Cost-Benefit Analysis

for the

Commissioning in Public Buildings Project

Submitted to

NORTHWEST ENERGY EFFICIENCY ALLIANCE
529 SW Third Avenue, Suite 600
Portland, OR 97204

Submitted by

SBW CONSULTING, INC.
2820 Northup Way, Suite 230
Bellevue, WA 98004

with

SKUMATZ ECONOMIC RESEARCH ASSOCIATES
762 Eldorado Drive, Suite 100
Superior, CO 80027

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Purpose of This Study

The Northwest Energy Efficiency Alliance is currently undertaking a long-term effort to expand and institutionalize the practice of building commissioning among state and local governments in the Pacific Northwest. Started in 1998, this Commissioning in Public Buildings project is coordinated on behalf of the Alliance by the Oregon Office of Energy. Part of its strategy is to demonstrate commissioning in a variety of new and existing buildings in each state. An important component of this demonstration effort is providing government officials with detailed case studies of commissioned buildings and the costs and benefits of the commissioning process for these buildings. Both commissioning service providers and potential recipients of commissioning services place high value on case studies that target buildings of interest to them, and provide well-documented, reliable estimates of the costs and benefits. The Alliance's third Market Progress Evaluation Report for this project recommended re-visiting the original cost-benefit data to determine whether more accurate estimates could be developed. To that end, the Alliance funded a study to analyze the costs and benefits of commissioning by quantifying both energy and non-energy impacts[1] for 21 of the 33 projects currently underway or already completed.

The primary objectives of the study were to develop quantitative estimates of the impacts—both costs and benefits—that resulted from the commissioning effort for each project, and to calculate payback ratios for each project. These include (1) direct payback, which only considers direct impacts such as reduced energy use and the commissioning agent cost, and (2) total payback, which also takes into account indirect effects, such as non-billable time spent and non-energy impacts.

How the Study Was Conducted

For each commissioning project included in this study, we obtained extensive project documentation that permitted us to identify critical project personnel, as well as significant issues that the commissioning process uncovered. We administered two telephone surveys, one to all key commissioning team members (e.g., commissioning agents, construction managers, and operations staff), and another to a subset of these, the agency managers and decision-makers. Data from these surveys formed the basis for calculating the incremental costs and the value of the non-energy benefits of commissioning. Technical information in the project documentation, coupled with supporting information from project personnel, permitted us to quantify the impacts of the significant commissioning issues that have been or soon will be resolved for the 21 projects.

For each project, we calculated four impacts: (1) ongoing energy, (2) ongoing non-energy, and (3) one-time direct, and (4) one-time indirect. Each element of these impacts could be positive or negative. Combining these impacts yielded payback ratios for each project, as well as by commissioning type and for the entire group combined. It should be noted that the average results presented in this study are based

[1] These difficult-to-quantify effects are commonly referred to generically as non-energy benefits. This report refers to them throughout as "non-energy impacts," which acknowledges the fact that these effects can be both positive and negative. A positive example would be the value of improved occupant comfort from deficiencies found and resolved through commissioning, while a negative example would be increased problems with coordination between project team members.

on a fairly small sample of projects. The flowchart in Figure 1 summarizes the methodology, and major

State	#	Building type	Cx type*	Building size (ft2)	Cx agent cost to agency** ($)	($/ft2)
Idaho	1	Courthouse	New	340,000	220,000	0.65
	2	Recreation center	New	90,148	40,280	0.45
	3	Offices	Retro	23,000	19,300	0.84
Montana	4	Maint. facility	Retro	56,000	12,300	0.22
	5	Middle school	Retro	64,000	8,700	0.14
	6	College/University	Retro	110,380	24,800	0.22
	7	Prison office	New	23,300	24,000	1.03
Oregon	8	Elementary school	Retro	65,000	11,044	0.17
	9	Library	New	69,500	83,380	1.20
	10	Transit center/office	New	160,000	60,880	0.38
	11	Day care center	New	18,300	12,400	0.68
	12	High school	New	250,000	85,000	0.34
	13	Offices	Retro	170,000	20,900	0.12
	14	College/University	Retro	213,000	14,280	0.07
	15	Elementary school	New	49,000	32,660	0.67
Washington	16	High school	New	144,000	41,860	0.29
	17	Museum	New	78,000	100,000	1.28
	18	Elementary school	Retro	95,405	65,102	0.68
	19	Prison	New	58,000	80,000	1.38
	20	Hospital	New	51,000	70,000	1.37
	21	College/University	New	60,000	82,820	1.38
Sum				2,188,033	1,109,706	n/a
Average				104,192	52,843	0.65

Cx = commissioning.

** Excludes additional costs associated with participation in the Alliance program, such as case study development.

aspects of it are described in further detail below.

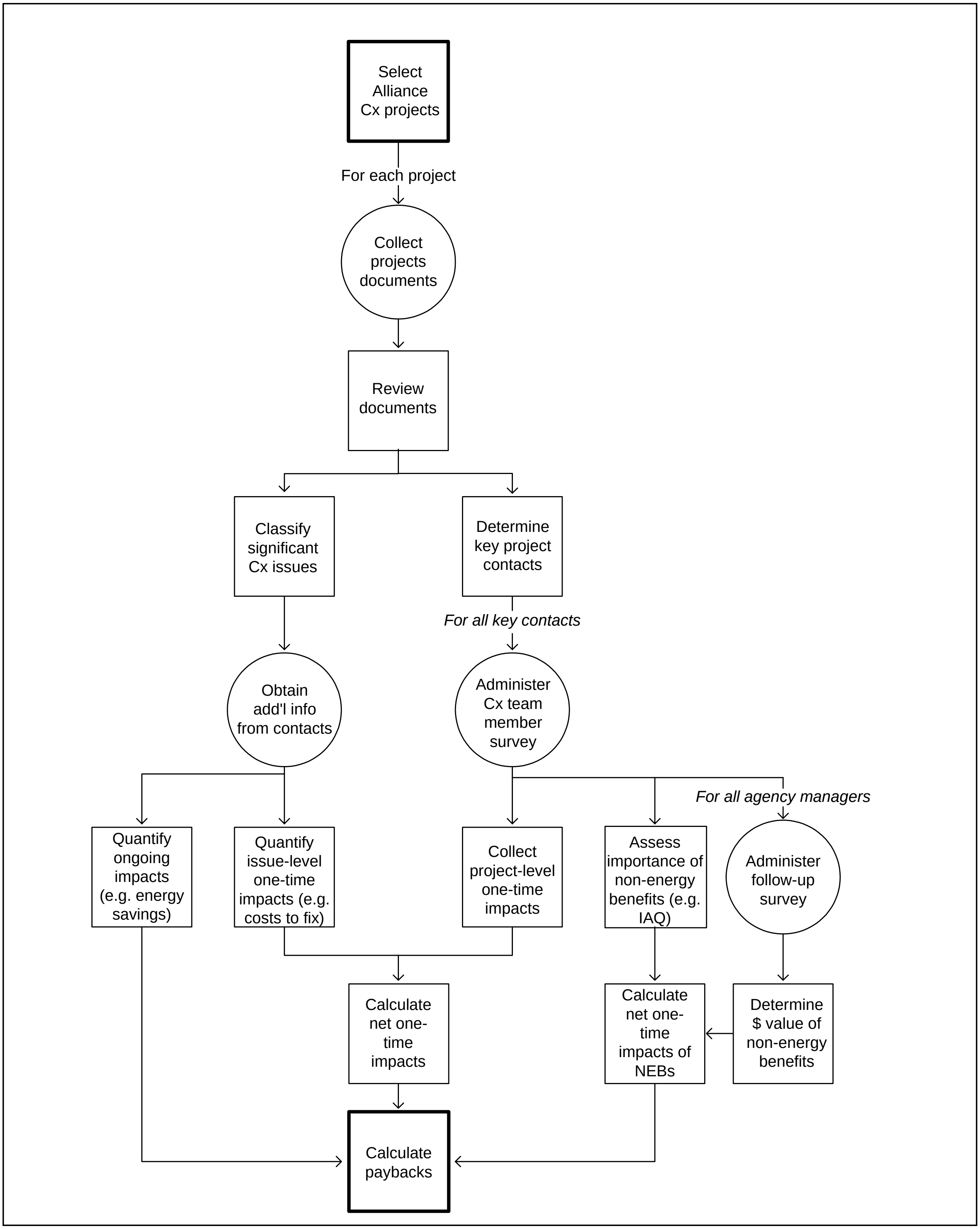
Table 1: Selected Commissioning Projects

1. **<u>Project Selection</u>**: These 21 projects selected by the Alliance for inclusion in the study comprise 64% of the 33 commissioning projects that have been completed or are currently ongoing through the Commissioning in Public Buildings project. Table 1 provides details about the associated facilities and the commissioning efforts for each of these projects. Combined, the commissioned buildings in this study account for nearly 2.2 million square feet of building area.

2. **<u>Project Documentation Review</u>**: Through preceding studies as well as this study, we collected all pertinent documentation for each project available as of early 2003. Key information sources included: (a) commissioning reports, (b) commissioning issue logs, (c) commissioning design review memoranda and project correspondence, (d) initial energy savings estimates prepared by the

commissioning agents for most of the retrocommissioning projects, (e) energy life cycle cost analyses that examine energy efficiency of alternative building systems, and (f) draft case study reports.

Figure 1: Methodology Flowchart



Once information was collected for a project, we reviewed it to determine how much information about commissioning issues and building parameters was available. We also searched for names and contact information for key members of the commissioning project team.

3. **Issue-Level Impact Assessment**: We categorized all commissioning issues (sometimes also called deficiencies) documented in the commissioning reports and issue logs for each project according to following criteria:

   - Significant: An issue (or group of related issues) was considered "significant" if it: (a) affected a large area or number of people (in relative terms for each project), (b) resulted in major immediate costs to resolve, and/or (c) would have resulted in long-term impacts had the issue not been found.
   - Resolved/Unresolved: Significant issues were then grouped based on whether or not they had already been or were likely to have been resolved within one year after the commissioning was complete. In cases where the documentation did not make this clear, we based our determinations on the opinion of the commissioning agent and/or facility manager.

   For each significant issue or issue grouping, we estimated both ongoing and one-time impacts, each of which could be positive or negative. *Ongoing impacts* included:

   - Energy: Measurable, quantifiable impacts on electric or gas usage of the project facility, as determined by standard engineering calculations or parametric modeling. For costing, we used current average commercial electricity and gas prices of $0.07/kWh and $0.85/therm, respectively, as provided by the Northwest Energy Efficiency Alliance, based on U.S. Energy Information Administration data for four Northwest states.

   - Non-energy: Measurable, quantifiable impacts on facility operation costs, such as less frequent lamp replacement and reduced water usage. Difficult-to-quantify non-energy impacts, such as improved occupant comfort, were assessed at the project level.

   Certain significant energy impacts proved impossible to quantify with the approaches described above. An example of this was a project with outside air dampers that stuck randomly in different positions. To address this, after evaluating all the significant issues for a given project, we compared the non-quantifiable issues to the quantified ones, and assigned a subjective rating of "high," "medium," or "low" to indicate the magnitude of all non-quantifiable energy impacts compared to all quantified energy impacts.

   One-time impacts included:

   - Issue resolution costs: Costs incurred to remedy a problem or deficiency that the commissioning process revealed. These costs could be direct, that is, resulting in a documented cost increase, as would be the case in a retrocommissioning project where a contractor was hired to install a new HVAC timeclock. On a new commissioning project, if a contractor issued a change order to make a commissioning-issue-related modification, then the cost of the change order would be considered a direct cost. They could also be indirect, in that the problem required some time to rectify, but that increment of time was not charged to the agency, so the agency saw no additional cost. Examples would be a controls contractor reprogramming an improper controls sequence without a change order within the warranty period, or regular maintenance staff resetting thermostats.

- Avoided repair costs: Direct and/or indirect costs that the project avoided because the commissioning process found and resolved issues early. An example would be a commissioning agent performing a design review that showed that temperature sensors were poorly located. Changing the design before construction was complete avoided a contractor change order to relocate the sensors later in the project.

4. **Project-Level Impact Assessment**: The primary tool for assessing commissioning costs and impacts at the project level was the commissioning team member survey. This survey was administered to all who had a key role in the commissioning process for each project, including commissioning agents, designers, contractors, and agency personnel. Data from this survey permitted us to estimate one-time impacts for each team member. As with the issue-level assessment, these impacts were classified as direct and indirect, and could be positive or negative. The impacts could include additional change orders, avoided repairs, resolution of commissioning issues, and identification of commissioning issues. The latter refers to the incremental costs associated with commissioning-related activities designed to identify issues and problems. These would occur regardless of whether or not specific problems were actually found. Examples include the time building engineers spent explaining HVAC control strategies to the commissioning agent, increases to contractor's initial bids to allow for commissioning activities, and commissioning agent fees.

   Another subgroup of indirect impacts is the non-energy impacts. Non-energy impacts are inherently difficult to document and assign quantitative values to, and can include beneficial and detrimental impacts during design and construction, such as contractor call-backs, change orders or warranty claims, potential for litigation, coordination and relationships between team members, project schedules, and time needed to get building systems working right. For facility operations, impacts could include fewer operational deficiencies, system documentation, staff knowledge, and extended equipment lifetime. For building occupants, some potential impacts are comfort, indoor air quality, productivity, and safety.

   The quantification process developed for this study involved two key parameters. The first, an *impact importance factor*, reflects commissioning team members' collective sense of the importance of a particular impact. The second parameter was monetized estimates of the economic worth of particular indirect impacts from the project agency's perspective. Individuals who had a sufficient overview of their agency's operations or the particular construction project to assess the value of the commissioning project to the agency and building occupants were asked in a follow-up survey about the presence and values of non-energy impacts on the project. We assessed the relative value of these non-energy impacts compared to a known value, the commissioning agent fees. Respondents were asked to compare the value of the stream of non-energy impacts from a particular source to the commissioning agents fees. This value could be either positive or negative in the quantification.

   Since prior studies of this type have commonly found discrepancies between computations of non-energy impacts based on the various measurement methods, we asked multiple sets of questions to derive a range of estimates. We assessed the total benefits three ways – willingness to pay (WTP), sum of the individual computed benefits, and the "overall net" value computed as the respondent's "overall net" value multiplier times the commissioning cost. We then kept the most conservative value – the minimum of these three values. The net value of a given non-energy impact is the product of its impact importance factor and its gross dollar valuation. If both are high, then the impact's net value will also be high. Because of limitations in the ability of survey respondents to provide suitable data, the value of non-energy impacts that could be expected to last over an extended period, such as improved occupant comfort, were expressed as one-time values, with these values representing the accumulated value over the life of the building.

5. **Payback Calculation**: We grouped the data developed in the previous steps to calculate paybacks for each project. We calculated two payback ratios for each project, as follows:

$$\textit{Direct payback} = \left|\textit{Direct one-time impacts}\right| \div \textit{Ongoing impacts}$$

$$\textit{Total payback} = \left|\textit{Direct + indirect one-time impacts}\right| \div \textit{Ongoing impacts}$$

Study Findings

Ongoing Impacts

Ongoing energy impacts consist of the net savings in electricity and natural gas that resulted from resolved commissioning issues. We estimated that the average quantifiable impacts per project are about 110,400 kWh/year and 4,200 therms/year, with a combined value of about $11,300 annually[2]. Normalized by floor area, these impacts are 1.06 kWh/SF/year and 0.04 therms/SF/year, respectively. The normalized combined value is $0.11/SF/year. On average, retrocommissioning projects, at $0.14/SF/year, yield much higher larger energy impacts than new commissioning projects ($0.09/SF/year). Based on a qualitative assessment of the amount of engineering uncertainty in these estimates, we found that the majority of the energy value resides with projects with low uncertainty, so it seems reasonable to conclude that the portion of energy impacts that is non-quantifiable is relatively small.

Ongoing non-energy impacts consisted of two types: (a) impacts to utilities other than electricity or gas, such as water, sewer, or propane service, and (b) quantifiable changes to operations and maintenance expenses. Examples of the latter were reduced air compressor maintenance costs and lamp replacement costs. On average, the direct non-energy impacts for these projects were minuscule.

One-Time Direct Impacts

One-time direct impacts include (a) issue identification costs, such as the cost to hire the commissioning agent, (b) issue resolution costs, such as billed cost to an agency to fix a problem that is out of scope, (c) additional change orders/project costs, such as billed cost to agency to add variable speed drives, and (d) avoided change orders/project costs, such as the money the agency saves by not having to pay to relocate thermostats. The latter are subtracted from the other direct costs. The net one-time direct impacts per project were about -$66,000, or -$0.63/SF/year. As shown in Table 2, issue identification accounts for about 80% of this impact, with issue resolution making up most of the remainder. In comparison, the net impact of additional and avoided change orders was small. Actual impacts per project varied significantly from these averages.

