EXISTING BUILDING COMMISSIONING: EXPLORATION OF USE AND IMPACTS

A Thesis

by

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ABSTRACT

Existing building commissioning (EBCx) is often considered a cost-effective method for reducing the energy consumption of a building while also driving improvements in occupant comfort and cost savings for the owner or operator. The commissioning of buildings can involve a significant number of measures and approaches, many of which depend on the specific systems and condition of each building. Generally, however, both existing building commissioning and new construction commissioning can provide an avenue for significant energy and cost savings in commercial buildings, and when applied at the national level, can have a measurable impact on the overall energy consumption of the commercial sector.

Many of the previous studies on building commissioning contain key median project-level and normalized values, such as project costs and cost savings per unit area, annual percent energy savings, and simple payback periods. However, these studies contained data that was often regionally focused and had an emphasis on individual project-level and measure-level savings, trends, and values, rather than a holistic look at the entire building commissioning market in the United States.

Thus, the aim of this project is to provide an estimated quantification of the implementation and impact of existing building commissioning, as well as the broader building commissioning, in terms of total cost and energy savings generated based on a selection of 198 Building Commissioning Association (BCxA) member companies and estimated annual revenue values. The calculations performed in this study have successfully generated approximate values that can be useful in understanding the magnitude of both the existing building commissioning and the general building commissioning for the sample of companies. The key calculated estimates for both existing building commissioning and building commissioning can be seen below:

- Existing Building Commissioning
    - Total Estimated Annual Revenue: $270 million per year
    - Total Estimated Annual Floor Area Commissioned: 780 million ft^2 per year
    - Total Estimated Annual Cost Savings: $290 million per year
    - Total Estimated Annual Energy Savings: 22 billion kBtu per year

- Total Building Commissioning (EBCx and NCCx)
    - Total Estimated Annual Revenue: $1.8 billion per year
    - Total Estimated Annual Floor Area Commissioned: 2.0 billion ft^2 per year
    - Total Estimated Annual Cost Savings: $540 million per year
    - Total Estimated Annual Energy Savings: 50 billion kBtu per year

These values are based on a portion of the building commissioning market, but adequately approximate the scale of revenue and savings for the sample. The values suggest a sizeable impact from existing building commissioning in terms of general scale, however further updating and refining the methodology, particularly with regard to the commissioning constants and revenue percentages, may lead to improved results, while a more expansive selection of companies may be able to approximate the implementation and impact of the entire U.S. market.

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NOMENCLATURE

Cx: Commissioning

EBCx: Existing building commissioning

NCCx: New construction commissioning

BCxA: Building Commissioning Association

CBECS: Commercial Buildings Energy Consumption Survey

EUI: Energy use intensity

GFA: Gross floor area

CC®: Continuous Commissioning®*

AHU: Air handling unit

VAV: Variable air volume

HVAC: Heating, ventilation, and air conditioning

LEED: Leadership in Energy and Environmental Design

ESL: Energy Systems Laboratory, a division of the Texas A&M Engineering Experiment Station

CHW: Chilled water

NG: Natural gas

MEP: Mechanical, electrical, and plumbing

ASHRAE: American Society of Heating, Refrigerating, and Air-Conditioning Engineers

LBNL: Lawrence Berkeley National Laboratory

*Continuous Commissioning and CC are registered trademarks of the Texas A&M Engineering Experiment Station, an agency of the State of Texas

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1. INTRODUCTION

1.1 Defining Existing Building and New Construction Commissioning

Existing Building Commissioning (EBCx) is defined by the Building Commissioning Association as "a systematic process for investigating, analyzing, and optimizing the performance of building systems through the identification and implementation of low/no cost and capital-intensive Facility Improvement Measures and ensuring their continued performance." The goal of EBCx is to make building systems perform interactively to meet current facility requirements and provide the tools to support the continuous improvement of system performance over time. The term EBCx is intended to be a comprehensive term defining a process that encompass the more narrowly focused process variations such as retro-commissioning, re-commissioning and ongoing commissioning that are commonly used in the industry." Because the process is intended to be a comprehensive, whole building approach to improve overall facility performance, the EBCx scope can include, but is not limited to, HVAC, building assembly, plumbing, electrical, and protective systems, among others[1].

New Construction Commissioning (NCCx) is a similar process to existing building commissioning in terms of its general concept. The aim is to review the design, verify the installation and start-up, test the performance, perform staff training, and complete documentation of all included HVAC and building systems. As the name suggests, however, it deals with the construction of new buildings rather than existing buildings, and the focus is placed on ensuring that the new systems are optimally integrated, tested, and functional for operation after completion of the construction project. New construction commissioning can also be more comprehensive, as it involves the numerous construction phases, including design, construction, occupancy, and initial operation. Each phase includes thorough reviews, with extensive evaluation, testing, training, and documentation[2]. Both processes can span a wide range of building systems and components, but in the scope of this study, the emphasis will be placed on HVAC-focused building commissioning.

1.2 The Existing Building Commissioning Process

At a high level, the EBCx process can be segmented into five general phases: 1.) The planning phase, 2.) The investigation phase, 3.) The implementation phase, 4.) The turnover phase, and 5.) The persistence phase. In the planning phase, the commissioning goals, facility requirements, and general commissioning plan are developed. It is crucial in this phase to develop clear EBCx goals, as well as defining Current Facility Requirements (CFR) for the commissioning process to account for. After a preliminary walkthrough and an understanding of current building systems and equipment, the general EBCx plan will be developed. The investigation phase consists of field inspections, data gathering, and analysis. The purpose of this phase is to assess the performance of the selected building systems and identify any improvement opportunities. A variety of site walkthroughs, occupant interviews, and system tests are conducted, with the intent to create a master list of findings. This master list should include detailed information about potential improvement measures, including a description of the finding, the measure to address the finding, the benefit and risk, the measure cost, the payback, and the implementation recommendation. The purpose of the detailed list is to aid in the selection of measures to implement in the next phase. In the implementation phase, the selected improvement measures are completed, and the results and performance are verified following the measure implementation. A measurement and verification (M&V) plan is also executed to evaluate project success and energy savings over time. The turnover phase is a systematic transition from the commissioning team to the operation and maintenance team or facility managers. From an operational standpoint, this phase also marks the transition from commissioning activities to standard operating procedures. The final phase of the EBCx process is called the persistence phase. This phase consists of the implementation of systems and tools to promote persistent benefit from the improvement measures, and continued operational improvement over time[1].

1.3 The New Construction Commissioning Process

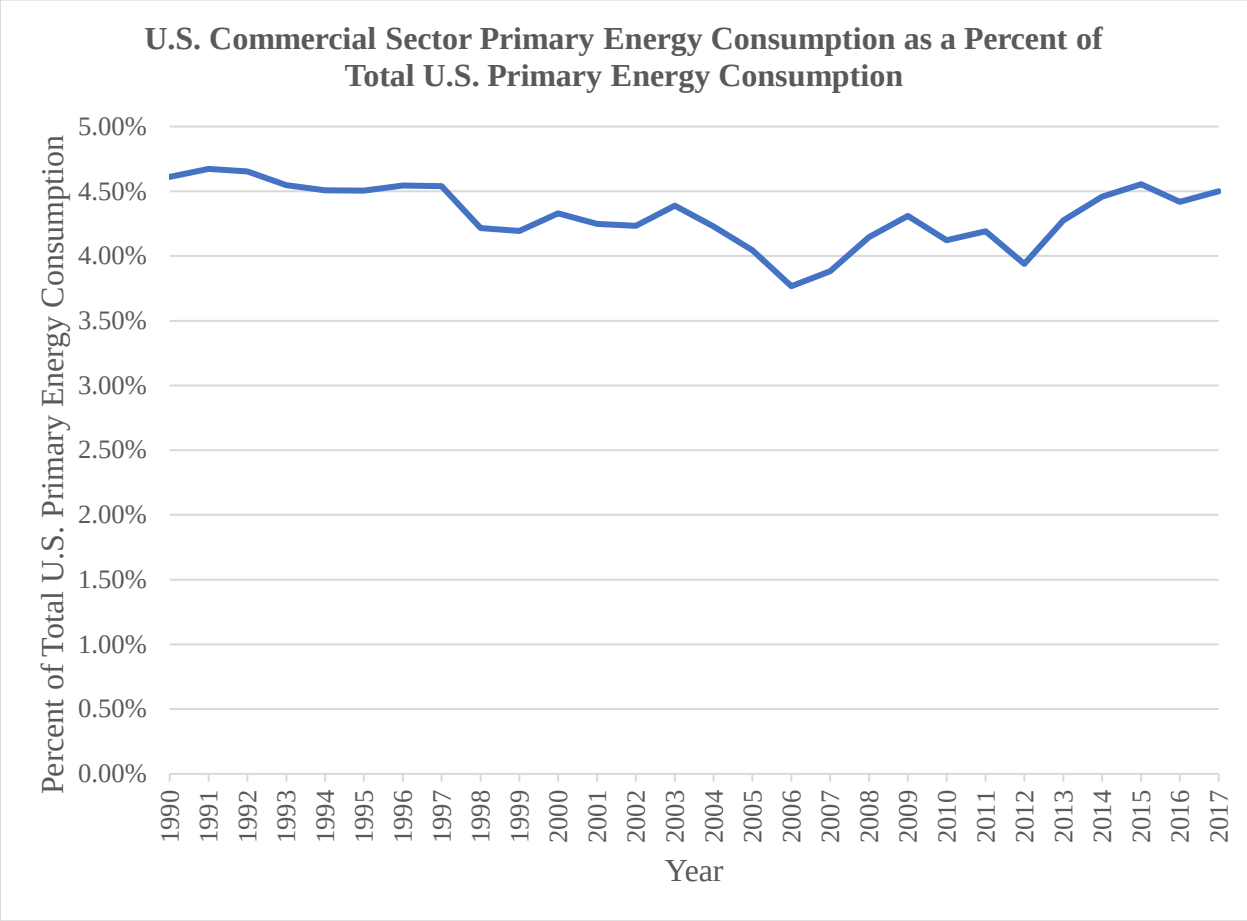
Like existing building commissioning, the new construction commissioning process can be split into multiple phases. In this case, the phases correspond with the typical construction phases, which include: Pre-design phase, design phase, construction phase, and occupancy and

operations phase. The pre-design phase sets the foundation for the project, outlines the commissioning plan, and constructs the commissioning team. Some of the key objectives include identifying the team, developing the Owner's Project Requirements (OPR), defining the initial scope and budget, and integrating the overall project process. The design phase confirms consistency among the design plans and specifications, ensures that the commissioning requirements are included, and that owner's project requirements are met. Some of the key objectives include communication of the commissioning requirements, verification of all documentation, and building engagement throughout the project team. The construction phase encompasses installation, start-up, testing and training of facility owners and operators. Key objectives include verification of proper equipment installation and function, provision of complete documentation for all operating systems, and proper training of all facility staff. Finally, the occupancy and operations phase consists of finalizing all pending testing, training, and documentation, while also finishing the optimization of the facility operation. Some key objectives include completion of all commissioning and documentation, evaluation of project success, optimization of facility performance, development of ongoing commissioning plan, and track energy performance over time[3].

1.4 Total Energy Consumption of the Commercial Sector

Throughout the last 27 years, total primary energy consumption of the U.S. commercial sector has consistently made up around 4% of the total annual U.S. primary energy consumption. Averaged over the same time period, the mean percentage of total primary energy consumption attributed to the commercial sector is around 4.32%. As shown in Figure 1, the percent of commercial primary energy consumption has generally fluctuated from from year to year, and went from 4.61% in 1990 to 4.50% in 2017[4]. These values suggest a small portion of the total primary energy consumption in the U.S comes from the commercial sector.

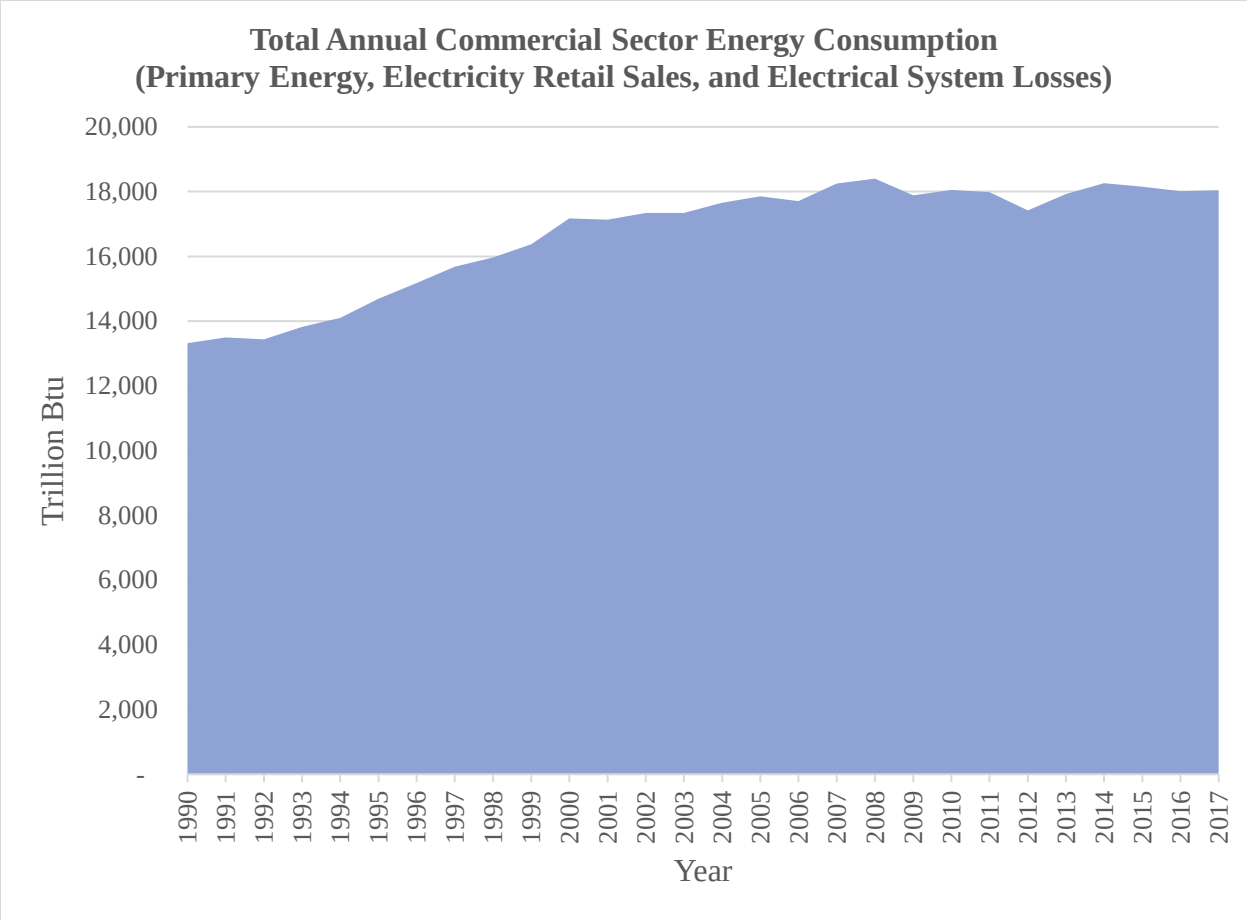
Figure 1: U.S. commercial sector primary energy consumption as a percent of total U.S. primary energy consumption, 1990 - 2017[4]



