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COMMISSIONING EXISTING BUILDINGS

Joan Gregerson

SUMMARY

Recent field data indicate that existing buildings can be commissioned for 5¢ to 40¢ per square foot, often resulting in whole-building energy savings of 5 to 15 percent and paybacks of two years or less.

The best targets for commissioning are buildings with deferred maintenance, buildings with high per-square-foot energy costs, or buildings such as medical institutions or research facilities. Yet, even some relatively efficient buildings, with annual energy costs of under $1 per square foot, have been commissioned with paybacks of under one year.

Though more detailed research and measurement is necessary, the results to date indicate that commissioning deserves the attention of building owners, utilities, and other energy service providers, as a potentially promising business opportunity.

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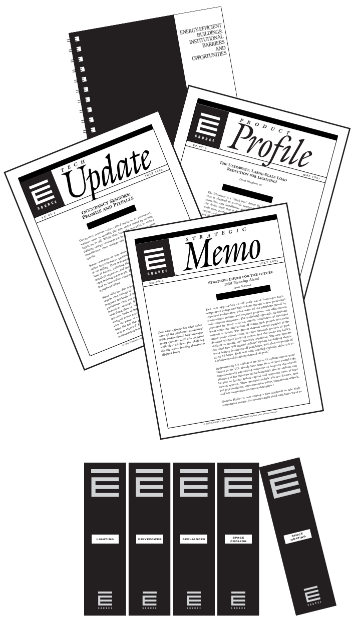

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E SOURCE, INC.
1033 Walnut Street
Boulder, Colorado 80302-5114 USA
Telephone 303.440.8500
Facsimile 303.440.8502
E-mail esource@esource.com
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COMMISSIONING EXISTING BUILDINGS

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Utilities and facility managers often dismiss the concept of commissioning existing buildings because they assume this strategy's benefits are not worth its cost and effort. However, recent field data indicate that payback periods for commissioning can be as good as—or better than—those of capital-intensive efficiency measures. Also, commissioning existing HVAC systems can yield substantial nonenergy benefits, such as improved occupant comfort and indoor air quality, and solutions to chronic maintenance problems.

Payback periods for commissioning can be as good as—or better than—those of capital-intensive efficiency measures.

The field test results described in this report appear promising, but they are incomplete. In most cases, either the commissioning cost or the savings were *estimated* (rather than measured). More research and analysis will be required for service providers to rigorously assess the cost-effectiveness of commissioning existing buildings, and identify the best approaches for various situations.

Business Opportunities from Commissioning

Commissioning existing buildings offers clear and present opportunities for commercial building owners and energy service providers. However, utilities are likely to encounter obstacles when trying to sell such services to commercial customers on a fee-for-service basis.

Commissioning Existing Buildings

Commissioning is the process of ensuring that a building performs according to its design intent and its owner's and occupants' needs. When applied to existing buildings, commissioning focuses on improving the operation and maintenance of building equipment. Usually the scope of such commissioning is limited to the HVAC system, but lighting also may be included.

Typically, commissioning involves identifying problems and then implementing changes (such as fixing inoperative valves, dampers, or other equipment; or optimizing control sequences and/or schedules). In addition, this process often includes tracking energy usage—which helps in diagnosing deficiencies and documenting long-term savings.

Successful commissioning efforts depend not only on a deep understanding of building systems, but also on a firm grasp of how *people* work—and how they interact. Strong interpersonal communication skills can help commissioning agents work successfully with facility staff while questioning and improving the staff's standard practices. Poor communication can lead to mistrust and misunderstandings that can hinder or derail the commissioning process, or create inaccuracies in the results.

The Building Owner's Perspective

Commissioning existing buildings often delivers simple paybacks of two years or less.

For commercial building owners, the true value of commissioning existing buildings becomes apparent when comparing this strategy to conventional energy efficiency improvements, such as retrofits. On this basis, commissioning often ranks as one of the best opportunities. This is because it has a relatively modest project cost (usually $10,000 to $50,000), and it typically results in whole-building energy savings of 5 to 15 percent or more (see page 4). For an investment of 5¢ to 40¢ per square foot, commissioning existing buildings delivers simple paybacks that rarely exceed four years—and are often just two years or less. Upon realizing this, some building owners take action to obtain these benefits all the time by becoming more serious about auditing and preventative maintenance (see box below).

The Utility Perspective

For utilities, commissioning existing buildings may be a way to offer a service their customers need, while making a small profit. However, the few utilities that have commissioned existing buildings on a fee-for-service basis so far have faced obstacles—such as the customer's lack of familiarity with commissioning, or regulations prohibiting utilities from selling fee-based services.

Southern California Edison (SCE) has commissioned about a dozen existing buildings to date as a stand-alone efficiency measure. Most of these have been demonstration or research projects.[1] Recently, SCE began to offer commissioning as one of several fee-for-service measures for commercial customers. So far, no SCE customer has signed up for commissioning services (although

Nordstrom Continuously Strives for Optimal Building Operation

In a 1994 demonstration project, Southern California Edison (SCE) commissioned seven buildings (free of charge to the owners), including a 170,000-square-foot, four-year-old Nordstrom retail store. This particular store had a history of chronic operation and maintenance problems.

A total of 21 operation and maintenance deficiencies were identified and corrected in this building during the commissioning. SCE spent 30¢ per square foot for this project, which produced estimated annual energy savings of 25¢ per square foot.[2] Had Nordstrom paid for the commissioning project, it would have resulted in a cost-effective 1.2-year simple payback. Nordstrom was impressed with these savings, and also with how commissioning worked as a tool to identify and correct deficiencies in the store's operation.[3]

Nordstrom and SCE discussed the possibility of commissioning other Nordstrom facilities on a fee-for-service basis. However, Nordstrom decided to optimize its operations through internal programs (audits and extensive preventive maintenance), rather than pay for a utility service. The goal of this strategy is to provide customer comfort while *continuously* optimizing energy efficiency.[4]

some customers have purchased other services such as simulations, instrumentation, and load profile or end-use studies). According to SCE, this is because most customers are unfamiliar with the definition, scope, and track record of commissioning and its practitioners—thus, they are hesitant to commit to it. SCE expects this hesitation to fade as customers grow more familiar with—and confident about—commissioning. The utility also expects that commissioning eventually will be perceived as a logical next step for customers who currently use other services, or as a precursor to the monitoring and verification of retrofits.[5]

Some utilities have had a more positive reaction from customers. For instance, based on the results of its pilot program for commissioning existing buildings, the New England Electric System Companies (NEES) concluded that it would not be very difficult to sell commissioning of existing buildings on a fee-for-service basis. NEES contends that the primary appeal of this service is its low cost (relative to other efficiency measures).[6]

NEES' pilot program included three existing buildings: a convention center, an office building, and a one-year-old college computer science facility. The utility found that this type of service could be priced to deliver a simple payback of less than two years for its customers, while offering a reasonable profit for the utility. An added bonus of this program was that the utility gained an opportunity to strengthen working relationships with customers.[7]

Today, though, a formidable obstacle is blocking NEES' commissioning service efforts. An order recently issued by the Massachusetts Department of Public Utilities prohibits the utility—at least temporarily—from offering fee-based services to its customers.[8] Utilities facing such regulatory barriers could consider offering commissioning services through unregulated subsidiaries.