One-Time Indirect Impacts

One-time indirect impacts are those that the project or agency experiences, but that do not lead to changes in the billed amounts to the agency as part of project costs. These can include (a) issue identification, such as labor cost for agency staff to attend commissioning meetings, (b) issue resolution, such as the labor costs for agency staff, or contractors if no change order, to rewrite a control sequence, (c) additional change orders/project costs, in the form of labor cost for agency staff to administer direct impact activities, and (d) avoided change orders/project costs, in the form of avoided labor costs for agency staff to administer direct impact activities. Table 2 shows that the one-time indirect impact per project, which

[2] Impacts that result in net costs and net savings are expressed as negative and positive numbers, respectively, in this report.

takes into account these four elements. The net indirect incremental costs per project were about -$11,200, or -$0.11/SF/year. This is 17% of the corresponding direct cost of -$0.63/SF/year. This cost is split nearly equally between issue identification costs and issue resolution costs.

The final category of indirect impacts is non-energy impacts that affected design and construction (such as project schedules), facility operations (such as operational deficiencies), or building occupants (such as indoor air quality). The value of these impacts is about $23,600 per project, or $0.23/SF/year. To provide a sense of the relative importance of all impacts, we calculated the percentage of the total impact that each individual impact comprised. By far the most significant impacts overall were reducing operational deficiencies and improving occupant comfort, with 28% and 22% shares, respectively, of the total dollar value of all indirect non-energy impacts. Other important impacts were reducing the time needed to get building systems working properly (9%), improving indoor air quality (7%), and increasing O&M staff's knowledge of how the building functions (7%).

Table 2: One-Time Impacts Across All Projects

	Direct $/SF	**Indirect** $/SF	**Total** $/SF
(a) Issue identification	-0.51	-0.06	-0.57
(b) Issue resolution	-0.13	-0.05	-0.18
(c) Change orders/new scope	0.01	0.00	0.01
(d) Non-energy	0.00	0.23	0.23
Total	**-0.63**	**0.12**	**-0.51**

Paybacks

Table 3 draws together the ongoing energy and non-energy impacts, and the one-time direct and indirect impacts derived in the previous sections. The average combined ongoing impact was about $11,200/year per project. Dividing the average one-time direct impact of -$66,000 by this figure yields a direct payback of 5.9 years. The retrocommissioning projects on average had much lower paybacks than the new commissioning projects, with an average direct payback of 4.0 years, versus 7.5 years for new.

Including the indirect costs impacts changes this significantly. The indirect one-time impacts are about $12,400/year per project. Including them in the payback calculation yields total payback of 4.8 years. The average paybacks for new and retrocommissioning are 6.1 and 3.2 years, respectively.

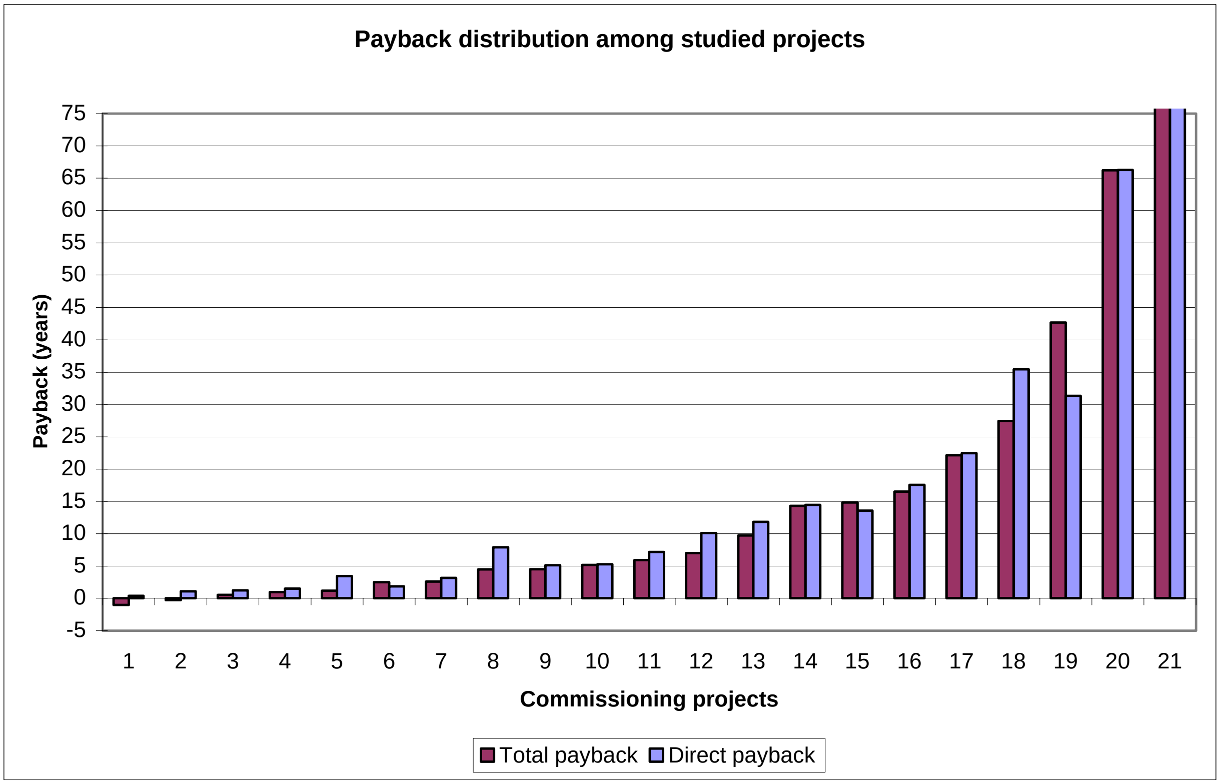
Figure 2 shows the wide variation in simple payback ratios among the projects. Direct paybacks ranged from 0.4 to 200 years, while total paybacks ranged from –1 to 158 years. The effect of including indirect impacts in the cost-effectiveness calculation also varied widely: percentage changes from direct to total payback ranged from a 353% decrease to a 36% increase. Overall, though, over half of the projects had total paybacks of seven years or less.

Table 3: Aggregate Results

		Ongoing Impacts					One-Time Impacts			Payback*	
		Electricity (kWh/yr)	Natural gas (therm/yr)	Energy ($/yr)	Non-energy ($/yr)	Total ($)	Direct ($)	Indirect ($)	Total ($)	Direct (years)	Total (years)
ABSOLUTE VALUES											
By Cx type, per project	New (N=13)	102,732	3,135	9,856	3	9,858	-73,536	13,609	-59,927	7.5	6.1
	Retro (N=8)	122,979	5,964	13,678	-259	13,419	-53,776	10,534	-43,242	4.0	3.2
	All (N=21)	**110,445**	**4,212**	**11,312**	**-97**	**11,215**	**-66,009**	**12,438**	**-53,571**	**5.9**	**4.8**
NORMALIZED VALUES (per SF)											
By Cx type	New	0.96	0.03	0.09	0.00	0.09	-0.69	0.13	-0.56		
	Retro	1.23	0.06	0.14	0.00	0.13	-0.54	0.11	-0.43		
	All	**1.06**	**0.04**	**0.11**	**0.00**	**0.11**	**-0.63**	**0.12**	**-0.51**		

* Direct payback = -(Direct one-time impacts) / Ongoing impacts
  Total payback = -(Direct + indirect one-time impacts) / Ongoing impacts

Figure 2: Distribution of Project Payback Ratios



Conclusions

This study used a thorough cost and energy impact evaluation, coupled with systematic quantification and valuation of non-energy impacts, to provide a more complete estimate of the value of commissioning. The payback for all projects studied was 5.9 years, when only considering direct costs and impacts, such as energy savings. Adding in the value of indirect effects, such as improved building comfort and operability, reduces the payback to 4.8 years. Retrocommissioning, on average, has a lower payback (3.2 years) than new commissioning (6.1 years). This may be partially explained by difficulties incorporating design-phase commissioning into the new construction projects. Individual projects exhibited widely varying results. This suggests that while commissioning on average may be cost-effective, it is difficult to predict whether it will be so for a particular project. It should be noted that over half of the projects studied had total paybacks less than seven years.

Personnel involved with the commissioning efforts were generally very pleased with the process. The analysis of non-energy impacts revealed that they particularly valued the reduced operational deficiencies and improved occupant comfort that commissioning can bring. Other important non-energy impacts were reduced time needed to get building systems working properly, improved indoor air quality, and increased O&M staff knowledge of how the building functions. Quantifying and including the value of these impacts in the overall economic analysis significantly enhanced the economic attractiveness of commissioning. As a result of their experiences with the demonstration projects, many agencies have begun incorporating commissioning into subsequent projects, as well as their policies and procedures.

1. Introduction

1.1 Background

The Northwest Energy Efficiency Alliance (the Alliance) is currently undertaking a long-term effort to expand and institutionalize the practice of building commissioning among state and local governments in the Pacific Northwest. Started in 1998, this Commissioning in Public Buildings project is coordinated on behalf of the Alliance by the Oregon Office of Energy (OOE). It is slated to run through the end of 2003. An important component of this effort is providing government officials with detailed case studies of commissioned buildings and the costs and benefits of the commissioning process for these buildings. Both commissioning service providers and potential recipients of commissioning services place high value on case studies that target buildings of interest to them, and provide well-documented, reliable estimates of the costs and benefits. In addition, the Alliance's third Market Progress Evaluation Report for this project recommended re-visiting the original cost-benefit data to determine whether more accurate estimates could be developed.

Until recently, the four states within the Alliance region—Oregon, Washington, Idaho, and Montana—had each undertaken individual efforts to develop case studies and the associated cost-benefit analyses. OOE and the Idaho Department of Water Resources (IDWR) hired an outside consultant, SBW Consulting, Inc. (SBW) to perform life-cycle cost-benefit analyses of 11 commissioning demonstration projects. These analyses, while they investigated the non-energy benefits of commissioning, focused mainly on quantifying energy benefits along with commissioning costs. Washington and Montana chose alternative avenues for performing the analyses and case studies.

In the summer of 2002, the Alliance funded a study to determine the feasibility and cost of analyzing the costs and benefits of commissioning by quantifying both energy and non-energy impacts. The methodology developed through this study could be applied uniformly to projects across all four states. In December 2002, the Alliance approved a follow-up study to implement this methodology on 21 of the 33 projects currently underway or already completed.

1.2 Objectives

The primary objectives of the follow-up study (henceforth referred to as "the study") are as follows:

1. For each commissioning project included in the study, develop quantitative estimates of the overall economic impacts, both positive and negative, that resulted from the commissioning effort.

2. Calculate payback ratios for each project, and provide results aggregated by commissioning type and for all studied projects combined.

1.3 Definitions

Terms important for understanding the analysis are listed below.

New commissioning: building commissioning projects that involve new buildings or major remodels or additions.

Retrocommissioning: building commissioning projects that involve tune-ups of existing buildings. Included in this category for this study were a recommissioning project (follow-up commissioning of a building that had been originally commissioned as a new building) and a chiller retrofit project.

Impacts: general term for the positive or negative effects of commissioning activities. These impacts can be *direct* or *indirect,* and *one-time* or *ongoing,* as defined below.

Direct: impacts with documentable financial effects. Examples include reduction in electric bills, and commissioning agent fees.

Indirect: impacts whose cost or value is difficult to document. Examples include non-billable time spent by the contractor on commissioning activities, and *indirect non-energy impacts* (defined below).

Indirect non-energy impacts: this term, as used in the study, is more commonly known as "non-energy benefits." Examples of these include fewer contractor callbacks after construction is complete, better knowledge of building systems for facility operators, and improved indoor air quality for building occupants.

Ongoing: impacts that affect energy use or non-energy costs, such as water consumption or lamp replacement costs, that occur throughout the lifetime of the building. These only include direct impacts.

One-time: impacts that typically affect first costs (both direct and indirect). These include costs to find and resolve commissioning issues, as well as additional and avoided change orders resulting from commissioning. Also included in this category are the present-value benefits from indirect non-energy impacts described above, such as improved occupant comfort.

Direct payback: Direct one-time impacts, divided by ongoing (direct) impacts.

Total payback: Direct and indirect one-time impacts, divided by ongoing (direct) impacts.

1.4 Report Organization

Section 2 of this report discusses the study methodology, including project selection, data sources, and analysis steps. Section 3 presents the results from two telephone surveys and the commissioning issue analysis, as well as from the impact quantification and simple payback calculations. Section 4 provides conclusions drawn from the results. The Appendices in Section 5 provide more detailed breakdowns of the results, as well as survey instruments.

2. Methodology

2.1 Overview

For each commissioning project included in this study, we obtained extensive project documentation that permitted us to identify significant issues that the commissioning process uncovered, as well as critical project personnel. We administered two telephone surveys, one to all key commissioning team members, and another to a subset of these, the agency managers and decision-makers. Data from these surveys formed the basis for calculating the incremental costs and the value of the indirect non-energy benefits of commissioning. Technical information in the project documentation, coupled with supporting information from project personnel, permitted us to quantify the direct and indirect impacts of the significant commissioning issues that have been or soon will be resolved for the 21 projects. Combining this information yielded payback ratios for each project, as well as by commissioning type and overall.

Figure 2-1 shows in tabular and graphical form how the various impacts—direct, indirect, one-time, and ongoing—are classified, as well as how they correspond to traditional notions of costs and benefits. The flowchart in Figure 2-2 summarizes the overall methodology used in this study.

2.2 Select Projects

We selected an initial sample of 18 projects from a pool of 33 demonstration efforts funded by the Alliance. These 18 projects all were amenable to further data collection, and would be complete in time to be included in this study. To these, we added three additional projects, where the cost of studying these was already covered through separate contracts with the relevant states. They are included to provide a more robust sample. Therefore, the final number of commissioning projects included in the study is 21. These are listed in Table 2-1.

These 21 projects comprise 64% of the 33 commissioning projects that have been completed or are currently ongoing through the Commissioning in Public Buildings project. The 21 projects include 13 new commissioning (64% of the total building area) and eight (36%) retrocommissioning projects. Combined, the commissioned buildings in this study account for nearly 2.2 million square feet of building area.

Nearly half (10 projects) of the facilities in the study are state-owned, with school districts owning facilities where six more projects took place. The remaining five projects occurred at a mix of city, county, and federal facilities. Eight of the projects are in Oregon, six in Washington, four in Montana, and three in Idaho. Nearly half of the building floor area (45%) is in Oregon, with Washington and Idaho accounting for nearly equal smaller portions (22% and 21% respectively). Montana projects make up the remaining 12%. The commissioned floor area ranges from 18,300 to 340,000 square feet. The commissioning agents' fees, not including any costs associated with participation in Alliance activities, ranged from $8,700 to $220,000. The corresponding billed commissioning cost per square foot ranged from $0.07/SF to $1.38/SF, with an average of $0.65/SF. As would be expected, these average costs were higher for new commissioning projects: $0.85/SF, compared with $0.31/SF for retrocommissioning projects.

Figure 2-1: Overview of Impact Cost/Benefit Framework

	ONGOING IMPACTS ($/year)		ONE-TIME IMPACTS($)	
	Energy	***Non-Energy***	***Direct***	***Indirect***
Elements (with examples)	**Electricity usage** (reduced fan run time lowers electric bills)	**Other utility usage** (lower water bill from reduced cooling tower evaporation)	**Issue identification** (cost to hire Cx agent)	**Issue identification** (labor cost for agency staff to attend Cx meetings)
			Issue resolution (billed cost to agency to fix a problem that is out of scope)	**Issue resolution** (labor costs for agency staff, or contractors if no change order, to rewrite control sequence)
	Natural gas usage (optimized boiler controls reduce gas bills)	**Maintenance expenses** (reduced lamp burn time delays replacement costs)	**Additional change orders / project costs** (billed cost to agency to add variable speed drives)	**Additional change orders / project costs** (labor cost for agency staff to administer direct cost activities)
			Avoided change orders / project costs (saved cost to agency for not relocating thermostats)	**Avoided change orders / project costs** (labor cost for agency staff to administer direct cost activities)
				Other non-energy impacts (value to agency of improved coordination among construction team, improved occupant comfort*)

* Some indirect non-energy impacts may be ongoing, but for methodological reasons, their value over time is treated as a one-time net present value.

