Continuous Commissioning® Opportunities in Hospital and Laboratory Facilities

Alaina Jones
Graduate Assistant - Research

David E. Claridge, Ph.D., P.E.
Professor and Director

W. Dan Turner, Ph.D., P.E.
Professor and Past Director

Song Deng, P.E.
Associate Director

Guanghua Wei, P.E.
Associate Director

Greg Zeig
Research Engineering Associate

Energy Systems Laboratory
Texas A&M University
College Station, TX USA

ABSTRACT

This paper compiles the Continuous Commissioning® (CC®) costs, savings, and opportunities implemented in 20 hospital and laboratory commissioning projects involving 48 buildings. The potential savings and costs from 25 CC assessments of 36 buildings are also analyzed and compared with the results of the implemented projects. The results from these projects including deficiencies and commissioning measures identified, and the cost and savings associated with CC are discussed. Case studies are also presented.

For the 20 completed hospital and laboratory CC projects, the median (average) pre-CC energy cost was $3.44/ft^2 ($4.46/ft^2) [$36.98/m^2 ($48.06/m^2)] with median (average) energy cost savings of $0.84/ft^2 ($1.19/ft^2) [$9.03/m^2 ($12.80/m^2)] or 20% (26%). The median (average) potential savings identified in the 25 CC assessments were $0.41/ft^2 ($0.44/ft^2) [$4.36/m^2 ($4.72/m^2)] or 15% (16%). The lower savings identified in the assessments may result from the conservatism inherent in an incomplete identification of all potential measures during the assessments, or may result from some other factor.

INTRODUCTION

Although hospital and laboratory facilities represent a relatively small percentage of the US building stock, these facilities are some of the most energy intensive facilities in existence. For this reason hospital and laboratory facilities are often good candidates for Continuous Commissioning®[1], an ongoing process to resolve operating problems, improve comfort, optimize energy use and identify retrofits for existing commercial and institutional buildings and central plant facilities (Liu, et al 2002).

This paper summarizes the CC efforts at 45 hospital/laboratory facilities conducted by the Energy Systems Laboratory at Texas A&M University. These CC efforts include both CC assessments and completed CC projects. Within the CC process the CC assessment is used to determine the facility's potential as a candidate for CC. If the facility owner decides to proceed based on the assessment, the CC process is implemented. This paper includes CC assessment results from 25 facilities, in which the facilities were assessed to determine possible CC measures which could be implemented and the possible effects and cost of those efforts. Several of the CC assessments were conducted in conjunction with Bes-Tech, Inc. Also included in the compilation are the results from 20 facilities in which the CC process was completed and CC measures were implemented. Of those completed projects, about half of the buildings had just undergone comprehensive energy retrofits, two were considered by their owners to be the state-of-the art buildings within their portfolios, and the remaining were typical buildings without significant known problems before the CC process was initiated.

The primary goal of this study was to determine the opportunities in commissioning existing hospital and laboratory buildings. Mills, et al (2004), established the largest available collection of standardized information on commissioning. Within this meta-analysis a methodology for characterizing, analyzing, and synthesizing the results of commissioning was developed. A similar methodology was employed for this study on hospital and laboratory facilities.

METHODOLOGY

Mills, et al (2004) recommended a modus operandi for cost-benefit analysis of commissioning. The methodology used for this study, on the opportunities in commissioning existing hospital and laboratory facilities, is adapted from Mills. Before commencing data collection efforts, desired metrics and indicators were defined, shown in Box 1. For

[1] Continuous Commissioning and CC are registered trademarks of the Energy Systems Laboratory, Texas Engineering Experiment Station, College Station, Texas.

Box 1: Commissioning Metrics

Building Characteristics and Demographics
- Vintage, location
- Year building commissioned
- Deficiencies identified, measures recommended

Energy utilization intensity (use or savings)
- Electricity: kWh/building-year, kWh/ft^2-year [J/building-year, J/ft^2-year]
- Peak electrical power: kW/building; W/ft^2
- Fuel: MMBTU/building-year; kBTU/ft^2-year [J/building-year, J/ft^2-year]
- Purchased thermal energy: MMBTU/building-year; kBTU/ft^2-year [J/building-year, J/ft^2-year]
- Total energy: MMBTU/building-year; kBTU/ft^2-year [J/building-year, J/ft^2-year]
- Energy cost: $/building-year; $/ft^2-year [$/m^2-year] (based on local energy prices; nominal [not corrected for inflation] and inflation-corrected to a uniform year's currency)
- Percent energy use savings
- Percent total energy cost savings

Commissioning cost
- $/building; $/ft^2 [$/m^2] (based on nominal costs or, preferably, inflation-corrected to a uniform year's currency levels. Can be gross value or net.)

Cost effectiveness
- Undiscounted payback time (commissioning cost/annualized energy bill savings). This indicator is preferably normalized to standard energy prices; costs and benefits are inflation corrected to a uniform year's currency levels

Deficiencies and measures
- Deficiencies/building; Deficiencies/100kft^2 [Deficiencies/m^2]
- Measures/building; Measures/100kft^2 [Measures/m^2]
- Unique codes to identify combinations of deficiencies and measures [see Measures Matrix]

each facility, available information deemed pertinent was collected. The full data-collection instrument (adapted from Mills, et al 2004) employed is shown in Appendix A.

