant issues.

This was not expected to be a study of the "best case" for commissioning. A best-case scenario would probably involve an owner who had conducted commissioning many times and design and construction teams who were already familiar with commissioning. A best case might also involve a school district where the current policies and procedures were very poor, and commissioning would prove a more significant improvement over standard practice. In this project, we were unable to implement some of the elements we considered important for commissioning, because of the need to respect the District's current procedures. Therefore, in addition to the benefits we actually observed, we identified the benefits we thought could be achieved under more ideal circumstances. The owner is considering implementing commissioning in future schools, based on only the preliminary results of this study.

In Heinemeier, et al., 2004, we describe our findings from the initial design phase of commissioning. Here we describe the findings of the analysis of the baseline school, and the definition of metrics for reporting the performance of the school, and the process for delivering the school.

Analysis of Baseline School

The study was conducted in a suburban school district in San Antonio. This is a very large school district with over 71,000 students and 88 facilities comprising over 7 million square feet. This area is growing rapidly, and bond issues of $817 million have been passed in the last decade for facility construction. Over a million square feet of facilities have been constructed within the last two years or are currently under construction.

The considerations for a baseline school were that it be recently built, have similar style, size, schedule, and mechanical systems. It would have been ideal to have the same architect, MEP designers, general contractor, and significant subcontractors. It is of course unrealistic to expect that a school could be found that would meet all these criteria. One of the most beneficial similarities would have been to have the same general contractor. Since the GC is not selected until after the design stage, it was impossible to use this as a criterion. It is not known at this point who the GC or the major subcontractors will be. The next most significant characteristic was that it be recently built, so that any differences in the district's policies and procedures would be minimal. The next most significant was that it be similar size and use. Both schools were initially designed to house 660 students, although early in the design stage a decision was made to add 140 students to the commissioned school. Both schools had the same architect, a well-respected firm in the area, who had designed no other new schools for this district, although they had done several other smaller projects. Since the same designer was designing schools with similar requirements within two years of each other, it is possible that the commissioned school would benefit from any mistakes or poor design choices that were made in the first school. Table 2 describes the characteristics of both schools, and how good of a match they were.

Table 2. Characteristics of Baseline and Commissioned Schools

Characteristic	Baseline School	Commissioned School
expected floor area	80,000 sqft	100,800 sqft
number of students	660	800
expected construction cost	$10,400,000	$11,200,000
year design was started	2001	2003
year of first occupancy	2003	2005
type of mechanical system	air-cooled chillers, air-handling units, fan-powered boxes,	same type of systems
air conditioned gymnasium	initially designed to be ventilated, conditioning added as change order	air conditioned
energy code	not applicable	IECC 2000
architect	first new school for this district	same architect
general contractor	well established with district	unknown at this time
major subcontractors	well established with district	unknown at this time

Building Construction Process

Through the commissioning process, we were able to get a sense for the standard practice for building facilities at this school district. Those observations, along with the artifacts that were collected for this baseline school (e.g., plans, change orders, punch list…) allowed us to understand the process used to build this building.

The fact that most of the construction in this district is funded by bond issues creates constraints on the construction process, and sets firm and ambitious start dates and end dates on the design and construction process. Because of the size of this district, the Facilities and Operations Division (headed by the Assistant Superintendent) is a substantial division consisting of three departments: Engineering Services, Facilities Construction, and Maintenance. Energy Management staff report directly to the Assistant Superintendent. Their typical roles in the delivery of a new facility are as follows:

- *Engineering Services*: update and publish the district's Facilities Systems Design Guide, evaluate new technologies, conduct trials of new technologies, specify sequences of operations
- *Facilities Construction:* update and publish the programmatic design guides, manage the design process, provide owners' construction management
- *Maintenance:* trade-specific supervision of maintenance staff, manage work-orders, oversee Energy Management Control System
- *Energy Management:* engage with other departments to improve energy performance of facilities, implement scheduling of facilities, evaluate energy efficiency technologies.