Comparatively, when looking at the total energy consumption of the commercial sector, which includes all primary energy, retail electricity sales, and electrical system losses, the general magnitude of annual consumption is much larger. Figure 2 shows the total annual energy consumption within the commercial sector from 1990 to 2017 in trillion Btu. In 2017, the total energy consumption of the commercial sector was 18,040.45 trillion Btu. In comparison, the total energy consumption in 1990 was 13,319.94 trillion Btu. Although consumption has fluctuated over time, particularly around the time of the economic recession near 2008, the total energy consumption of the commercial sector has remained around 18,000 trillion (18 quadrillion) Btu over the last few years[4]. The total commercial sector energy demand will likely continue to grow with increased new building construction, and one method of minimizing the potential increase in energy consumption is improving the energy efficiency of existing buildings through the

implementation of EBCx projects, and minimizing additional energy consumption due to new buildings through the implementation of NCCx projects.

Figure 2: Total Annual U.S. commercial sector energy consumption, 1990-2017[4]



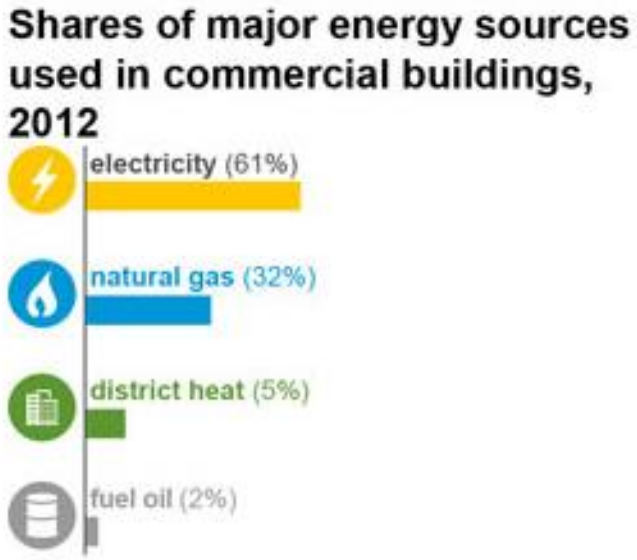
The changes in percent makeup and general energy consumption of the commercial sector could be driven by a few different factors, including fluctuations in total primary energy consumption in the U.S., growth in the gross floor area and number of commercial buildings through new construction projects, and economic instability, among others. Despite these fluctuations, total commercial source energy consumption has grown to around 18 quadrillion Btu (18 quads) in the last few years, with only a small portion of that total coming from primary energy consumption, and a majority coming from retail electricity sales[4]. Existing building and new

construction commissioning provide an avenue to improve the energy efficiency of the commercial building stock over time, reducing total energy consumption and associated carbon emissions, while also delivering cost savings to the building owner.

1.5 Commercial Building Energy Use Breakdown

When taking a closer look at commercial building energy consumption, there is distinct trend in energy sources consumed as well as the distribution of energy consumption by end use. In 2012, the top 5 energy-consuming commercial building types included the following: Mercantile and Service (15%), Office (14%), Education (10%), Health Care (8%), and Lodging (6%). This variety of building types presents a distinct set of challenges from a commissioning standpoint due to their differences in operating requirements and occupancy trends, however, as shown in Figure 3 on the following page, the major energy sources used in commercial buildings in 2012 heavily favored electricity and natural gas. Electricity and natural gas combined to make up 93% of the energy consumed by commercial buildings in 2012, while district heat and fuel oil made up the remaining 7%[5].

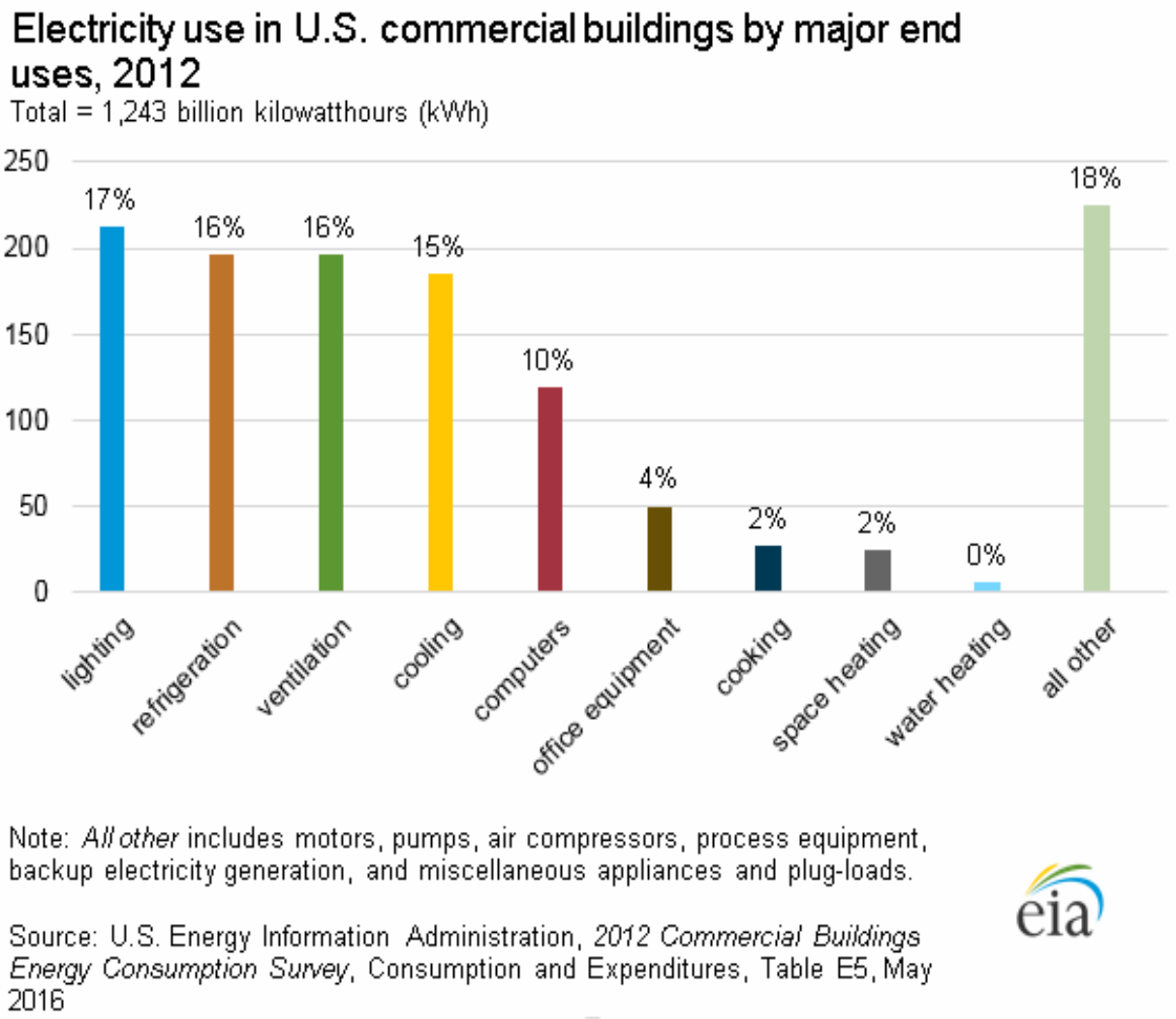
Figure 3: Shares of major energy sources used in commercial buildings, 2012[5]



Source: U.S. Energy Information Administration, *2012 Commercial Building Energy Consumption Survey: Energy Usage Summary*, Table 1 (March 2016)

Typically, natural gas is used in commercial buildings for space heating, water heating, and occasionally for cooling equipment or combined heat and power systems[5]. Electricity, on the other hand, is used for a wide variety of functions within commercial buildings. Figure 4 shows the breakdown of major electricity end uses in commercial buildings.

Figure 4: Electricity use in U.S. commercial buildings by major end uses, 2012[5]



As shown in the figure above, electricity serves a variety of end uses, including lighting, refrigeration, ventilation, cooling, and other miscellaneous loads such as fan motors, pumps, compressors, and plug loads. This collection of end uses, both natural gas and electricity based, is often targeted in NCCx and EBCx projects, and demonstrates the energy reduction capacity of commissioning existing commercial buildings.

1.6 Common Existing Building Commissioning Measures and Benefits

As noted when defining each type of building commissioning, the process is meant to be comprehensive and can include a variety of building systems, which in turn means that there is a vast array of measures and approaches to building commissioning. Some examples of commonly implemented HVAC measures in existing building commissioning, taken from a study conducted by Portland Energy Conservation Inc. in 2009, include the following: Optimize airside economizer, reduce equipment runtime, reduce or reset duct static pressure setpoint, and add variable frequency drive to pump motor[6]. In this case, the measures were focused around HVAC system improvements, but once again can vary widely based on the individual commissioning project and building needs.

Regardless of which measures are implemented in a building commissioning project, the process offers multiple benefits to the building owner and operator. The most common reason behind existing building commissioning projects is the cost savings that can be generated. Improving the operational efficiency of a building and reducing overall energy consumption helps to drive the overall operating costs down and saves the building owner money. Outside of the financial gain, commissioning buildings to be more energy efficient also reduces the building's greenhouse gas emissions and subsequent environmental impacts. The commissioning of existing buildings can also provide a variety of non-energy benefits. For example, equipment life can be extended, indoor air quality can improve, and thermal comfort can improve for the building occupants. Commissioning is also required for getting a building LEED certified. These benefits can lead to increased productivity and reduced maintenance costs over time[6]. The same can be said about new construction commissioning. Although the focus is on the verification of the proper installation and operation of new building equipment, rather than the operation of aging building equipment, the same benefits and motivations can apply. New construction commissioning can result in lower energy consumption, lower operating costs, reduced maintenance, and improved occupant comfort and productivity[7].

1.7 Thesis Objectives

As a whole, existing building commissioning and new construction commissioning can deliver savings to building owners, improve the energy efficiency of HVAC systems, and drive improvements in occupant comfort. At the total U.S. commercial sector level, building commissioning can provide a conduit for significant impact in terms of energy savings and provide broader social benefits such as reduced carbon emissions.

The aim of this project is to collect typical commissioning values through a meta-analysis of previous building commissioning-focused studies, apply them to a selection of annual revenue estimates from a sample of firms that provide building commissioning services, and begin to quantify some of the previously mentioned impacts. The thesis can be split into the following primary and secondary objectives:

- Primary Objective
    - Quantify the implementation and impact of EBCx based on a selection of commissioning providers
        - Estimated Annual Revenue
        - Estimated Annual Floor Area Commissioned
        - Estimated Annual Cost Savings
        - Estimated Annual Energy Savings
- Secondary Objective
    - Quantify the implementation and impact of Cx based on a selection of commissioning providers (EBCx and NCCx)
        - Estimated Annual Revenue
        - Estimated Annual Floor Area Commissioned
        - Estimated Annual Cost Savings
        - Estimated Annual Energy Savings

2. LITERATURE REVIEW

The following section is meant to review previous studies that have presented general trends and values pertaining to new construction and existing building commissioning, through analysis of real project data. Many of the reviewed studies consider some combination of total energy and cost savings from building commissioning projects. Additionally, many of the studies provide measure-based analysis in terms of implementation frequency and energy savings by measure type. A variety of studies are included to provide a breadth of data types to provide a general understanding of the building commissioning market. Additionally, specific values from selected studies will be utilized in calculations to estimate the extent and impact of existing building commissioning in a given sample of commissioning providers.

2.1 Existing Building and New Construction Commissioning by Building Use Type

Building commissioning can be applied to a wide range of building types and sizes. The basis of this project, however, will be rooted in the implementation of commissioning in the commercial building stock. The information presented in this section of literature review will assist in demonstrating trends in project implementation among the different building types within the commercial sector. Key data covered in this section of review will be used to generate a typical distribution of commissioning by building use type in a given sample of commissioned floor area. The section will also look to distinguish the difference in building use type distribution between new construction commissioning and existing building commissioning.