Commercial building owners interviewed by E SOURCE indicated that utilities may have an advantage in offering commissioning services—as long as customers can pay the cost of this service through their utility bills.[9] This approach would help minimize commissioning's transaction cost by avoiding the expense, complexity, and waiting usually involved when securing internal or third-party funding. In fact, according to NEES, one customer was willing to buy the commissioning service *only* if the cost could be charged on its utility bill.[10] (This was before regulations prohibited NEES from providing this service.) NEES envisioned several possible billing strategies, including a minimum basic charge, or shared savings paid monthly for about two years.

Utilities may have an advantage in offering commissioning services if the cost can be put on the customer's bill.

The State of Tennessee is discussing a similar concept with the Tennessee Valley Authority (TVA), which seeks to offer energy services to its customers. The state hopes that TVA (in conjunction with local utilities) will be able to offer commissioning services to all state-owned buildings by adding a charge to the utility bill.[11]

The best commissioning targets are buildings with deferred maintenance, energy-intensive buildings, and medical or research facilities.

The ESCO Perspective

Most ESCOs *rely* on the fact that buildings often are not operated optimally. One ESCO employee put it this way: "That's our business—taking an existing building and making it work better."[12]

Nonutility energy service providers have long offered commissioning of existing buildings (usually bundled with other measures) through shared-savings contracts. Often, as a "controls" measure, ESCOs fix improperly functioning controls and optimize schedules. If savings begin to lag because owners or occupants change optimized settings, the energy service provider can ensure the guaranteed savings level by enforcing the agreed-to control settings.[13] Aggressive commissioning of existing buildings also can benefit companies which offer facilities management services—especially if they are paid through shared savings.

Economics: Promising Field Results Show Good Payback Potential

Recently, several projects have demonstrated the cost-effectiveness of commissioning existing buildings. These are summarized in **Table 1**. The best targets for commissioning offer paybacks of two years or less. Based on our analysis of these projects, here are what E SOURCE believes to be the best targets for commissioning:

- buildings with deferred maintenance (where optimized operation has not been a high priority),

- energy-intensive buildings (annual total energy costs greater than $2 per square foot), and

- medical or research facilities (which tend to require large amounts of outside air and have long operating hours).

Unfortunately, *only a few of the case studies E SOURCE has identified offer both measured savings and measured commissioning costs.* For several projects, costs were known but savings were estimated; in some cases (particularly the Texas LoanSTAR buildings), savings were known, but per-building costs had to be estimated. The rigor with which savings were calculated varies significantly from one building to the next, so caution is in order when comparing these results.

Savings

In the context of this report, "commissioning savings" includes only reductions in energy costs. There can be other savings. For instance, sometimes commissioning can save the building owner money by avoiding the installation of new or additional equipment.

Sometimes commissioning can save the building owner money by avoiding the installation of new or additional equipment.

Savings attributable to commissioning can be difficult to quantify. Savings from buildings commissioned by Texas A&M University's Energy Systems Laboratory (see box, page 8) and Portland Energy Conservation Inc. (PECI) were calculated rigorously using monitored data and engineering models', but for several projects commissioned by others, savings were estimated less rigorously. The important point demonstrated by the available data is that *per-building savings from commissioning vary widely*. For the buildings in Table 1, measured and estimated energy cost savings ranged from less than three percent to more than 40 percent, with an average of 19.2 percent. **Figure 1** indicates that the percentage of savings (as a percentage of the total pre-commissioned annual energy cost) may depend—at least in part—on the *type* of facility being commissioned.

Costs

The commissioning costs for the projects included in our analysis include:

The cost of commissioning is not *strongly related to a building's size or age.*

- the cost of the commissioning agent's time,
- monitoring costs (if any), and
- the cost of implementing operations changes if performed by outside contractors, or if additional facility labor or materials are required. This includes costs for contractors' time or overtime charges for facility staff (usually incurred when performing substantial changes, such as a major equipment overhaul or retrofit),[14] but excludes facility staff time during normal working hours (for instance, for simple measures such as valve replacement).

Most of the buildings in Table 1 cost about $10,000 to $30,000 to commission. The most expensive project, 203 N. LaSalle Street (see box, page 9), cost $80,000 but still resulted in a six-month payback. This particular project included a $45,000 overhaul of the air-handling system—a costly measure unlikely to be included in most commissioning projects.

Table 1: **Summary of recent cost and savings for commissioning existing buildings**

Recent commissioning projects are summarized here. This table includes only projects for which measured or estimated data was available for both costs and savings.