Staff from all four areas are engaged in all phases of the design and construction.

Design Guides. The district has a very detailed set of documents that comprise the design guide that serves as the master specification. Staff from different departments have different opinions

on the appropriate level of specificity to be provided in this guide, and they attempt to provide a balance between providing enough specificity to ensure consistency across schools to facilitate maintenance, and providing enough latitude to allow designers to design the best solutions for the particular school. The design guide is periodically updated with input from a range of stakeholders, although the district admits that the guide is very much out of date. It is now in the process of being revised. The results of this study may provide input for this revision.

Pre-Design. The district planners make the determination as to where new schools are to be built, and the number of students to be accommodated there. Because of the dramatic growth in population in this part of the city, it is not uncommon for schools that are only 1-2 years old to be supplied with portable classrooms. Accommodation is made in the site layout for adding these portables. The design guide provides most of the information needed for programming of a new school, although a particular school may have its own requirements, such as the number of special education classrooms or computer labs, or the library facilities. In addition, the district has evolving requirements such as increasing needs for security lighting, or a policy to provide air-conditioned gymnasiums. These considerations are made in the very early planning stages and communicated to the designers. A review of the 35% Schematic Design—which includes any of these special considerations, political issues, and site plans and renderings—is held with the design team and the owner's representatives, and the Board of Trustees approves the concepts at this stage. Decisions such as exterior materials and roof color are made at this point.

Design. During the design phase, there is periodic interaction between the design team and the owner's construction staff. A design review is held at the 65% complete stage. Although the district has clear requirements as to the level of completion expected at this stage, it is very common that the MEP design will greatly lag the architectural design: the engineering designers are hesitant to put much time into details of the design when major elements of the architectural design are still in flux (for example, any preliminary load calculations done at this point would have to be redone). This design review is typically attended by representatives of each of the design disciplines, and by representatives of all four Facilities and Operations areas. At this meeting, the design is laid out on a table, the designer presents the key elements, and the most affected owner's representatives view the plans and make comments. The logistics of this type of review (i.e., inability of more than one or two people to view the drawings at a time) make the review somewhat difficult. The 95% complete design review is intended to review a complete design for any integration oversights. However, in practice, it is really the first opportunity for review of the detailed MEP designs. The date on which the project will go out to bid is set in advance of the completion of the design, so the plans must be issued regardless of the status of any review comments. What this means in practice is that issuing an addendum shortly after the release of the design is common. This makes review of the final design very time constrained.

Construction. The director of the Facilities Construction department serves as the Construction Manager for the project, and construction inspectors within that department provide much of the day-to-day oversight of the project. While the district does not have a commissioning process in place, they feel that they get the most out of the contractors due to their size and the contractors' desire for future work with the district. During the construction process, there are key times when the Maintenance Managers are invited to tour the site, so that they can see where

equipment is before it is covered up by walls and ceilings, and so that they can provide any necessary feedback on the facility. Unfortunately, this process has not worked well: the tours are scheduled at the last minute, so that the Maintenance staff is sometimes unavailable, and the comments made by the Maintenance staff have not always been constructively communicated. Bi-weekly construction meetings are held, and very clear logs are maintained of requests for clarification, requests for information, proposed and accepted change orders.

Completion. The design guide/specification includes some criteria for completion of the project, but they are not located in a single location in the spec, and the process for evaluating them and for identifying what will take place if the criteria are not met is not clear. O&M Manuals are routinely provided, although the spec does not include requirements for what is to be included, and they are not always consistent from project to project. Training is also somewhat ad hoc: the requirements for training are not made clearly and in sufficient detail in the spec. Very detailed site inspections and punch lists are created at the end of the project.

Occupancy. After substantial completion, the school staff begins occupying the building. At this point, the maintenance staff maintains a make-ready list and supports activities to get the building ready for school to start. A very big focus is put on the school dedication, approximately three months into the first year of occupancy, and all departments engage in activities to ensure that the building will be at its best on that one day. The Maintenance department has a Computerized Maintenance Management System, and all work orders are issued through that system and logged. The district has in the past held post-occupancy evaluations and lessons learned workshops, although now that the pace of construction has picked up, this is not common practice.