In 2004, Evan Mills of the Lawrence Berkeley National Laboratory (LBNL) published a study in conjunction with Portland Energy Conservation Inc. and the Texas A&M Energy Systems Laboratory titled 'The Cost-Effectiveness of Commissioning' The study summarized commissioning data from 175 projects spanning 224 total buildings with the intent of providing a meta-analysis of commissioning data from a variety of sources. The total floor area commissioned across all projects was 30,413,000 ft^2, with 22,247,000 ft^2 coming from 150 existing buildings included in 106 projects and 8,165,000 ft^2 coming from 74 new buildings in 69 projects. The study provides a breakdown of floor area commissioned for each commissioning type based on a

selection of 17 different CBECS building use types. For commissioning in existing buildings, the most prevalent building use type by floor area was office buildings, which totaled to 10,950,000 ft^2. Outpatient healthcare was the second largest, with 2,895,000 ft^2 of commissioned floor area. The remaining three building types, making up the top five use types, were higher education, inpatient healthcare, and K-12 buildings, with 2,405,000 ft^2, 1,278,000 ft^2, and 1,052,000 ft^2 of commissioned building space respectively. These five use types combined to make up 83.59% of the total commissioned floor area in existing buildings. Comparatively, in new construction commissioning, public order and safety made up 2,159,000 ft^2 of the building space, laboratory space made up 1,982,000 ft^2 of commissioned building area, inpatient healthcare was the third largest, with 1,043,000 ft^2 of building space commissioned, while public assembly with 707,000 ft^2 and office buildings with 644,000 ft^2 rounded out the top five use types. These five building types made up 80.05% of the floor area included in the sample[8]. This data suggests that the building use types targeted in commissioning projects may differ based on whether the commissioning is new construction or existing building. The data is also summarized in Table 1.

Table 1: Distribution of EBCx and NCCx floor area by building use type, 2004[8]

Building Use Type	**EBCx Floor Area**	**% EBCx Total**	**NCCx Floor Area**	**% NCCx Total**
K-12	1,052,000 ft^2	4.73%	581,000 ft^2	7.12%
Higher Education	2,405,000 ft^2	10.81%	319,000 ft^2	3.91%
Food Sales	-	0.00%	127,000 ft^2	1.56%
Food Service	4,000 ft^2	0.02%	-	0.00%
Inpatient	1,278,000 ft^2	5.74%	1,043,000 ft^2	12.78%
Outpatient	2,895,000 ft^2	13.01%	206,000 ft^2	2.52%
Laboratory	932,000 ft^2	4.19%	1,982,000 ft^2	24.28%
Lodging	637,000 ft^2	2.86%	149,000 ft^2	1.83%
Retail	615,000 ft^2	2.76%	-	0.00%
Service	227,000 ft^2	1.02%	25,000 ft^2	0.31%
Office	10,965,000 ft^2	49.29%	644,000 ft^2	7.89%
Public Assembly	397,000 ft^2	1.78%	707,000 ft^2	8.66%
Public Order/Safety	758,000 ft^2	3.41%	2,159,000 ft^2	26.45%
Religious Worship	-	0.00%	-	0.00%
Warehouse/Storage	14,000 ft^2	0.06%	162,000 ft^2	1.98%
Other	67,000 ft^2	0.30%	60,000 ft^2	0.73%
Vacant	-	0.00%	-	0.00%
Total	**22,246,000 ft^2**	**100%**	**8,164,000 ft^2**	**100%**

It is important to consider the fact that different building use types also have different average floor areas per building. Mills et al. also provided the number of buildings commissioned for each building use type. For existing buildings, the five most frequent building types were office (70), higher education (57), laboratory (20), retail (13), and K-12 (10). For new construction, the five most frequent building types were office (17), laboratory (16), inpatient healthcare (11), K-12 (9), and public assembly (8)[8]. While there is some overlap between total floor area commissioned and number of buildings commissioned, there are also some slight differences in the distributions between the two.

Mills and the Lawrence Berkeley National Laboratory published a similar study in 2011 titled 'Building commissioning: a golden opportunity for reducing energy costs and greenhouse gas emissions in the United States'. The study aimed to aggregate a large amount of commissioning project data and provide a robust and normalized analysis of trends in a single, expansive study. In total, the study encompassed 409 projects, spanning 643 new and existing buildings and covering 99,224,809 ft^2 of building space. More specifically, existing building commissioning totaled to 332 projects in 561 buildings, covering 90,410,884 ft^2. The sample was somewhat smaller for new construction commissioning, which consisted of 77 projects in 82 buildings, covering 8,813,925 ft^2 of building space[9]. The study provides a table detailing the total square footage of building space commissioned, segmented by existing and new construction, as well as building use type. In this case, Mills retained many of the same building use types contained in his previous 2004 study, but also included a few additional building types, such as cleanrooms and data centers, for a total of 20 building use types. Table 2 summarizes the building type and respective floor area for all included building use types in Mills' study.

Table 2: Distribution of EBCx and NCCx floor area by building type, 2011[9]

Building Use Type	**EBCx Floor Area**	**% EBCx Total**	**NCCx Floor Area**	**% NCCx Total**
K-12	2,467,661 ft^2	2.73%	656,093 ft^2	7.44%
Higher Education	11,401,833 ft^2	12.61%	627,687 ft^2	7.12%
Food Sales	848,039 ft^2	0.94%	135,363 ft^2	1.54%
Food Service	187,724 ft^2	0.21%	-	0.00%
Outpatient	4,319,124 ft^2	4.78%	206,300 ft^2	2.34%
Cleanrooms	-	0.00%	301,000 ft^2	3.42%
Data Center	12,888 ft^2	0.01%	-	0.00%
Laboratory	4,561,593 ft^2	5.05%	1,965,065 ft^2	22.30%
Inpatient	6,791,029 ft^2	7.51%	687,959 ft^2	7.81%
Lodging	9,880,307 ft^2	10.93%	156,984 ft^2	1.78%
Retail	2,926,038 ft^2	3.24%	-	0.00%
Service	227,000 ft^2	0.25%	-	0.00%
Office	39,972,765 ft^2	44.21%	894,296 ft^2	10.15%
Public Assembly	2,476,985 ft^2	2.74%	689,626 ft^2	7.82%
Public Order/Safety	2,485,277 ft^2	2.75%	2,271,672 ft^2	25.77%
Religious Worship	12,500 ft^2	0.01%	-	0.00%
Warehouse/Storage	13,500 ft^2	0.01%	161,879 ft^2	1.84%
Industrial	475,000 ft^2	0.53%	-	0.00%
Other	1,351,622 ft^2	1.49%	60,000 ft^2	0.68%
Vacant	-	0.00%	-	0.00%
Total	**90,410,885 ft^2**	**100%**	**8,813,924 ft^2**	**100%**

For existing building commissioning, the five largest individual floor areas were office buildings with 39,972,765 ft^2, higher education with 11,401,833 ft^2, lodging with 9,880,307 ft^2, inpatient healthcare with 6,791,029 ft^2, and laboratory space, with 4,561,593 ft^2. These top five uses made up around 80.31% of the total floor area commissioned in existing buildings. The five largest individual floor areas commissioned for new construction, on the other hand, consisted of public order and safety with 2,271,672 ft^2, laboratory space with 1,956,065 ft^2, office space with 894,296 ft^2, public assembly with 689,626 ft^2, and inpatient healthcare with 687,959 ft^2. The top five uses in this case accounted for 73.84% of the total commissioned floor area[9]. This data once again suggests some differences in floor area makeup by building type between existing building commissioning and new construction commissioning. As noted previously, these trends in the data may be reflecting, in part, differing typical building sizes between building use types rather than project volume per building use type. Specific project volumes segmented by building type may

help identify more detailed trends in project implementation. However, understanding general trends in total commissioned floor area by building type will still prove useful in this analysis.

PECI. et al conducted a similar study in 2009. Although the focus of this study was to conduct a cost benefit analysis of various EBCx measures implemented in a selection of projects, building-level data was also provided in the report. The study sample consisted of 112 total projects with distinguishable building types. The building types included large office, hotel/motel, hospital, large retail, K-12 school, and miscellaneous[10]. The distribution of the building types is shown in Table 3.

Table 3: Number of projects by reported building type[10]

Building Type	*Large Office*	*Lodging*	*Misc.*	*Hospital*	*Large Retail*	*K-12 School*
Number of Projects	86	18	3	2	2	1
Percent of Total	76.8%	16.1%	2.7%	1.8%	1.8%	0.9%

In this case, most of the projects were conducted in large office buildings and lodging buildings, with large office buildings accounting for about 76.8% of the total projects and lodging accounting for 16%[10]. However, this may be an indication of a small data set, rather than a statistically significant trend in project implementation. A larger sample of projects may provide a more viable distribution of commissioning by building use type.

Lastly, a 2008 study conducted by Bynum et al. utilized a framework similar to the Mills' studies to analyze aggregate data from Continuous Commissioning® projects in a number of buildings commissioned by staff at the Energy Systems Laboratory at Texas A&M University. Like Mills' studies, and others contained in this review, the aim was to better understand trends in savings, costs, and measures implemented – in total and across different building use types. The project data included information from 71 sites, totaling to 222 total buildings and spanning 21,820,000 ft^2 of building space. In terms of building types, the projects spanned a wide range, and the project data was organized into building use types mirroring a majority of the CBECS categories used in the LBNL studies referenced previously. There were some slight differences in

building types, such as the inclusion of a separate category for shopping malls and some condensed categories, but in total the 16 building use types cover the same main commercial building segments. Within the study, the building use data was organized in two different manners. For analysis purposes, the building use floor area was organized based on the primary function of the building, which was defined as the function making up the largest portion of the total building area. This method accounts for differences in average floor areas of different building types. When organized by primary function, the CC® projects were concentrated in education (28.4% of total commissioned floor area), office (28.4%), health care (16.4%), and laboratory (15.0%), making up 88% of the total commissioned floor space. For the general data set description, the building use data was organized by total floor area, which meant that in instances of multi-use buildings, the respective floor areas were split up based on each building function[11]. The total floor area breakdown by building use was provided as a percent of total floor area. Using these percent breakdowns, and the total floor area of the study, the respective floor area values for each building use type were calculated and included with the percentage values. This data is summarized in Table 4.

Table 4: Floor area Continuous Commissioned® by building use type[11]

Building Use Type	**% CC® by Floor Area**	**Commissioned Floor Area (Calculated)**
Education	27.9%	6,087,780 ft^2
Food Sales	0.6%	130,920 ft^2
Food Service	0.9%	196,380 ft^2
Healthcare	30.8%	6,720,560 ft^2
Laboratory	8.1%	1,767,420 ft^2
Lodging	0.1%	21,820 ft^2
Retail	0.4%	87,280 ft^2
Malls	0.0%	-
Office	20.9%	4,560,380 ft^2
Public Assembly	3.7%	807,340 ft^2
Public Order/Safety	0.0%	-
Religious Worship	0.0%	-
Service	1.1%	240,020 ft^2
Warehouse/Storage	0.0%	-
Other	5.4%	1,178,280 ft^2
Vacant	0.0%	-

In this selection of projects, the five largest commissioned building types by area were healthcare (combined inpatient and outpatient) with an estimated 6,720,560 ft^2 of commissioned floor area, education (K-12 and higher education) with an estimated 6,087,780 ft^2 of floor area, office space with an estimated 4,560,380 ft^2 of floor area, laboratory with 1,767,420 ft^2 of floor area, and other with an estimated 1,178,280 ft^2 of commissioned floor space[11].

The data from this selection of studies suggests that there is some overlap, as well as some differences, in the types of buildings typically targeted in each type of commissioning. For example, some of the largest percentages by floor area in each of the studies for existing buildings were office, healthcare, education and laboratories. On the other hand, some of the largest percent areas commissioned in new construction included public order and safety, laboratories, public assembly and healthcare. It is important to note that these differences could, in part, be a function of general building size as well as project volume. As noted previously, average floor areas can differ by building type and may have an impact on the distribution of commissioned building types when evaluating by floor area. However, this distribution data will be important when making larger estimations dealing with floor area, and a selection of these values will be utilized in this study to approximate annual energy and cost savings for a given sample of commissioning providers.

2.2 Overall Commissioning Costs, Energy Savings, and Cost Savings

A variety of studies have been conducted with the intent of quantifying overall costs as well as energy and cost savings opportunities based on a large selection of EBCx and NCCx project data. The selection of studies typically gave a median whole-building percent savings value, a median or average cost savings per square foot value, and an average simple payback value based on all projects included in each respective study. Some studies also took a more in depth look at the same values for specific sets of commercial building use types.

As mentioned in the previous section, the 2004 Mills et al. LBNL study, 'The Cost-Effectiveness of Commissioning', summarized data from 175 total projects spanning 224 buildings and provided some project-level values relating to cost and energy savings. The projects were split

between existing building commissioning and new construction commissioning, and data was compiled and analyzed to determine a variety of key commissioning metrics. The data used to calculate these values came from 106 existing building commissioning projects in 150 buildings and 69 new construction commissioning projects in 74 buildings. For existing building commissioning, the median whole-building savings from the set of projects was 15% with a median cost savings of \$0.27/ft^2-year. The interquartile range of the data set in terms of whole-building energy savings was from 7% to 29%. In terms of local energy prices, the median project payback was around 1 year, and the median simple payback using standardized U.S. energy prices was even lower at 0.70 years. In terms of costs, the median cost per unit area for existing building commissioning projects was \$0.27/ft^2-year and the median cost per project was \$33,696 per project. For new construction commissioning, a median percent savings value was not given because there is not a prior year of pre-commissioned energy consumption to compare with in an un-built building. However, cost and cost savings data was provided, with a median cost per unit area of \$1.00/ft^2-year, a median cost per project of \$74,267, and cost savings per unit of \$0.05/ft^2-year. The median simple payback period was higher for new construction commissioning, with local energy prices providing a 5.6 year simple payback, and standardized U.S. energy prices providing a 4.8 year simple payback. All dollar values contained within this study were normalized to 2003 dollars[8]. The data in this study shows the distinct differences in overall costs and savings between the two types of commissioning. Table 5 summarizes the key data points below.