For comparison purposes between CC projects, spanning several years, dollar normalization was appropriate. To account for inflation all cost/savings were inflation adjusted to 2006 dollars using the implicit price deflators published by USDOE/EIA in the 2006 Annual Energy Review (see Appendix B).

Deficiencies (or problems) and corrective measures were recorded in a separate "Measures Matrix" (adapted from Mills, et al 2004) for each facility. The combination of the deficiency and related measure are represented by a unique code, see details in sample matrix in Appendix C.

This study did not require the level of detail used by Mills, et al (2004). Consequently, fewer commissioning metrics and a less detailed data collection instrument and measures matrix were used. Additionally, costs were inflation adjusted but not normalized to account for varying energy prices, and persistence of savings, commissioning scope and non-energy impacts are not considered.

SAMPLE CHARACTERISTICS

This summary is a compilation of the commissioning efforts at 45 hospital/laboratory facilities representing 18.13 million square feet of floor area [1.68 million m^2]. Data was collected for 74 buildings spanning 21 states.

Completed CC Projects

The compilation includes CC results for 48 buildings (20 projects) spanning Maryland, Minnesota, Pennsylvania and Texas representing a combined floor area of 6.81 million square feet [632,420 m^2]. The median (average) building size was 200,000 (340,000) square feet [18,750 (31,620) m^2] and the median year of construction was 1975.

CC Assessments

The compilation includes CC assessment results for 36 buildings (25 projects) spanning Alabama, Arizona, California, Colorado, Georgia, Hawaii,

Kansas, Kentucky, Louisiana, Maryland, Missouri, North Carolina, New Mexico, New York, Oklahoma, South Carolina, Texas, Virginia and Washington representing a combined floor area of 11.33 million square feet [1.05 million m^2]. The median (average) building size was 440,000 (450,000) square feet [40,880 (42,090) m^2] and the median year of construction was 1976.

FINDINGS

Key findings are provided in

Table 1, Figure 1, and Figure 2. These findings are followed by specific findings related to energy costs/savings, commissioning costs, payback period, deficiencies and measures. Within this study costs and savings associated with CC assessments are estimated and potential, respectively. However, costs and savings associated with completed CC projects are actual values.

Table 1. Key Findings

	All		Completed CC projects				CC Assessments			
	Total	Sample Size	Total	Median per project	Average per project	Sample Size	Total	Median per project	Average per project	Sample Size
Number of projects	45	45	20			20	25			25
Number of buildings	74	45	38	**1**	**1.85**	20	36	**1**	**1.44**	25
Number of states	21	45	4			20	19			25
Total project floor area, million square feet	18.13	45	6.81	**0.20**	**0.34**	20	11.33	**0.44**	**0.45**	25
million square meter	1.68		0.63	**0.02**	**0.03**		1.05	**0.04**	**0.04**	
Year built				**1975**	**1976**	19		**1976**	**1974**	21
Number of deficiencies identified	741	45	339	**11**	**13.95**	20	402	**15**	**15.16**	25
Total commissioning costs										
Thousands of dollars	14,376	39	1,440	**31.51**	**96.00**	15	12,936	**334.53**	**539.00**	24
Dollars per square foot				**0.26**	**0.41**	15		**0.86**	**1.16**	24
Dollars per square meter				**2.76**	**4.44**			**9.25**	**12.49**	
Total savings										
Thousands of dollars per year	10,448	45	5,484	**260.11**	**274.22**	20	4,964	**164.69**	**198.54**	25
Dollars per square foot per year				**0.84**	**1.19**	20		**0.41**	**0.44**	25
Dollars per square meter per year				**9.03**	**12.80**			**4.36**	**4.72**	
Whole-building energy-cost savings, percent				**19.99**	**25.72**	18		**15.42**	**16.47**	23
Simple payback time, local energy prices, years				**0.38**	**0.94**	15		**2.45**	**2.48**	24

Note: All costs are given in 2006$.