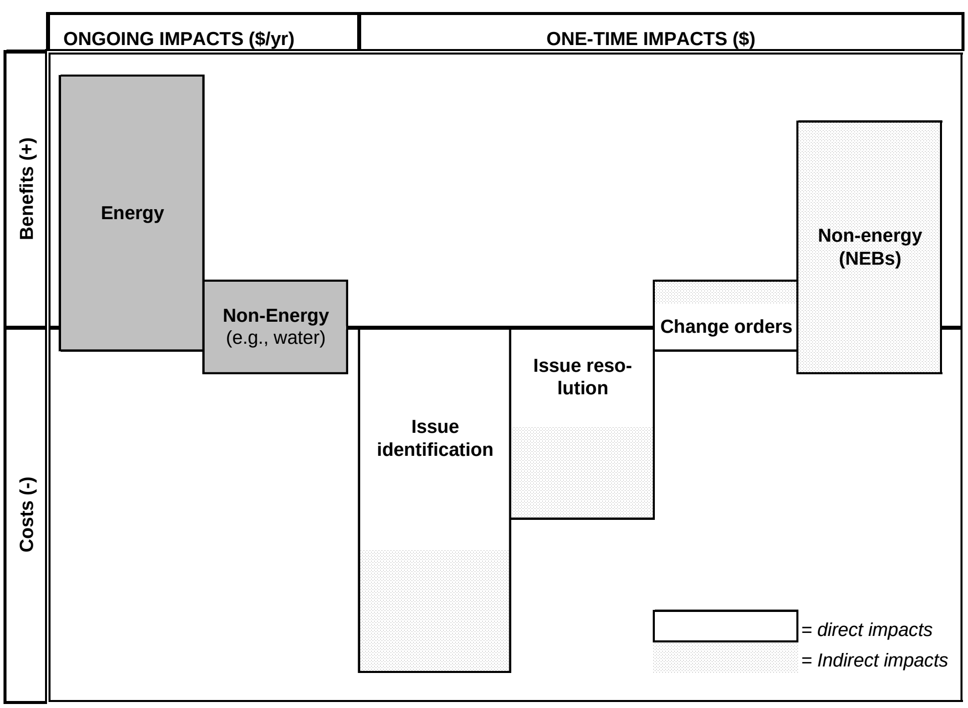


Figure 2-2: Methodology Flowchart

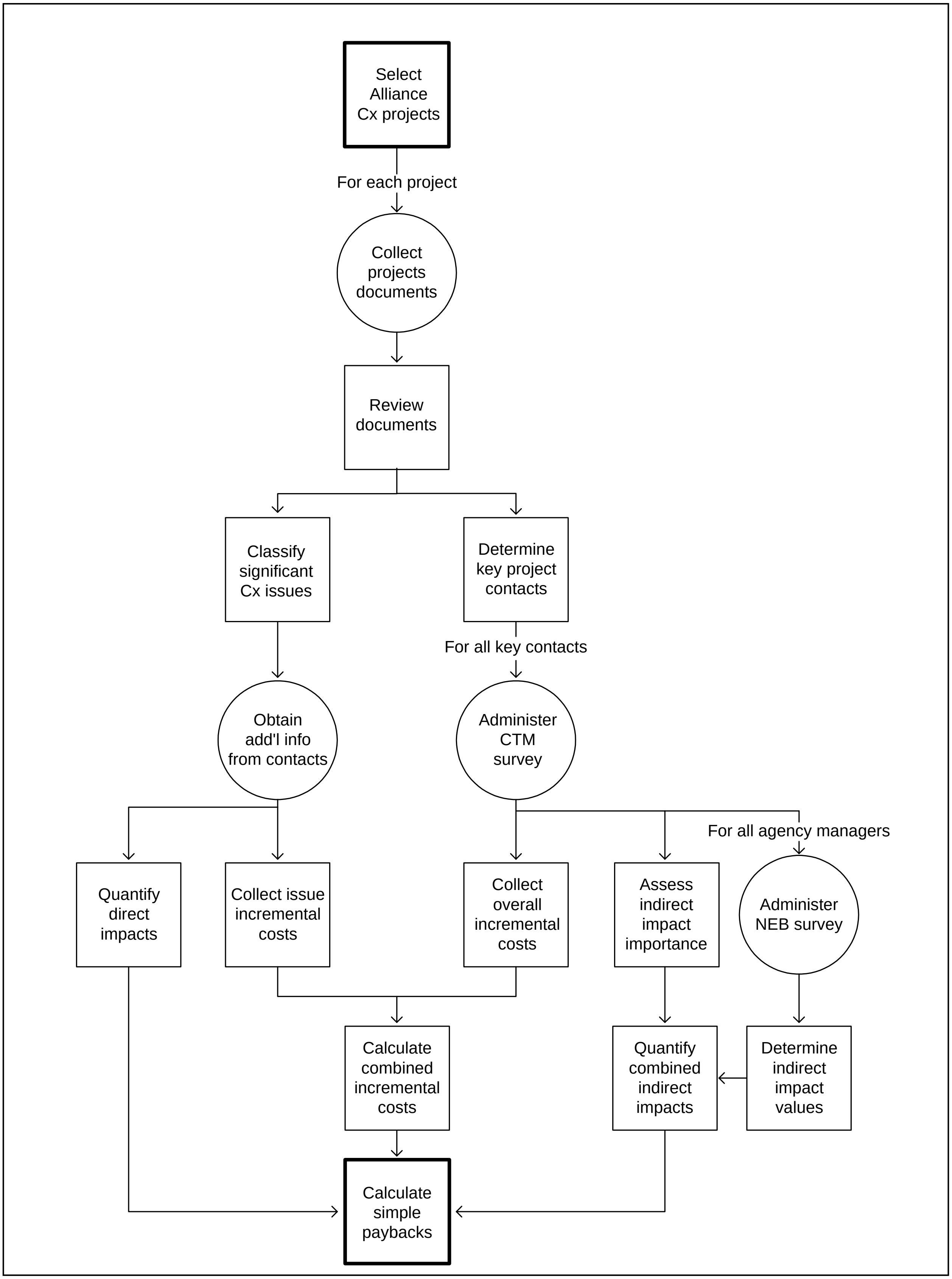


Table 2-1: Selected Commissioning Projects

State	#	Building type	Cx type*	Building size (ft2)	Cx agent cost to agency** ($)	($/ft2)
Idaho	1	Courthouse	New	340,000	220,000	0.65
	2	Recreation center	New	90,148	40,280	0.45
	3	Offices	Retro	23,000	19,300	0.84
Montana	4	Maint. facility	Retro	56,000	12,300	0.22
	5	Middle school	Retro	64,000	8,700	0.14
	6	College/University	Retro	110,380	24,800	0.22
	7	Prison office	New	23,300	24,000	1.03
Oregon	8	Elementary school	Retro	65,000	11,044	0.17
	9	Library	New	69,500	83,380	1.20
	10	Transit center/office	New	160,000	60,880	0.38
	11	Day care center	New	18,300	12,400	0.68
	12	High school	New	250,000	85,000	0.34
	13	Offices	Retro	170,000	20,900	0.12
	14	College/University	Retro	213,000	14,280	0.07
	15	Elementary school	New	49,000	32,660	0.67
Washington	16	High school	New	144,000	41,860	0.29
	17	Museum	New	78,000	100,000	1.28
	18	Elementary school	Retro	95,405	65,102	0.68
	19	Prison	New	58,000	80,000	1.38
	20	Hospital	New	51,000	70,000	1.37
	21	College/University	New	60,000	82,820	1.38
Total for all projects				**2,188,033**	**1,109,706**	
New only				1,391,248	933,280	
Retro only				796,785	176,426	
Average				**104,192**	**52,843**	**0.65**
New only				107,019	71,791	0.85
Retro only				99,598	22,053	0.31

Cx = commissioning.

** Excludes additional costs associated with participation in the Alliance program, such as case study development.

2.3 Review Project Documentation

Through preceding studies as well as this study, we collected all pertinent documentation for each project available as of early 2003. Key information sources are listed below.

a) Commissioning reports.

b) Commissioning issue logs.

c) Commissioning design review memoranda (for several projects) and project correspondence.

d) Initial cost and energy savings estimates. These were prepared by the commissioning agents for most of the retrocommissioning projects, and by state energy engineers for two of the new commissioning projects. We reviewed these estimates and incorporated information from them as we deemed appropriate.

e) Energy Life Cycle Cost Analyses that compare the energy efficiency of alternative building systems, as well as evaluate compliance with state codes. These analyses are available for most of the Washington projects, and include detailed information about building characteristics.

f) Draft case study reports prepared for the Alliance.

Note that with the exception of the first two, this information was available for some, but not all of the projects. In addition, the format, degree of detail, and bases for classifying commissioning issues/deficiencies vary widely among the documentation. The manner in which commissioning agents listed issues ranged widely. For example, some listed many repetitions of similar issues as separate issues, whereas others aggregated them into a single issue.

Once information was collected for a project, we reviewed it to determine how much information about commissioning issues and building parameters was available. We also searched for names and contact information for key members of the commissioning project team.

2.4 Assess Issue-Level Impacts

2.4.1 Quantifiable Impacts

All commissioning issues/deficiencies documented in the commissioning reports and issue logs for each project were entered into a commissioning issues database. We then categorized these issues according to the following criteria:

- *Significant*: An issue (or group of related issues) was considered "significant" if it: (a) affected a large area or number of people (in relative terms for each project), (b) resulted in major immediate costs to resolve, and/or (c) resulted in long-term impacts had the issue not been found. As part of categorization, we briefly documented the rationale for selecting issues as being significant.

- *Resolved*: Significant issues were then grouped based on whether or not they had already been or were likely to have been resolved within one year after the commissioning was complete. In cases where the documentation did not make this clear, we based our determinations on the opinion of the commissioning agent and/or facility manager.

For each significant issue or issue grouping, we estimated both ongoing and one-time impacts, each of which could be positive or negative. For energy impacts, we determined first-year impacts in engineering units, such as kWh or therms, as well as dollars. If we determined that an issue was not likely to be resolved within the next year, then the impact was set to zero, i.e., the commissioning process did not cause the issue to be resolved. All impacts for significant issues were entered into the commissioning issues database. Ongoing impacts for each project consisted of one or more of the following:

- *Energy*: Measurable, quantifiable impacts on electric or gas usage of the project facility, as determined by standard engineering calculations or parametric modeling. The calculations included the best available information and assumptions that could be obtained within study budget constraints. As appropriate, we contacted agency staff and commissioning agents for technical information to enhance the analysis. In cases where commissioning agents had already estimated energy savings for some issues, we reviewed these calculations and adjusted and standardized them as appropriate.

The baseline for calculating impacts were the conditions that would have existed had commissioning not occurred. In some cases, this meant that commissioning increased energy use—such as when closed-off outside air dampers are adjusted to be open at least 20% at all times as a result of the commissioning process, thereby improving air quality. Non-energy benefits to increasing outside air are accounted for through the non-energy benefits valuation process described in Section 2.6.

The cost of energy impacts makes use of average electric and gas rates of $0.07/kWh and $0.85/therm, respectively, based on U.S. Energy Information Administration data for four Pacific Northwest states. These standardized rates made it easier to compare results across projects.

- *Non-energy*: Measurable, quantifiable impacts on facility costs, such as less frequent lamp replacement and reduced water usage. Like the direct energy impacts, these were estimated with standard engineering/economic calculations. Difficult-to-quantify indirect non-energy impacts, such as improved occupant comfort, were assessed at the project level.

One-time impacts at the issue level fell into these groups:

- *Issue resolution*: Costs to remedy a problem or deficiency that the commissioning process revealed. These costs could be direct, that is, resulting in a documented cost increase, as would be the case in a retrocommissioning project where a contractor was hired to install a new HVAC timeclock. On a new commissioning project, if a contractor issued a change order to make a commissioning-issue-related modification, then the cost of the change order would be considered a direct cost. They could also be indirect, in that the problem required some time to rectify, but that increment of time was not charged to the agency. Examples would be a controls contractor reprogramming an improper controls sequence without a change order, or regular maintenance staff resetting thermostats.

- *Avoided costs*: Direct or indirect expense that the commissioning process "saved" the project by finding and resolving issues early. An example would be a commissioning agent performing a design review that showed that temperature sensors were poorly located. Changing the design before construction was complete avoided a contractor change order to relocate the sensors later in the project.

In many cases, the commissioning documentation contained estimates of issue resolution and avoided costs. For situations without such estimates, we used standard cost estimating guidebooks and engineering judgment to develop values. Note that Section 2.5 discusses issue resolution and avoided repair costs, estimated at the project level using a different approach. We reviewed both the issue-level and project-level costs together for each project to ensure that no double counting occurred.

2.4.2 Non-quantifiable Impacts

Certain significant energy impacts still fell outside of the approaches described above. Some issues proved impossible to quantify within the resources of the study. An example of this was a project with outside air dampers that stuck randomly in different positions. Without an extensive monitoring effort, it would be impossible to determine if fixing the problem would increase or decrease energy use. We flagged such issues in the database, and after evaluating all the significant issues for a given project, we compared the non-quantifiable issues to the quantified ones, and assigned a subjective rating of "high," "medium," or "low" to indicate the magnitude of all non-quantifiable energy impacts compared to all quantified energy impacts.

2.5 Assess Project-Level Impacts

The primary tool for assessing commissioning costs and impacts at the project level was the commissioning team member survey (referred to as the "CTM survey" for the remainder of the report). This survey was administered to all who had a key role in the commissioning process for each project, including commissioning agents, designers, contractors, and agency personnel. The purpose of the CTM survey was to help determine the incremental costs of commissioning, as well as the overall subjective benefits and drawbacks that key team members perceived. The three main sections of the survey, and the type of information they elicited, were as follows:

1. Team Member Role: Respondent's role in the project; whether they had a sufficient overview to be able to assess the overall value of commissioning to the agency. Appropriate respondents who answered "yes" were asked to participate in the follow-up indirect non-energy benefits (NEB) survey, which is described below.
2. Commissioning-Related Costs: Contracted (direct) and indirect commissioning costs and time spent, including additional and avoided change orders.
3. Impacts of Commissioning: General impressions; significant effects, both positive and negative, on design/construction, facility operations, and occupant conditions.

The appendix contains a copy of the CTM survey instrument.

We entered the information collected from the CTM surveys into a database, then double-checked the data sets to verify that responses were consistent and fell within reasonable ranges. From the survey data, we estimated incremental commissioning costs for each team member. These costs included those related to change orders, issue resolution, and issue identification. The latter consists of incremental costs associated with commissioning-related activities designed to identify issues and problems. These would occur regardless of whether or not specific problems were actually found. Examples include the time building engineers spent explaining HVAC control strategies to the commissioning agent, increases to contractor's initial bids to allow for commissioning activities, and commissioning agent fees. In the CTM survey, we also asked questions to verify that the costs above did not include any extra costs associated with preparing case studies or providing cost-benefit analysis input for the Alliance.

2.6 Assign Monetary Values to Indirect Non-Energy Impacts

Indirect non-energy impacts (also commonly referred to as non-energy benefits, or "NEBs") are inherently difficult to document and assign quantitative values to. They can include beneficial and detrimental impacts relating to the following:

During design and construction:

- Contractor call-backs
- Change orders or warranty claims
- Potential for litigation
- Coordination and relationships between team members
- Project schedules
- Time needed to get building systems working right

For facility operations:

- Operational deficiencies
- System documentation
- Staff knowledge
- Equipment lifetime

For building occupants:

- Comfort
- Indoor air quality
- Productivity
- Safety

The quantification process we developed for this study involves two key parameters, (1) an impact importance factor that reflects commissioning team members' collective sense of which issues were important, and (2) monetized estimates of the economic worth of particular indirect non-energy impacts from the project agency's perspective. The net value of a given indirect non-energy impact is the product of the impact importance factor and the impact valuation. If both are high, then the impact's net value will also be high.

2.6.1 Establish Importance Factors

The CTM and NEB surveys both asked each respondent to identify which commissioning indirect impacts listed above (as well as any others they could think of) were significant to their project. We developed a scheme for averaging and weighting their responses that took into account two things: the fact that the number and type of respondents varied from project to project, and the assumption that the commissioning agents and facility staff, as a rule, had a better overall perspective on the commissioning effort than contractors and designers.

First respondents were grouped into four categories:

CX: Commissioning agents.

FA: Facility staff, including facilities managers, project construction managers, and operations and maintenance staff.

CO: Contractors, including general, mechanical, controls, electrical, and testing & balancing.

DE: Designers, including architects, mechanical engineers, and electrical engineers.

The responses from each respondent were assigned a weight of 3 for those in the CX and FA categories, and 2 for those in the CO and DE categories. These weighted responses were summed and divided by the sum of the weights to calculate the impact importance factor for a given impact. This factor will equal 100% if all respondents feel that commissioning had a beneficial and substantial effect on the impact in questions. If no respondents feel this way, then the factor will be 0%. This factor can be less than zero as well, if respondents felt commissioning was detrimental in some way.

2.6.2 Calculate Gross Monetary Values

Data from the telephone interviews with key project team members were used to calculate the overall economic value of specific indirect non-energy impacts associated with a particular commissioning project. Those surveyed were individuals who, based on their responses in the CTM survey, had a sufficient overview of their agency's operations or the particular construction project to be able to assess the overall value of the commissioning project to the agency and building occupants. In the NEB survey, we asked about the presence and values of indirect non-energy impacts for each project. The appendix contains a more detailed discussion of the various measurement approaches that were incorporated in the survey. This work included the following elements:

Develop Approach and Collect Data

- Reviewed previous studies to identify a preliminary list of indirect non-energy impact categories applicable to commissioning.

- Identified candidate "comparators" that we believed were the most appropriate to use in assessing the relative value of the indirect non-energy impacts for the commissioning projects. While energy savings has been a commonly used comparator for past work, this was not appropriate for commissioning projects. We initially decided on the annualized commissioning cost, but during the pretest we found respondents could not understand the concept. We ultimately used the commissioning agent fees as the comparator for the "multiplier" approach. Comparisons were made to the stream of benefits from a particular source to the commissioning agents fees, so that questions were generally asked in the form "was the (comfort) benefit (over the life of the building) more valuable or less valuable than the cost of commissioning. How much more / less valuable?"