Commissioning performed by	Project funder	Building name or location	Monitoring hardware	Ending date	Building type	Building area (ft^2)	Pre-commissioning energy cost ($\$/ft^2/yr$)
PECI	U.S. EPA & U.S. DOE	Oregon	Portable logger	1995	Office	278,000	1.25
		Tennesse: Citizen's Plaza	Portable logger	1995	Office	250,000	1.81
		Arizona	Portable logger	1995	Office	80,000	1.95
		Colorado	Portable logger	1995	Retail	122,000	0.88
		Massachusetts	Portable logger	1995	Retail	107,000	2.40
Herzog/Wheeler	Building owner	High-tech research facility	Portable logger	1984	Research facility	44,000	4.35
Sieben Energy	Building owner	203 N. LaSalle St.	One-time tests	1995	Office	623,000	1.28[e]
Texas A&M ESL	Texas LoanSTAR	*State Capitol Complex*					
		Capitol Building	Long-term logger	1996	Computer facilities/Office	282,499	1.63
		S.F. Austin Building & CP	Long-term logger	1993	Computer facilities/Office	470,000	1.24
		John H. Reagan Building	Long-term logger	1996	Computer facilities/Office	169,756	1.56
		Insurance Building	Long-term logger	1996	Offices	102,000	1.28
		Archives Building	Long-term logger	1996	Libraries	120,000	0.37
		Starr Building	EMCS & portable	1995	Office	99,000	2.16
		Central Services Building	EMCS & portable	1996	Office	100,000	n/a
		State Preservation Board					
		Capitol Extension	Long-term logger	1996	Computer facilities/Office	592,781	0.84
		U.T.H.S.C. Houston					
		School of Public Health	Long-term logger	1994	Medical institution	233,738	1.62
		Medical School Building	Long-term logger	1994	Medical institution	887,187	3.16
		Texas Department of Health	Long-term logger	1995	Medical institution	298,700	1.54
		Fort Worth ISD					
		Sims Elementary School	Long-term logger	1994	School districts	62,400	0.79
		Dunbar Middle School	Long-term logger	1993	School districts	92,884	1.41
		U.T. M.D.A. Cancer Center					
		Boiler Room	Long-term logger	1994	Medical institution	412,872	1.72
		Basic Research	Long-term logger	1994	Medical institution	120,376	3.77
		Old Clinic & Lutheran Pavillion	Long-term logger	1994	Medical institution	499,013	2.05
		New Clinic	Long-term logger	1995	Medical institution	276,466	1.59
		UTMB Galveston					
		John Sealy North	Long-term logger	1993	Medical institution	54,494	6.61
		Clinical Sciences	Long-term logger	1995	Medical institution	124,870	2.83
		Basic Sciences	Long-term logger	1993	Medical institution	137,856	4.00
		Moody Memorial	Long-term logger	1994	Libraries	67,380	2.48
		John Sealy South	Long-term logger	1994	Medical institution	373,085	2.48
	Bay City	Bay City Courthouse	Portable logger	1996	Office	65,000	n/a
	Texas A&M University	Reed McDonald	Long-term logger	1996	Office/Classroom	77,435	n/a
		Large Animal	Long-term logger	1996	Medical institutions	140,865	n/a
		Research Facility	Long-term logger	1996	Office/Classroom/Lab	114,666	n/a
		Heep Center	Long-term logger	1996	Office/Classroom/Lab	158,979	n/a
		Richardson Petroleum	Long-term logger	1996	Office/Classroom	113,700	n/a
		Kleberg	Long-term logger	1996	Office/Classroom/Lab	165,031	n/a
		Harrington Tower	Portable logger	1996	Office/Classroom	90,000	n/a
		Small Animal	Portable logger	1996	Medical institution	150,000	n/a
PECI	Southern California Edison	—	Portable logger	1994	Retail	146,000	2.09
		—	Portable logger	1994	Office	152,000	1.64
Note: Energy cost, savings, and simple payback include electricity only for these six buildings.		Nordstrom	Portable logger	1994	Retail	170,000	2.26
		—	Long-term logger	1994	Office	48,000	1.25
		—	Long-term logger	1994	Office	50,000	1.82
		—	Long-term logger	1994	Office	120,000	1.45

Commissioning cost ($)	Commissioning cost ($/ft^2)	Energy cost savings ($/yr)	Energy cost savings (% of total cost)	Simple payback (years)
12,745 [a]	0.05	8,145	2.3	1.6
23,967 [a]	0.10	42,045	9.3	0.6
14,546 [a]	0.18	16,194	10.4	0.9
11,310 [a]	0.09	13,779	12.8	0.8
12,801 [a]	0.12	8,042	3.1	1.6
14,000	0.32	59,840	31.3	0.2
80,000	0.13	150,000 [d]	18.8	0.5
24,000 [b]	0.08	88,812	19.2	0.3
28,000 [b]	0.06	30,385	5.2	0.9
24,000 [b]	0.14	50,680	19.2	0.5
24,000 [b]	0.24	14,823	11.3	1.6
24,000 [b]	0.20	9,867	22.5	2.4
20,000 [b]	0.20	48,000 [c]	22.5	0.4
15,000	0.15	8,000 [c]	n/a	1.9
28,000 [b]	0.05	89,758	18.0	0.3
24,000 [b]	0.10	63,502	16.8	0.4
28,000 [b]	0.03	879,101	31.4	0.0
24,000 [b]	0.08	11,550	2.5	2.1
20,000 [b]	0.32	14,310	29.0	1.4
24,000 [b]	0.26	11,802	9.0	2.0
28,000 [b]	0.07	154,660	21.8	0.2
24,000 [b]	0.20	208,857	46.1	0.1
28,000 [b]	0.06	397,749	38.8	0.1
24,000 [b]	0.09	209,164	47.5	0.1
20,000 [b]	0.37	177,984	49.4	0.1
24,000 [b]	0.19	23,638	6.7	1.0
24,000 [b]	0.17	235,151	42.7	0.1
20,000 [b]	0.30	35,064	21.0	0.6
28,000 [b]	0.08	176,904	19.1	0.2
10,000	0.15	6,000 [c]	n/a	1.7
24,000 [b]	0.36	40,000 [c]	n/a	0.6
24,000 [b]	0.20	226,000 [c]	n/a	0.1
24,000 [b]	0.24	144,000 [c]	n/a	0.2
24,000 [b]	0.18	65,000 [c]	n/a	0.4
24,000 [b]	0.25	60,000 [c]	n/a	0.4
24,000 [b]	0.17	395,000 [c]	n/a	0.1
5,000	0.21	12,000 [c]	n/a	0.4
5,000	0.17	25,000 [c]	n/a	0.2
41,555	0.28	21,900 [d]	7.4	1.9
45,065	0.30	12,160 [d]	5.2	3.7
52,336	0.31	42,500 [d]	11.2	1.2
16,634	0.35	16,320 [d]	27.0	1.0
21,713	0.43	11,000 [d]	12.2	2.0
16,454	0.14	3,600 [d]	2.4	4.6

The data in this table is presented graphically in Figures 1, 4, and 5.

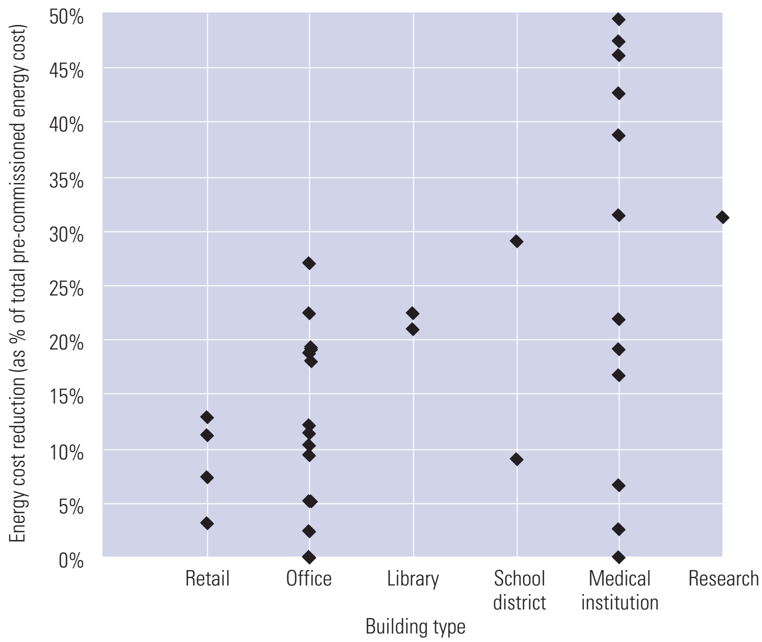
Notes:
n/a - information was not available
a: Commissioning cost included facility staff time for these buildings. This amount was not included in the costs of other projects.
b: Commissioning cost per building is estimated for these buildings, based on known *project* cost (which included several buildings).
c: Annual commissioning savings is projected, based on measured savings for less than a full year.
d: Savings were estimated from utility bills and/or simplified engineering calculations for these buildings.
e: Energy cost excludes cost of tenant lighting and plug loads for this building.