Table 5: Median cost, savings and payback values, EBCx and NCCx, 2004[8]

(2003 \$)	**EBCx**	**NCCx**
Commissioning Cost per Unit Area	\$0.27/ft^2-year	\$1.00/ft^2-year
Commissioning Cost per Project	\$33,696	\$74,267
Commissioning Cost Savings per Unit Area	\$0.27/ft^2-year	\$0.05/ft^2-year
Whole-Building Energy Savings	15%	-
Simple Payback (Years)	0.70	4.80

Similarly, the aforementioned Mills 2011 study 'Building commissioning: a golden opportunity for reducing energy costs and greenhouse gas emissions in the United States' provides comparable results when evaluating a different set of commissioning projects. The study contained

332 commissioning projects in existing buildings, which totaled 90,410,884 ft^2 of building space. In this set of 332 projects, 6,652 deficiencies were found, and 4,104 measures were implemented. For this sample of projects, the median electricity savings value was 9%, while the median peak demand savings was 5%. The median fuel savings was 16%, combined central thermal was 31%, central hot water was 12%, central chilled water was 16%, and the median savings for central steam was 19%. At the whole-building level, the median energy savings was found to be 16% for existing buildings, while the interquartile range of whole building energy savings was from 9% to 31%. In terms of cost savings, the median value for existing buildings was around \$0.29/ft^2/year in 2009 equivalent USD. From the cost perspective, the median commissioning project cost was calculated to be \$49,075 per project and the median cost per square foot of commissioning existing buildings was \$0.30/ft^2. Both of these cost values are given in 2009 dollars. The median simple payback for the selection of projects was found to be about 1.10 years. For the sample of new construction commissioning projects, which totaled to 77 projects in 88 buildings, the median primary energy savings was 13% and the median cost savings was \$0.18/ft^2. In terms of commissioning costs, the median cost per new construction commissioning project was \$86,546 per project and the median cost per unit area was \$1.16/ft^2. The median simple payback for the selection of projects was 4.20 years. Once again, all dollar values were adjusted to 2009 dollars for the study[9]. The key findings are summarized in Table 6. The data presented in this study further suggests distinct differences in typical costs and savings between existing building commissioning and new construction commissioning.

Table 6: Median cost, savings, and payback values, EBCx and NCCx, 2011[9]

(2009 \$)	**EBCx**	**NCCx**
Commissioning Cost per Unit Area	\$0.30/ft^2-year	\$1.16/ft^2year
Commissioning Cost per Project	\$49,075	\$86,546
Commissioning Cost Savings per Unit Area	\$0.29/ft^2- year	\$0.18/ft^2-year
Whole-Building Energy Savings	16%	13%
Simple Payback Period (Years)	1.10	4.20

In a more recent study conducted by Coyner et al. in 2017, data from projects in 186 buildings spanning a variety of use types and geographical locations was evaluated to determine energy savings, project cost, and undiscounted payback periods. In this case, the average energy savings for the data set was around ~10 to ~15% of annual source energy and the average simple payback period was 1.8 years. The average commissioning cost from the selection of projects was \$0.41/ft^2[12].

The 2009 study conducted by PECI et al. had a focus on measure-level data analysis, but still provided some data on general energy savings. The two building use types with statistically significant sample sizes were office buildings and hotels/motels. The median savings for projects conducted in large office buildings was 3.02 kBtu/ft^2/year, with a simple payback of ~0.55 years. Hotels and motels, on the other hand, had a median savings of 2.17 kBtu/ft^2/year and a simple payback of ~1.20 years. The following building use types contained three or less projects, and thus the savings data is not as significant as the two building types with much larger frequency values. The two hospital projects had a median savings value of 3.54 kBtu/ft^2/year. The two large retail projects had a median savings value of 2.73 kBtu/ft^2/year. The three miscellaneous building types had a median savings value of 5.60 kBtu/ft^2/year, while the one K-12 school building had a savings value of 0.95 kBtu/ft^2/year[10]. Table 7 summarizes the energy savings data from the study.

Table 7: Median energy savings and simple payback of EBCx by building use type[10]

Building Use Type	**Median Energy Savings**	**Median Simple Payback**	**Sample**
Office	3.02 kBtu/ft^2	0.55	86
Lodging	2.17 kBtu/ft^2	1.20	18
Healthcare	3.54 kBtu/ft^2	1.30	2
Retail	2.73 kBtu/ft^2	0.20	2
Education	0.95 kBtu/ft^2	0.80	1
Misc.	5.60 kBtu/ft^2	0.35	3

Despite this limited sample size for most of the building types, the data suggests that there are different typical energy savings values per unit area dependent upon the use type of the building. For example, a healthcare facility operating critical equipment at all times may have a

higher energy use intensity compared to a school building that only operates during the weekdays and is unoccupied for a quarter of each year. Thus the achievable savings in terms of energy per unit area are likely to differ due to the energy demands and operation of each building type.

Looking specifically at new construction commissioning, PECI published a paper in 2000, which was revised in 2002, titled 'Establishing Commissioning Costs' with the intent of better understanding costs of commissioning during the design phase of new buildings. It was determined that generally, total commissioning costs in the design and construction phases made up roughly 0.6% to 1.8% of the overall construction costs of a project. The paper also looked at the commissioning cost per unit area during the construction phase, and emphasized the variability in cost dependent upon a variety of factors. For example, the number of pieces of equipment and the complexity of the project can drive the cost per unit area up significantly. In one example given in the paper, a project in a new 10,000 square foot building with complex systems and LEED requirements could have a commissioning cost of $4 per square foot, while the same building with simple systems and no LEED requirements could have a commissioning cost of $2 per square foot. In turn, the commissioning costs of a new building can vary significantly depending on the size of the building and the complexity of the project. These cost per unit area values were plotted based on total floor area and building complexity. The chart shows commissioning costs decrease with increased building area, and begin to level out as the total floor area of the building becomes larger and larger. Additionally, a cost curve was plotted for each level of building complexity. In this case, each increased level of complexity shifted the cost curve upward, indicating increased costs per unit area at all building areas with increased levels of complexity. Simple complexity was defined as office buildings and classrooms, packaged systems, and common controls. Moderate complexity was defined as more complex offices, classrooms with labs, more automation and control, and fewer packaged systems. Complex buildings were defined as moderate with most floor area using complex systems, such as hospitals, labs, clean rooms, or additional systems commissioned such as power quality, communications, and security. Lastly, specialty is defined as highly complex facilities such as prisons[13]. This paper highlights some of the significant variability in estimating the costs of commissioning during the design and construction phases as well as some of the factors that can influence these significant changes in cost. This degree of

variability will be important to acknowledge when applying typical new construction commissioning costs in calculations for estimating impacts of large project volumes.

A similar paper was published by Peter D'Antonio of PCD Engineering Services, Inc. with the intent of determining whether or not LEED-NC certified projects are cost effective, particularly in relation to the commissioning portion. The study looked at 11 LEED-NC projects in Colorado and sampled a variety of data ranging from soft costs and benefits to hard costs and benefits. For the purpose of this literature review, the key component of the study was the commissioning cost associated with each project. Detailed commissioning details were collected from 10 of the included projects, which helped to establish the total cost of commissioning, and the implementation of fundamental and/or enhanced commissioning. The average cost of new construction commissioning per unit area, as a component of LEED-NC projects, was \$0.55/ft^2. On average, the commissioning component made up roughly 60% of the total LEED-NC soft costs, and the cost of LEED-NC Version 2.1 ranged from 1% to 6% of total construction costs, which came from buildings of varying sizes. The range of the costs per unit area for all of the included projects was \$0.19/ft^2 to \$1.50/ft^2. It is suggested in the paper that some of the lower commissioning costs are due to the repetitive design of a set of buildings and the fact that the commissioning was performed by a commissioning firm that also owned the buildings in the project[14]. This study provides a range of values that is comparable to some of the general costs provided in the previous new construction commissioning study.

A 2011 study published by the National Institute of Standards and Technology as a component of a larger International Energy Agency – Energy Conservation in Buildings and Community Systems program titled 'Annex 47 Report 3: Commissioning Cost-Benefit and Persistence of Savings' aimed to further analyze general commissioning costs as well as define the methodologies behind calculating these costs. As an additional component, the study looked at the persistence of commissioning savings over time and methods for determining them. The study provided a comprehensive literature review in order to understand general values for commissioning costs and savings, and evaluate the methodologies used to determine them. 12 total studies were included in this review, including the 2004 Mills et al. study included above. Average values were taken from the collection of studies, for both existing building commissioning and

new construction commissioning, and the ranges of values were presented. For existing buildings, the range of average values for commissioning costs was \$0.08/ft^2 to \$0.40/ft^2. The range of average values for cost savings, on the other hand, was \$0.11/ft^2 to \$0.26/ft^2. Comparatively, for new construction commissioning, the range of average values for commissioning costs was \$0.19/ft^2 to \$1.00/ft^2 and the range for average cost savings was \$0.05/ft^2 to \$0.64/ft^2[15].

Additionally, the typical costs per unit area of each commissioning type were analyzed based on the complexity of the cost calculations. Calculation methodologies were segmented into 3 categories based on their complexity: Simple, moderate, and complex. The simple methodology utilizes one or two cost categories, which are generally simple and easy to obtain, to determine the overall cost of commissioning. Moderate methodologies use more than two cost categories to determine the overall commissioning cost, usually including a wider array of costs. Lastly, complex methodologies utilize a variety of different cost categories and also attempt to validate the cost figures. Generally, the cost values increased as the complexity of the methodologies increased, as they accounted for a variety of additional costs outside of the commissioning agent fee and other basic costs[15]. This component of the study further suggests that there is significant variability in the costs and savings when commissioning buildings. Average cost and savings values span a wide range based on the selection of studies, and costs can vary significantly depending on the how rigorous the utilized calculation methodologies are. Additionally, the study demonstrates similar differences in general values between new construction and existing building commissioning, as shown in previously reviewed studies.

The study also reviewed data from 5 projects, in either new construction or existing buildings, which had incorporated the persistence of commissioning benefits over time. In existing buildings, the data generally showed some degradation in savings over time. In the given periods studied, which ranged from 3 years after commissioning to 8 years after commissioning, the savings persistence ranged from 50% to 100% for almost all of the included buildings, with an average persistence of 75% of original savings[15].

A significant amount of work and research has been conducted by Texas A&M's Energy Systems Laboratory (ESL) surrounding building energy efficiency and commissioning. A key component of the ESL's research is Continuous Commissioning® (CC®), which is a process that incorporates many of the common HVAC focused commissioning measures and works to optimize

and maintain building performance over time[16]. The following section contains various studies evaluating aggregated data from Continuous Commissioning® projects as well as a variety of case studies involving CC® practices and commissioning measures.

The 2008 Bynum et al. study mentioned in the previous section took bulk CC® project data and analyzed it under the same key parameters. The median cost savings from this study was \$0.36/ft^2/year and the median annual savings was just below 13%, while the mean was 14%. The median simple payback across all projects was 1.26 years and the average simple payback was 1.58 years. In terms of cost, the average and median cost per unit area across all projects were \$0.42/ft^2. When evaluating the data by building use type, the study found that office buildings had an average savings of \$0.51/ft^2, while education and health care buildings had average savings of \$0.30/ft^2 and \$0.38/ft^2 respectively. Separating the simple payback by building use type gave an average 1.64 year simple payback for office buildings, an average 1.45 year simple payback for healthcare buildings, and an average 2.39 year simple payback for education buildings[11]. A summary of the key data points from the study is included in Table 8**.**

Table 8: Median CC® cost, savings, and payback – building type and total[11]

(2006 \$)	**Office**	**Education**	**Health Care**	**All Use Types (Median)**
CC® Cost	\$0.48/ft^2	\$0.33/ft^2	\$0.42/ft^2	\$0.42/ft^2
CC® Cost Savings	\$0.51/ft^2	\$0.30/ft^2	\$0.38/ft^2	\$0.36/ft^2
Annual Cost Savings	18.66%	8.71%	14.87%	12.75%
Simple Payback Period	1.64	2.39	1.45	1.68

In another 2008 study by Jones et al., a set of 20 CC® projects and 25 CC® assessments conducted in a total of 84 hospital and laboratory buildings was analyzed in a similar manner. The completed projects had a median cost savings of \$0.84/ft^2/year while the assessments predicted a median cost savings of \$0.41/ft^2/year. At the whole-project level, the completed CC® projects had a median total cost savings of \$260,000/year. The median simple paybacks for the completed projects and assessments were 0.38 years and 2.45 years respectively. Completed projects in the study were found to have a median whole-building energy savings of 19.99% while the assessments had a median savings of 15.4%[17]. There was a noticeable difference in values

between the completed projects and assessments, although both sets of values still align well with the same value types from other, similar studies. These key values are summarized in Table 9.

Table 9: Comparison of completed CC® projects and CC® project assessments[17]

	Completed Projects	**Project Assessments**
Median Cost Savings per Unit Area	\$0.84/ft^2	\$0.41/ft^2
Median Whole-Building Energy Savings	19.99%	15.4%
Median Simple Payback	0.38 years	2.45 years

A more recent study with similar objectives was conducted by Oh et al. in 2014. The study looked at 32 CC® projects conducted by the Energy Systems Laboratory at Texas A&M, spanning a total of 126 buildings within the school, hospital, and office use types, totaling to 9,524,849 ft^2 of conditioned floor area. Looking at all projects, the overall average cost savings was \$0.29/ft^2/year. When looking at individual building use types, schools had average savings of \$0.25/ft^2/year, and consisted of 43 buildings within the sample. Hospitals had an average savings of \$0.27/ft^2/year and made up 68 buildings in the sample. Lastly, offices had an average savings of \$0.77/ft^2/year and only made up 4 buildings contained in the sample. This study shows some variation in savings per unit area by building type in CC projects[18].

In an early 1994 paper composed by Claridge et al., a series of case studies were put together to illustrate the general process by which individuals could identify no-cost/low-cost measures (O&M measures) that can drive increased energy efficiency. These O&M measures could be put into the following broad categories: shut off lighting/equipment while the building is unoccupied, use of efficient temperature settings, use of efficient system operation strategies/settings, and other measures. A majority of these measures are present after a traditional audit and retrofit are completed. One example from a 1978 case study shows the savings potential of these O&M measures in a 139,400 ft^2 chemistry laboratory. O&M measures identified in an energy audit of the building made up a majority of the immediate and 0-1 year payback measures. 80% of the savings from the 1-3 year payback measures came from the installation of an energy

management control system. In total, the immediate, 0-1 year, and 1-3 year payback measures accounted for over half of the potential savings identified in the audit[19].