- Developed the draft NEB survey. The survey instrument collected information that allowed computation of dollar values for individual indirect non-energy impacts associated with each commissioning project, and allowed aggregation as needed.

- Pretested and revised the NEB survey. Conducted interviews with the balance of the respondents identified via the CTM survey.

Perform Analysis and Reporting

- Entered survey information into a database and conducted quantitative analyses to compute monetized values for indirect non-energy impacts, by project, impact type, and other categories.

To be conservative, we took the following steps:

- Assumed the multipliers for the individual NEB categories were appropriate for assigning relative sizes between categories – that is, we preserved the "percent" of the values represented by each of these individual NEB categories, e.g., operational deficiencies and comfort.

- Assessed total benefits three ways – WTP, sum of the individual computed benefits, and the "overall net" figure computed as the respondent's "overall net" value multiplier times the commissioning cost. We then kept the most conservative value – the minimum of these three values.

- Used this total to recalibrate the individual benefits categories – multiplying the percentages for each individual category times the “minimum” of the value provide for the “total” benefits. Each adjusted individual NEB value, stated in dollars, was considered the gross dollar value for that NEB for that project in subsequent analysis.

2.6.3 Calculate Net Dollar Values

The net dollar value for a given NEB for a given project is simply the impact importance factor, multiplied by the NEB gross dollar value. An example will clarify how this works.

> For Project #1, a new courthouse, five individuals completed interviews for the CTM survey. These included two commissioning agents, two facilities personnel, and the construction general contractor. No designers responded to the survey. Both commissioning agents and the facilities manager indicated that the commissioning effort would significantly reduce the number of contractor callbacks. Using the weighting scheme described in Section 2.6.1, the impact importance factor for contractor callbacks is 5 / 8 = 63%. The gross dollar value for the contractor callbacks, as calculated with the approach described in Section 2.6.2, is $7,570. This latter number, multiplied by 63%, yields a net dollar value of $4,731 for reduced contractor callbacks as a result of commissioning on the project.

2.7 Calculate Paybacks

The commissioning impacts fell into several broad categories: ongoing energy, ongoing non-energy, one-time direct, and one-time indirect. We calculated two payback ratios for each project. The direct payback only considers direct one-time and ongoing impacts, while the total simple payback also includes indirect one-time impacts. The latter thus represents the most comprehensive benefit-cost assessment. We also calculated these payback ratios for all projects combined, as well as for each commissioning type (new and retro).

3. Results

3.1 Survey Disposition

3.1.1 CTM Survey

From reviewing project documentation and contacting commissioning team members, we identified 128 people who appeared to have played important roles in the commissioning efforts for the 21 projects included in this study. This corresponds to slightly over six people per project. Nearly half of these were agency personnel, with the remainder divided somewhat evenly among commissioning agents, contractors, and designers. We were able to complete CTM surveys for 97 of these people, or 76% of the identified population. These included 24 commissioning agents, 32 designers and contractors, and 41 agency personnel. The number of commissioning agents exceeded the number of projects because for several projects, the commissioning authority assigned more than one person to the project.

The 54% response rate for contractors was considerably worse than the 75% to 96% response rate for other team members. Among the 31 people we attempted to survey but were unable, nearly two-thirds either could not be reached or refused to be surveyed. The remaining third were either not familiar enough with the project to be able to answer the survey questions, or stated that no one in their organization had specific knowledge of the project. These missing data points are not surprising, given that many of the projects occurred over a year ago. They add some uncertainty to the analysis, but this was mitigated by the fact that generally, we were able to speak to someone for each project who could give us a general overview of the commissioning effort across all participants.

3.1.2 NEB Survey

We identified 29 potential respondents for the NEB survey who had a sufficient overview of the project and/or agency operations to assess the value of commissioning to the agency, or occupants. We were able to complete interviews with 27 of them, who collectively represented all but two of the sample projects. The interviews were conducted with 14 facility managers and four facility staff, six construction managers, and three designers that served as project managers. Most of the respondents were able to answer the NEB value-related questions. A few could not provide value assessments. Some were only comfortable responding to overall values. Comparisons were made to the stream of benefits from a particular source to the commissioning agents fees. As a result, in the final survey the questions were generally asked in the form “was the (comfort) benefit (over the life of the building) more valuable or less valuable than the cost of commissioning. How much more / less valuable?”

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

3.2 Survey Respondent Impressions

Some of the general respondent impressions of the value of commissioning that came out of the surveying efforts include the following:

- Most respondents were either satisfied or very satisfied with the commissioning process, and felt it was worth the cost. Many mentioned that since the initial commissioning project, owners have incorporated commissioning into subsequent projects.

- A commissioning process that starts with the design phase of a new construction project is inherently more effective and more efficient that one that starts in the construction phase. Many respondents in variety of project roles mentioned this. Commissioning agents in particular were adversely affected by commissioning processes that began late in the project. Several respondents said that owners had learned the hard way to begin commissioning early in a project, and thus were doing so in subsequent projects.
- Getting problems fixed up front is valuable. This keeps occupants from getting a bad first impression of the building that they may never completely lose.
- Commissioned buildings work better from control and comfort perspectives. They are also cheaper to run, because maintenance is easier and constantly tweaking and fixing the systems over time is avoided. Training building staff can also be a valuable aspect of the commissioning process that can yield lasting benefits.

3.3 Issue Analysis

From the commissioning documentation and discussions with commissioning team members, we identified 1,616 commissioning issues (sometimes also called deficiencies) among the 21 projects. It is important to note that the commissioning reports defined issues in many different ways across projects. For example, an issue that affected four air handlers might be aggregated by one commissioning agent, so that it counted as one issue, while another commissioning agent might have treated the same situation as four issues, one for each air handler. As a result, the number of issues per project provides only a very rough indication of the nature of the commissioning effort.

As Table 3-1 shows, the total number of issues identified per project ranged from 19 to 249, with an average of 77 issues per project. Of these, about 15% (235 issues, or 11.2 per project) could be considered significant, and were or are about to be resolved. Significance is defined for this study as (a) affecting a large area or number of people (in relative terms for each project), (b) resulting in major immediate costs to resolve, and/or (c) resulting in significant long-term impacts had the issue not been found. The number of unresolved issues was small: only 16 spread across four projects. These 16 unresolved issues accounted for 6% of all significant issues. Nine of these issues occurred at a single project, where many of the commissioning recommendations were not implemented because a major building renovation was scheduled to occur. It seems reasonable to conclude that significant issues are generally resolved during or soon after the commissioning process.

Table 3-1: Significant Issue Distribution

	Total # of issues	Significant	Significant & resolved	% significant & resolved
Total, all projects (N=21)	1,616	251	235	15%
Project maximum	249	38	38	84%
Project minimum	19	1	1	3%
New Cx average (N=13)	75	9.1	8.7	12%
Retro Cx average (N=8)	79	16.6	15.3	19%
Average, all projects	**77**	**12.0**	**11.2**	**15%**

Table 3-2 breaks out the significant resolved issues by affected building system. The preponderance of significant resolved issues (93%) pertain to the HVAC system and associated controls. This is not surprising, since the scope of many commissioning projects encompassed primarily or solely HVAC.

Table 3-2: Significant Resolved Issues by Affected Building System

Building System	# significant issues	# significant & resolved issues	**# significant/ resolved as % of total**
Mechanical - controls	181	174	**74%**
Mechanical - HVAC	49	44	**19%**
Electrical - lighting	8	8	**3%**
Mechanical - plumbing	5	5	**2%**
Electrical - general	2	2	**1%**
Architectural	5	1	**0%**
Other	1	1	**0%**
Total	**251**	**235**	**100%**

3.4 Ongoing Energy Impacts

Ongoing energy impacts consist of the net savings in electricity and natural gas that resulted from resolved commissioning issues. The average quantified impacts per project are 110,445 kWh/year and 4,212 therms/year, with a combined value of about $11,300 annually at current energy prices in the Pacific Northwest[3]. Normalized by floor area, these impacts are 1.06 kWh/SF/year and 0.04 therms/SF/year, respectively. The normalized combined value is $0.11/SF/year. These results are shown in Table 3-3. The table shows that on average, retrocommissioning projects, at $0.14/SF/year, yield 49% more ongoing energy impacts than new commissioning projects, which average $0.09/SF/year. Figure 3-1 presents a distribution graph of normalized ongoing impacts, on a project level.

Table 3-3: Ongoing Energy Impacts

	Absolute Values			**Normalized Values**		
	Electricity, kWh/yr	Natural gas, therm/yr	Total, $/yr	Electricity, kWh/ft2/yr	Natural gas, therm/SF/yr	Total, $/SF/yr
Total, all projects (N=21)	2,319,342	88,461	237,546	1.06	0.04	0.11
Project maximum	392,100	26,575	50,036	7.99	0.47	0.15
Project minimum	-33,908	-4,570	-6,258	-0.49	-0.04	-0.34
New Cx average (N=13)	102,732	3,135	9,856	0.96	0.03	0.09
Retro Cx average (N=8)	122,979	5,964	13,678	1.23	0.06	0.14
Average, all projects	**110,445**	**4,212**	**11,312**	**1.06**	**0.04**	**0.11**

When we estimated the ongoing energy impacts, we also encountered issues where the nature of the problem prevented us from making defensible estimates. As part of our analysis, we performed a rough assessment of how much uncertainty these unquantifiable impacts produced. After evaluating all quantifiable energy impacts for a given project, we then compared the non-quantifiable issues to the quantified ones, and assigned a subjective rating of "high," "medium," or "low" to the project to indicate the magnitude of all non-quantifiable energy impacts compared to all quantified energy impacts. This gave some sense of the uncertainty surrounding the quantified energy impacts.

We rated 13 projects with "low", four with "medium" and four with "high" uncertainty. On a dollar basis, the quantified energy impacts for the low category account for 66% of the total, while the high category only accounts for 4%. Since the majority of the projects and the majority of the energy value reside with projects with low uncertainty, it seems reasonable to conclude that on average across all projects, the portion of energy impacts that is non-quantifiable is relatively small compared to the portion that we did quantify. This provides some assurance that the estimates of ongoing energy impacts that we developed were meaningful.

3.5 Ongoing Non-Energy Impacts

Ongoing non-energy impacts for the studied projects consisted of two types. The first was impacts to utilities other than electricity or gas, such as water, sewer, or propane service. The second consisted of quantifiable changes to operations and maintenance expenses. Examples of the latter that we found were reduced air compressor maintenance costs and lamp replacement costs. The largest single impact we found affected one project where a gas boiler was brought back on line to reduce overall energy costs per the commissioning agent's recommendation, resulting in additional boiler maintenance costs that offset energy cost savings somewhat. On average, however, as Table 3-5 and Figure 3-1 show, the ongoing non-energy impacts for these projects were minuscule. We only quantified these types of impacts for six projects.

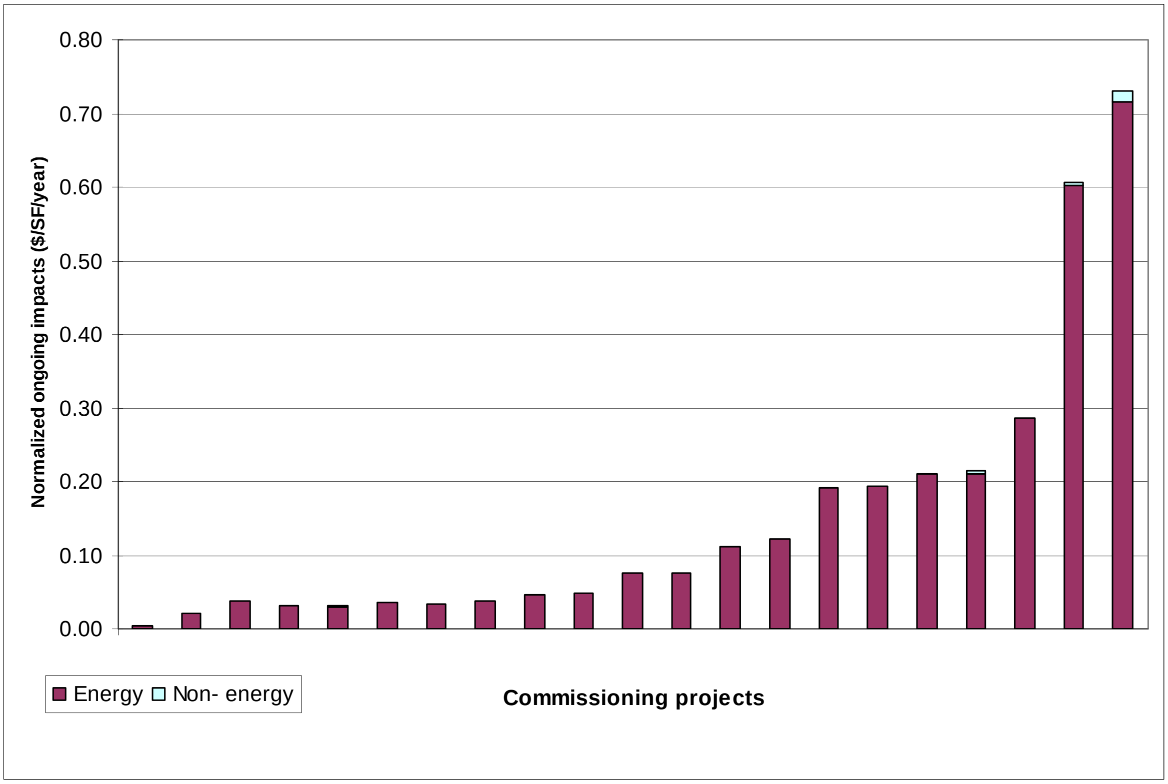
Table 3-4: Ongoing Non-Energy Impacts

	Absolute Values		
	Other utilities, $/year	Major ongoing O&M, $/year	Total non-energy, $/year
Total, all projects (N=21)	130	-2,167	-2,037
Project maximum	354	300	654
Project minimum	-260	-2,743	-3,003
New Cx average (N=13)	3	0	3
Retro Cx average (N=8)	12	-271	-259
Average, all projects	**6**	**-103**	**-97**

Note: Values normalized by building area are extremely small, and thus are not shown.

[3] Impacts that result in net costs and net savings are expressed as negative and positive numbers, respectively, in this report.

Figure 3-1: Distribution of Normalized Ongoing Impacts



3.6 One-Time Direct Impacts

One-time impacts generally occur during or shortly after the commissioning effort. The direct components of these impacts—that is, the portions with documentable financial effects on the projects—include the following:

1. Issue identification costs, such as the cost to hire the commissioning agent.

2. Issue resolution costs, such as billed cost to an agency to fix a problem that is out of scope.

3. Change orders/project costs and savings. This include additional costs, such as billed cost to agency to add variable speed drives, as well as cost savings, such as the money the agency saves by not having to pay to relocate thermostats.

As shown in Table 3-5, the net one-time direct impact per project was about -$66,000. On a normalized basis, this corresponds to -$0.63/SF, as shown in Table 3-6. Figure 3-2 presents a distribution graph of normalized one-time direct impacts, on a project level.

Table 3-7 breaks down normalized one-time impacts into the categories listed above. About 80% of the direct impact consists of commissioning agent fees. The bulk of the -$0.63/SF consists of issue identification costs (-$0.51/SF) and issue resolution costs (-$0.13/SF). The net impact of additional and avoided change orders is $0.01/SF. It is highly likely that change order estimates are low, since survey respondents in some cases could not remember these costs well enough to make accurate estimates.