Metrics for School Performance

How well did this process work at this school? Overall, the baseline school is a very good school. The occupants are very happy with the school, and its energy performance is good. In reviewing the artifacts created during the school design and construction, several key metrics can be defined. They are discussed here, although their significance will be much more evident when the analogous metrics are available for the commissioned school, for comparison.

Requests For Information. The Request for Information is the formal mechanism for the contractor or subcontractors to ask for clarification on a design element, to comment on items that may not work as designed, or to suggest an alternative design or specification. RFIs are submitted during a construction meeting, a date for clarification is requested, and a response is issued. All of these steps require paperwork, tracking, and some amount of time at a construction meeting to discuss or resolve. For example, even a simple RFI may take a half hour to prepare, 10 minutes to discuss at a construction meeting with 10 individuals in attendance, and 10 minutes at the next meeting to discuss the results. This equates to almost four person-hours of effort.

RFIs can be the result of unclear designs, inappropriate designs, incomplete understanding of the documents by the contractor, or understandable improved perspective of the contractor once the

building is underway. Hence, RFIs can be seen as a negative (unclear or incorrect design), or as a positive (everyone working as a team to come up with the best design). It can be expected that commissioning will facilitate the design review and construction communication processes, so that unnecessary RFIs can be reduced and constructive RFIs can be facilitated.

At this school, there were 92 RFIs submitted, of which 22 were related to MEP. The number of days in review for the MEP related RFIs ranged from 0 to 32, with an average of 9 days. Of these RFIs, several resulted in change orders, and it appears that several of the issues could have been addressed during the design stage.

Change Orders. Change Orders accommodate situations where the work required by the contractor is different from what was assumed during the bidding process. This can be due to unforeseen circumstances (such as unforeseen conditions at the site), a change in requirements by the designer or owner (such as a desire to add new equipment), or a response to an RFI. In this district, the project budget includes a contingency allowance to pay for any change orders that arise. When a proposed change order is issued, the contractor is asked to provide a proposal to supply the additional labor and materials. If accepted, the cost is either deducted from the contingency allowance, or added to the contractors contract.

This construction project had approximately 90 change orders. Of these change orders, 37 were related to MEP, at a cost of almost $95,000, or about 1% of the entire construction cost. Table 3 shows the cost of the change orders. There were several categories of change orders that are notable.

Table 3: Cost of MEP-Related Change Orders at Baseline School, by Category

	Number of Change Orders		*Cost of Change Orders*
drainage in playground	4	$	43,577
gym air conditioning	2	$	24,322
misc PLUMBING	10	$	11,099
misc ELECTRICAL	10	$	4,820
misc HVAC	3	$	3,693
plumbing/HVAC conflicts	1	$	3,556
ventilation for electrical room	1	$	2,497
misc FIRE/SECURITY	2	$	1,409
pressure valve	1	$	-
weatherstripping on doors	1	$	-
library dehumidifier	2	$	-
TOTAL	**37**	**$**	**94,973**

- *Drainage in the Playground:* There were considerable problems with the drainage at the facility, particularly in the playground. Several options were considered to remedy the problem, and the final cost was significant.

- *Air Conditioning in the Gym:* During the course of this construction process, the district enacted a policy change to provide air conditioning to gymnasiums. Therefore, there were significant changes made to the design of the system: adding an air-handling unit for the gym, deleting the ventilation system, and adding capacity to the chillers. The amount of paperwork to accomplish this was significantly higher than if it had been included in the original design. While commissioning could not have foreseen this change in the requirements, the necessary response is an indication of what is required when a significant system change is added at the last minute.
- *Vestibule Conflicts:* An RFI was issued due to conflicts with the water, waste piping, and ducting in vestibule that joins two wings of the school. This kind of conflict should be able to be avoided by commissioning in the design phase.
- *Ventilation for Electrical Rooms:* Late in the construction stage, the design was changed to provide ventilation for electrical rooms. This change was interesting because there is very good documentation in the records as to the penalty for adding an item such as this as a change order rather than in the original design. The costs that appear to be required only because of the fact that it was issued as a change order represent about 41% of the price. The details of the costs are shown in Table 4 below.