Similar procedures were applied in case studies in a variety of building types over time. Building use types ranged from student recreation centers, to government office buildings, to schools and medical centers. The continuing trends in these case studies include the need for access to measured energy consumption data over time to utilize as an ongoing tool to monitor building performance, and the variation in O&M opportunities in different buildings, and involvement of the building operations staff is key to driving and maintaining energy efficiency, as well as understanding typical building operation. When applied to the Texas LOANStar program, $4,000,000/year in O&M opportunities were discovered across 133 buildings and 10,000,000 ft^2 of building area. These identified measures accounted for 23% of the energy costs at the facilities surveyed[19]. The data and case studies present the significant opportunity for recommissioning of buildings and set the stage for the development of Continuous Commissioning®.

In a 2007 case study by Turner et al., the CC® process was applied to the HVAC systems of three K-12 school buildings in the Austin Independent School District in Austin, Texas. The conditioned areas of the school buildings were 116,000 ft^2, 83,000 ft^2, and 300,000 ft^2 respectively, resulting in 499,000 ft^2 of total commissioned floor area. Investigations of each of the school buildings were conducted by engineers, and a compilation of measures were selected for implementation at one of more of the school buildings after analyzing the findings. Some of the general measures implemented in the project included optimization of AHU operation and setpoints, cooling tower operation, terminal boxes, water loops, and economizer mode, among others. The commissioning process began in 2005, and a majority of the measures were implemented a year later. The total implementation costs of the project totaled to $210,800. Following the completion of the commissioning process, the three schools experienced 10-14% savings on their utility bills, and a total annual cost savings for the first year of $80,200, which translates to a cost savings per unit area of $0.16/$ft^2$. The cumulative cost savings from the beginning of the project to October 2006 totaled to around $110,000 and the project had roughly a 2.5 year simple payback[20]. Pertinent data points from the case study are summarized in Table 10.

Table 10: Key data from AISD CC Project[20]

	CC® Project Value
CC® Cost per Unit Area (Calculated)	\$0.42/ft^2-year
First Year Cost Savings	\$80,200
CC Cost® Savings (Calculated)	\$0.16/ft^2-year
Annual Energy Savings	10 – 14%
Simple Payback	2.50 years

A 2006 study conducted by Deng et al. had the aim of providing an overview of the ten year long Continuous Commissioning® project being conducted in buildings throughout the Texas A&M University campus, and present some of the trends and results from the last ten years of commissioning. The project involved commissioning 150 existing campus buildings, 5 central utility plants, and their distribution infrastructure. The 150 campus buildings in total made up over 15,000,000 ft^2 of total floor space and have varying degrees of individual floor area. At the beginning of the commissioning project in FY1996, the university had a source energy use index (EUI) of 426 kBtu/ft^2. In FY2006, after ten years of Continuing Commissioning®, the university had an EUI of 276 kBtu/ft^2, which represents a 35% reduction in energy consumption. Although there are other factors at play influencing the energy consumption of the university, this reduction includes significant energy savings from the CC® process. At the end of FY2006, commissioning had been applied to 76 buildings, which totaled to over 7,000,000 ft^2 [21].

The project contained a variety of commissioning measures, which ranged from optimization of central chiller and boiler plant operation, to supply temperature and differential pressure reset schedules on water loops, to optimization of pump operation. Some other measures and approaches include the optimization of central plants and economically efficient power generation, accurate energy management control system sensors and data flow, lighting retrofits, and metering for measurement and verification, as well as ongoing management. Over the ten-year duration of the CC® process, the implementation of measures briefly mentioned above have resulted in significant savings over time. Total savings have reached around \$35,000,000 from 1996 to the end of fiscal year 2006. The cost for the commissioning services has reached about \$7,000,000[21].

A subsequent study was performed two years later, in 2008, by Deng et al. with the same overall goal as the previous study. The same CC® project at Texas A&M University was evaluated

with the intent of quantifying the additional savings and costs associated with the continuation of the project. In this case, when comparing the FY1998 EUI of 398 kBtu/ft^2 to the FY2007 EUI of 260 kBtu/ft^2, there was once again a 35% reduction in overall energy use index, suggesting consistent energy savings over time. By the end of FY2008, commissioning had been applied to over 80 university buildings, which totaled to over 8,000,000 ft^2. The commissioning approach and measure focus had not changed between the first and second study, and much of the same information is presented. In total, from 1996 to the end of FY2008, the cumulative savings in chilled water, hot water, and electricity consumption through Continuous Commissioning® existing Texas A&M buildings totaled to over $58,500,000. The cost to the university for the implementation of these measures and processes had amounted to $10,000,000[22].

A similar study was conducted in 2009, in which a CC® project was contracted at the Austin City Hall. The Austin City Hall building, which is LEED Gold certified, was constructed in 2004 in downtown Austin, Texas. The building had approximately 115,000 ft^2 of conditioned space and had a 3-story below ground parking garage. As with previous case studies mentioned above, engineers conducted an investigation of the building, compiled a list of identified deficiencies, and selected a set of commissioning measures for implementation to address the issues. Many of the selected measures in the Austin City Hall case study overlap with the measures selected in the Austin Independent School District case study above. Some of the selected commissioning measures in the project included implementing economizer mode with improved OA control, reset AHU duct static pressure, unoccupied VAV box temperature and flow setbacks, and water loop differential pressures resets, among others. These selected measures were implemented over the period from June 2008 to March 2009. The energy cost savings from the project over the first 12 months amounted to $70,151, which is equivalent to a rough cost savings per unit area of $0.61/ft^2. In order to evaluate the impact of the commissioning project on energy consumption, weather normalized baselines were developed for the electricity, chilled water, and natural gas consumption of the building. These baselines were compared to consumption during and after the completion of the commissioning project. The measured energy savings totaled to 7.9% savings in electricity, 17.3% savings in chilled water, and 41.6% savings in natural gas consumption[23].

Another Continuous Commissioning® project from 2009 was carried out in a LEED certified high-rise building in Nashville, Tennessee. The building was a 320,000 ft^2 high rise office building that was awarded the LEED-EB Gold Certification. The certification included a retro-commissioning prerequisite, which was included as a portion of the contracted CC® project. The intent was to obtain the LEED certification and energy savings through the initial commissioning, while also gaining additional savings through the CC® component of the project. A majority of the implemented measures during the initial commissioning process were some of the same measures appearing throughout this collection of case studies. Some of the key measures from this case study included AHU discharge air temperature and duct static pressure resets and chilled water differential pressure and temperature resets. Following completion of the project, it was determined that the energy use intensity for the most recent month, August 2009 was 95.2 $kBtu/ft^2/yr$. Comparatively, the energy use intensity of the building prior to the project, in January 2008, was 107.5 $kBtu/ft^2/yr$. The project resulted in energy savings of 12.3 $kBtu/ft^2$, which was an 11.4% reduction in energy consumption. The savings generated by the initial building commissioning, as well as the Continuous Commissioning®, also provided a simple payback of 2 years[24].

An additional case study was produced for a CC® project conducted in a two-story office building in 2006. The building had a floor area of 310,000 ft^2 consisting mostly of open office space. Following the same procedure as other CC® projects, the building was first audited for any addressable problems, and a set of measures were compiled and selected for implementation in the building. Some of the major measures implemented in the project included optimization of terminal box air flow, supply air temperature and duct static pressure resets, and improved economizer control. In this case study, the implemented measures were shown to significantly improve the energy efficiency of the building. The electricity and natural gas consumption of the building were both reduced substantially following the completion of the project. Looking at six months of utility data following the completion of the project, electricity consumption was reduced by 33.2%. Similarly, based on 5 months of utility data following the project completion, natural gas consumption was reduced by 51.2%[25].

A final case study composed by Wei et al. in 2006 looked at the impact of Continuous Commissioning® as an embedded component of an energy efficiency retrofit program. The CC® process was embedded as an included measure within a much larger energy efficiency program, which totaled to about $2,700,000 in cost and spanned four campuses and two administrative buildings of the Alamo Community College District, totaling 2,350,000 ft^2. The overall project included a lighting retrofit, automation system and HVAC upgrades, and Continuous Commissioning®. Despite making up only a portion of the project, Continuous Commissioning® accounted for a majority of the cost savings. The estimated annual energy cost savings breakdown consisted of the following: Lighting retrofit (22%), Other Measures (16%) and Continuous Commissioning® (62%). Following the standard CC® procedures, the commissioning team was able to compile a list of deficiencies and proposed a variety of measures for implementation, including chiller and boiler control optimization, AHU temperature and duct static pressure resets, VAV box calibration, and chilled and hot water loop differential pressure resets, among others[26]. The CC® measures were successfully implemented by the summer of 2003, while the other measures were just beginning to enter implementation after design and bidding were completed. From June 2002 to September 2003, energy cost savings totaled to around $315,556 based on pre-commissioning energy consumption models. By May of 2006, the total cumulative energy cost savings from electricity consumption, electricity demand, and natural gas consumption reductions had exceeded $1,700,000. The payback on the CC® measures were around 3 years, and this relatively short payback period allowed for the implementation of larger capital-intensive measures while still maintaining a 5.4 year payback on the total project[26]. This case study demonstrates the advantages of Continuous Commissioning® in terms of streamlined project implementation, quick project paybacks, and significant cost savings opportunities that can be easily integrated into a larger overarching energy efficiency program.

In total, the values presented in this selection of studies covers a wide range for both existing building commissioning and new construction commissioning. For existing building commissioning, the cost per unit area values ranged from $0.08/$ft^2$ to $0.40/$ft^2$. Cost savings per unit area ranged from $0.11/$ft^2$ to $0.84/$ft^2$, and percent savings ranged from 10% to 35%. The range of simple paybacks for the selection of existing building studies was 0.35 years to 5.40 years. The included studies contained both existing building commissioning and continuous

commissioning projects. Many of these values could be considered outliers relative to the rest of the data, as existing building commissioning costs and cost savings were typically closer to \$0.30/ft^2 to \$0.40/ft^2, percent savings were closer to the 10% to 20% range, and simple payback periods were usually under 3 years. For new construction commissioning, the selection of included studies gave a similarly large ranges of cost and cost savings per unit area, with the range of costs being \$0.30/ft^2 to \$2.60/ft^2 and the range of cost savings being \$0.05/ft^2 to \$0.64/ft^2. Only one percent energy savings value was provided for new construction, which was 13%, and two simple payback values were included, 4.20 years and 4.80 years. This section of review highlights the differences in typical costs, savings, and paybacks between existing building commissioning and new construction commissioning. However, these studies also demonstrate the inherent variability in the cost and savings values associated with building commissioning in general. Building use type, building size, project complexity, project goals, and a variety of other variables can impact the values associated with a commissioning project. It is important to take these factors into consideration when applying general values to large volumes of data to generate estimates for a portion of the larger commissioning market. In order to generate these estimates, a selection of the reviewed values will be taken and used in the subsequent calculations.

2.3 Measure Implementation Frequency and Energy Savings

As mentioned above, many of the reviewed studies contained sections looking at project level data as well as sections looking at measure focused data. This section will focus on the measure specific data presented in the reviewed studies, both in terms of implementation frequency and energy savings.

Mills' 2011 study organized 4,104 reported measures into a set of broad measure categories. The most common measure type was 'installation modification' which was implemented ~495 times. 'Calibration' measures were the second most frequently implemented at ~420 times, while 'advanced resets' were the third most common measure, with ~410 reported instances of implementation[9].

The studies conducted by Bynum et al. and Jones et al. used the same categorization system while evaluating CC® project data. The study conducted by Bynum et al. found that 22% of the measures included in the study were 'advanced resets', while 15% related to 'equipment sequencing', 9.1% of the measures related to 'calibration' and 8.4% of the measures related to adjusting setpoints. It was also determined that 55% of the measures impacted air handling units, while 15.8% of the measures impacted cooling plants and 13% of the measures impacted heating plants[11].

Similarly, the study conducted by Jones et al. found that in both completed projects and assessments, four measures were included in the top five most frequent measures for each respective category. These measures included: 'implement advanced reset', 'calibration', 'retrofit/equipment replacement', and 'modify sequence of operation'. The study also found that 62% of the measures dealt with air handling units, while 14% dealt with cooling plants and 11% dealt with heating plants[17].

The study conducted by PECI et al. looked at both the frequency of individual measure implementation as well as the energy savings generated by each measure. When looking at general numbers of measure implementation, the top five most frequently implemented measures were 'Optimize airside economizer with a frequency of 47, 'reduce equipment runtime' with a frequency of 44, 'reduce/reset duct static pressure setpoint' with a frequency of 31, 'revise control sequence' with a frequency of 23, and 'add/optimize supply air temperature reset' with a frequency of 22, out of 492 total measures. It was also found that ~51% of the measures impacted air handling units, while ~9% of the measures impacted chiller plants, ~5% of measures impacted boiler plants, and ~5% of the measures impacted cooling towers[10].

In the study, it was determined that a set of widely implemented measures made up around 75% of the total savings. Included in this selection was 'revise control sequence' with 21% of total savings, 'reduce equipment runtime' with 15% of total savings, 'optimize airside economizer' with 12% of total savings, and 'add/optimize supply air temperature reset' with 8% of total savings. However, when looking at individual energy savings by measure, a significant portion of the measures generating the highest median site energy savings were implemented very infrequently. For example, 'tune/upgrade controls' had a median savings of 15.4 kBtu/ft^2/year but was only

implemented two times. Similarly, 'add variable frequency drive to chiller' had a median savings value of 1.4 kBtu/ft^2/year and was also only implemented twice, possibly due to the inherent risk of implementing the measure. Infrequent measures such as 'add variable frequency drive to chiller' and 'relocate/shield temp sensor' had simple paybacks of 4.3 years and 11.35 years respectively, which may have played a role in their infrequent implementation[10].