Table 3-5: One-Time Impacts (in dollars)

	ONE-TIME IMPACTS ($)						
	Direct			Indirect			
	Cx agent fees	Other direct impacts	**Total direct**	Non-energy impacts	Other indirect impacts	**Total indirect**	**Total one-time**
Total, all projects (N=21)	**-1,109,706**	**-276,475**	**-1,386,181**	**496,396**	**-235,201**	**261,195**	**-1,124,986**
Project maximum	-8,700	20,000	-2,912	111,186	1,878	88,188	7,380
Project minimum	-220,000	-166,955	-201,600	-1,536	-31,268	-17,255	-175,932
New Cx average (N=13)	-71,791	-1,746	-73,536	27,767	-14,157	13,609	-59,927
Retro Cx average (N=8)	-22,053	-31,723	-53,776	16,929	-6,395	10,534	-43,242
Average, all projects	**-52,843**	**-13,165**	**-66,009**	**23,638**	**-11,200**	**12,438**	**-53,571**

Table 3-6: One-Time Impacts (in dollars per square foot)

	NORMALIZED ONE-TIME IMPACTS ($/SF)						
	Direct			Indirect			
	Cx agent fees	Other direct impacts	**Total direct**	Non-energy impacts	Other indirect impacts	**Total indirect**	**Total one-time**
Total, all projects (N=21)	**-0.51**	**-0.13**	**-0.63**	**0.23**	**-0.11**	**0.12**	**-0.51**
Project maximum	-0.07	0.22	-0.01	0.56	0.08	0.43	0.05
Project minimum	-1.38	-2.98	-3.20	-0.07	-0.36	-0.35	-3.14
New Cx average (N=13)	-0.67	-0.02	-0.69	0.26	-0.13	0.13	-0.56
Retro Cx average (N=8)	-0.22	-0.32	-0.54	0.17	-0.06	0.11	-0.43
Average, all projects	**-0.51**	**-0.13**	**-0.63**	**0.23**	**-0.11**	**0.12**	**-0.51**

Figure 3-2: Distribution of Normalized One-Time Impacts

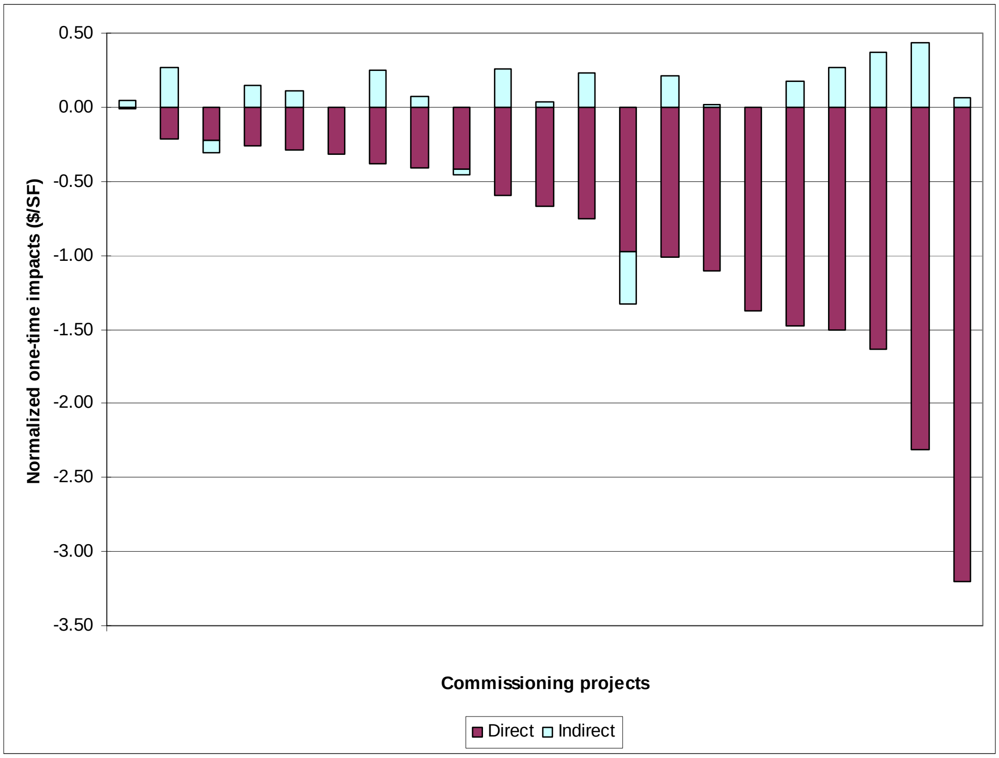


Table 3-7: Normalized One-Time Impacts by Type

	Direct $/SF	Indirect $/SF	Total $/SF
(a) Issue identification	-0.51	-0.06	-0.57
(b) Issue resolution	-0.13	-0.05	-0.18
(c) Change orders/new scope	0.01	0.00	0.01
(d) Non-energy	0.00	0.23	0.23
Total	**-0.63**	**0.12**	**-0.51**

3.7 One-Time Indirect Impacts

One-time impacts generally occur during or shortly after the commissioning effort. The indirect components of these impacts—that is, the portions that affect the projects but do not lead to changes in the amounts billed to the agencies as part of the project costs— include the following:

1. Issue identification costs, such as the labor cost for agency staff to attend commissioning meetings.

2. Issue resolution costs, such the labor costs for agency staff, or contractors if no change order, to rewrite a control sequence.

3. Change orders/project costs and savings. This includes costs and savings associated with agency staff supervising and administering additional contractor activities from commissioning-related changes.

4. Non-energy impacts, including:

   During design and construction:
   - Contractor call-backs
   - Change orders or warranty claims
   - Potential for litigation
   - Coordination and relationships between team members
   - Project schedules
   - Time needed to get building systems working right

   For facility operations:
   - Operational deficiencies
   - System documentation
   - Staff knowledge
   - Equipment lifetime

   For building occupants:
   - Comfort
   - Indoor air quality
   - Productivity
   - Safety

As shown in Table 3-5, the net one-time indirect impact per project was about $12,400. On a normalized basis, this corresponds to $0.12/SF, as shown in Table 3-6. Figure 3-1 presents a distribution graph of normalized one-time indirect impacts, on a project level.

Table 3-7 breaks down normalized one-time indirect impacts into the categories listed above. The non-energy impacts result in value over twice the magnitude of the other indirect impacts. The $0.12/SF is dominated by the $0.23/SF of value associated with non-energy impacts. The latter is offset by issue identification costs (-$0.06/SF) and issue resolution costs (-$0.05/SF).

Table 3-8 provides a detailed listing of non-energy impacts by type. By far the most significant impacts overall were reducing operational deficiencies and improving occupant comfort, with 27% and 22% shares, respectively, of the total dollar value of all indirect non-energy impacts. Other important impacts were reducing the time needed to get building systems working properly (8%), improving indoor air quality (8%), and increasing O&M staff's knowledge of how the building functions (7%).

Table 3-8: Indirect Non-Energy Impacts by Commissioning Type

	Design & Construction					Facility O&M				Occupants				ALL	
	Contractor callbacks	Change orders, warranty claims	Team member coordination	Project schedules	Time to get systems working right	Operational deficiencies	System documentaion	Staff knowledge	Equipment lifetime	Comfort	Indoor air quality	Productivity	Safety/lighting quality	($)	($/SF)
Total, all projects (N=21)	26,735	19,652	24,238	-871	41,606	136,308	22,186	36,827	12,171	109,768	37,834	13,769	16,172	496,396	0.23
Project maximum	6,607	8,259	7,500	185	12,617	18,925	6,597	7,570	5,143	34,065	12,209	8,516	10,409	111,186	0.56
Project minimum	-136	-1,321	-27	-1,138	0	-1,075	0	-475	0	-277	-368	0	0	-1,536	-0.07
New Cx average (N=13)	1,995	1,500	1,824	-67	3,138	6,206	958	1,662	552	6,586	1,160	1,042	1,210	27,767	0.26
Retro Cx average (N=8)	100	19	66	0	101	6,954	1,216	1,903	625	3,018	2,845	27	55	16,929	0.17
Average, all projects	**1,273**	**936**	**1,154**	**-41**	**1,981**	**6,491**	**1,056**	**1,754**	**580**	**5,227**	**1,802**	**656**	**770**	**23,638**	**0.23**
% of all	5%	4%	5%	-0.2%	8%	27%	4%	7%	2%	22%	8%	3%	3%	100%	

3.8 Payback Ratios

Table 3-9 draws together the ongoing energy and non-energy impacts, and the one-time direct and indirect impacts derived in the previous sections. The average combined ongoing impact was about \$11,200/year per project. Dividing the average one-time direct impact of -\$66,000 by this figure yields a direct payback of 5.9 years. The retrocommissioning projects on average had much lower paybacks than the new commissioning projects, with an average direct payback of 4.0 years, versus 7.5 years for new. Including the indirect impacts changes this significantly. The indirect one-time impacts are about \$12,400/year per project. Including them in the payback calculation yields total payback of 4.8 years. The average paybacks for new and retrocommissioning are 6.1 and 3.2 years, respectively.

Table 3-10 and Figure 3-3 show the wide variation in simple payback ratios among the projects. Direct paybacks ranged from 0.4 to 200 years, while total paybacks ranged from –1 to 158 years. The effect of including indirect impacts in the cost-effectiveness calculation also varied widely: percentage changes from direct to total payback ranged from a 353% decrease to a 36% increase. It should be noted that over half of the projects studied had total paybacks less than seven years.

Table 3-9: Analysis Summary

		Ongoing Impacts					One-Time Impacts			Payback*	
		Electricity (kWh/yr)	Natural gas (therm/yr)	Energy ($/yr)	Non-energy ($/yr)	Total ($)	Direct ($)	Indirect ($)	Total ($)	Direct (years)	Total (years)
ABSOLUTE VALUES											
By Cx type, per project	New (N=13)	102,732	3,135	9,856	3	9,858	-73,536	13,609	-59,927	7.5	6.1
	Retro (N=8)	122,979	5,964	13,678	-259	13,419	-53,776	10,534	-43,242	4.0	3.2
	All (N=21)	**110,445**	**4,212**	**11,312**	**-97**	**11,215**	**-66,009**	**12,438**	**-53,571**	**5.9**	**4.8**
NORMALIZED VALUES (per SF)											
By Cx type	New	0.96	0.03	0.09	0.00	0.09	-0.69	0.13	-0.56		
	Retro	1.23	0.06	0.14	0.00	0.13	-0.54	0.11	-0.43		
	All	**1.06**	**0.04**	**0.11**	**0.00**	**0.11**	**-0.63**	**0.12**	**-0.51**		

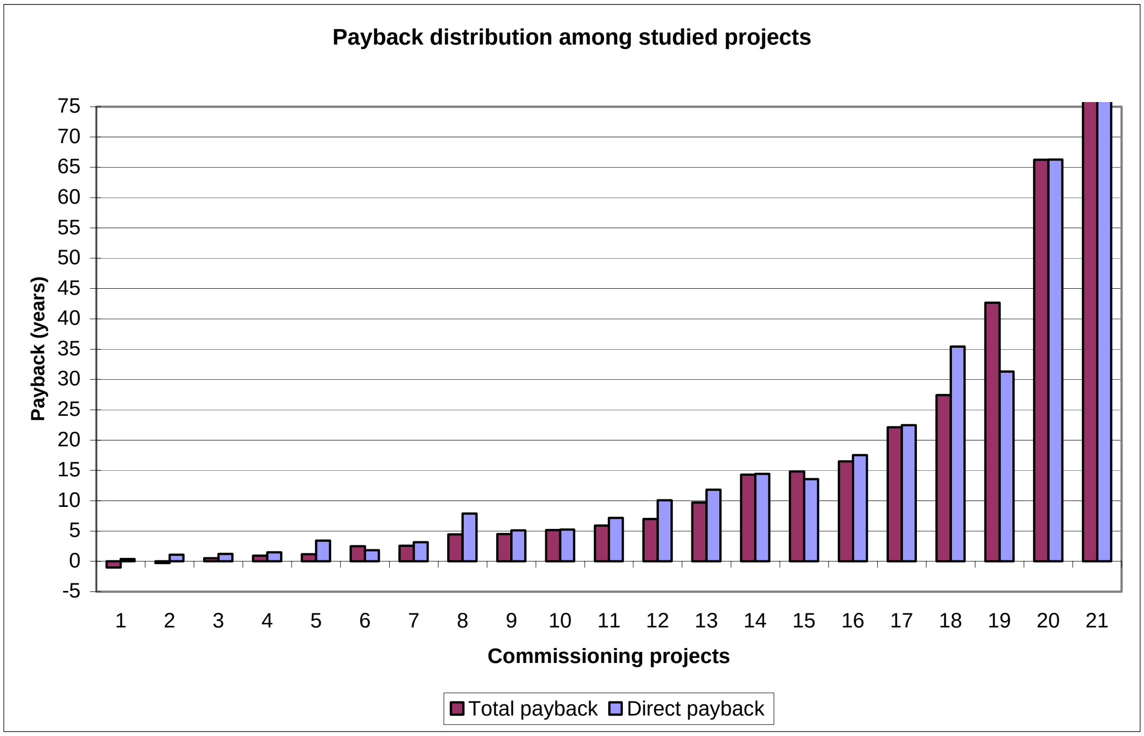
* Direct payback = -(Direct one-time impacts) / Ongoing impacts
Total payback = -(Direct + indirect one-time impacts) / Ongoing impacts

Table 3-10: Payback Ratios

	#	Building Size (ft2)	Payback* Direct (years)	Payback* Total (years)
Idaho	1	340,000	7.9	4.4
Idaho	2	90,148	1.8	2.5
Idaho	3	23,000	3.2	2.6
Montana	4	56,000	5.3	5.2
Montana	5	64,000	11.8	9.7
Montana	6	110,380	1.2	0.5
Montana	7	23,300	22.5	22.2
Oregon	8	65,000	1.1	-0.3
Oregon	9	69,500	199.5	158.4
Oregon	10	160,000	3.4	1.2
Oregon	11	18,300	17.5	16.5
Oregon	12	250,000	13.5	14.8
Oregon	13	170,000	14.4	14.3
Oregon	14	213,000	0.4	-1.0
Oregon	15	49,000	31.3	42.7
Washington	16	144,000	1.5	0.9
Washington	17	78,000	7.2	5.9
Washington	18	95,405	10.1	7.0
Washington	19	58,000	66.3	66.2
Washington	20	51,000	5.1	4.5
Washington	21	60,000	35.4	27.4
Project maximum			199.5	158.4
Project minimum			0.4	-1.0
New Cx average (N=13)			7.5	6.1
Retro Cx average (N=8)			4.0	3.2
Weighted average, all projects (N=21)			**5.9**	**4.8**

* Direct payback = -(Direct one-time impacts) / Ongoing impacts
Total payback = -(Direct + indirect one-time impacts) / Ongoing impact

Figure 3-3: Distribution of Project Simple Payback Ratios



4. Conclusions

Based on the information collected and the findings we developed, we reached the following conclusions about the overall effects of the 21 commissioning projects performed through the Alliance Commissioning in Public Buildings program.

A. The simple payback for the projects studied was 5.9 years, when only considering direct impacts, such as energy savings.

B. The cost-effectiveness of commissioning is enhanced by including indirect impacts, such as improvements in building comfort and operability. Adding in the value of all indirect effects reduces the simple payback to 4.8 years. Even though doing so increases the incremental cost of commissioning by about 17%, this is more than offset by the value of the corresponding benefits, which reduce the incremental cost by 36%.

C. Retrocommissioning, on average, has a lower payback (3.2 years) than new commissioning (6.1 years). This occurs primarily because the energy savings from retrocommissioning projects are 49% higher and the initial costs are 22% lower, when normalized by building area. This may be partially explained by difficulties incorporating design-phase commissioning into the new construction projects.

D. The most valuable indirect non-energy benefits that resulted from commissioning were reduced operational deficiencies and improved occupant comfort. Reducing the time needed to optimize building system during the construction, increasing O&M staff knowledge of building systems, and improving indoor air quality were also important benefits.

E. Most significant issues or deficiencies uncovered by commissioning are resolved during or soon after the commissioning process is complete.

F. Based on anecdotal evidence from survey interviews, both agency and non-agency personnel involved with the commissioning efforts were generally very pleased with the process. As a result of these experiences, some agency personnel have already begun incorporating commissioning into subsequent building projects.