Sources: Various, as noted below:

- For the buildings commissioned by Portland Energy Conservation Inc. (PECI) on behalf of the U.S. EPA and U.S. DOE: Tudi Haasl et al. [15].
- For the "High-tech research facility" commissioned by Herzog/Wheeler & Associates: Peter H. Herzog, "Commissioning Existing Buildings to Achieve Energy Efficient Operation—Four Case Studies," presented at the Third National Conference on Building Commissioning (May 1–3, 1995), sponsored by PECI.
- For 203 N. LaSalle Street commissioned by Sieben Energy Associates: Helen J. Kessler et al. [17].
- For Texas LoanSTAR buildings commissioned by ESL: Savings: Energy Systems Laboratory (ESL), LoanSTAR Monitoring and Analysis Program, "Annual Energy Consumption Report" (1995) and "Monthly Energy Consumption Report" (September 1996). Cost: ESL estimated commissioning cost per building from the known total cost *per project* (each project included several buildings). ESL estimated the cost per building to be $20,000 for buildings under 75,000 square feet, $24,000 for buildings from 75,000 to 300,000 square feet, and $28,000 for buildings over 300,000 square feet. (Source: Aamer Athar [22])
- For Texas A&M buildings commissioned by ESL: Aamer Athar [22], unpublished spreadsheet "SAVINGS.XLS" (which included data through September 1996).
- For buildings commissioned by PECI on behalf of Southern California Edison: Nancy B. Solomon [1] and Christie R. Kjellman, et al. [1].

Figure 1: **Commissioning savings vs. building type**

The amount of energy and money that commissioning existing buildings can save may vary according to building type. Field results show that libraries, offices, school districts, and research facilities can offer significant savings (as high as 20 to 30 percent)—however, in several specific cases these buildings saved less than 10 percent. Medical facilities can attain the largest savings of all (as high as 50 percent), but again there are exceptions—a few medical facilities exhibited savings lower than 10 percent. As a group, retail exhibited the lowest savings potential (3 to 13 percent).



Source: Various (see Table 1)

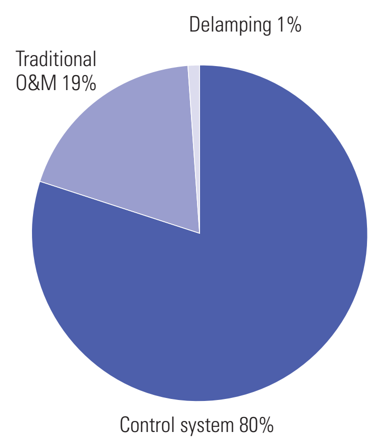
Savings from the Energy Systems Laboratory's "Continuous Commissioning" Program

Texas A&M's Energy Systems Laboratory (ESL) has commissioned dozens of buildings. Its "Continuous Commissioning" program, established in 1993, has been probably the largest commissioning effort in the U.S. This program has delivered paybacks of less than one year for 24 of the 31 buildings in this program (as shown in Table 1).

Figure 2 presents a look at where the savings come from in ESL's buildings.[15] ESL's in-depth attention to the optimization of control systems pays off—accounting for 80 percent of savings due to commissioning.

Figure 2: **Distribution of ESL commissioning savings**

ESL has found that controls systems (for HVAC and to a lesser extent lighting) are primary targets for commissioning.



Source: ESL

Case Study: 203 North LaSalle Street

The 203 North LaSalle Street building is a 623,000-square-foot, mixed-use facility in downtown Chicago (**Figure 3**, next page). In 1994, Sieben Energy Associates performed a comprehensive energy audit on this facility which was co-funded by local utility Commonwealth Edison.[16] By interviewing building engineers and investigating building equipment and documentation, the commissioning agents recognized that the building's air-handling system needed commissioning. After the audit, all 640 fan-powered boxes and zone thermostats were overhauled. Also, the chiller plant was optimized by lowering chilled water temperature, improving chiller and condenser water pump sequencing, and other modifications.[17]

This commissioning project, which cost about $80,000, has cut annual energy costs by an estimated $150,000, yielding about a six-month payback. In addition, the commissioning process has improved tenant comfort—there are now 60 percent fewer "too hot" or "too cold" complaints. Commissioning also allowed the postponement of a $200,000 chiller purchase—this new chiller may no longer be needed since occupant comfort now can be maintained even during peak cooling conditions.[18]

How can one tell in advance which commissioning projects are likely to cost the most? Right now, there is no easy answer to that question. The cost of commissioning apparently depends more on the scope and complexity of the tasks to be performed—which are difficult parameters to quantify. Contrary to popular opinion, the cost of commissioning is *not* strongly related to building size (**Figure** 4, page 11). Also, a building's age does not seem to affect how much commissioning costs—in the seven buildings commissioned by SCE, there was no relationship between cost and age.[19]

Payback

To compete as a stand-alone energy efficiency measure, commissioning must deliver a payback comparable to (or better than) those of competing efficiency measures. This means that for commissioning to be a viable service offering for energy service providers, it should have a payback of two years or less. The average simple payback of the 44 buildings listed in Table 1 is 0.9 years. Of these buildings, 38 had simple paybacks of less than two years—leaving a handful with longer paybacks (up to 4.6 years).

It is typical for commissioning of "efficient" buildings (with annual energy costs of less than $1 per square foot), to achieve simple payback in two years.

What types of commissioning projects typically offer great paybacks? **Figure 5** (page 11) shows that all of the buildings listed in Table 1 which originally had high energy costs ($2 per square foot per year or more) attained simple payback in two years or less. The few cases in which payback exceeded four years had baseline energy costs of *less* than $2 per square foot per year. Still, it was not uncommon for "efficient" buildings (with annual energy costs of less than $1 per square foot), to achieve simple payback in two years (see box, page 12). Therefore, cautious optimism is warranted for commissioning buildings that already operate fairly efficiently.

Figure 3: **203 North LaSalle Street**

The large building with the atrium (center) is 203 North LaSalle Street. Commissioning this downtown Chicago office building saved an estimated $150,000 per year in energy costs.