Table 4: Additional Costs for Providing Ventilation as a Change Order

Prepare Opening in SR Ceiling	Sheet Metal Labor: Reassignment of Manpower
Touch up Painted Ceiling	Sheet Metal Labor: Concurrent Operations
Material Handling	Sheet Metal Labor: Beneficial Occupancy
Clean Up	Sheet Metal Labor: Site Access
PM Coordination Time	Coordination
Estimating Time	Drafting/As-Built Drawings
Field Clerk	Testing
As-built & Shop Drawings	Administrative fee

- *Pressure-Reducing Valve:* A pressure-reducing valve was installed as a change order after occupancy due to several problems with the plumbing (see Occupant Interviews).
- *Weather-stripping:* Weather-stripping was added to several exterior doors as a change order after occupancy due to leaks (see Occupant Interviews).

Punch List. The punch list is the result of an on-site inspection, including both contractors and owner's representatives, near the end of the construction phase. Any last items that are not complete are noted, and a long list is created. All of these items must be completed prior to as a part of Substantial Completion. At the point of creating and working through the punch list, the contractors are typically very eager to be complete on the project, and the owner is very eager to take possession of the building, so it is tempting on both sides to overlook issues that should be resolved. Needless to say, everybody is happier when these issues are dealt with earlier in the project, and not left until this date to be raised.

At the baseline school, "punch lists" include both Above-Ceiling Inspections and a final punch list. Table 5 summarizes the issues identified in the inspections. There were a total of 214 issues identified at the above-ceiling inspections, and 372 in the punch list. On average, there were about two and a half issues noted in each room at each of the inspections. The comments range

in severity from "caulk around temperature sensor" and "clean light fixture lenses" to "the light fixture is not operational" and "replace the damaged supply air device" and "The installed flexible conduit system is not acceptable. Properly replace all fan final connections with [another form of] conduit". Most of the items are simply the final steps in completing a project, and one would not expect them to be complete prior to the inspection. There are other items, however, that could have been averted with more of a quality assurance process during the design or construction phases.

Table 5: MEP-Related Punch List Issues at Baseline School

	Above Ceiling Inspections		Final Punchlist	
	Total Issues	*Avg. Issues / Room*	*Total Issues*	*Avg. Issues / Room*
Building A	69	3.0	82	2.5
Building B	30	2.0	41	1.5
Building C	59	2.2	56	1.7
Building D	56	4.7	109	3.9
Mechanical Rooms	-	-	84	8.4
TOTAL	**214**	**2.6**	**372**	**2.8**
GRAND TOTAL	**586**	**2.7**		

Occupant Interviews and Surveys. We obtained information about the performance of the school from the occupants in two separate ways: in a survey of all staff members, and in an interview with the Principal and the Head custodian.

The survey was administered at a staff meeting, where our team described the study briefly, and handed out a one-page survey, which asked the following questions:

> The District is studying new ways to design and construct school heating, cooling, ventilation, electrical and plumbing systems. In relation to these systems, please provide a description of any problems you have encountered at this school since it opened. For each category (Health, Comfort, Equipment reliability, Time to get problems fixed, Interruptions when repairs are done, Energy waste, Other), please describe the problem in detail, indicate how severe (Noticeable, Inconvenient, or Disruptive), indicate how frequent (Daily, Weekly, or Monthly), and indicate whether problem was ever resolved. Also indicate your job category (teacher, food service, librarian, administration, custodian, and other).

Unfortunately, the teachers did not provide much input. The survey was administered just prior to the winter break, which probably contributed to the teachers' lack of input. The most complete response was from the Head Custodian.