5. Appendices

5.1 Project-Level Results

Table A-1: Significant Issue Distribution by Project

State	Project #	**Total # of issues**	Significant	Significant & resolved	**% significant & resolved**
Idaho	1	**97**	9	7	**7%**
	2	**183**	5	5	**3%**
	3	**19**	16	16	**84%**
Montana	4	**112**	25	25	**22%**
	5	**103**	14	14	**14%**
	6	**249**	38	38	**15%**
	7	**71**	13	13	**18%**
Oregon	8	**37**	11	2	**5%**
	9	**57**	16	16	**28%**
	10	**101**	13	13	**13%**
	11	**22**	4	4	**18%**
	12	**75**	15	15	**20%**
	13	**22**	18	16	**73%**
	14	**55**	7	7	**13%**
	15	**74**	11	11	**15%**
Washington	16	**148**	14	11	**7%**
	17	**45**	4	4	**9%**
	18	**38**	4	4	**11%**
	19	**26**	1	1	**4%**
	20	**39**	8	8	**21%**
	21	**43**	5	5	**12%**

Table A-2: Ongoing Energy Impacts by Project

		Absolute Values			Normalized Values		
State	#	Electricity, kWh/yr	Natural gas, therm/yr	Total, $/yr	Electricity, kWh/SF/yr	Natural gas, therm/SF/yr	Total, $/SF/yr
Idaho	1	325,000	3,250	25,513	0.96	0.01	0.08
	2	122,950	2,870	11,046	1.36	0.03	0.12
	3	183,838	4,254	16,485	7.99	0.18	0.72
Montana	4	158,993	26,575	33,718	2.84	0.47	0.60
	5	5,161	2,184	2,218	0.08	0.03	0.03
	6	210,968	10,045	23,306	1.91	0.09	0.21
	7	4,770	960	1,150	0.20	0.04	0.05
Oregon	8	161,163	1,602	12,643	2.48	0.02	0.19
	9	-33,908	3,207	352	-0.49	0.05	0.01
	10	172,031	6,739	17,770	1.08	0.04	0.11
	11	9,981	0	699	0.55	0.00	0.04
	12	35,848	6,127	7,717	0.14	0.02	0.03
	13	147,947	-4,570	6,472	0.87	-0.03	0.04
	14	48,167	4,795	7,447	0.23	0.02	0.03
	15	42,540	-1,756	1,485	0.87	-0.04	0.03
Washington	16	392,100	0	27,447	2.72	0.00	0.19
	17	105,950	10,500	16,342	1.36	0.13	0.21
	18	67,593	2,827	7,134	0.71	0.03	0.07
	19	0	1,420	1,207	0.00	0.02	0.02
	20	132,450	6,302	14,628	2.60	0.12	0.29
	21	25,800	1,130	2,767	0.43	0.02	0.05

Table A-3: Non-quantifiable Energy Impacts

State	#	Total direct energy impacts ($/yr)	Assessment of non-quantifiable energy impact
Idaho	1	25,513	Low
	2	11,046	Low
	3	16,485	Low
Montana	4	33,718	Low
	5	2,218	Medium
	6	23,306	Medium
	7	1,150	Low
Oregon	8	12,643	Low
	9	352	High
	10	17,770	Medium
	11	699	Low
	12	7,717	High
	13	6,472	Low
	14	7,447	Low
	15	1,485	High
Washington	16	27,447	Medium
	17	16,342	Low
	18	7,134	High
	19	1,207	Low
	20	14,628	Low
	21	2,767	Low
TOTAL		237,546	

Table A-4: Ongoing Non-Energy Impacts by Project

State	#	Other utilities, $year	Major ongoing O&M, $/year	**Total non-energy, $/year**
Idaho	1	0	0	**0**
	2	0	0	**0**
	3	0	300	**300**
Montana	4	0	276	**276**
	5	0	0	**0**
	6	354	0	**354**
	7	0	0	**0**
Oregon	8	0	0	**0**
	9	0	0	**0**
	10	0	0	**0**
	11	0	0	**0**
	12	0	0	**0**
	13	0	-2,743	**-2,743**
	14	-260	0	**-260**
	15	36	0	**36**
Washington	16	0	0	**0**
	17	0	0	**0**
	18	0	0	**0**
	19	0	0	**0**
	20	0	0	**0**
	21	0	0	**0**

Table A-5: Indirect Non-Energy Impact Importance Factors by Project

		Design & Construction							Facility O&M					Occupants			
State	#	Contractor callbacks	Change orders	Litigation	Coordination	Schedule	System optimization	Other	Deficiencies	Document	Knowledge	Lifetime	Other	Comfort	IAQ	Productivity	Other (safety, lighting
Idaho	1	63%	25%				63%		75%	38%	75%	19%		75%	38%	19%	38%
	2	75%	25%		13%	13%	88%		100%	66%	91%	19%		100%	53%	9%	47%
	3								50%		100%	50%		100%	50%		25%
Montana	4	50%	50%				50%		25%	25%	25%	100%		100%	25%	25%	25%
	5								100%				50%	100%			
	6								100%		50%	100%		100%	50%	50%	
	7	10%			-40%	-10%		30%	40%		30%			10%	30%		
Oregon	8								75%	100%	50%		25%	100%	75%		25%
	9	40%	20%	30%	30%	-10%	40%	20%	70%	15%	15%	60%		55%	15%	40%	
	10	50%	-10%	60%	20%	20%	10%	-30%	70%	10%				100%	10%	20%	10%
	11	30%	-20%				30%	50%	100%	30%	60%			20%			
	12	80%	60%	40%	80%	40%	60%		30%	15%	45%	15%	10%	70%		30%	10%
	13								100%	50%	100%	50%		50%			
	14	-13%	13%		25%		-13%		100%	75%	63%	50%		13%	13%	13%	
	15	20%	40%		-20%	-10%		-10%	50%						-10%		
Washington	16	75%	75%		25%	-25%	25%		100%	38%	63%	38%	25%	100%	63%	38%	
	17	30%	40%		50%		40%	20%	60%	70%	40%		50%	70%	25%	30%	25%
	18								100%	83%	83%	33%		100%	33%	17%	
	19	25%		38%	75%	-38%	-38%	-13%	38%	63%	25%			38%			
	20				43%		14%	14%	100%	43%	10%	43%		48%	81%	43%	19%
	21	40%	30%	10%	70%	30%	40%		100%	10%	15%	45%		60%		30%	

Table A-6: Indirect Non-Energy Impact Valuation by Project

		Design & Construction							Facility O&M					Occupants				TOTAL
State	#	Contractor callbacks	Change orders & warranty claims	Litigation	Coordination, team m	Schedule	System optimization	Other	O&M deficiencies	Document	Knowledge	Lifetime	Other	Comfort	IAQ	Productivity	Other (safety, lighting)	
Idaho	1	7,570	10,093		20,187	25,234	20,187		25,234	10,093	10,093	2,523		45,421	20,187	45,421	27,757	270,000
	2	4,584	6,736		1,011	1,478	2,009		7,463	1,140	1,986	247		2,279	270		9,131	38,333
	3	526	110		318		513		7,224	1,825	2,445	1,097		3,342	5,269	281	228	23,180
Montana	4	1,619	162				1,619		6,477	324	3,238	162		3,238	6,477	162	162	23,640
	5	274	57		165		267		3,759	949	1,272	571		1,739	2,741	146	119	12,060
	6	664	139		401		647		9,118	2,303	3,086	1,384		4,219	6,650	355	288	29,256
	7	-1,355	-2,067		-1,766	-884	-2,723		-2,686	-763	-1,584	-388		-2,772	-1,227	-1,731	-1,181	-21,128
Oregon	8								16,099	543				543	16,279		1,357	34,820
	9	6,429	6,429		8,571		8,571		17,143	4,286	8,571	8,571		12,857	8,571			90,000
	10	2,641	13,206		5,283		19,809		26,412	2,641				26,412	13,206	13,206	5,282	128,100
	11	1,598	1,066						1,604	53	1,172			3,197	1,598	3,197		13,485
	12	1,545	1,545		2,061		1,545		3,091	1,545	1,545			4,121				17,000
	13	1,791					1,791		7,407		1,709			4,884	1,709	1,709		21,000
	14	88	573		2,114				6,166	3,348	3,392	3,171		5,638	2,643			27,132
	15	105	160		137	68	210		208	59	122	30		214	95	134	91	1,633
Washington	16	4,550	4,550			4,550	4,550		4,853	3,033	3,033			6,370	4,550	1,821		41,860
	17	7,514	7,194		13,963	4,853	26,606		9,482	2,501	7,194			3,193				82,500
	18								11,875	7,917	7,917	3,958		7,917	7,917			47,500
	19				10,000					5,000	10,000							25,000
	20	3,124	4,764		4,072	2,038	6,277		6,193	1,760	3,652	894		6,389	2,829	3,991	2,722	48,704
	21	16,518	27,530		2,002		18,520		5,506		16,018	2,503		1,502				90,099

Table A-7: Indirect Non-Energy Impacts (Net) by Project

		Design & Construction							Facility O&M					Occupants				ALL	
State	#	Contractor callbacks	Change orders	Litigation	Coordination	Schedule	System optimization	Other	Deficiencies	Document	Knowledge	Lifetime	Other	Comfort	IAQ	Productivity	Other	($)	($/SF)
Idaho	1	4,731	2,523				12,617		18,925	3,785	7,570	473		34,065	7,570	8,516	10,409	**111,186**	**0.33**
	2	3,438	1,684		126	185	1,758		7,463	748	1,800	46		2,279	143		4,280	**23,951**	**0.27**
	3								3,612		2,445	548		3,342	2,634		57	**12,640**	**0.55**
Montana	4	810	81				810		1,619	81	810	162		3,238	1,619	40	40	**9,310**	**0.17**
	5								3,759					1,739				**5,498**	**0.09**
	6								9,118		1,543	1,384		4,219	3,325	178		**19,766**	**0.18**
	7	-136			707	88			-1,075		-475			-277	-368			**-1,536**	**-0.07**
Oregon	8								12,074	543				543	12,209		339	**25,708**	**0.40**
	9	2,571	1,286		2,571		3,429		12,000	643	1,286	5,143		7,071	1,286			**37,286**	**0.54**
	10	1,321	-1,321		1,057		1,981		18,489	264				26,412	1,321	2,641	528	**52,693**	**0.33**
	11	480	-213						1,604	16	703			639				**3,229**	**0.18**
	12	1,236	927		1,648		927		927	232	695			2,885				**9,479**	**0.04**
	13								7,407		1,709			2,442				**11,558**	**0.07**
	14	-11	72		529				6,166	2,511	2,120	1,586		705	330			**14,007**	**0.07**
	15	21	64		-27	-7			104						-9			**145**	**0.00**
Washington	16	3,413	3,413			-1,138	1,138		4,853	1,137	1,896			6,370	2,844	683		**24,607**	**0.17**
	17	2,254	2,878		6,981		10,642		5,689	1,751	2,878			2,235				**35,308**	**0.45**
	18								11,875	6,597	6,597	1,319		7,917	2,639			**36,944**	**0.39**
	19				7,500					3,125	2,500							**13,125**	**0.23**
	20				1,745		897		6,193	754	348	383		3,043	2,290	1,710	518	**17,881**	**0.35**
	21	6,607	8,259		1,402		7,408		5,506		2,403	1,126		901				**33,612**	**0.56**

Table A-8: One-Time Impacts by Project

		ONE-TIME IMPACTS ($)										
		Direct					**Indirect**					
State	#	Cx agent fees	Issue identification	Issue resolution	Change orders	**Total direct**	Non-energy impacts	Issue identification	Issue resolution	Change orders	**Total indirect**	**Total one-time**
Idaho	1	-220,000	-3,000		21,400	**-201,600**	111,186	-22,358	-1,780	1,140	**88,188**	**-113,412**
	2	-40,280			20,000	**-20,280**	23,951	-12,284	-18,984		**-7,317**	**-27,597**
	3	-19,300		-33,844		**-53,144**	12,640	-330	-2,394		**9,916**	**-43,228**
Montana	4	-12,300		-166,955		**-179,255**	9,310	-2,148	-3,839		**3,323**	**-175,932**
	5	-8,700		-17,500		**-26,200**	5,498		-875		**4,623**	**-21,577**
	6	-24,800		-4,131		**-28,931**	19,766	-1,760	-1,967		**16,040**	**-12,891**
	7	-24,000	-2,747	-2,053	2,982	**-25,818**	-1,536	-2,700	-1,800	6,378	**342**	**-25,476**
Oregon	8	-11,044		-2,970		**-14,014**	25,708	-7,560	-675		**17,473**	**3,459**
	9	-83,380			13,075	**-70,305**	37,286	-9,400	-13,900	484	**14,469**	**-55,836**
	10	-60,880				**-60,880**	52,693	-4,950	-8,300		**39,443**	**-21,437**
	11	-12,400			150	**-12,250**	3,229	-2,501			**728**	**-11,522**
	12	-85,000	-7,000	-4,000	-8,500	**-104,500**	9,479	-9,750	-9,750		**-10,021**	**-114,521**
	13	-20,900		-32,960		**-53,860**	11,558	-2,580	-8,435		**543**	**-53,317**
	14	-14,280			11,368	**-2,912**	14,007	-2,846	-3,000	2,131	**10,292**	**7,380**
	15	-32,660			-15,000	**-47,660**	145	-10,975	-6,425		**-17,255**	**-64,915**
Washington	16	-41,860				**-41,860**	24,607	-4,410	-4,090		**16,107**	**-25,753**
	17	-100,000			-17,500	**-117,500**	35,308	-10,379	-3,971		**20,958**	**-96,542**
	18	-65,102	-670	-11,120	5,000	**-71,892**	36,944	-9,960	-4,920		**22,064**	**-49,828**
	19	-80,000				**-80,000**	13,125	-4,250	-8,800		**75**	**-79,925**
	20	-70,000	-2,500		-2,750	**-75,250**	17,881	-6,120	-2,740		**9,021**	**-66,229**
	21	-82,820	-113	-5,138	-10,000	**-98,070**	33,612	-4,870	-6,560		**22,183**	**-75,887**

Table A-9: Normalized One-Time Impacts by Project

		NORMALIZED ONE-TIME IMPACTS ($/SF)										
		Direct					**Indirect**					
State	#	Cx agent fees	Issue identification	Issue resolution	Change orders	**Total direct**	Non-energy impacts	Issue identification	Issue resolution	Change orders	**Total indirect**	**Total one-time**
Idaho	1	-0.65	-0.01		0.06	**-0.59**	0.33	-0.07	-0.01	0.00	**0.26**	**-0.33**
	2	-0.45			0.22	**-0.22**	0.27	-0.14	-0.21		**-0.08**	**-0.31**
	3	-0.84		-1.47		**-2.31**	0.55	-0.01	-0.10		**0.43**	**-1.88**
Montana	4	-0.22		-2.98		**-3.20**	0.17	-0.04	-0.07		**0.06**	**-3.14**
	5	-0.14		-0.27		**-0.41**	0.09		-0.01		**0.07**	**-0.34**
	6	-0.22		-0.04		**-0.26**	0.18	-0.02	-0.02		**0.15**	**-0.12**
	7	-1.03	-0.12	-0.09	0.13	**-1.11**	-0.07	-0.12	-0.08	0.27	**0.01**	**-1.09**
Oregon	8	-0.17		-0.05		**-0.22**	0.40	-0.12	-0.01		**0.27**	**0.05**
	9	-1.20			0.19	**-1.01**	0.54	-0.14	-0.20	0.01	**0.21**	**-0.80**
	10	-0.38				**-0.38**	0.33	-0.03	-0.05		**0.25**	**-0.13**
	11	-0.68			0.01	**-0.67**	0.18	-0.14			**0.04**	**-0.63**
	12	-0.34	-0.03	-0.02	-0.03	**-0.42**	0.04	-0.04	-0.04		**-0.04**	**-0.46**
	13	-0.12		-0.19		**-0.32**	0.07	-0.02	-0.05		**0.00**	**-0.31**
	14	-0.07			0.05	**-0.01**	0.07	-0.01	-0.01	0.01	**0.05**	**0.03**
	15	-0.67			-0.31	**-0.97**	0.00	-0.22	-0.13		**-0.35**	**-1.32**
Washington	16	-0.29				**-0.29**	0.17	-0.03	-0.03		**0.11**	**-0.18**
	17	-1.28			-0.22	**-1.51**	0.45	-0.13	-0.05		**0.27**	**-1.24**
	18	-0.68	-0.01	-0.12	0.05	**-0.75**	0.39	-0.10	-0.05		**0.23**	**-0.52**
	19	-1.38				**-1.38**	0.23	-0.07	-0.15		**0.00**	**-1.38**
	20	-1.37	-0.05		-0.05	**-1.48**	0.35	-0.12	-0.05		**0.18**	**-1.30**
	21	-1.38	0.00	-0.09	-0.17	**-1.63**	0.56	-0.08	-0.11		**0.37**	**-1.26**

5.2 Database Descriptions

<u>Commissioning issues database</u> (1617 observations)

Field Name	Description
STATE	State where project takes place.
SITE	3-letter project code for this study.
IDENTIFIER	Issue identification number or string, generally taken from Cx report or issue log.
I_ID	Issue ID for this study, composed of STATE, SITE, and IDENTIFIER fields.
I_DESC	Issue description
I_NOTE1	Other annotations and comments about issue.
I_NOTE2	
S_SIGNIF	Flag indicating whether issue was deemed "significant" for the analysis. **NOTE: Subsequent fields were completed only for significant issues.**
S_SIGREA	Brief description of reasons why issue was deemed significant.
S_RESOLV	Flag indicating whether issue has been resolved or not.
S_RESYR	For unresolved issues, flag indicating whether or not issue was likely to be resolved within a year.
S_DRESCO	Total estimated direct costs to resolve issue.
S_IRESCO	Total estimated indirect costs to resolve issue.
S_ISSDOC	Flag indicating whether issue was documented in the formal Cx issue logs.
S_NOTES	General notes about cost estimates and issue resolution.
C_PHASE	Cx phase (design/construction/operation for new Cx; O&M/capital for retroCx)
C_AREA	Building system affected by Cx issue, e.g., "Mechanical - controls" or "Electrical - lighting".
D_ELEC	Electric usage impact in kWh/year
D_GAS	Natural gas usage impact in therms/year
D_OTUTIL	Usage impact for other utilities (e.g., water/sewer) in $/year
D_O&M	Impact on ongoing O&M expenses in $/year
D_AVDIR	Avoided direct cost for repairs, in one-time $.
D_AVIND	Avoided indirect cost for repairs, in one-time $.
D_UNKNOW	Flag indicating that direct energy impacts are not quantifiable.
D_NOTES	Other notes about direct impacts.