Source: Sieben Energy Associates

Approaches to Commissioning

There are several ways to commission a facility, as discussed below. All of these methods require commissioning agents who have specific technical and strong interpersonal communication skills:

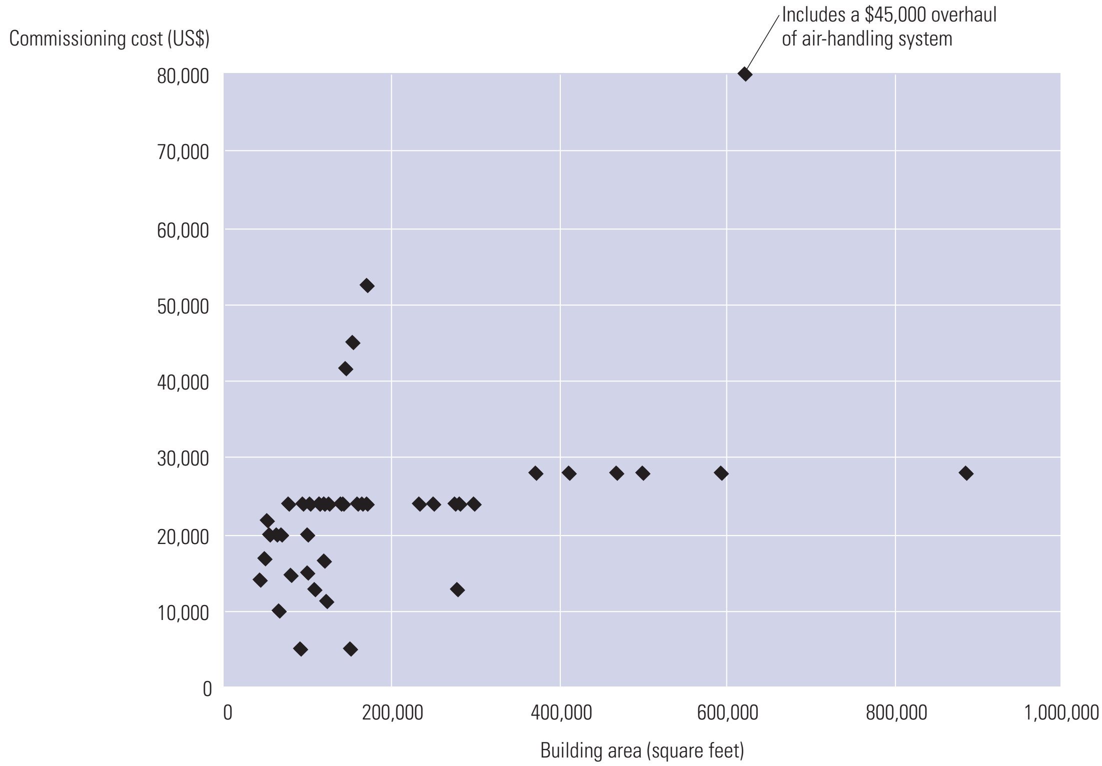
The nature of commissioning puts the commissioning staff in a delicate situation.

- *Technical expertise* must include the ability to understand controls and building systems, identify problems and opportunities, and implement changes without decreasing occupant comfort. While some commissioning methods rely heavily on the knowledge and skill of technical experts, others use automated data-gathering and data-processing systems. This allows *some* of the work to be done by less-skilled (and less-expensive) personnel.

- *Interpersonal communication skills* are as important as technical skills. The nature of commissioning puts the commissioning staff in a delicate situation—they must work alongside facility staff while diligently questioning and investigating existing operations. They must listen to the staff's suggestions and concerns, and recommend and implement improvements without offending the staff or creating unnecessary friction.

Figure 4: **Commissioning cost vs. building area**

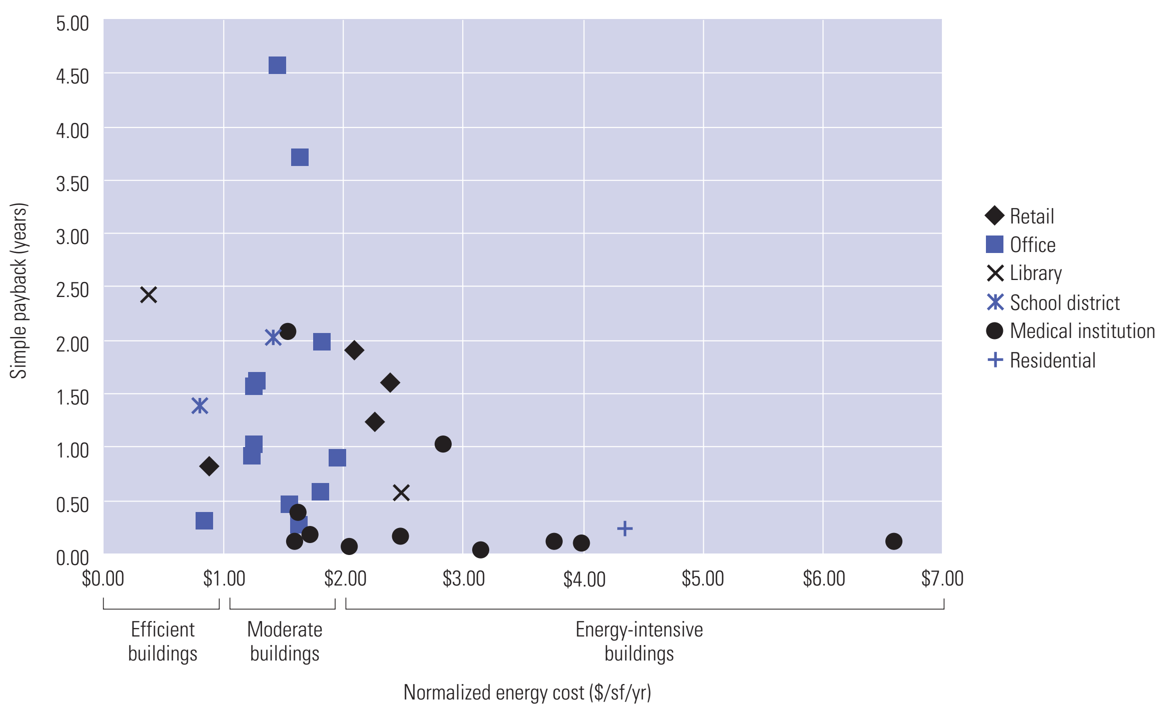
Presented here are commissioning costs vs. building area for all projects listed in Table 1. According to this data, there is no strong relationship between commissioning cost and the size of a building.



Source: Various (see Table 1)

Figure 5: **Simple payback vs. normalized annual energy cost**

This figure compares simple payback from commissioning to normalized energy cost. All of the "energy-intensive" buildings had short paybacks (less than two years), but so did several of the "efficient" buildings.