The variety of Continuous Commissioning® case studies mentioned at the end of the previous section also provided basic outlines of the measures implemented in each of the respective projects. Although the case studies took place at different times, in different building use types, and consisted of projects of varying sizes, there were some consistently reoccurring measures throughout. The selection of case studies contained outlines of project measures ranging from four to more than ten measures, most of which used slightly varying naming conventions and levels of detail in terms of measure description. However, comparable measures that appeared in at least three of the selected CC® case studies include the following:

- Optimize terminal box airflow
- Optimize/improve airside economizer
- Air handler duct static pressure rest
- Air handler discharge air temperature reset
- Chilled/hot water loop temperature and/or differential pressure reset[18, 19, 20, 21, 22, 23, 24, 25, 26]

This section of review shows a few distinct trends based on the presented data. Across multiple studies, a majority of the implemented measures were intended to improve the operation and efficiency of the air handling units in the buildings. Measures impacting chiller and boiler plants were often the second and third most frequent respectively. When looking at general measure categories, 'advanced resets', 'modifying sequencing', and 'calibration' categories typically make up the top three more frequent measures when applicable in the selected studies. Similarly, in studies listing more specific measures, temperature and pressures resets, optimized economizer, and controls sequencing measures were common. Thus, there appears to be specific measures that can be widely applied throughout different commissioning projects, impacting the major building equipment types.

2.4 Improvements in Occupant Comfort

There are a variety of benefits that can be achieved through the commissioning of an existing building that are not directly related to increased energy efficiency or energy-based cost savings. Non-energy benefits are often a major driver in the decision to contract a commissioning project[6].

In their 2004 study, Mills et al. included a brief evaluation of non-energy impacts reported as a result of completed EBCx projects. In a total of 36 projects conducted in existing buildings, 81 total non-energy benefits were reported, which averages to about two benefits per project. Some non-energy impacts related to the O&M of the building, such as improved equipment life and reduced change orders and warranty claims. However, there were also various benefits that pertained to occupant comfort. 21% of the reported benefits related to improved thermal comfort in the building. Another 17% of the reported benefits pertained to improved indoor-air quality. Lastly, 5% of the reported benefits dealt with improved occupant productivity and safety. In total, around 43% of the reported non-energy impacts were somehow tied to occupant comfort or were a result of improved occupant comfort[8].

In his 2011 study, Mills once again evaluated some of the reported non-energy benefits of commissioning projects in existing buildings and new construction. In total, the study included 332 projects spanning 561 buildings. Of those 561 buildings, 68 buildings provided data regarding the non-energy impacts of completed projects. Once again, within the selection of buildings that had reported non-energy benefits, improvements in occupant comfort made up a significant percentage. In terms of improved thermal comfort, around 80% of the reporting buildings had included this as an observed benefit following project completion. Indoor-air quality improvements were also reported, with around 45% of buildings listing it as an observed benefit. Lastly, productivity and safety improvements were reported in just under 20% of the responses[9]. Both studies demonstrate the various non-energy benefits that can be obtained from existing building commissioning. Improved occupant comfort is a crucial component of the reported benefits and is often a central non-energy benefit following project completion. However, the extent of occupant-based comfort improvements following commissioning projects is difficult to document due to limited data availability. More detailed and consistent reporting on occupant-

based comfort changes after commissioning projects is needed for future studies to better understand impacts.

2.5 Key Literature Review Values for Calculations

The intent of the following section is to compile various key values from the selection of studies included in the literature review, and use the collection of values to determine a set of general values for use in later calculations. Some of the key values will include the percent by floor area of major commercial building use types, commissioning costs and cost savings per unit area, annual percent whole-building energy savings, and undiscounted simple payback periods, for both existing building commissioning and new construction commissioning. In the case of dollar values, the selection of studies contained in the literature review present cost values in a wide range of dollar values over time. To normalize cost data for analysis, selected dollar values will be adjusted for inflation. Ranges for the entire set of values contained within the literature review will also be given to provide additional comparison with the calculation values.

2.5.1 Floor Area Commissioned by Building Use Type

Multiple studies contained within the literature review took selections of building commissioning project data and analyzed the projects based on the different building types in which commissioning was performed. Three major studies organized the data into similar sets of CBECS building use types, and percentages were given for each building type based on total floor area of building space commissioned. Two of the studies, conducted by Mills et al. in 2004 and Mills in 2011 were focused on standard existing building commissioning and new construction commissioning, while the third study conducted by Bynum et al. in 2008 evaluated Continuous Commissioning of existing buildings. In total, the three studies encompassed a total of 134,477,884 ft^2 of commissioned existing building space. The two Mills studies combined to include 16,977,924 ft^2 of commissioned new construction. These three studies were the most comprehensive evaluations of building commissioning by floor area in building use types, and utilized the same general categories which assisted in making simple comparisons. This data is summarized in Table 11.

Table 11: Percent of EBCx and NCCx floor area by building use type

Building Use Type	EBCx			NCCx	
	Mills et al. 2004[8]	**Mills 2011**[9]	**Bynum et al. 2008**[11]	**Mills et al. 2004**[8]	**Mills 2011**[9]
K-12	4.73%	2.73%	27.9%	7.12%	7.44%
Higher Education	10.81%	12.61%		3.91%	7.12%
Food Sales	0.00%	0.94%	0.6%	1.56%	1.54%
Food Service	0.02%	0.21%	0.9%	0.00%	0.00%
Outpatient	13.01%	4.78%	30.8%	2.52%	2.34%
Inpatient	5.74%	7.51%		12.78%	7.81%
Cleanrooms	N/A	0.00%	N/A	N/A	3.42%
Data Center	N/A	0.01%	N/A	N/A	0.00%
Laboratory	4.19%	5.05%	8.1%	24.28%	22.30%
Lodging	2.86%	10.93%	0.1%	1.83%	1.78%
Retail	2.76%	3.24%	0.4%	0.00%	0.00%
Malls	N/A	N/A	0.0%	N/A	N/A
Service	1.02%	0.25%	1.1%	0.31%	0.00%
Office	49.29%	44.21%	20.9%	7.89%	10.15%
Public Assembly	1.78%	2.74%	3.7%	8.66%	7.82%
Public Order/Safety	3.41%	2.75%	0.0%	26.45%	25.77%
Religious Worship	0.00%	0.01%	0.0%	0.00%	0.00%
Warehouse/Storage	0.06%	0.01%	0.0%	1.98%	1.84%
Industrial	N/A	0.53%	N/A	N/A	0.00%
Other	0.30%	1.49%	5.4%	0.73%	0.68%
Vacant	0.00%	0.00%	0.0%	0.00%	0.00%
Total Floor Area	**22,246,000 ft^2**	**90,410,885 ft^2**	**21,798,180 ft^2**	**8,164,000 ft^2**	**8,813,924 ft^2**

2.5.2 Commissioning Cost and Savings Metrics

A variety of studies were reviewed to better understand the general costs and savings associated with building commissioning. A majority of these studies focused on existing building commissioning and Continuous Commissioning® project data, while a smaller number looked at new construction commissioning. The studies included for existing building commissioning and CC® ranged from large, expansive studies spanning hundreds of projects to individual case studies summarizing individual projects. There was also some variability in what values were provided in each study. For the purpose of this study, general commissioning values were selected, although some studies also included the same types of values for individual building types. Generally, these

sample sizes were too small and did not match with the number of building categories used in the floor area breakdowns to be utilized in calculations. Table 12 shows the selection of EBCx values taken from the reviewed studies. In this case, the study values are shown for cost and cost savings per unit area, energy savings, and simple payback. Ranges for each category are also provided with the most common unit provided.

Table 12: Key EBCx cost and savings values from literature review

Study	**Cost per Unit Area**	**Cost Savings per Unit Area**	**Energy Savings**	**Simple Payback**
Mills et al. 2004[8]	$0.27	$0.27	15%	0.70
Mills 2011[9]	$0.30	$0.29	16%	1.10
Coyner et al. 2017[12]	$0.41	-	10 -15%	1.80
PECI et al. 2009[10]	-	-	0.95 - 5.60 kBtu/ft^2	0.35 - 1.30
Friedman et al. 2011[15]	$0.08 - $0.40	$0.11 - $0.26	-	-
Bynum et al. 2008[11]	$0.42	$0.36	12.75%	1.68
Jones et al. 2008[17]	-	$0.84	19.99%	0.38
Oh et al. 2014[18]	-	$0.29	-	-
Claridge et al. 1994[19]	-	-	23%	-
Turner et al. 2007[20]	$0.42	$0.16	10% - 14%	2.50
Deng et al. 2006[21]	-	-	35%	-
Deng et al. 2008[22]	-	-	35%	-
Turner et al. 2009[23]	-	$0.61	7.9% Elec, 17.3% CHW, 41.6% NG	-
McCown 2009[24]	-	-	11.40%	2.00
Liu et al. 2006[25]	-	-	33.2% Elec, 51.2% NG	-
Wei et al. 2006[26]	-	-	-	5.40
Range	**$0.08 - $0.42**	**$0.11 - $0.84**	**10% - 35%**	**0.35 - 5.40**

The same categories of values were collected for new construction commissioning, although there were significantly less studies included in the review. Even in the small sample of studies, there was significant variety in the scale of the studies with regard to individual sample sizes. Some studies contained building counts close to 100 while others included single digit

building counts. Once again, the values are given for each respective category and a range is given based on all included values. Table 13 shows this data compilation.

Table 13: Key NCCx cost and savings values from literature review

Study	**Cost per Unit Area**	**Cost Savings per Unit Area**	**Energy Savings**	**Simple Payback**
Mills et al. 2004[8]	$1.00	$0.05	-	4.80
Mills 2011[9]	$1.16	$0.18	13%	4.20
PECI 2002[13]	$0.30 - $2.60	-	-	-
Friedman et al. 2011[15]	$0.19 - $1.00	$0.05 - $0.64	-	-
D'Antonio 2007[14]	$0.19 - $1.50 $0.55 avg.	-	-	-
Range	**$0.19 - $2.60**	**$0.05 - $0.64**	**13%**	**4.20 - 4.80**

3. METHODOLOGY

The project consisted of three main components: Literature review for key commissioning metrics, selection of commissioning companies and collection of corresponding company data, and calculations using the collected data to estimate the implementation and impact of existing building commissioning and general building commissioning for the sample of companies.

3.1 Key Commissioning Values for Calculations

As summarized in the literature review section, a variety of building commissioning studies were evaluated to compile a set of key metrics for use in performing calculations to estimate the impact of a selection of commissioning providers. Studies generally took sets of real commissioning project data and evaluated a variety of parameters, ranging from project-level savings and costs per unit area, payback periods, building types impacted, and occupant comfort improvements, to measure implementation frequency and measure-level savings. While this wide range of data is useful in understanding the broader trends of the commissioning market, the following metrics were the key components in calculating the desired estimates based on the project sample:

- Commissioning cost per unit area, EBCx and NCCx [$/ft^2-year]
- Commissioning cost savings per unit area, EBCx and NCCx [$/ft^2-year]
- Undiscounted simple payback period, EBCx and NCCx [years]
- Annual whole-building energy savings, EBCx and NCCx [%]
- Breakdown of commissioned floor area by building type, EBCx and NCCx [%]

In reviewing the selected data, and considering the varying degrees of comprehensiveness among the selection of studies, the two most expansive studies, Mills et al. 2004 and Mills 2011[8,9], were selected as the sources of the key commissioning metrics. The studies followed the same general methodologies and provided the same types of key values. The included values were taken from each of the respective studies and averaged to serve as multipliers and constants in the final calculations.

In the case of commissioning costs and cost savings, dollar values were adjusted for inflation to the year 2017. Dollar values were adjusted based on the normalized dollar values specified in each study. To determine the average annual inflation, average annual percent change in consumer price index (CPI) values were taken from each study's normalized dollar year to 2017 and averaged to give an annual inflation rate. The dollar values used in the studies were 2003 dollars and 2009 dollars[8, 9]. The annual percent CPI changes were compiled from a Bureau of Labor Statistics database and averaged. The values were annual percent change averages for all items less food and energy, shown as U.S. city average for all urban consumers with no seasonal adjustment[27]. Thus, the dollar values from each respective study were adjusted using the typical annual compounding interest (inflation) equation shown as:

$$DV_{2017} = DV_{Original} * (1 + r)^t \qquad \text{(Eq. 1)}$$

where,

$DV_{Original}$: original dollar value used in each selected study, $, see Table 14;

r: average annual inflation rate from study dollar year to 2017, %, see Table 15;

t: years from study dollar year to 2017, years, see Table 15;

Table 14 summarizes the original dollar values, for both types of building commissioning, from the selected studies that were inflation adjusted, while Table 15 summarizes the average inflation rates and number of years applied to convert the selected dollar values based on the dollar years used in each study.

Table 14: Original dollar values before inflation adjustment[8 ,9]

	$DV_{Original}$ (2003 Dollars[8])	
	Cost per Unit Area	**Cost Savings per Unit Area**
EBCx	$0.27/ft^2	$0.27/ft^2
NCCx	$1.00/ft^2	$0.05/ft^2
	$DV_{Original}$ (2009 Dollars[9])	
	Cost per Unit Area	**Cost Savings per Unit Area**
EBCx	0.30/ft^2	$0.29/ft^2
NCCx	$1.16/ft^2	$0.18/ft^2

Table 15: Average annual inflation rates and number of years applied to each set of dollar values

	2003 Dollars	**2009 Dollars**
t	13 years	8 years
r	1.89%	1.76%

Energy savings and payback values, as well as adjusted cost and cost savings values from the Mills et al. 2004 and Mills 2011 studies[8, 9] were then compiled and averaged for use in the final calculations to estimate sample-level commissioning impacts, including estimated floor area commissioned and estimated commissioning cost savings. These values are summarized in Table 16.

Table 16: Assumed commissioning values for calculations

Assumed Values for Calculations	**EBCx**	**NCCx**
Cost per Unit Area	\$0.35/ft^2	\$1.30/ft^2
Cost Savings per Unit Area	\$0.34/ft^2	\$0.14/ft^2
Percent Annual Energy Savings	16%	13%
Simple Payback	0.90 years	4.50 years

To estimate the total energy savings of the sample, different building use types needed to be taken into consideration for both new construction and existing building commissioning. Generally, different building types have different energy consumption profiles and operating requirements, and thus, have different energy savings potentials. To account for different building types, the calculated total commissioned floor area was split into existing building and new construction based on the reported breakdown of commissioning business provided by the sampled companies. These sets of floor areas were then divided into 16 general use types based on the two selected commissioning studies, Mills et al. 2004 and Mills 2011[8, 9]. These two studies divided the respective samples of commissioning projects into building use types by percent of the total floor area. These percentage values were averaged between the two selected studies to give a building use type make up, by floor area, for both new construction and existing buildings, which

could then be applied to calculated commissioned floor area to approximate the makeup by building type. The average floor area breakdowns for each type of commissioning are given in Table 17.