CTM survey database (146 observations)

Field Name	CTM Survey Field?	Description
2A-Role	Yes	Role in Cx process
2A-RoleDesc	Yes	
2B-FacOther	Yes	Overview of Cx value to agency and occupants (if yes, then do NEB survey)
2B-FacOverviewYN	Yes	
2C-ProjOther	Yes	Overview of Cx value to design & construction process (if yes, then do NEB survey)
2C-ProjOverviewYN	Yes	
3A-CA$	Yes	Invoiced Cx agent cost
3B-Support$	Yes	Cx agent time, $ spent on Alliance support
3B-Support$Notes	Yes	
3C-BidIncrease$	Yes	Designer/contractor bid icnrease for Cx
3D-NonLabor$	Yes	Additional non-labor expenses for Cx
3D-NonLabor$Notes	Yes	
3E-AddlCost$	Yes	Additional change orders or project costs for Cx
3E-AddlCostNotes	Yes	
3F-AvoidedCO$	Yes	Avoided change orders or project costs for Cx
3F-AvoidedCONotes	Yes	
3G-IDHours	Yes	Additional hours for Cx issue identification activities.
3G-ResolveHours	Yes	Additional hours for Cx issue resolution activities.
3H-LaborRate	Yes	Applicable labor rate for 3G.
4A-Impressions	Yes	General impressions of Cx on project.
4B-ResolvedProblems	Yes	Major problems found or resolved by Cx.
4C-OtherIssues	Yes	Cx issues not listed in Cx report
4D-NEBSurvey	Yes	OK to do NEB survey
4E-Callback	Yes	Design & construction impacts - helped/hindered/no effect
4E-ChangeOrder	Yes	
4E-Coordination	Yes	
4E-D&COther	Yes	
4E-D&COtherText	Yes	
4E-Litigation	Yes	
4E-Schedule	Yes	
4E-WorkingRight	Yes	
4F-Deficiencies	Yes	Facility operations impacts - helped/hindered/no effect
4F-Document	Yes	
4F-Knowledge	Yes	
4F-Lifetime	Yes	
4F-OperOther	Yes	
4F-OperOtherText	Yes	
4G-Comfort	Yes	Occupant impacts - helped/hindered/no effect
4G-IAQ	Yes	
4G-OccOther	Yes	
4G-OccOtherText	Yes	
4G-Productivity	Yes	
Abbreviation	--	3-letter project code for this study.
CD-ADDL	--	Total additional CO/project costs (direct) mentioned by respondent
CD-AVOID	--	Total avoided CO/project costs (direct) mentioned by respondent
CD-IDENT	--	Total Cx issue ID costs (direct) mentioned by respondent
CD-RESOL	--	Total Cx issue resolution costs (direct) mentioned by respondent
CI-ADDL	--	Total additional CO/project costs (indirect) mentioned by respondent
CI-AVOID	--	Total avoided CO/project costs (indirect) mentioned by respondent
CI-IDENT	--	Total Cx issue ID costs (indirect) mentioned by respondent
CI-RESOL	--	Total Cx issue resolution costs (indirect) mentioned by respondent
CTGroup	--	Cx team member grouping (CX, CO, DE, FA)
CTMS ID#	--	CTM survey ID #
Cx team member survey (CTMS)	--	CTM survey disposition (DONE, No-..., etc.)
Cx type	--	Cx project type (new, retro, re)
Date CTMS done	--	CTM survey completion date
Firm	--	Name of respondent company or agency
Include in analysis	--	Flag for including respondent information in analysis
NEB survey	--	Whether NEB survey is required
Phone	--	Respondent phone number
Respondent	--	Respondent name/title
SERA notified	--	Date SERA notified of need for NEB survey
Site	--	Project name
State	--	State where project takes place (ID, MT, OR, WA)

5.3 Survey Disposition Results

Table A-10: CTM Survey Disposition by Project Role

	Successful		Rejected		All
Project Role	N	% of all	N	% of all	N
Cx agents	**24**	**96%**	**1**	**4%**	**25**
General	6		4		10
Controls	3		2		5
Electrical	3		0		3
Mechanical	2		6		8
All Contractors	**14**	**54%**	**12**	**46%**	**26**
Architect	9		1		10
Engineer	9		3		12
All Designers	**18**	**82%**	**4**	**18%**	**22**
Manager - O&M	16		3		19
Manager - project construction	12		3		15
Staff	13		8		21
All Agency Personnel	**41**	**75%**	**14**	**25%**	**55**
TOTALS	**97**	**76%**	**31**	**24%**	**128**

Table A-11: Reasons for CTM Survey Rejection

Reason for rejection	**N**	**% of total**
Could not reach	17	55%
Unfamiliar with project	9	29%
People familiar w/project are gone	2	6%
Refused to be surveyed	3	10%
TOTAL	**31**	**100%**

Table A-12: NEB Survey Respondents by Project Role

	Successful	
Project Role	N	% of total
Architect	1	
Engineer	2	
All Designers	**3**	**11%**
Manager - O&M	14	
Manager - project construction	6	
Staff	4	
All Agency Personnel	**24**	**89%**
TOTAL RESPONDENTS	**27**	**100%**

5.4 Commissioning Team Member (CTM) Survey Instrument

Project Name/ID:
Cx type (circle one)*:* *NEW* *RETRO* *RE* *Survey ID#:*
Respondent:
Company/Role: *Date Surveyed:*

Northwest Energy Efficiency Alliance
Cost-Benefit Analysis for the Public Sector Commissioning Project

COMMISSIONING TEAM MEMBER SURVEY

January 30, 2003 draft

1. Introduction

Introduce yourself and begin a brief discussion so the respondent knows what this is about and how SBW fits in. Skip background info if respondent is already familiar with the Alliance project.

- The Northwest Energy Efficiency Alliance is a non-profit consortium, funded by utilities, that is working to expand the market for energy-efficient products and services in the Pacific Northwest.
- So far, it has supported over 30 Cx demo projects in public buildings in the region. Case studies of these will help other government agencies incorporate Cx into future projects.
- The Alliance has hired us, SBW Consulting, to perform cost-benefit analyses as an independent third party.

- To support our effort, we will need just a few pieces of information from you. This should not require very much of your time. The two steps are:

    1) Provide estimates of the additional costs you incurred because of Cx on this project.

    2) Tell us your opinion about the effects of Cx on this project.

2. Team Member Role

2A. Describe your role in the Cx process for this project (*as appropriate, ask about their organization's overall role*):

(*Select as appropriate*)
- ☐ 1 - Cx agent
- ☐ 2 - Facilities staff
- ☐ 3 - Manager - facilities
- ☐ 4 - Manager - project construction
- ☐ 5 - Designer *(choose one)* architect / mechanical engineer / electrical engineer / other
- ☐ 6 - Contractor *(choose one)* general / mechanical / electrical / controls / TAB / other

2B. *(If "3 – Manager – facilities" applies)* Do you feel you have a sufficient overview of your agency's operations to be able to assess commissioning's overall value to the agency and building occupants?

- ☐ (For YES, ask*): Is there anyone else in the agency besides you who might be able to comment generally on commissioning's value? Write name/position/phone# below:*

- ☐ (For NO, ask*). Who might be in a better position to do so? Write name/position/phone# below:*

2C. *(If "4 – Manager – project construction" applies)* Do you feel you had a sufficient overview of the project to be able to assess commissioning's overall value to the design and construction process for the owner?

☐ YES ☐ NO (if no, who might be in a better position to do so?
Get name/position/phone# ________________________________)

3. Commissioning-Related Costs

Now I have a few questions about commissioning-related costs for you. <Note: Questions A-F are to determine direct cost impacts (those that appear on invoices) for contracted parties. Questions G-H are meant to determine indirect impacts (time spent on Cx, but not necessarily "billable" for all respondents except Cx agents.>

3A. <*For Cx Agents Only*> What was the total dollar amount you invoiced for your Cx services?

3B. <*For Cx Agents Only*> How much time have you had to spend to support Alliance-related activities, such as case studies, extra documentation, or interviews such as this? Have you been compensated for this time, and if so, by what dollar amount?

3C. <*For Designers/Contractors Only* > How much, if any, did you increase your bid for this project to account for Cx activities?

3D. Were there any significant additional non-labor costs associated with Cx? (for example, additional travel) If so, what for, and for roughly what dollar amount?

3E. Did the Cx process lead to additional change orders or project costs? If so, for whom, what for, and for roughly what dollar amount?

3F. Did the Cx process help avoid change orders or project costs? <*Give appropriate example.*>

NEW Cx: An example might be the Cx agent identifying improperly located thermostats before they were installed, thus avoiding having the contractor relocate them afterwards.

RETRO Cx: An example might be the Cx agent optimizing an old system so that only one, rather than two, heating units need to run, thus eliminating the need to replace the one that was failing.

If there were avoided costs, for whom, what for, and for roughly what dollar amount?

3G. <*For all respondents except Cx agents*> How much additional time have you or anyone else in your organization incurred because of Cx? *(prompt for ranges or rough estimates, depending on the respondent's memory)*

- By this, we mean time beyond normal practices, such as meetings with the Cx agent or reviewing Cx bid specs.
- Also, we want to differentiate between time spent setting up to find Cx issues, as opposed to time spent fixing problems that Cx identified. For example, the time spent helping develop a test plan (which would be considered "identifying" issues), versus the time spent replacing a faulty control that the test revealed (which would be considered "resolving" an issue).

Identifying issues: _____________ hours   Resolving issues: _____________ hours

3H. <*If respondent did not provide cost information*>What hourly labor rate(s) would best apply to these hours spent identifying and/or resolving issues?

Survey ID#:

4. Impacts of Commissioning

4A. What were your general impressions of the commissioning process for this project?

4B. What do you recall were the major problems that were found or issues that were resolved by commissioning?

4C. *<For Cx agents only>* Were there any significant issues or deficiencies not listed in the Cx report that we should be aware of? If so, what? Were these issues resolved?

"Key Manager" Screen: IF RESPONDENT ANSWERED "YES" TO QUESTIONS (2B) OR (2C), THEN ADMINISTER (4D) BELOW. ELSE SKIP TO (4E).

4D. From your previous responses, it appears you played a key managerial role for this Cx effort. If you don't mind, I am going have a researcher from another firm, Skumatz Economic Research Associates, contact you in the near future. They have about 15 minutes' worth of follow-up questions to help establish the benefits of commissioning that are more difficult to quantify, such as improved indoor air quality.

- ☐ *YES (when would be the best time to be contacted?_______________)*
- ☐ *NO*

This concludes this portion of our survey. Thank you very much for your time.

Survey ID#:

"Not a Key Manager" Screen: IF RESPONDENT DID NOT NEED TO ANSWER OR ANSWERED "NO" TO QUESTIONS (2B) OR (2C), THEN ADMINISTER (4E) BELOW.

For each of the three categories, ask the open-ended question first, and note significant responses in the matrix. If the respondent cannot think of any more aspects, then read off additional choices below.

4E. *(For new Cx only)* Did Cx on this project affect the design & construction effort—either positively or negatively—compared to what would have happened without Cx? If so, how?

Aspect	***Helped (+1)***	***No effect (0)***	***Hindered (-1)***	***Don't know/ refused (D)***
Contractor callbacks				
Change orders or warranty claims				
Potential for litigation				
Coordination, relationships between team members				
Project schedules				
Time needed to get building systems working right				
Other				

4F. Assuming all Cx recommendations were implemented, how will this Cx effort significantly affect facility operations? *(If necessary, differentiate between Phase 1 retro-Cx (low-/no-cost measures) and Phase 2 retro-Cx (major capital measures))*

Aspect	***Helped (+1)***	***No effect (0)***	***Hindered (-1)***	***Don't know/ refused (D)***
Operational deficiencies				
System documentation				
Staff knowledge				
Equipment lifetime				
Other				

4G. Assuming all Cx recommendations were implemented, how will this Cx effort significantly affect building occupants? *(If necessary, differentiate between Phase 1 retro-Cx (low-/no-cost measures) and Phase 2 retro-Cx (major capital measures))*

Aspect	***Helped (+1)***	***No effect (0)***	***Hindered (-1)***	***Don't know/ refused (D)***
Comfort				
Indoor air quality				
Productivity				
Other				

This concludes our survey. Thank you very much for your time.

Survey ID#:

Background Information for NEB Surveyor < *To be completed by CTM surveyor after the survey is complete, if the follow-up NEB survey is required. Some of this information comes from survey responses, and other information from project databases. It is intended to provide context for the NEB surveyor so they can better understand the Cx project prior to their contacting the respondent.*>

1. Respondent name	
2. Company/agency	
3. Phone number	
4. Date CTM Survey administered	
5. Role in Cx project	
6. Type of building / business	
7. Cx timeframe	
8. Cx type:	
9. Cx agent cost:	
10. Alliance/state subsidies for Cx cost:	

5.5 Non-Energy Benefit (NEB) Survey Instrument

SERA

Skumatz Economic Research Associates, Inc.
Boulder Office: 762 Eldorado Drive, Superior, CO 80027
Phone: 303/494-1178 FAX: 303/494-1177
email: skumatz @serainc.com; web: serainc.com; payt.org

SUBJECT: Revised-cubed Draft NEB Survey Questions

S. BACKGROUND INFORMATION FOR STRATIFICATION / ANALYSIS / BACKGROUND PURPOSES (to be transferred from CTM survey)

S1. Name:
S2. Company:
S3. Phone number:
S4. Role (title) & involvement / familiarity with commissioning:
S5. Type of building:
S6. Type of business:
S7. Date of Cx action (year, to see if elapsed time affects benefits): ________
S8 Type of commissioning:

- π New construction
- π Retrofit / recommissioning
- π Other

S9. Phase of commissioning effort they were involved in: OR PHRASE HOW YOU THINK BEST –WE'LL TRANSFER FROM YOUR SURVEY

- π Design/construction
- π Facility Operations
- π Building Occupant
- π Other

S10. Gross cost for Cx: $________
S11. Rebate from NEEA for Cx (or net cost and we'll back out the 3rd number): $_________
S12. Size of Building / Square Footage: ___________

RECRUITMENT SCRIPT: Hello, my name is __________. SBW Consulting contacted you some time ago to discuss the costs and benefits associated with commissioning the ______________ facility. I understand you are the best person to talk about regarding that facility and work. ...
You may recall that work was sponsored by the Oregon Office of Energy. The Northwest Energy Efficiency Alliance is expanding that project to look at commissioning efforts all over the region, and as part of that work I'm investigating what you might call "hard to quantify" benefits – like indoor air quality or improved operability associated with the commissioning. I wonder if you have a few minutes <about 15 minutes, if they ask> to talk about these impacts from the commissioning work.
Is this a good time, or is there some other time we could arrange to speak? ____________________

Scheduled for: ____________________

Survey administered by: __________

Date: __________

Start Time: __________

End Time: __________

A. OPEN-ENDED ASSESSMENT OF BENEFITS

A1. Which of the following systems were commissioned? (check all that apply, and TRANSFER MEASURE TYPES TO A1 BOXES)

- π **HVAC**
- π **Other (please specify) ________________**
- π **Don't know / refused**

A1. Are there any benefits – beyond possibly energy savings – that you believe result from the commissioning efforts? (open ended – add to table B2)

A2. Are there any negative effects that you believe resulted from the commissioning efforts? (open ended, add to Table B1)

B. BENEFITS IN DETAIL

B1. I am interested in finding out how important a number of considerations are to you when you are working on building like the one we are talking about. Could you please rank how important – on a scale of High, Medium, and Low –these considerations are to you. Could you also let me know which one is Most Important to you? <Code H=High, M=Medium, L=Low, D=Don't know / refused, X=most important>.

B2-B3. We'd like to ask about the benefits or negative effects you have realized from the commissioning efforts. <ask about the relevant set of categories based on the answers to S9, whether they were involved in Cx related to Design/Construction, O&M, or Occupant>.

B2. Did the commissioning result in any changes – positive or negative – in any of the following areas, compared to what you would have experienced without the commissioning efforts? <read list for the relevant subsection, including any benefits they added in the open-ended response, A1 and A2>

	For B2 & B3 + is always the BETTER situation. Circle +, 0, or – for pos/none/neg, D= DNK/Refused,X=most impt	**B1. Importance** (code H/M/L/D/X)	**B2. Actually Implemented**	**B3. Assuming all Rec's implemented**
DESIGN / CONSTRUCTION				
A	**Contractor call-backs** (fewer, same, more)	**H M L D X**	**+ 0 - D**	**+ 0 - D**
B	**Change orders** (fewer, same, more)	**H M L D X**	**+ 0 - D**	**+ 0 - D**
C	**Warranty claims** (fewer, same, more)	**H M L D X**	**+ 0 - D**	**+ 0 - D**
D	**Time to optimize system** (less, same, more)	**H M L D X**	**+ 0 - D**	**+ 0 - D**
E	**Project schedule** (faster, same, delays)	**H M L D X**	**+ 0 - D**	**+ 0 - D**
F	**Coordination** (better, same, difficulties)	**H M L D X**	**+ 0 - D**	**+ 0 - D**
G	**Team member relationships** (improved, no diff, conflicts)	**H M L D X**	**+ 0 - D**	**+ 0 - D**
H	**Other** __________ from a2/a3(better, same, worse)	**H M L D X**	**+ 0 - D**	**+ 0 - D**
O&M				
I	**Operational deficiencies** (better, same, worse)	**H M L D X**	**+ 0 - D**	**+ 0 - D**
J	**System documentation** (better, same, worse)	**H M L D X**	**+ 0 - D**	**+ 0 - D**
K	**Knowledge for O&M staff** (better, same, worse)	**H M L D X**	**+ 0 - D**	**+ 0 - D**
L	**Equipment maintenance** (better, same, worse)	**H M L D X**	**+ 0 - D**	**+ 0 - D**
M	**Equipment lifetime** (longer, same, shorter)	**H M L D X**	**+ 0 - D**	**+ 0 - D**
N	**Other** ____________(better, same, worse)	**H M L D X**	**+ 0 - D**	**+ 0 - D**
OCCUPANTS				
O	**Comfort** (better, same, worse)	**H M L D X**	**+ 0 - D**	**+ 0 - D**
P	**Indoor Air Quality** (improved, same, worse)	**H M L D X**	**+ 0 - D**	**+ 0 - D**
Q	**Illnesses / sick days** (fewer, same, more)	**H M L D X**	**+ 0 - D**	**+ 0 - D**
R	**Tenant or worker complaints** (fewer, same, more)	**H M L D X**	**+ 0 - D**	**+ 0 - D**
S	**Productivity (e.g. process, lite)** (better, same, worse)	**H M L D X**	**+ 0 - D**	**+ 0 - D**
T	**Safety** (better, same, worse)	**H M L D X**	**+ 0 - D**	**+ 0 - D**
U	**Quality of light** (better, same, worse)Very rarely applicable.	**H M L D X**	**+ 0 - D**	**+ 0 - D**
V	**Other they mentioned** ____________	**H M L D X**	**+ 0 - D**	**+ 0 - D**
W	**Other they mentioned** ____________	**H M L D X**	**+ 0 - D**	**+ 0 - D**
X	**Other they mentioned** ____________	**H M L D X**	**+ 0 - D**	**+ 0 - D**
Y	**Other they mentioned** ____________	**H M L D X**	**+ 0 - D**	**+ 0 - D**
Z	**Don't know / refused**	**H M L D X**	**+ 0 - D**	**+ 0 - D**

B3. Assuming all commissioning recommendations were implemented, do you believe all the commissioning actions will result in any changes – positive or negative – in any of the following areas, compared to what you would have experienced without the commissioning efforts? <code in table above>

B4: Are there any of these categories you find to be too closely related or overlap too much to separate – benefits that we should talk about "jointly"?