Source: Various (see Table 1)

Case Study: Texas State Capitol Extension

Commissioning can be cost-effective even in a one-year-old building. This was the case for the Texas State Capitol Extension, a 392,000-square-foot underground building which houses hearing rooms and offices. This facility was commissioned by Texas A&M's Energy Systems Laboratory (ESL),[20] and it was designed for energy efficiency (its precommissioning annual energy cost was only $1 per square foot). Its HVAC system comprises more than 50 dual- and single-duct systems, which are governed by a direct digital control energy management and control system (EMCS).[21]

The commissioning agents concluded that optimizing operating setpoints and schedules would yield significant savings in the consumption of hot water, chilled water, and electricity. These improvements were implemented, and measured savings total about $89,000 per year—a 15 percent whole-building energy cost reduction. This project cost about $28,000 (including implementation of the improvements), for a four-month simple payback.[22]

Simple commissioning techniques can be less expensive, and are less dependent on sophisticated hardware and software tools. Sophisticated techniques may catch more elusive problems, and also may deliver more accurate measurement of energy savings from commissioning.

Method 1: Basic Building Tune-up by Facility Staff

The U.S. EPA, as part of its Energy Star Buildings Program, publishes guidelines for "tuning up" a building.[23] EPA recommends performing a tune-up before undertaking any retrofit. This is a two-step process:

- Review historical documentation of the building's energy use (including utility bills, archived EMCS data, maintenance logs, complaint logs, and previous energy audits).

- Inspect the building's systems, following the checklists included in the *Energy Star Buildings Manual.*

While this method requires little or no expense other than staff time, it may not always be an appropriate strategy. For instance, most facility staff members probably do not have the time or training to perform these tasks. For this method to be successful, the facility staff's priorities must be reordered to allow more time and training for preventative maintenance and analysis of operating strategies, as well as more flexibility to test new operating strategies.

Method 2: HVAC Experts and One-Time Tests

This approach, which was used to commission the 203 North LaSalle Street building (see page 9), relies heavily on the skills of HVAC system experts. It usually is performed by an outside contractor on behalf of the building owner. In this process, a team of experts identifies necessary changes through several tasks (performing audits, reviewing utility bills and design documents, interviewing facility staff members, taking one-time measurements, and performing basic engineering calculations).[24]

Method 3: Corporate Engineering Team Commissions Its Own Sites

For large companies with several facilities, corporate-level engineering talent can perform commissioning in conjunction with the staff of specific facilities. For example, Westin Hotels and Resorts has its own commissioning "SWAT team," called the "Pool of Westin Engineering Resources (POWER) team." The Westin POWER team for a specific project typically includes one or two corporate engineers, an outside contractor (mechanical engineer), and facility operators from other Westin sites. A POWER team descends on a Westin facility and stays for two weeks—which costs about $20,000.[25]

During this time, the POWER team works side-by-side with the site's staff to question and understand how and why the facility operates as it does. The team splits up to investigate various systems, then regroups to discuss findings. Every assumption about how the building's systems are designed and operated is open to scrutiny. The POWER team first targets no-cost and low-cost measures during its visit. Therefore, by the time the team leaves it has already begun to generate savings for the site—which helps cover the cost to send the POWER team to the facility.

For large companies, corporate-level engineering talent can perform commissioning in conjunction with the staff of specific facilities.

Follow-up POWER team visits may involve air balancing, water balancing, or controls commissioning. The team also generates documents that can help the facility continue to improve its efficiency (such as budgeting information for future energy efficiency retrofits).

Westin recognizes that the POWER team process itself has potential for continuous improvement. Although the team's array of technical skills are important, by emphasizing moderating and facilitating skills Westin ensures that facility staff are not threatened by the POWER Team. Rather, the facility staff becomes part of the team—and part of the solution.

Method 4: Energy Management and Control System Optimization

An EMCS can be used to operate a building efficiently. It also can track the performance of the building systems to ensure proper operation—as long as the appropriate points in the building's systems are being monitored. The best place to start in facilities which have a functioning but underutilized EMCS is to optimize schedules and setpoints and ensure proper EMCS calibration and operation.[26]

The best place to start in facilities which have a functioning but underutilized EMCS is to optimize schedules and setpoints and ensure proper EMCS calibration and operation.

Often, an ESCO or other outside commissioning agent can successfully utilize the EMCS to monitor performance and ensure savings. Unfortunately, facility staff often have trouble accomplishing these same goals in-house—due to a lack of training or competing demands for their time and attention. In addition, not all EMCS systems include the specific types of control points needed to optimally control building systems.

Short-term monitoring may help identify operations and maintenance problems (and their solutions) which could go undetected by less-sophisticated commissioning methods.

Method 5: Short-Term Portable Data Logging

Short-term monitoring captures detailed data on how systems work, and thus may help identify operations and maintenance problems (and their solutions) which could go undetected by less-sophisticated commissioning methods.[27]

Several commissioning teams rely on portable data loggers as the backbone of their diagnostics service. For example, Texas A&M's Energy Systems Laboratory (ESL) often uses inexpensive portable data loggers (such as the Hobo™ data logger[28] in **Figure 6**) to track key parameters. Data from loggers is used in engineering models which determine how a system actually works and how it can be optimized. ESL sometimes uses this method in conjunction with optimizing an existing EMCS or to get detailed information which is not gathered by a permanent long-term monitoring system.

Figure 6: **Hobo™ loggers**

The Energy Systems Laboratory of Texas A&M University often uses portable data loggers, such as these Hobo Loggers by Onset Computer Corporation, in commissioning projects.

The ENFORMA™ system developed by Architectural Energy Corporation (AEC) is a more comprehensive and automated approach to short-term diagnostics (**Figure** 7).[29] This system consists of software (for determining the monitoring plan, programming loggers, and analyzing data) and hardware (portable battery-powered loggers and sensors).

After surveying a building, a user enters information into the ENFORMA software. The software then develops a monitoring plan based on the type of building and building systems, and the user installs loggers and sensors according to that plan. A typical monitoring plan includes values such as air temperature,

Figure 7: **AEC's portable data logger and sensors**

Portable data loggers and sensors can be used in conjunction with specialized software to perform short-term monitoring and diagnostics in building commissioning projects.

Source: Architectural Energy Corporation

humidity, static pressure, air velocity, current, and power. Monitoring typically lasts about two weeks. After that, the loggers are retrieved and their data are analyzed. The software then generates graphs specific to the type of system being analyzed. By reviewing these graphs, a skilled building systems analyst can identify deficiencies in building systems.[30]

Long-term monitoring provides information useful for one-time commissioning as well as for continued monitoring of energy usage.