We asked essentially the same questions during an interview of the Principal and the Head Custodian, and received much more complete response. Following are the issues raised during this interview:

- *Air Conditioning in the Gymnasium Did Not Work:* Upon occupancy, the temperature in the gym was acceptable, but about a month into the school year, the system began humidifying the air, and the conditions were very hot and muggy. Teachers and parents

were complaining about the conditions, and the doors were propped open to get fresh air. It took over a month to get the problem resolved.

- *Problems with the Plumbing System:* There were a number of problems that apparently were related to extreme pressure in the pipes. A pipe burst in one classroom over a weekend, causing flooding of about 4 classrooms. This required moving several classrooms of kids temporarily, and a big cleanup effort. There were also problems with noisy toilets, a burst irrigation pipe that resulted in a flooded field, and water fountains working improperly.
- *Window and Door Leaks:* There was a problem with the way the windows were installed, and most of the windows leaked. The contractor had to return to the school and re-caulk all of the windows. Also, there was no weather-stripping on some of the exterior doors, causing a large leak and water running down the corridor.
- *Premature Ballast Failures:* The fluorescent light ballasts were failing at an unacceptable rate, causing the District to replace all of the ballasts.
- *Dusty Rooms:* Some of the classrooms were very dusty, even immediately after dusting. It appeared that the contractors did not remove the air-filtering media after construction, as required.

Most of these issues could have been avoided with commissioning.

Work Orders. We obtained a log of all work orders for the baseline school about midway through the first year. The work order log includes 278 items total, with an associated cost of about $10,000 for materials and $23,000 for about 1400 hours of labor (including both contractor and M&O Department personnel). For just MEP-related issues, there were 122 items, with a cost of about $1,600 for materials and $7,500 in labor (400 hours). The issues included in this list include items such as preventive maintenance, routine maintenance repair, and warranty issues. These data are summarized in Table 6.

The work orders issued include work such as addressing the problems with leaking water, the AC in the gym, and the ballasts, which were reported by the occupants. Other items include work related to getting the school ready for occupancy and for the dedication, and hot and cold calls. Some of the issues that had to be addressed, particularly the warrantee issues, and the routine maintenance issues, could have been avoided with commissioning.

Table 6: MEP-Related Work Orders at the Baseline School

	Number of Work Orders		*Cost of Work Orders*
Routine Maintenance	65	$	7,088
Preventive Maintenance	27	$	898
Warranty Issues	18	$	-
Vandalism	5	$	537
Contractor Support for Projects Not Initiated by Maintenance	5	$	466
New Work	2	$	60
TOTAL	**122**	**$**	**9,049**

Utility Bills. We obtained the utility bills for the baseline school, and information about the district's average energy use.

Figure A shows the energy consumption for the first six months of occupancy. The average monthly energy use is about 5.1 kBtu/square foot: 4.0 kBtu/sqft for electricity, and 1.2 kBtu/sqft for gas. Monthly energy costs were about 9 cents per square foot, or about $7,200. For comparison, the school is using somewhat less than the 5.7 kBtu/sqft average for an educational building in the southern part of the US from CBECS 1999. The average monthly use so far is somewhat higher than the 3.9 kBtu/sqft average for elementary schools in this district, although it is likely that the average will be somewhat lower when a full year of data are available. On the other hand, one might expect this school to use more energy than other elementary schools in the district, since it is the first to have an air-conditioned gymnasium.