***NOW THINKING ABOUT THE COMMISSIONING WORK YOU HAD DONE*, I'd like you to think about the amount you spent on the commissioning work. The costs happen all at once, but the effects last many years. So I'd like you to think about those costs**

being spread out over time – as if there was a payment plan[4]. Is that fairly clear? <if not, explain again.> Let's call that the annual share, or estimated "annualized commissioning costs", or "commissioning costs" for short.[5]

B5-B8. Now, thinking about some of the <u>benefits</u> you mentioned for the commissioning recommendations that were <u>implemented</u>…

		FOR <u>POSITIVE</u> BENEFITS IN TABLE B2"+" <u>Commissioning Efforts Actually Implemented</u> **IF B1A1 ="+"… and in turn for each cell that ="+"**	**B5.** Now thinking about the individual <a-z> benefits that you mentioned were associated with the commissioning effort… which is more valuable to you				**B6A. IF ANNUALIZED AMOUNT MORE VALUABLE**: How much more valuable are the annualized commissioning costs than the <a-z> benefit? Would you say they are… **B6B. IF BENEFITS MORE VALUABLE**: How much more valuable are the <a-z> benefits than the annualized commissioning costs? Would you say they are ….					**B7A. IF ANNUALIZED AMOUNT MORE VALUABLE**: Now we'd like to get a bit more numeric. Would you say that, compared to the <a-z> benefits, your annualized commissioning costs are…… **B7B. IF BENEFITS MORE VALUABLE**: Now we'd like to get a big more numeric. Would you say that, compared to the annualized commissioning costs, the <a-z> benefits are ….					**B8.** Please rank which benefits are most valuable to you (top 3 in order)
B1+Positive		**+**	Annualized amount spent on Cx	The (a-z) benefits – pos & negative	Both annual. Cx cost & benefits equally	Don't know / refused	Somewhat more valuable	Much more valuable	Much more valuable	Very much more valuable	About the same	About 10% more valuable	About 1-1/2 times as valuable	Twice as valuable	More than twice as valuable	Don't know / refused	
		DESIGN/CONSTRUCTION										**ONE TIME?**					
π	**A**	**Contractor call-backs**															
π	**B**	**Change orders**															
π	**C**	**Warranty claims**															
π	**D**	**Time to optimize system**															
π	**E**	**Project schedule**															
π	**F**	**Coordination**															
π	**G**	**Team member relationships**															
π	**H**	**Other ______** from a2/a3															
		O&M										**ONE TIME OR PER YEAR?**					
π	**I**	**Operational deficiencies**															
π	**J**	**System documentation**															
π	**K**	**Knowledge for O&M staff**															
π	**L**	**Equipment maintenance**															
π	**M**	**Equipment lifetime**															
π	**N**	**Other ____________**															
		OCCUPANTS										**PER YEAR? TOTAL?**					
π	**O**	**Comfort**															
π	**P**	**Indoor Air Quality**															
π	**Q**	**Illnesses / sick days**															
π	**R**	**Tenant or worker complaints**															
π	**S**	**Productivity process, lite)**															
π	**T**	**Safety**															
π	**U**	**Quality of light**.															
π	**V**	**Other ment. _________**															

[4] If the pre-test indicates this concept is too difficult for respondents, we will ask about the amount they spent on commissioning, without trying the annualized version.

[5] We will pre-test both providing the number, and not providing the number. Providing the number may affect the WTP results later in the survey.

π	W	Other ment. __________															
π	X	Other ment. __________															
π	Y	Other ment. __________															
π	Z	Don't know / refused															
π																	

B9-13. Now, thinking about the <u>negative</u> effects you mentioned for the commissioning recommendations that were <u>implemented</u>..

		FOR <u>NEGATIVE</u> BENEFITS IN TABLE B1 – Commissioning Efforts <u>Actually</u> <u>Implemented</u>	**B9.** Now thinking about the individual negative effects on <a-z>, would you say the <a-z> effect was more costly than the annualized. Cx cost, less costly, or about the same?				**B10A. IF ANNUALIZED AMOUNT MORE COSTLY**: How much more costly were the annualized commissioning costs than the <a-z> benefit? Would you say they were… **B10B. IF BENEFITS MORE COSTLY**: How much more costly are the <a-z> benefits than the annualized commissioning costs? Would you say they are ….					**B11A. IF ANNUALIZED AMOUNT MORE COSTLY**: Now we'd like to get a bit more numeric. Would you say that, compared to the <a-z> negative impacts, your annualized commissioning costs are…… **B11B. IF BENEFITS MORE COSTLY**: Now we'd like to get a big more numeric. Would you say that, compared to the annualized commissioning costs, the <a-z>negative impacts are ….					**B12.** Please rank which are the three most negative effects (top 3 in order, worst=1)
B1 - Negative		**" _ "**	Annualized amount spent on Cx	The (a-z) benefits – pos & negative	Both annualized Cx cost & benefits	Don't know / refused	Somewhat more costly	Much more costly	Much more costly	Very much more costly	About the same	About 10% more costly	About 1-1/2 times as costly	Twice as costly	More than twice as costly	Don't know / refused	
		DESIGN/CONSTRUCTION										**ONE-TIME?**					
π	**A**	**Contractor call-backs**															
π	**B**	**Change orders**															
π	**C**	**Warranty claims**															
π	**D**	**Time to optimize system**															
π	**E**	**Project schedule**															
π	**F**	**Coordination**															
π	**G**	**Team member relationships**															
π	**H**	**Other** _____from a2/a3															
		O&M										**One time? Per Year?**					
π	**I**	**Operational deficiencies**															
π	**J**	**System documentation**															
π	**K**	**Knowledge for O&M staff**															
π	**L**	**Equipment maintenance**															
π	**M**	**Equipment lifetime**															
π	**N**	**Other** ____________															
		OCCUPANTS										**PER YEAR?**					
π	**O**	**Comfort**															
π	**P**	**Indoor Air Quality**															
π	**Q**	**Illnesses / sick days**															
π	**R**	**Tenant or worker complaints**															
π	**S**	**Productivity process, lite)**															
π	**T**	**Safety**															
π	**U**	**Quality of light**.															
π	**V**	**Other ment.** _________															
π	**W**	**Other ment.** _________															
π	**X**	**Other ment.** _________															
π	**Y**	**Other ment.** _________															
π	**Z**	**Don't know / refused**															

B13. Now thinking about <u>all</u> the positive and negative results you mentioned that were associated with all the commissioning efforts you undertook, which is more valuable to you…

SURVEY ID CODE: ____________

ALL BENEFITS & NEGATIVES COMBINED																

SURVEY ID CODE: ____________

B14-17. Now, thinking about some of the <u>benefits</u> you mentioned for ALL the commissioning recommendations that were <u>recommended</u>…

		FOR <u>POSITIVE</u> BENEFITS IN TABLE B1 – Commissioning Efforts <u>RECOMMENDED</u>	**B14.** Now thinking about the individual <a-z> benefits that you mentioned were associated with the commissioning effort… which is more valuable to you				**B15A. IF ANNUALIZED AMOUNT MORE VALUABLE**: How much more valuable are the annualized commissioning costs than the <a-z> benefit? Would you say they are… **B15B. IF BENEFITS MORE VALUABLE**: How much more valuable are the <a-z> benefits than the annualized commissioning costs? Would you say they are ….					**B16A. IF ANNUALIZED AMOUNT MORE VALUABLE**: Now we'd like to get a bit more numeric. Would you say that, compared to the <a-z> benefits, your annualized commissioning costs are…… **B16B. IF BENEFITS MORE VALUABLE**: Now we'd like to get a big more numeric. Would you say that, compared to the annualized commissioning costs, the <a-z> benefits are ….					**B17.** Please rank which benefits are most valuable to you (top 3 in order)
B1 + Positive			Annualized amount spent on Cx	The (a-z) benefits – pos & negative	Both annualized Cx cost & benefits	Don't know / refused	Somewhat more valuable	Much more valuable	Much more valuable	Very much more valuable	About the same	About 10% more valuable	About 1-1/2 times as valuable	Twice as valuable	More than twice as valuable	Don't know / refused	
		DESIGN/CONSTRUCTION										**ONE TIME?**					
π	**A**	**Contractor call-backs**															
π	**B**	**Change orders**															
π	**C**	**Warranty claims**															
π	**D**	**Time to optimize system**															
π	**E**	**Project schedule**															
π	**F**	**Coordination**															
π	**G**	**Team member relationships**															
π	**H**	**Other** ______from a2/a3															
		O&M										**ONE TIME? PER YEAR?**					
π	**I**	**Operational deficiencies**															
π	**J**	**System documentation**															
π	**K**	**Knowledge for O&M staff**															
π	**L**	**Equipment maintenance**															
π	**M**	**Equipment lifetime**															
π	**N**	**Other** ____________															
		OCCUPANTS										**PER YEAR?**					
π	**O**	**Comfort**															
π	**P**	**Indoor Air Quality**															
π	**Q**	**Illnesses / sick days**															
π	**R**	**Tenant or worker complaints**															
π	**S**	**Productivity process, lite)**															
π	**T**	**Safety**															
π	**U**	**Quality of light**.															
π	**V**	**Other ment.** __________															
π	**W**	**Other ment.** __________															
π	**X**	**Other ment.** __________															
π	**Y**	**Other ment.** __________															
π	**Z**	**Don't know / refused**															
π																	

SURVEY ID CODE: ____________

B18-22. Now, thinking about the <u>negative</u> effects you mentioned for the commissioning recommendations that were <u>RECOMMENDED</u>..

		FOR <u>NEGATIVE</u> BENEFITS IN TABLE B1 – Commissioning Efforts <u>RECOMMENDED</u>	**B18.** Now thinking about the individual negative effects on <a-z>, would you say the <a-z> effect was more costly than the annual. Cx cost, less costly, or about the same?				**B19A. IF ANNUALIZED AMOUNT MORE COSTLY**: How much more costly were the annualized commissioning costs than the <a-z> benefit? Would you say they were… **B19B. IF BENEFITS MORE COSTLY**: How much more costly are the <a-z> benefits than the annualized commissioning costs? Would you say they are ….					**B20A. IF ANNUALIZED AMOUNT MORE COSTLY**: Now we'd like to get a bit more numeric. Would you say that, compared to the <a-z> negative impacts, your annualized commissioning costs are…… **B20B. IF BENEFITS MORE COSTLY**: Now we'd like to get a big more numeric. Would you say that, compared to the annualized commissioning costs, the <a-z>negative impacts are ….					**B21.** Please rank which are the three most negative effects (top 3 in order, worst=1)
B1 - Negative			Annualized amount spent on Cx	The (a-z) benefits – pos & negative	Both annual. Cx cost & benefits equally	Don't know / refused	Somewhat more costly	Much more costly	Much more costly	Very much more costly	About the same	About 10% more costly	About 1-1/2 times as costly	Twice as costly	More than twice as costly	Don't know / refused	
		DESIGN/CONSTRUCTION										**ONE TIME?**					
π	**A**	**Contractor call-backs**															
π	**B**	**Change orders**															
π	**C**	**Warranty claims**															
π	**D**	**Time to optimize system**															
π	**E**	**Project schedule**															
π	**F**	**Coordination**															
π	**G**	**Team member relationships**															
π	**H**	**Other ______**from a2/a3															
		O&M										**ONE TIME OR PER YEAR?**					
π	**I**	**Operational deficiencies**															
π	**J**	**System documentation**															
π	**K**	**Knowledge for O&M staff**															
π	**L**	**Equipment maintenance**															
π	**M**	**Equipment lifetime**															
π	**N**	**Other ____________**															
		OCCUPANTS										**PER YEAR?**					
π	**O**	**Comfort**															
π	**P**	**Indoor Air Quality**															
π	**Q**	**Illnesses / sick days**															
π	**R**	**Tenant or worker complaints**															
π	**S**	**Productivity process, lite)**															
π	**T**	**Safety**															
π	**U**	**Quality of light**.															
π	**V**	**Other ment. __________**															
π	**W**	**Other ment. __________**															
π	**X**	**Other ment. __________**															
π	**Y**	**Other ment. __________**															
π	**Z**	**Don't know / refused**															

B22. Now thinking about <u>all</u> the positive and negative results you mentioned that were associated with all the commissioning efforts that were RECOMMENDED, which is more valuable to you…

B23. Are there any other important positive or negative effects that occur to you?

π No
π Yes ➔ what are they? ____________________

O. OVERALL CHECK

We would like to ask a few more questions about the overall benefits you received.

O1. Now, we'd like you to think about the amount you paid for the commissioning efforts. Using a scale of "0" to "100", where 0 is not at all important, and 100 means one of the most important aspects of the building and its operation, how would you rank the importance of these expenditures or costs? ____

O2. Now we're going to talk about the value of all the benefits you received in dollar terms. We're trying to gauge how valuable these benefits are to building <owners, facility staff>, but please understand this does not mean you will be charged for any of these benefits. We are only trying to determine an equivalent dollar value for these benefits. If all the non-energy benefits (and negative effects) that we talked about were taken away, what do you think would be the maximum amount you would be willing to pay to get back those benefits, on an annual or monthly basis? [6]

1. $____ (select ___ per week __ per month __ per year)
2. Don't know / refused

O3. (IF no answer to O2) Hypothetically, for this combination of benefits would you be willing to pay…(randomize starting point on list and ask appropriate direction of follow-ups)?

1. Up to $50 per month
2. Up to $100 per month
3. Up to $250 per month
4. Up to $500 per month
5. Up to $1000 per month
6. More than $1000 per month ➔ specify: ____________________
7. Nothing ($0)
8. Don't know / refused.

O2. Now thinking about *__all the commissioning recommendations__* -- If all the non-energy benefits (and negative effects) that we talked about were taken away, what do you think would be the maximum amount you would be willing to pay to get back those benefits, on an annual or monthly basis? [7]

3. $____ (select ___ per week __ per month __ per year)

[6] We originally phrased this in the positive – as "When you think about the value you received from all the benefits from the commissioning efforts (positive and negative), what is the maximum amount you would be willing to pay for these benefits, either per month or per year?". However, we believe it may be easier for respondents to conceptualize the negative version – taking benefits away – we've been finding that to be the case on another project. If the pre-test shows this is not easy to answer, we will try the original version. Alternatively, timing on the pretest may show we could ask it both ways.

[7] We originally phrased this in the positive – as "When you think about the value you received from all the benefits from the commissioning efforts (positive and negative), what is the maximum amount you would be willing to pay for these benefits, either per month or per year?". However, we believe it may be easier for respondents to conceptualize the negative version – taking benefits away – we've been finding that to be the case on another project. If the pre-test shows this is not easy to answer, we will try the original version. Alternatively, timing on the pretest may show we could ask it both ways.

4. Don't know / refused

O3. (IF no answer to O2) Hypothetically, for this combination of benefits would you be willing to pay…(randomize starting point on list and ask appropriate direction of follow-ups)?

1. Up to $50 per month
2. Up to $100 per month
3. Up to $250 per month
4. Up to $500 per month
5. Up to $1000 per month
6. More than $1000 per month ➔ specify: ____________________
7. Nothing ($0)
8. Don't know / refused.

Thank you very much for your patience and for helping us to assess the costs and benefits associated with commissioning efforts. We, and the Northwest Energy Efficiency Alliance thank you for your time.