Method 6: Long-Term Monitoring and Engineering Modeling

Long-term monitoring has been used by ESL in commissioning several state buildings and school districts under the Texas LoanSTAR program (including the Texas State Capitol, see page 12), and now also on buildings on the Texas A&M campus. In buildings such as these, which have no record of per-building energy usage, long-term monitoring provides information useful for one-time commissioning as well as for continued monitoring of energy usage.

When using long-term monitoring, ESL begins by installing a permanent data logger (**Figure 8**) in each building. Each hour, the logger measures overall electric, chilled water, and hot water (or steam) usage. This monitoring system typically costs from $12,000 to $15,000 installed.[31] Ideally, the logger is left in place for a full year before the next phase of the commissioning process begins. However, in some cases the monitoring period may be as short as one or two months.

Figure 8: **Long-term monitoring**

For long-term monitoring, ESL installs a Synergistics logger (left) in each building to monitor and report hourly values for whole-building electric, hot water (or steam), and chilled water usage.

Loggers communicate via modem with a central computer at ESL, where each building's usage is monitored, tracked, and analyzed. ESL has developed software which automatically polls the modems, processes the data, and generates monthly and annual reports.[32] These reports include two- and three-dimensional graphs for easy analysis and for identification of targets for possible efficiency improvements (such as nighttime shutdown or seasonal shutdown of preheat coils). This information also is sent to on-site building engineers, who use it to track performance before and after commissioning.

Improvements typically recommended by ESL include air balancing, water balancing, chilled-water system optimization, and implementing supply-air reset schedules. Once efficiency improvements have been identified, ESL uses its EModel™ and AirModel™ software to estimate savings for each proposed change through a combination of measured data and engineering models.[33] Using this information, ESL fine-tunes its recommendations to deliver optimal site-specific operating conditions.

ESL also performs on-site tasks including a daytime walk-through, a nighttime walk-through, short-term shutdown tests, inspection and measurement of energy and control systems, and meetings with facility staff in which ESL's observations are discussed. Like, other commissioning agents, ESL also has found that a good relationship with facility staff is critical to successful commissioning.

Keeping Up with Commissioning

Each year, PECI organizes a Conference on Building Commissioning, held in the spring. The conference brings together leaders in the commissioning business—which typically includes utilities, building owners and managers, and commissioning agents.

For information about this annual conference or on obtaining conference proceedings, contact:

Debby Dodds
Conference Manager
Portland Energy Conservation, Inc.
921 SW Washington, #840
Portland, OR 97205
tel 503-248-4636 ext. 205
fax 503-295-0820
e-mail peci@teleport.com

Case Study: State of Tennessee, Citizen's Plaza

In 1995, PECI commissioned five buildings across the U.S. using Architectural Energy Corp.'s ENFORMA system to perform short-term diagnostics.[34] One of these buildings was the 250,000-square-foot Citizen's Plaza office building in Nashville, Tennessee (**Figure 9**).[35] Prior to commissioning, this building's annual energy cost was $1.81 per square foot.

After deploying data loggers for two weeks and analyzing the data, several possible improvements were identified—including improved scheduling of lights and HVAC equipment, and fixing chilled water leaks found past coil valves. The largest savings from a single change came from returning the chilled water pump to variable-speed operation. Earlier, a status switch had gone bad and had been bypassed—thus the pump had been operating at full speed for some time. Once the switch was repaired, the pump operated at just 10 to 15 percent of full speed. This repair alone produced annual savings of about $7,000.[36]

After these measures were implemented, loggers were deployed again for an additional two weeks of monitoring. Energy savings were determined using a combination of monitoring data, engineering calculations, and building energy simulations. The total annual savings due to the changes was calculated as $42,045, or 9.3 percent of the annual energy bill—which brought annual energy costs down to $1.64 per square foot.[37] The commissioning cost, including cost to implement measures, was $23,967 (10¢ per square foot), which yielded a simple payback of about seven months.

Based on the success of this project, the state is looking to develop guidelines that could be used to commission other existing state buildings.

Figure 9: **Citizen's Plaza**

Commissioning this State of Tennessee office building yielded a simple payback of about seven months.

Source: State of Tennessee

While the initial costs of purchasing and installing permanent loggers are significant, the loggers continue to gather data after the commissioning process is completed. This provides a way to accurately determine savings from commissioning, and to continuously track energy consumption—which can help ensure the longevity of savings from commissioning.

Notes

1 These seven projects are summarized in Table 1 (see page 6).

2 Nancy B. Solomon, "Building Commissioning: A New Delivery Method for Ensuring Successful Building Performance Gains Ground," *Architecture* (June 1995), pp. 123–129; and Christie R. Kjellman, Deborah Dodds, and Tudi Haasl, "A Building Commissioning Study in the Home Stretch: Obstacles, Benefits, and Discoveries," presented at the Third National Conference on Building Commissioning (May 1–3, 1995), sponsored by Portland Energy Conservation, Inc. (PECI).

3 Bill McQueen, personal communication (January 8, 1997), Corporate Facilities Manager, Nordstrom, Inc., 1321 2nd Avenue, Seattle, WA 98112, tel 206-233-6812, fax 206-233-6503.

4 Bill McQueen [3].

5 Gregg D. Ander, personal communication (November 1, 1996), Manager, Design & Engineering Services, Southern California Edison Company, Customer Solutions, 300 North Lone Hill Avenue, San Dimas, CA 91773, tel 909-394-8734, fax 909-394-8597, e-mail andergd@sce.com.

6 Michael P. Della Barba, personal communication (December 19, 1996), Senior Marketing Analyst, NEES Companies, 25 Research Drive, Westborough, MA 01582-0099, tel 508-389-3650, fax 508-366-6551, e-mail dellab@neesnet.com.

7 Michael P. Della Barba, "The Need for Building Commissioning: The Nature of the Beast," Fourth National Conference on Building Commissioning (April 29–May 1, 1996), sponsored by PECI.

8 Michael Della Barba [6].

9 Sources (building owners or managers): Gus Newbury, personal communication (December 8, 1996), Director of Engineering, Westin Hotels & Resorts, 2001 Sixth Avenue, Seattle, WA 98121, tel 206-443-8918, fax 206-443-5240, e-mail gus_newbury.westin@notes.worldcom.com; Craig Schuttenberg, personal communication (December 18, 1996), Director, Energy Planning and Management, University of Chicago, Energy, 555 South Ellis Avenue, Chicago, IL 60637, tel 312-702-3416, fax 312-702-5814, e-mail Craig_Schuttenberg@fpm.UCHICA; and Bill McQueen [2]. Additional source (commissioning agent): Jack Wolpert, personal communication (December 18, 1996), President, E-Cube, 1900 Folsom Street, #212, Boulder, CO 80302, tel 303-443-2610, fax 303-443-3704, e-mail jwolpert@ecube.com.