Table 17: Average floor area makeup by building use type

Building Type	**% GFA EBCx**	**% GFA NCCx**
K-12	3.73%	7.28%
Higher Education	11.71%	5.51%
Food Sales	0.47%	1.55%
Food Service	0.11%	0.00%
Inpatient	6.63%	10.29%
Outpatient	8.90%	2.43%
Laboratory	4.62%	24.99%
Lodging	6.90%	1.80%
Retail	3.00%	0.00%
Service	0.64%	0.15%
Office	46.75%	9.02%
Public Assembly	2.26%	8.24%
Public Order/Safety	3.08%	26.11%
Religious Worship	0.01%	0.00%
Warehouse/Storage	0.04%	1.91%
Other	1.17%	0.71%

In order to approximate the annual energy savings from the sample of companies, energy use intensities (EUI) for each building use type were collected from an ENERGY STAR technical reference[28]. In this case the median source EUIs were taken from the description that most closely matched the CBECS building types taken from the two selected studies. The selected EUIs are given in Table 18 for the selection of building use types, along with the ENERGY STAR building label associated with each respective value.

Table 18: Median Source EUIs selected for each building use type[28]

Building Type, j	**Median Source EUI (kBtu/ft^2-year)**[28]	**ENERGY STAR Label**[28]
K-12	141.4	K-12 School
Higher Education	262.6	College/University
Food Sales	480	Supermarket
Food Service	432	Restaurant
Inpatient	389.8	Hospital
Outpatient	155.2	Outpatient Rehab/Surgical Center
Laboratory	123.1	Laboratory
Lodging	162.1	Hotel
Retail	114.4	Retail Store
Service	100.4	Other - Services
Office	148.1	Office
Public Assembly	85.1	Entertainment/Public Assembly
Public Order/Safety	169.9	Courthouse/Prison
Religious Worship	70.7	Worship Facility
Warehouse/Storage	60.6	Warehouse/Distribution Center
Other	123.1	Other

3.2 Collection of Sample Companies, Company Data, and Market Estimates

In order to collect a sample of companies performing building commissioning services, the Building Commissioning Association (BCxA) was contacted to assist in compiling a sample of companies. The BCxA provided an unpublished spreadsheet containing the basic information for their corporate member companies as of 2018, spanning over 250 total companies[29]. This enabled a comprehensive selection of companies that were known to be involved in building commissioning for use in putting together initial estimates of larger U.S. commissioning impacts. Although this list of companies is not exhaustive, and numerous companies included in the membership list did not have revenue and company size estimates available online, it provided a large sample size to begin making approximations at a large scale. All identifiable company information has been excluded from this report to ensure the included companies remain anonymous.

The list of BCxA member companies was then used to compile revenue and company size estimates. A large portion of the companies had revenue and company sizes listed within a Texas

A&M Libraries database, Building Source Ultimate[30]. The database provided a company information search function, which gave a basic page for each listed company, including information such as the executive leadership team, products and industries of operation, and headquarters location, as well as the estimated annual revenue and company size in terms of number of employees. There was some variation between these values being labeled as estimates or actual values, particularly with the company sizes. In total, data for 117 companies was collected using this database, accounting for 59.1% of the sample. For companies not listed within the Business Source Ultimate database, general business information websites were used to source estimated company size and annual revenue values. In this case, websites such as manta.com, glassdoor.com, govtribe.com, inc.com, and most predominantly, buzzfile.com provided single value estimates that could be used as approximations for estimated revenue and company size[31, 32, 33, 34, 35]. Buzzfile was used to collect estimates for 70 companies, making up 35.4% of the sample. Manta accounted for 6 companies, making up 3.0% of the sample, while Glassdoor, Inc, and GovTribe accounted for a combined 5 companies, and made up 2.5% of the sample. In some cases, a range of values were provided for each estimate, and to produce one single value, the range was averaged. Although these websites provide estimates that may be less accurate relative to the values sourced from the Business Source Ultimate database, the values will contribute toward putting forth initial estimates. The values for each company were compiled, rounded to two significant figures, and anonymized for use in the calculations of the sample-wide estimates.

A key consideration when evaluating the companies included in the sample was the percent of total revenue coming from building commissioning. The sample contained companies performing a wide range of services and operating in a variety of industries. In an effort to better estimate commissioning revenue, the companies were assigned to generic company categories based on the services and industries listed on each respective company website. The categories were also assigned a percentage value estimating the portion of total revenue coming from general building commissioning. The company categories and respective percent estimates are shown in Table 19. The 'Building Commissioning' category represented firms that offered building commissioning as their primary service and was assigned a value of 100%. The 'MEP Design/Engineering' category represented firms that offered services focusing specifically on MEP and other building systems, which included commissioning. This category was assigned a

value of 50%. The 'Energy Services' category represented companies the offered energy efficiency and green building services, with an emphasis on sustainability and demand-side energy management. This category was given a percentage value of 40%. The 'Building/Facilities Engineering/Architecture' category was for companies that provided a variety of general engineering and architectural services specifically related to buildings and facility management. This category was assigned a value of 20% for commissioning revenue. The 'Architecture, Engineering, Environmental and Construction Services' category represented large interdisciplinary engineering firms that offered a wide range of services, as indicated by the name, but still included building commissioning as a small portion of the overall offering. This category was assigned a percentage value of 5%. Lastly, the 'Construction, Utility, Misc.' category represented large construction companies, utilities, and any other companies that did not fit under any of the previous categories. In this case, it was assumed that commissioning made up a very small portion of total revenue, and thus this category was assigned 2%.

Table 19: Company categories for estimating commissioning revenue

Company Category	**Percent Revenue from Commissioning**
Building Commissioning	100%
MEP Design/Engineering	50%
Energy Services	40%
Building/Facilities Engineering and Architecture	20%
Architecture, Engineering, Environmental and Construction Services	5%
Construction, Utility, Misc.	2%

The BCxA also provided assistance in sampling the selection of member companies to acquire crucial details regarding the makeup of select company's commissioning business, which facilitated the approximation of the average makeup of commissioning revenue between existing buildings and new construction. The BCxA provided anonymous unpublished results from an internal survey conducted in 2017. Participants were asked to provide the number of EBCx and NCCx projects contracted in the last 12 months, in terms of number of buildings. The participants were able to select ranges of building counts, which included the following: 1 to 2, 3 to 5, 6 to 10,

11 to 20, and Over 20[36]. Percent values for each building count range were given in chart form and were approximated for use in calculating a percent revenue makeup of EBCx and NCCx. To estimate the revenue makeup, the building count ranges were averaged to get single numbers, resulting in the following: 2, 4, 8, 16, and 25. Weighted averages were then taken based on the reported percentage values from respondents for both EBCx and NCCx, which gave the average number of buildings commissioned in the last 12 months for each type of commissioning (14 NCCx and 9 EBCx). Average cost per unit area values ($1.30/ft^2 NCCx and $0.35/ft^2 EBCx) were applied to these average building counts, with the assumption that costs are equivalent to revenue, to more accurately represent the revenue makeup. In this case, the percent of revenue coming from EBCx was estimated to be 15% and the revenue from NCCx was estimated to be 85%, as shown in Table 20. These values were applied to all companies included in the analysis to generally approximate the revenue differences between the two types of commissioning.

Table 20: Percent of total Cx revenue in terms of EBCx and NCCx

Commissioning Type	**Percent of Total Commissioning Revenue**
Existing Building Commissioning	15%
New Construction Commissioning	85%

3.3 Building Commissioning Sample Estimate Calculations

To estimate the commissioning implementation and impacts of the sample, the following values were calculated for both existing building and overall building commissioning:

- Total Estimated Annual Commissioning Revenue, EBCx and Cx [$/year]
- Total Estimated Floor Area of Building Space Commissioned, EBCx and Cx [ft^2/year]
- Total Estimated Commissioning Cost Savings, EBCx and Cx [$/year]
    - Using Simple Payback Periods
    - Using Cost Savings per Unit Area
- Total Estimated Commissioning Energy Savings, EBCx and Cx [kBtu/year]

These values are primarily intended to estimate the total impact of existing building commissioning, and secondarily intended to estimate general building commissioning – existing building commissioning and new construction commissioning combined, based on the sample of commissioning providers. Thus, these values will be broken out in terms of existing building commissioning as well as general commissioning, with an emphasis being placed on estimating existing building commissioning. These estimates were calculated using the key commissioning metrics taken from previous studies, and applying them to the estimated revenues and approximated makeup of commissioning types applied to each firm included in the analysis. Each calculation outlined in further detail in the following sections.

3.3.1 Total Estimated Annual Commissioning Revenue

The first set of calculations is used to approximate the total annual revenue for the sample of companies in terms of overall commissioning, which includes existing building commissioning and new construction commissioning. In order to approximate annual commissioning revenue, the total estimated annual revenue for each i company is multiplied by the respective assumed percent of annual revenue coming from building commissioning, expressed as:

$$CxR_i = ER_i * \%Cx_i \qquad \text{(Eq. 2)}$$

$$CxR_{Total} = \sum_{i \in I} ER_i * \%Cx_i \qquad \text{(Eq. 3)}$$

i = each individual firm included in the analysis (n = 198)

i ∈ I = {all included firms}

where,

ER_i: estimated annual revenue, $/year, see Appendix A;

$\%Cx_i$: percent of estimated annual revenue from building commissioning, %, see Appendix A;

3.3.2 Total Estimated Annual Existing Building Commissioning Revenue

To approximate annual existing building commissioning revenue, the estimated annual commissioning revenue for each i company, calculated using Equation (2), is multiplied by the assumed percent of commissioning revenue coming from existing building commissioning. The estimated annual existing building commissioning revenue values for each company are then summed across the entire selection of companies to estimate the total for the sample, giving:

$$EBCxR_i = CxR_i * \%EBCx \qquad \text{(Eq. 4)}$$

$$EBCxR_{Total} = \sum_{i \in I} CxR_i * \%EBCx \qquad \text{(Eq. 5)}$$

i = each individual firm included in the analysis (n = 198)

i ∈ I = {all included firms}

where,

CxR_i: estimated annual commissioning revenue, $/year, see Appendix A;

$\%EBCx$: percent of commissioning revenue coming from existing building commissioning, 15%;

3.3.3 Total Estimated Floor Area Commissioned

The third set of calculations is intended to estimate the total floor area of building space commissioned for the selection of companies, in terms of existing building commissioning as well as both existing building and new construction commissioning combined. Assuming commissioning revenue is equivalent to the costs of commissioning, the estimated total floor area commissioned from existing building commissioning for the sample was calculated using the following:

$$GFA_{EBCx} = \sum_{i \in I} \left(\frac{CxR_i \ * \ \%EBCx}{CxC_{EB}} \right)$$

(Eq. 6)

i = each individual firm included in the analysis (n = 198)

i ∈ I = {all included firms}

where,

CxR_i: estimated annual commissioning revenue, $/year, see Appendix A;

$\%EBC$: percent of commissioning revenue from existing building commissioning, 15%;

CxC_{EB}: assumed existing building commissioning cost per unit area, $0.35/ft^2;

Similarly, the estimated total floor area commissioned for both existing building commissioning and new construction commissioning combined was calculated using Equation (6) but included an additional term to account for commissioned floor area from new construction commissioning, shown in the following:

$$GFA_{Cx} = \sum_{i \in I} \left(\frac{CxR_i * \%EBCx}{CxC_{EBCx}} + \frac{CxR_i * \%NCCx}{CxC_{NCCx}} \right)$$

(Eq. 7)

i = each individual firm included in the analysis (n = 198)

i ∈ I = {all included firms}

where,

CxR_i: estimated annual commissioning revenue, $/year, see Appendix A;

$\%EBCx$: percent of commissioning revenue from existing building commissioning, 15%;

CxC_{EBCx}: assumed existing building commissioning cost per unit area, $0.35/ft^2;

$\%NCCx$: percent of commissioning revenue from new construction commissioning, 85%;

CxC_{NCCx}: assumed new construction commissioning cost per unit area, $1.30/ft^2

3.3.4 Total Estimated Annual Cost Savings using Simple Payback Periods

Two methods were used for calculating the estimated annual commissioning cost savings for the sample, in order to evaluate estimated savings using two different calculation factors. The

first method utilized the average simple payback periods for both new construction commissioning and existing building commissioning. The second method utilized the average cost savings per unit area of existing building and new construction commissioning.