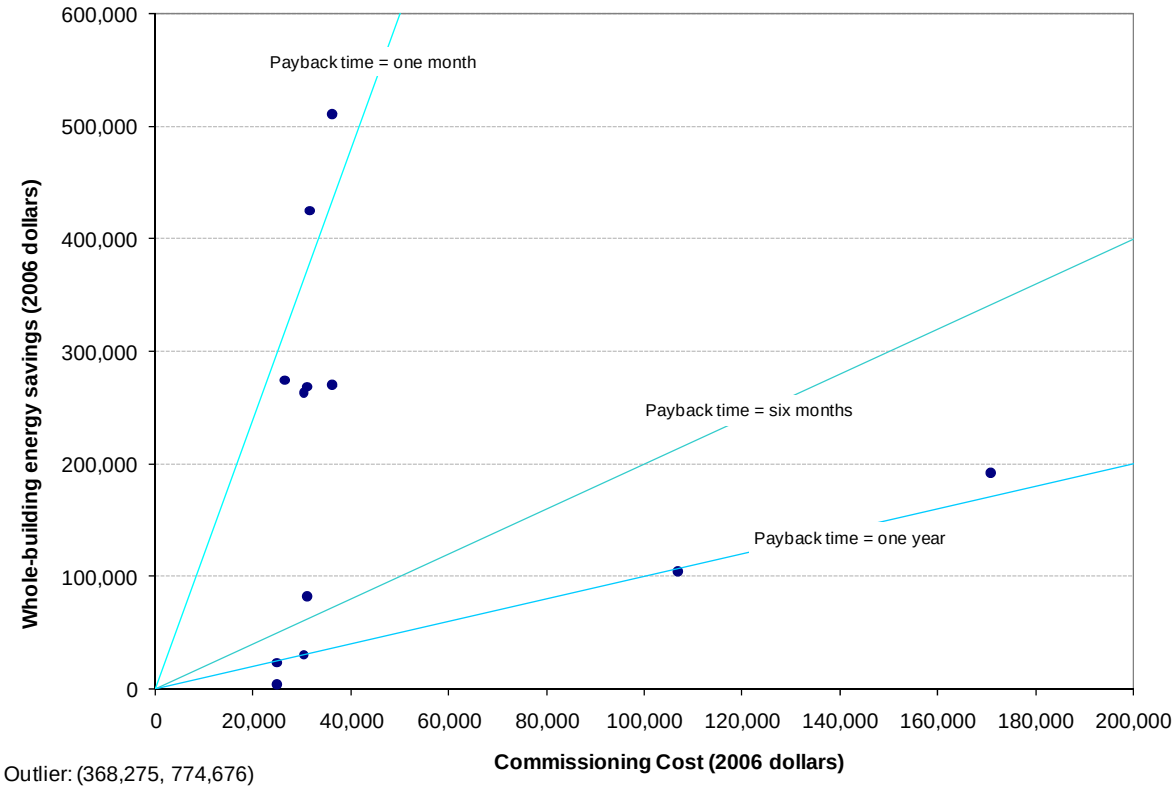

Figure 1. Completed CC Projects: Costs, Savings & Payback Periods

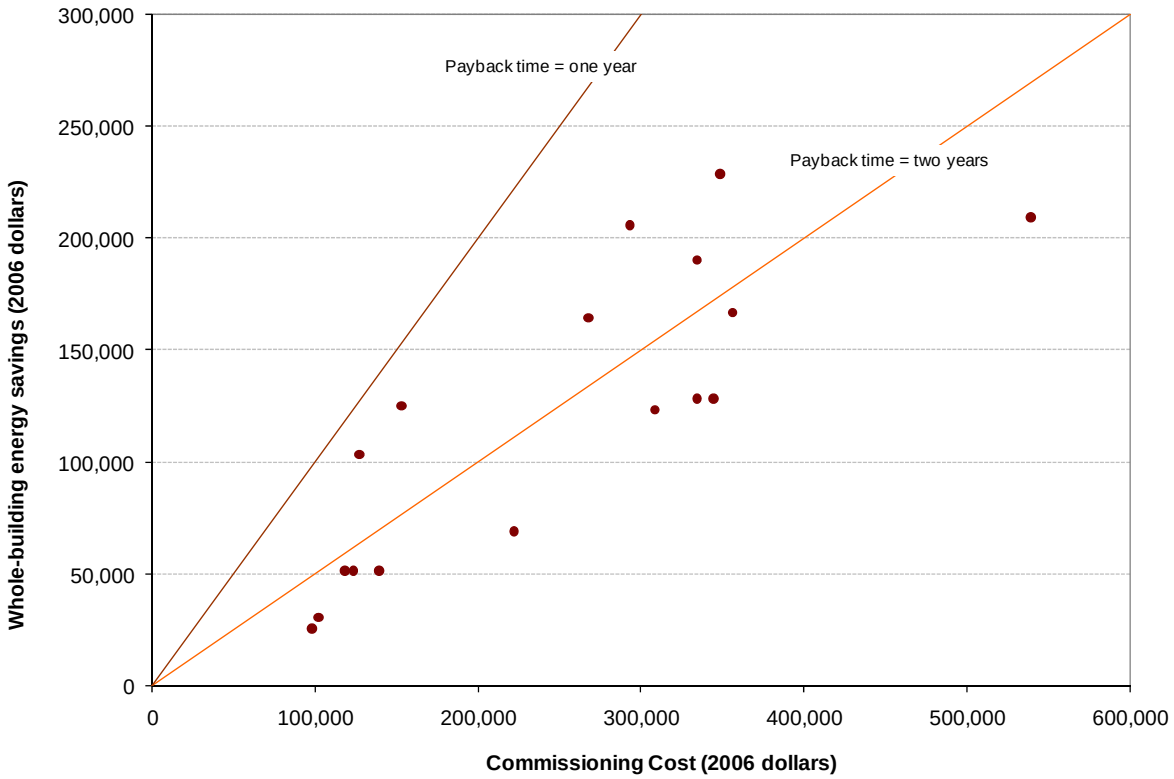

Figure 2. CC Assessment: Estimated Costs, Potential Savings & Payback Periods

Energy Costs/Savings

The pre-commissioning energy costs exceeded $54 million per year (41 projects). Energy savings data was available for 45 projects providing a total annual savings of $10,447,960, includes actual savings from completed CC projects and potential savings from CC assessments. Within the completed CC projects, the median (average) whole building energy cost savings was 20% (26%) (18 projects). The energy savings were determined from analysis of measured pre-CC and post-CC energy consumption data using IPMVP (International Performance Measurement & Verification Protocol, 2001) Option C. There was a total savings of $5,484,400 with a median (average) of $260,100 ($274,220) for 20 projects reporting. Figure 3 depicts the pre-CC cost ($/sf) and cost savings ($/sf and %). Within the CC assessments, the median (average) potential whole building energy cost savings was 15% (16%) (23 projects). There was a total potential savings of $4,963,560 with a median (average) of $164,690 ($198,540) for 25 projects reporting. Figure 4 depicts the pre-CC cost ($/sf) and potential cost savings ($/sf and %).

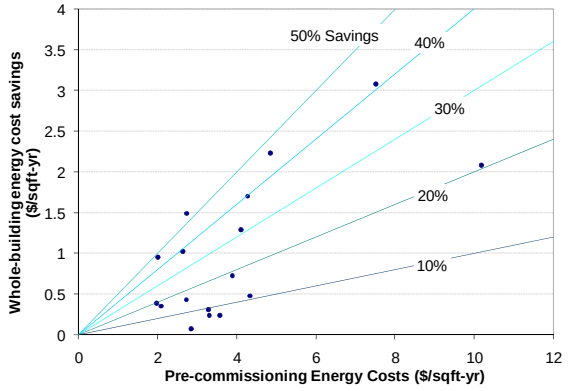

Figure 3. Completed CC Projects: Pre-CC Energy Costs and Energy Savings

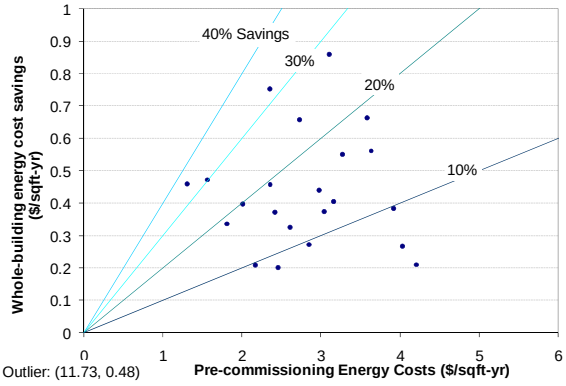

Figure 4. CC Assessments: Pre-CC Energy Costs and Potential Energy Savings

Commissioning Cost

The commissioning cost data was available for 39 of the projects summarized equating to $14,375,960. For the completed CC projects, from a sample of 15 buildings, the median commissioning costs were found to be 26 cents (4 cents to $2.14) per square foot [$2.76 (44 cents to $23) per m^2] with an average of $0.41/sf [$4.44/m^2]. For the CC assessments, from a sample of 24 buildings, the median prospective commissioning costs were found to be 86 cents (25 cents to $4.58) per square foot [$9.25 ($2.64 to $49) per m^2], with an average of $1.16/sf [$12.49/m^2].