10 Michael Della Barba [6].

11 Dave Edmunds, personal communication (February 3, 1997), Program Manager for Building Energy Management Program, State of Tennessee, Energy Management Administration, 312 8th Avenue North, Eighth Floor, Tennessee Tower, Nashville, TN 37243-0554, tel 615-741-9357, fax 615-532-2305, e-mail dedmunds@mail.state.tn.us. Also, Sam DeLay, personal communication (February 18, 1997), Product Manager for Commercial and Industrial Products and Services, Tennessee Valley Authority, Mail Code MR2J, 1101 Market Street, Chattanooga, TN 37402, tel 423-751-7902, fax 423-751-4303.

12 Scott Pettro, personal communication (December 19, 1996), Project Manager, NORESCO, 20277 Valley Boulevard, Suite G, Walnut, CA 91789, tel 909-444-9500 ext. 12, fax 909-444-7591.

13 Peter Oatman, personal communication (December 16, 1996), Vice President, EUA Highland, 2970 Wilderness Place, Boulder, CO 80301, tel 303-786-9310, fax 303-786-8033, e-mail peter.oatman@euahighland.com.

14 The only exception to this were the five buildings commissioned by PECI on behalf of the U.S. EPA and U.S. DOE. Commissioning costs for these projects did include facility staff time. Source: Tudi Haasl, Karl Stum, and Mark Arney, "Better Buildings through Improved O&M—A Five-Building Case Study," table 4, presented at the Fourth National Conference on Building Commissioning (April 29–May 1, 1996), sponsored by PECI.

15 Mingsheng Liu, "Distribution of O&M Savings" (1996), unpublished presentation, Energy Systems Laboratory, Building Energy Analysis Division, Texas Engineering Experiment Station, 053 WERC, Texas A&M University, College Station, TX 77483-3581, tel 409-862-1234, fax 409-862-2457, e-mail mingshen@esl.tamu.edu.

16 Marilyn Brooks, personal communication (February 1997), former property manager of 203 North LaSalle Street, currently with Kastle Systems, 225 West Wacker Drive, Suite 300, Chicago, IL 60606, tel 312-849-8800, fax 312-849-8811; and Helen J. Kessler, personal communication (December 1996), Executive Vice President, Sieben Energy Associates Ltd., 401 North Wabash Street, Suite 536, Chicago, IL 60611, tel 312-828-0700, fax 312-828-0755, e-mail hjkessler@compuserve.com.

17 Helen J. Kessler, Jack W. Wolpert, Gary Schroeder, Marilyn Brooks, Tom Vannatta, and Brian Hoeger, "Commissioning the Air Handling System in an Existing Office Facility," presented at the Fourth National Conference on Building Commissioning (April 29–May 1, 1996), sponsored by PECI.

18 Helen J. Kessler, et al. [17].

19 Nancy B. Solomon [2].

20 Denis Feary, personal communication (November 15, 1996), Energy Manager, General Services Commission, Senate Print Shop, 311 East 14th Street, Austin, TX 78711, tel 512-475-2455, fax 512-475-2508, e-mail Denis.Feary@Notes.GSC.State.TX.US.

21 Mingsheng Liu [15], "O&M Case Study: Texas Capital Extension Building" (February 1996), unpublished case study presentation.

22 Aamer Athar, personal communication (January 10, 1997), Senior Research Associate, Energy Systems Laboratory, Building Energy Analysis Division, Texas Engineering Experiment Station, 053 WERC, Texas A&M University, College Station, TX 77843-3581, tel 409-845-9213, fax 409-862-2457, e-mail athar@esl.tamu.edu.

23 U.S. EPA, "Energy Star Buildings Manual: A Guide for Implementing the Energy Star Buildings Program," EPA 430-B-95-007 (July 1995).

24 Jack Wolpert [9].

25 Gus Newbury [9].

26 D.P. W. Solverg and M.D. Teeters, "Specification of Spreadsheet Trend Log Sets for DDC/EMCS and HVAC Systems Commissioning, Energy Monitoring, Life Safety Cycles, and Performance-Based Service Contracts," *ASHRAE Transactions: Symposia*, BA-92-8-2 (1992), pp. 553–560.

27 Mark Arney, Tudi Haasl, and Karl Stum, "Uncovering Hidden O&M Problems with Short-Term Diagnostic Testing," Fourth National Conference on Building Commissioning (April 29—May 1, 1996).

28 Hobo is a registered trademark of Onset Computer Corporation, Box 3450, Pocasset, MA 02559, tel 508-563-9000, fax 508-563-9477, web www.onsetcomp.com.

29 ENFORMA is a registered trademark of Architectural Energy Corporation, 2540 Frontier Avenue, Suite 201, Boulder, CO 80301, tel 303-444-4149, fax 303-444-4304, e-mail aecinfo@aol.com. ENFORMA was developed with support from the Electric Power Research Institute, and with funding from seven utilities.

30 Mark Arney, et al. [27]; also Donald J. Frey, Peter C. Jacobs, and Karl F. Johnson, "Commercial Building Performance Evaluation System," presented at the Building Simulation '93 Conference (1993), sponsored by the International Building Performance Simulation Association Conference.

31 Aamer Athar [22].

32 MAP Monitoring Analysis Program, version 1.0, ©1996. ESL developed and markets a PC-version of this program which can poll Synergistics loggers, process data, generate reports, and graph and analyze data. For more information, contact: Robert Sparks, ESL, Texas A&M University, WERC 072, College Station, TX 77843, tel 409-847-8779, fax 409-862-2457, e-mail rjsparks@esl.tamu.edu.

33 Software programs developed and marketed by ESL include E-Model, AirModel, Look3D, and Animate for Windows. All are copyrighted by Texas Engineering Experiment Station, Texas A&M University. E-Model allows users to perform engineering modeling based on measured data. For example, a user can estimate savings due to proposed changes using baseline data and an engineering model of the improved condition. Alternatively, this program can calculate energy savings from commissioning from pre- and post-commissioning data sets. AirModel is an internal systems modeling program, which may be marketed in the future. For more information, contact: Robert Sparks [32].

34 This project was funded jointly by the Atmospheric Pollution Prevention Division of the U.S. EPA and by the U.S. Department of Energy. It is summarized in Table 1.

35 Dave Edmunds [11].

36 Mark Arney, personal communication (January 31, 1997), Senior Engineer, Architectural Energy Corporation, 2540 Frontier Avenue, #201, Boulder, CO 80301, tel 303-444-4149, fax 303-444-4304, e-mail aecinfo@aol.com.

37 Tudi Haasl, et al. [14].

E SOURCE, INC.
1033 Walnut Street
Boulder, Colorado 80302-5114 USA
Telephone 303.440.8500 Facsimile 303.440.8502
E-mail esource@esource.com Web www.esource.com

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