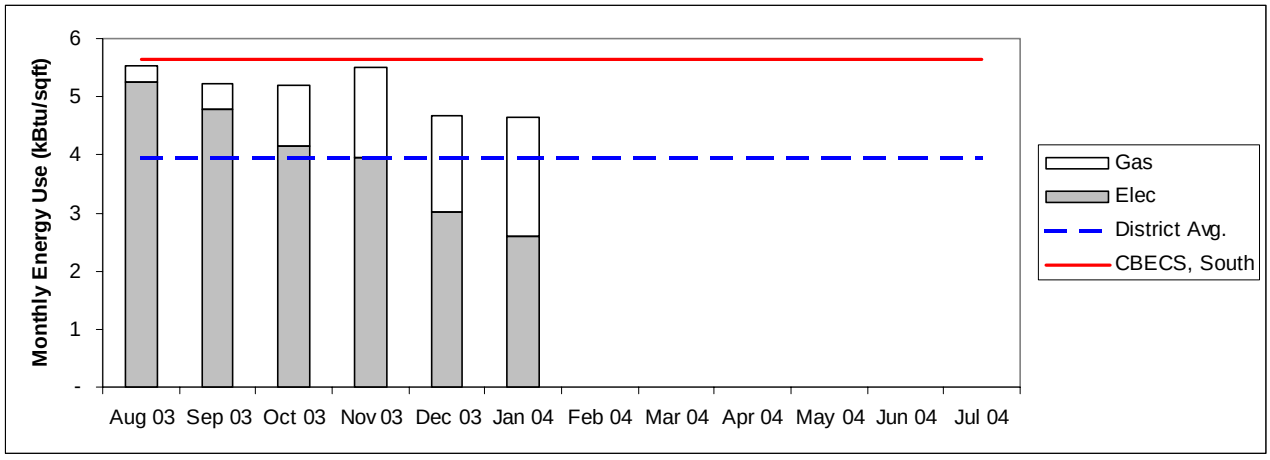

Figure A: Energy Consumption for Baseline Building During First Year of Occupancy

Summary and Recommendations

In considering the benefits of commissioning, one must remember that performance is more than energy use. It is more than post-occupancy occupant satisfaction or maintainability. Performance can be construed to apply to the design and construction processes as well, since some of the most significant benefits from commissioning will be realized in the streamlining of these processes.

We have described in great detail the process of designing, constructing, and maintaining one school facility in San Antonio, Texas. In doing so, we have defined metrics to describe the impacts of these processes. We hope that these metrics will be useful in comparing the performance of this school to the performance of the commissioned school, so that we can identify and quantify the benefits of commissioning of the new school. We have also described the process of collecting and evaluating these metrics.

Table 7 summarizes the preliminary metrics described in the earlier sections. To facilitate comparison of the metrics with other facilities, all the metrics have been normalized in a reasonable way—by floor area or by construction cost—and only MEP-related items were included. After we have completed commissioning of the new school facility, we will compile these same metrics and compare the performance of the two schools. We hope to find significant improvements in some of these factors.

Table 7: Summary of Metrics for MEP-Related Performance of Baseline School

RFIs	Number of MEP-Related RFIs (per 10,000 sqft)	2.6	
	Average Number of Days in Review	9	
Change Orders	Number of MEP-Related Change Orders (per 10,000 sqft)	4.4	
	Cost of MEP-Related Change Orders (% of Construction Cost)	0.9%	
Punchlist	Average Number of MEP-Related Punchlist Issues per Room	2.7	
Post-Occ Eval.	Number of Significant MEP-Related Issues Identified in First Year	5	*
Work Orders	Number of MEP-Related Work Orders in First Year (per 10,000 sqft)	14.5	*
	Cost of MEP-Related Work Orders in First Year (per 10,000 sqft)	$1,079	*
Energy Use	Electricity (annual kBtu/sqft)	23.7	*
	Natural Gas (annual kBtu/sqft)	7.0	*
		* = first six months	

The results are by nature anecdotal, since only two buildings will be included in the study. However, the metrics we have defined may be helpful in comparing different construction processes. We believe that the definition of metrics is a key advancement of the industry, because it will allow for more precise statement of expected or achieved savings. We hope that others in the industry will take the time to document the benefits of commissioning, so that other owners will better understand the benefits they can achieve through commissioning, and will not perceive this process as an unknown. Providing a protocol for documenting the benefits of commissioning, as has been done by the California Commissioning Collaborative, is essential in creating a more compelling set of evidence. We hope that the study described here will provide additional suggestions for metrics to be included in future protocol development efforts, and we support the concept of developing a nationwide case-study database to document such performance improvements.

References

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