Payback Period

The simple payback period varied widely between completed CC projects and CC assessments. Within completed CC projects, for 15 projects with information available there was a median payback of about 4.5 months (<1 month to 7.3 years); average of 11 months. Within CC assessments, for 24 projects with information available there was a median possible payback of 2.5 years (1.1 to 5.3 years); average of 2.5 years.

Deficiencies & Measures

Deficiencies, the problems affecting the performance of the facility, are identified by the specific building system they affect. The corresponding corrective measures identified are broken into the following categories: (1) operations and control; (2) maintenance and (3) design, installation, retrofit, replacement. Each of these categories contains specific measures which are listed in Figure 6 and Figure 8. As an example, an air handling and distribution deficiency may be remedied by an operations and control corrective measure, specifically the implementation of an advanced reset. A total of 741 deficiencies were identified for all the projects.

Completed CC Projects.

339 deficiencies (38 unmatched to specific measures) were identified in the 20 completed CC projects with a median (average) of 11 (14) deficiencies per project. The most prevalent deficiencies dealt with air handling and distribution (62 %) followed by cooling plant (14 %) and heating plant (11 %). The associated measures were most frequently operations and control type measures with implementation of advanced reset (65 measures) being the most common followed by modifying sequence of operations (37 measures). Calibration and retrofit/equipment replacement were also commonly reported measures. The number of deficiencies identified by building system are

represented percentage wise in Figure 5. The frequency of recommended measures is shown in Figure 6.

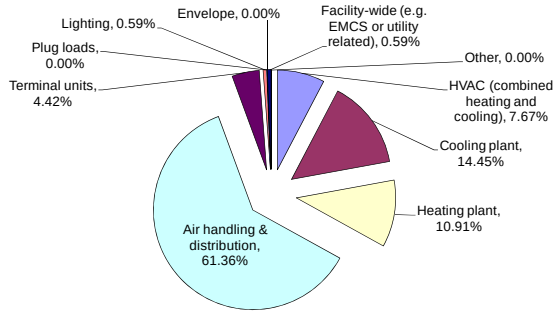

Figure 5. Completed CC Projects: Number of Deficiencies by Building System

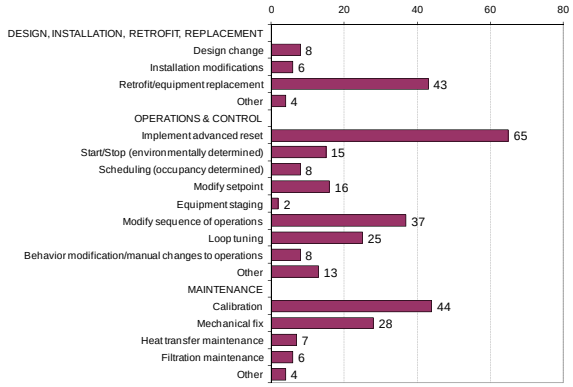

Figure 6. Completed CC Projects: Frequency of Measures

CC Assessments.

402 deficiencies (24 unmatched to specific measures) were identified in the 25 CC assessments with a median and average of 15 deficiencies per project. The most prevalent deficiencies dealt with air handling and distribution (43 %) followed by cooling plant (17 %) then HVAC representing combined heating and cooling (16 %). The associated potential corrective measures were most frequently operations and control type measures with modifying sequence of operations (116 measures) being the most common followed by implementation of advanced reset (78 measures). Calibration and retrofit/equipment replacement were also commonly proposed measures. The number of deficiencies identified by building system are represented percentage wise in Figure 7. The frequency of recommended measures is shown in Figure 8.

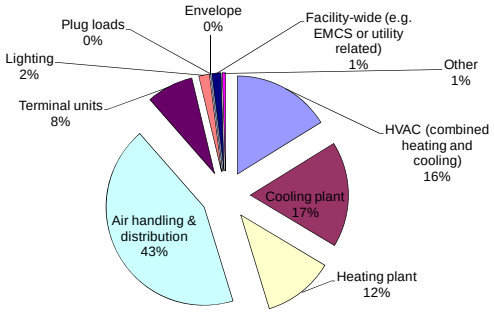

Figure 7. CC Assessments: Number of Deficiencies by Building System

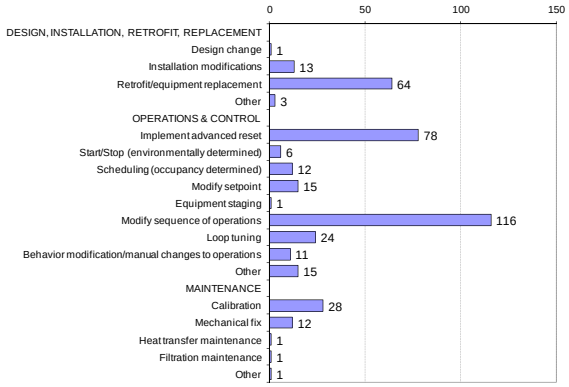

Figure 8. CC Assessments: Frequency of Proposed Measures

CASE STUDIES

A case study of a CC assessment at Walter Reed Army Institute of Research (WRAIR) located in Silver Spring, Maryland, is presented, followed by, a case study of the completed CC project at WRAIR

Within these case studies specific deficiencies and corrective measures are highlighted. The cost/benefit analyses of the projects are also included. Of the 45 projects analyzed, WRAIR is the only facility with CC assessment and completed CC information available. The use of WRAIR for case study purposes allows for a comparison between a CC assessment and a completed CC project that is not influenced by facility differences.

CC Assessment – Walter Reed Army Institute of Research

The Walter Reed Army Institute of Research is a 4 story, 520,000 square foot [48,310 m^2] facility located in Silver Spring, MD. WRAIR houses medical research and is comprised of offices, meeting spaces and laboratories. The CC assessment of WRAIR was conducted in May 2003.

Several deficiencies and potential corrective measures were identified and are listed below.

Air Handling and Distribution
1) Reset discharge air flow rate based on occupancy
2) Calibrate key sensors
3) Balance air flows
4) Reduce static pressure set point

Terminal Box
5) Calibrate VAV boxes

Air-to-Air Heat Exchangers
6) Heat exchangers not working properly
7) Fix water spray in heat exchangers
8) Optimize summer/winter "switch" temperatures of heat exchangers

Primary System and Water Loops
9) Chiller design capacity too low
10) Operate chiller based on outside air temperature (OAT)
11) Reset chilled water supply temperature based on OAT
12) Balance water loops
13) Optimize boiler operation

In terms of this compilation on CC opportunities in hospital/laboratory facilities, the pre-CC average annual energy costs were $1,548,623 (2006 $) or $2.98/sqft [$32/m^2]. The estimated cost of CC was $348,985 (2006 $) or $0.67/sqft [$7.22/m^2] and the projected average annual energy cost savings were $229,022 (2006 $) or $0.44/sqft [$4.74/m^2] which would realize a simple payback of 1.5 years. The estimated potential energy cost savings at WRAIR were 15% which is the median potential savings percentage for all CC assessments of this compilation.

CC – Walter Reed Army Institute of Research
WRAIR was commissioned from January 2004 thru March 2006 and several commissioning measures, listed below, were implemented during this period.

Air Handling and Distribution Major Measures
1) Verify and calibrate all temperature, humidity, and pressure sensors
2) Optimize the operation of AHU 10 outside air dampers
3) Reset schedules for static pressure and supply temperature
4) Repair valves and other malfunctioning components

Terminal Box Major Measures
5) Correct airflow sensor readings
6) Enable unoccupied periods

Air-to-Air Heat Exchangers Major Measures
7) Optimize the operation
8) Repair the water spray cooling

Chilled Water System Major Measures
9) Winter shut-off
10) Adjust chiller lead/lag sequence
11) Differential pressure reset schedule
12) Adjust cooling tower control
13) Reheat system reset schedules
14) Repair reheat expansion tank
15) Correct heating bypass valve operation

Energy Management Control System Major Measure
16) Improve operator control capabilities

The pre-CC annual energy costs at WRAIR were $1,420,000 (2006 $) or $2.73/sqft [$29/m^2]. The cost of CC was $368,275 (2006 $) or $ 0.71/sqft [$7.62/m^2] and the annual energy cost savings were $774,676 (2006 $) or $1.49/sqft [$16/m^2] for a simple payback of 5.7 months. The energy cost savings at WRAIR were 55% which is much higher than the median 20% savings for CC projects of this compilation.

In comparing the WRAIR CC assessment and completed CC, it can been seen that some deficiencies identified in the assessment were rectified by similar measures as proposed such as calibrating key sensors, optimizing heat exchanger operation and repairing the water spray cooling. However several previously unidentified measures were implemented such as resetting the reheat water temperature and differential pressure based on OAT, optimizing the operation of outdoor air dampers, repairing the reheat expansion tank, and adjusting control of the cooling towers. This is likely due to the limited time and resources usually involved in the CC assessment process.

CC PROJECT/ASSESSMENT COMPARISON
The average commissioning cost for the CC assessments was higher than the commissioning cost for the completed CC projects. This difference appears to be due to the following factors: some of the completed CC projects were performed on campus where no indirect cost was charged, some

projects were performed early in the CC evolution and were less complete than later projects, and some projects involved little or no travel expense because they were on campus facilities or closer to the campus. The energy savings in the CC assessments are typically lower than those in completed projects. This is likely due to a systematically conservative approach to estimating savings in the assessments. As an extreme example, the CC assessment of WRAIR estimated $229,000 annual energy cost savings. However, the actual CC energy cost savings upon CC completion were $774,676 per year.

In both the completed CC projects and the CC assessments the most common deficiencies reported related to air handling and distribution and the most frequently reported measures involved operations and control. The main difference was that it was more common in a completed CC project to implement an advanced reset while it was more common in a CC assessment to suggest a modification of the sequence of operations. Also of interest, the median number of deficiencies identified was greater for CC assessments than completed CC projects. It is possible that some of the measures suggested during an assessment will not be implemented during the actual commissioning process; equally as plausible previously unidentified measures may be deemed necessary.

CONCLUSIONS

From the findings of this study it is evident that there are several opportunities in commissioning hospital/laboratory facilities. The most prevalent deficiencies are air handling and distribution related, comprising over 60% of the deficiencies in the completed CC projects, followed by cooling plant, representing less than 15% of deficiencies in the completed CC projects, then heating plant deficiencies. The most prevalent corrective measures are related to operations and controls, accounting for 56% of measures implemented in completed CC projects; with the most frequent specific measures being implementation of an advanced reset or modification of the sequence of operation.

The total CC cost associated with 39 of 45 projects in this compilation is $14,375,960 (2006 $), including actual cost for completed CC projects and estimated cost for CC assessments. Similarly the pre-CC energy cost for 41 of 45 projects is $54,202,720 (2006 $). The total CC associated savings for all projects is $10,447,960 (2006 $), including actual savings for completed CC projects and potential savings for CC assessments. Key cost and savings findings are provided in Table 2.

Table 2. Key Cost and Savings Findings

	Completed CC Projects	CC Assessments
Key Cost Findings	*Actual Cost*	*Estimated Cost*
Pre-CC Energy Cost		
Median	$3.44/ft^2/yr	$2.85/ft^2/yr
	$36.98/m^2/yr	$30.64/m^2/yr
Average	$4.46/ft^2/yr	$3.19/ft^2/yr
	$48.06/m^2/yr	$34.29/m^2/yr
CC Cost		
Median	$0.26/ft^2	$0.86/ft^2
	$2.76/m^2	$9.25/m^2
Average	$0.41/ft^2	$1.16/ft^2
	$4.44/m^2	$12.49/m^2
Key Savings Findings	*Actual Savings*	*Potential Savings*
Simple Payback		
Median	< 5 months	2.5 years
Average	0.9 years	2.5 years
Energy Cost Savings		
Median	$0.84/ft^2/yr	$0.41/ft^2/yr
	$9.03/m^2/yr	$4.36/m^2/yr
	20%	15%
Average	$1.19/ft^2/yr	$0.44/ft^2/yr
	$12.80/m^2/yr	$4.72/m^2/yr
	26%	16%

Considering completed CC projects only, associated with the 6.81 million square feet [632,420 m^2] of hospital/laboratory facilities analyzed are $5,484,400 of CC resultant savings. If these findings are scaled up to the 3.1 billion square feet [288 million m^2] of hospital/laboratory facilities in the United States (in 2003 according to USDOE - CBECS) there is a potential of $2.5 billion annual savings from Continuous Commissioning.

ACKNOWLEDGEMENTS

The Continuous Commissioning projects analyzed in this study were conducted by the TEES Energy Systems Laboratory of Texas A&M University. The assessments summarized were performed by the Lab or by Bes-Tech, Inc., a CC licensee. The information included in this paper is largely based on internal commissioning reports.

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APPENDICES

APPENDIX A: Data Collection Instrument

Data Collection Instrument		VERSION: 2006
	Units	**Notes**
PROJECT DESCRIPTION		
Was the building previously commissioned?	Y; N	
Commissioning project leader's level of experience	number of projects previously completed (number only; no text)	Applies to project leader, not firm. Do not include general "energy efficiency experience"; R/Cx only
Building name and street address	text	Data will be kept confidential, I.e. not included in final report
Campus	text	
Location - City	text	
Location - State	Postal Abbreviation	
Building Ownership	Public; Private	
Number of buildings	Number	
Year Constructed	Year (NNNN)	
Floor Area:		
Entire building	square feet	
Area served by commissioned systems	square feet	
Net or Gross; Parking areas	N(p); G(p)	Include "(p)" in code if data include parking/garage spaces.
Is the facility part of a campus with central heating and/or cooling?	Y; N	
Year commissioning project/assessment completed	NNNN	Use four-digit format
PROBLEMS & STRATEGIES	"Count" should agree with that in the "Interventions" worksheet for the items that apply.	If information is available, complete separate "Interventions" worksheet first. Definitions available on "Interventions" Tab.
Is an "Interventions" Tab filled out for this project?	Y/N	Indicates whether more data is provided on the indicated Tab
Number of Problems Identified, by Component:		
Total	(Number)	This should agree with the grand total from the bold-outlined cells in the "Measures" tab (if used), including unitemized measures
HVAC (combined heating and cooling)	"	"
Cooling plant	"	"
Heating plant	"	"
Air handling & distribution	"	"
Terminal units	"	"
Lighting	"	"
Envelope	"	"
Plug loads	"	"
Facility-wide (e.g. EMCS or utility related)	"	"
Other	"	"
Number of Measures Recommended To Resolve Problems:		Includes accepted as well as rejected measures.
Total	"	This should agree with the grand total from the bold-outlined cells in the "Measures" tab (if used), including unitemized measures
Design, Installation, Retrofit, Replacement		
Design change	"	"
Installation modifications	"	"
Retrofit/equipment replacement	"	"
Other	"	"
Implement advanced reset	"	"
Start/Stop (environmentally determined)	"	"
Scheduling (occupancy determined)	"	"
Modify setpoint	"	"
Equipment staging	"	"
Modify sequence of operations	"	"
Loop tuning	"	"
Behavior modification/manual changes to operations	"	"
Other	"	"
Calibration	"	"
Mechanical fix	"	"
Heat transfer maintenance	"	"
Filtration maintenance	"	"
Other	"	"
Diagnostics and Automation Techniques	Text	List tools/methods used, e.g. WBD, ACRX, PacRat, Enforma
Verification of Measure Installation	Yes-all; Yes-some; No	Subsequent cost and savings data entered should exclude that for recommended interventions known to have been rejected.

COST DATA [Total; show by task on separate Tab]		Give costs in year of original data; do not correct for inflation
Year that costs reported below were incurred [NNNN]	NNNN	If multi-year project, list mid-point
Total building construction cost (if new building) [$]	$	
Total commissioning cost [$]	$	Should include study costs.
BASELINE ENERGY USE AND SAVINGS		
End Uses Included [Whole Building, or finite set of end uses based on "Components" defined above]	WB or C	
Are data weather-normalized?	Y;N	
If yes, using what method?	name method	
Year of Energy Use and Savings Data	Year (NNNN)	If possible, do not use first post-commissioning year's data (savings often manifest slowly). Use year-2 or -3.
Total Electricity usage:		
Before commissioning	kWh/year	
After commissioning (or as-commissioned, if new building)	kWh/year	
Total Peak electrical demand:		
Before commissioning	peak kW	
After commissioning (or as-commissioned, if new building)	peak kW	
Total Fuel usage:		
Before commissioning	Millon BTU/year	
After commissioning (or as-commissioned, if new building)	Million BTU/year	
Total Chilled and/or Hot water [enter only if energy data not available]		
Before commissioning	MMBtu	
After commissioning (or as-commissioned, if new building)	MMBtu	
Total energy cost (electric, peak, fuel):	$/year	
Before commissioning	$/year	
After commissioning (or as-commissioned, if new building)	$/year	
Energy prices associated with cost estimates		Use values corresponding to cost data provided above
electricity	$/kWh	
peak electricity demand	$/kW	
fuel	$/million BTU	
hot or chilled water	$/million BTU	
Energy Savings Determination	A; B; C; or D	If multiple methods are used, choose ONE of the following to reflect the most prevalent form of determination.
Engineering Estimates/Simulations (no measurements)	Y;N	
Measured Savings - Option A. Partially measured retrofit isolation	Y;N	IPMVP Category: See "M&V Options Tab for definitions"
Measured Savings - Option B. Retrofit isolation	Y;N	IPMVP Category: See "M&V Options Tab for definitions"
Measured Savings - Option C. Whole facility	Y;N	IPMVP Category: See "M&V Options Tab for definitions"
Measured Savings - Option D. Calibrated simulation	Y;N	IPMVP Category: See "M&V Options Tab for definitions"
Do the preceeding savings data reflect all commissioning activities described and costed above?	Y;N	
If "no", list % increase in reported savings anticipated upon completion	%	
OTHER		
Data Source(s) - provide full citation	text	Use, abbreviated citation here (e.g. "Claridge et al. 1999") and report full bibliographic info on the "Data Sources" Tab next to the row representing this project.
Comments (summarize concisely here; attach Tabs if desired)	text	

APPENDIX B: Deflators

Year	Implicit Price Deflator (2006 = 1.0000)
1993	0.76
1994	0.78
1995	0.79
1996	0.81
1997	0.82
1998	0.83
1999	0.84
2000	0.86
2001	0.88
2002	0.90
2003	0.92
2004	0.94
2005	0.97
2006	1.00

APPENDIX C: Sample Measures Matrix

Project ID Number: 1 Terrell Community Hospital Bldg # all buildings

	Components (locus of fault)										Measures																				
											Design, Installation, Retrofit, Replacement				Operations & Control									Maintenance							
	HVAC (combined heating and cooling)	Cooling plant	Heating plant	Air handling & distribution	Terminal units	Lighting	Envelope	Plug loads	Facility-wide (e.g. EMCS or utility related)	Other	Design change	Installation modifications	Retrofit/equipment replacement	Other	Implement advanced reset	Start/Stop (environmentally determined)	Scheduling (occupancy determined)	Modify setpoint	Equipment staging	Modify sequence of operations	Loop tuning	Behavior modification/manual changes to operations	Other	Calibration	Mechanical fix	Heat transfer maintenance	Filtration maintenance	Other	# of times measure present	Measures Code	Detail problems and remediation measures
	V	C	H	A	T	L	E	P	F	O	D1	D2	D3	D4	OC1	OC2	OC3	OC4	OC5	OC6	OC7	OC8	OC9	M1	M2	M3	M4	M5			
			x																		x								7	H-OC7	new hot water pump control scheme
		x																			x								4	C-OC7	new chilled water pump control scheme based on cold deck temp
		x																			x								2	C-OC7	new chilled water pump on/off control based on DP
		x																		x									2	C-OC6	new chilled water pump speed control based on OA temp
		x														x													4	C-OC2	new chilled water pump on/off control based on OA temp
			x												x														6	H-OC1	new hot water supply temp reset schedule
				x											x														3	A-OC1	new cold deck temperature reset
				x											x														5	A-OC1	new hot deck temperature reset
					x																x								2	T-OC7	modify VAV box control
				x												x													1	A-OC2	operate supply air fan based on OA temp
	x																x												3	V-OC3	on/off schedule based on occupancy
				x														x											1	A-OC4	static pressure sp based on supply air fan speed
				x																				x					9	A-M1	calibrate space temperature sensors
	x																			x									1	V-OC6	balance chilled & hot water loop
				x																			x						4	A-OC9	adjust total air flow rate
	x												x																2	V-D3	upgrade controls to DDC
			x																		x								1	H-OC7	new gas heater on/off control scheme
		x													x														1	C-OC1	reset chilled water supply temperature
				x																					x				5	A-M2	repair broken dampers or damper actuators/linkages
Other (#)	4			19	2				1				7				1	1				5	1	4	4	2	1		26		
Rejected (#)																													0		
Count or total:	10	13	14	47	4	0	0	0	1	0	0	0	9	0	15	5	4	2	0	3	16	5	5	13	9	2	1	0	89		
Grand Totals:	89										89																				