To calculate estimated cost savings from existing building commissioning using an assumed typical simple payback period, the estimated total existing building commissioning revenue, which is assumed to be equivalent to total existing building commissioning costs, was divided by the assumed typical simple payback period to approximate a single year of cost savings, giving:

$$TCS_{EBCx} = \sum_{i \in I} \left(\frac{CxR_i * \%EBCx}{SPB_{EBCx}} \right)$$

(Eq. 8)

i = each individual firm included in the analysis (n = 198)

i ∈ I = {all included firms}

where,

CxR_i: estimated annual commissioning revenue, $/year, see Appendix A;

$\%EBCx$: percent of commissioning revenue from existing building commissioning, 15%;

SPB_{EBCx}: assumed existing building commissioning simple payback period, 0.90 years;

Estimated total commissioning cost savings was calculated in a similar manner, using Equation (8) from above, but adding an additional term to account for new construction commissioning, shown by:

$$TCS_{Cx} = \sum_{i \in I} \left(\left(\frac{CxR_i * \%EBCx}{SPB_{EBCx}} \right) + \left(\frac{CxR_i * \%NCCx}{SPB_{NCCx}} \right) \right)$$

(Eq. 9)

i = each individual firm included in the analysis (n = 198)

i ∈ I = {all included firms}

where,

CxR_i: estimated annual commissioning revenue, $/year, see Appendix A;

$\%EBCx$: percent of commissioning revenue from existing building commissioning, 15%;
SPB_{EBCx}: assumed existing building commissioning simple payback period, 0.90 years;
$\%NCCx$: percent of commissioning revenue from new construction commissioning, 85%;
SPB_{NCCx}: assumed new construction commissioning simple payback period, 4.50 years;

3.3.5 Total Estimated Annual Cost Savings Using Cost Savings per Unit Area

To calculate total estimated cost savings using cost savings per unit area, typical cost savings per unit area values for existing building and new construction commissioning were applied to calculated estimated commissioned floor areas. Total estimated annual existing building commissioning cost savings, using Equation (6) to calculate commissioned floor area, was approximated by:

$$TCS_{EBCx} = \sum_{i \in I} \left(\frac{CxR_i * \%EBCx}{CxC_{EBCx}} * CxC_{EBCx} \right) \quad \text{(Eq. 10)}$$

i = each individual firm included in the analysis (n = 198)

i ∈ I = {all included firms}

where,
CxR_i: estimated annual commissioning revenue, \$/year, see Appendix A;
$\%EBCx$: percent of commissioning revenue from existing building commissioning, 15%;
CxC_{EBCx}: assumed existing building commissioning cost per unit area, \$0.35/ft^2;
CxC_{EBCx}: assumed existing building commissioning cost savings per unit area, \$0.34/ft^2

Utilizing Equation (10) and adding an additional term to include new construction commissioning cost savings, the total estimated annual building commissioning cost savings was approximated by:

$$TCS_{Cx} = \sum_{i \in I} \left[\left(\frac{CxR_i * \%EBCx}{CxC_{EBCx}} * CxC_{EBCx} \right) + \left(\frac{CxR_i * \%NCCx}{CxC_{NCCx}} * CxS_{NCCx} \right) \right]$$

(Eq. 11)

i = each individual firm included in the analysis (n = 198)

i ∈ I = {all included firms}

where,

CxR_i: estimated annual commissioning revenue, $/year, see Appendix A;

$\%EBCx$: percent of commissioning revenue from existing building commissioning, 15%;

CxC_{EBCx}: assumed existing building commissioning cost per unit area, $0.35/ft^2;

CxC_{EBCx}: assumed existing building commissioning cost savings per unit area, $0.34/ft^2

$\%NCCx$: percent of commissioning revenue from new construction commissioning, 85%;

CxC_{NCCx}: assumed new construction commissioning cost per unit area, $1.30/ft^2

CxS_{NCCx}: assumed new construction commissioning cost savings per unit area, $0.14/ft^2;

3.3.6 Total Estimated Commissioning Energy Savings

Total estimated annual existing building commissioning energy savings is approximated by:

$$TES_{EBCx} = \sum_{j \in J} \left(\left(\sum_{i \in I} \frac{CxR_i * \%EBCx}{CxC_{EBCx}} \right) * \%GFA_{EBj} * EUI_j * \%E_{EBCx} \right)$$

(Eq. 12)

i = each individual firm included in the analysis (n = 198)

i ∈ I = {all included firms}

j = each individual building use type included in the analysis (n = 16)

j ∈ J = {K-12, Higher Education, Food Sales, Food Service, Inpatient, Outpatient, Lab, Lodging, Retail, Service, Office, Public Assembly, Public Order/Safety, Religious Worship, Warehouse/Storage, Other}

where,

CxR_i: estimated annual commissioning revenue, $/year, see Appendix A;

$\%EBCx$: percent of commissioning revenue from existing building commissioning, 15%;

CxC_{EBCx}: assumed existing building commissioning cost per unit area, \$0.35/ft^2;

$\%GFA_{EBCx,j}$: percent of exiting building floor area commissioned by use type, %, see Table 21;

EUI_j: Median Source EUI by building type, kBtu/ft^2-year, see Table 21;

$\%E_{EBCx}$: Assumed annual whole-building existing building commissioning energy savings, 16%;

Total estimated annual building commissioning energy savings is approximated by using Equation (12) above and adding an additional term to account for annual energy savings from new construction commissioning, given by:

$$TES_{Cx} = \sum_{j \in J} \left\{ \left(\left(\sum_{i \in I} \frac{CxR_i * \%EBCx}{CxC_{EBCx}} \right) * \%GFA_{EBCx,j} * EUI_j * \%E_{EBCx} \right) + \left(\left(\sum_{i \in I} \frac{CxR_i * \%NCCx}{CxC_{NCCx}} \right) * \%GFA_{NCCx,j} * EUI_j * \%E_{NCCx} \right) \right\}$$

(Eq. 13)

i = each individual firm included in the analysis (n = 198)

i ∈ I = {all included firms}

j = each individual building use type included in the analysis (n = 16)

j ∈ J = {K-12, Higher Education, Food Sales, Food Service, Inpatient, Outpatient, Lab, Lodging, Retail, Service, Office, Public Assembly, Public Order/Safety, Religious Worship, Warehouse/Storage, Other}

where,

CxR_i: estimated annual commissioning revenue, \$/year, see Appendix A;

$\%EBCx$: percent of commissioning revenue from existing building commissioning, 15%;

CxC_{EBCx}: assumed existing building commissioning cost per unit area, \$0.35/ft^2;

$\%GFA_{EBCx,j}$: percent of existing building floor area commissioned by use type, %, see Table 21;

EUI_j: Median Source EUI by building type, kBtu/ft^2-year, see Table 21;

$\%E_{EBCx}$: Assumed annual whole-building existing building commissioning energy savings, 16%;

$\%NCCx$: percent of commissioning revenue from new construction commissioning, 85%;

CxC_{NCCx}: assumed new construction commissioning cost per unit area, \$1.30/ft^2;

$\%GFA_{NCCx,j}$: percent of new construction floor area commissioned by use type, %, see Table 21;

$\%E_{NCCx}$: Assumed annual whole-building new construction commissioning energy savings, 13%;

Table 21 shows the floor area percentages for existing building commissioning and new construction, as well as the median source energy use intensities, for each building use type included in Equations (12) and (13) above.

Table 21: Average floor area makeups and energy use intensities by building type

Building Type, j	**$\%GFA_{EBCx,j}$**	**$\%GFA_{NCCx,j}$**	**EUI_j [28]**
K-12	3.73%	7.28%	141.4
Higher Education	11.71%	5.51%	262.6
Food Sales	0.47%	1.55%	480
Food Service	0.11%	0.00%	432
Inpatient	6.63%	10.29%	389.8
Outpatient	8.90%	2.43%	155.2
Laboratory	4.62%	24.99%	123.1
Lodging	6.90%	1.80%	162.1
Retail	3.00%	0.00%	114.4
Service	0.64%	0.15%	100.4
Office	46.75%	9.02%	148.1
Public Assembly	2.26%	8.24%	85.1
Public Order/Safety	3.08%	26.11%	169.9
Religious Worship	0.01%	0.00%	70.7
Warehouse/Storage	0.04%	1.91%	60.6
Other	1.17%	0.71%	123.1

4. SAMPLE

Companies were sourced from a Building Commissioning Association (BCxA) member list provided by Liz Fischer of the BCxA. Company information was used to obtain revenue and company size estimates and has been anonymized for use in this project. The sample totaled to 198 BCxA member companies, and was limited to companies that listed a U.S. city and state within the member list.

4.1 Geographic Distribution

A city and state location was provided for each company in the list of BCxA members. It is important to note that larger companies often have multiple offices and operate throughout the United States. However, it is still valuable to review the single location associated with each company to better understand the state-by-state commissioning presence based on the project sample. In total, the 198 companies spanned 38 states throughout the United States. The state with the highest number of companies was Washington, which contained 17 companies, making up 8.5% of the sample. The second most frequent state was California, with 15 companies, making up 7.5% of the sample. Finally, the third most common state was New York with 14 companies, making up 7.0% of the sample. Other states with large concentrations of commissioning companies were Colorado, Texas, North Carolina, and Oregon[29]. Companies were located in almost every ASHRAE Climate Zone, including zones 2A, 2B, 3A, 3B, 3C, 4A, 4B, 4C, 5A, 5B, 6A, 6B, and 7A. Climate zones were based on the county corresponding to the listed city and state for each respective company and sourced from OpenEI[37]. The summary of companies included in the study organized by state is contained in Table 22. The sample suggests a distribution of companies throughout the United States, operating in a variety of climate zones.

Table 22: Geographic distribution of companies based on given location[29]

State	Count	% of Total
WA	17	8.6%
CA	15	7.6%
NY	14	7.1%
CO	13	6.6%
TX	11	5.6%
NC	9	4.5%
OR	8	4.0%
VA	8	4.0%
FL	7	3.5%
PA	7	3.5%
MA	6	3.0%
AZ	5	2.5%
CT	5	2.5%
GA	5	2.5%
IL	5	2.5%
MD	5	2.5%
MN	5	2.5%
MI	4	2.0%
MO	4	2.0%

State	Count	% of Total
NJ	4	2.0%
NV	4	2.0%
AL	3	1.5%
OH	3	1.5%
UT	3	1.5%
VT	3	1.5%
WI	3	1.5%
AK	2	1.0%
DC	2	1.0%
IA	2	1.0%
IN	2	1.0%
KS	2	1.0%
KY	2	1.0%
MT	2	1.0%
NE	2	1.0%
NM	2	1.0%
TN	2	1.0%
NH	1	0.5%
SC	1	0.5%

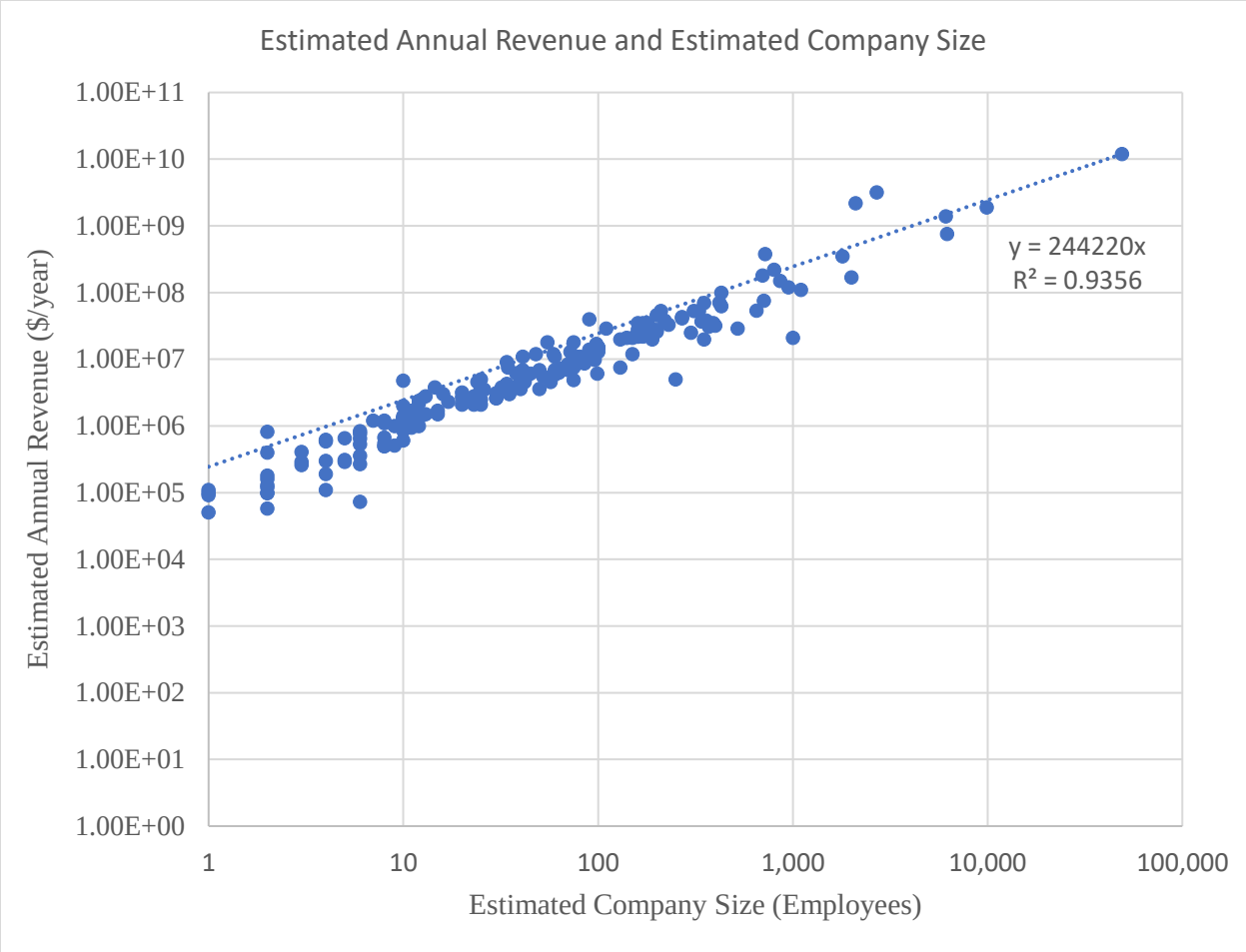
4.2 Estimated Annual Revenue and Estimated Company Size

The companies included in the sample covered a significant range of sizes, revenue estimates, and lines of business. The range for estimated company size, in number of employees, was 1 to 49,000. The median company size was 43 employees, while the mean company size was 520 employees. This wide range of company sizes suggests that building commissioning can be performed by a variety of companies, from small businesses to large national corporations.

There was a similarly wide range when looking at the total estimated annual revenues. The values had a range of $51,000 per year to $12,000,000,000 per year. The median estimated annual revenue for the sample was $5,800,000 per year, while the mean estimated annual revenue was $130,000,000 per year. Revenue is in part a function of company size, and thus there is a significant range of estimated revenues throughout the sample of companies similar to that of estimated company size. The sample of estimated company sizes and estimated total revenue can be seen in Figure 5. Due to some significant outliers in the data, the chart is plotted on a logarithmic scale.

However, the chart suggests a general trend of increased total revenue with increased company size, which follows logical intuition.

Figure 5: Plot of estimated total revenue and estimated company size

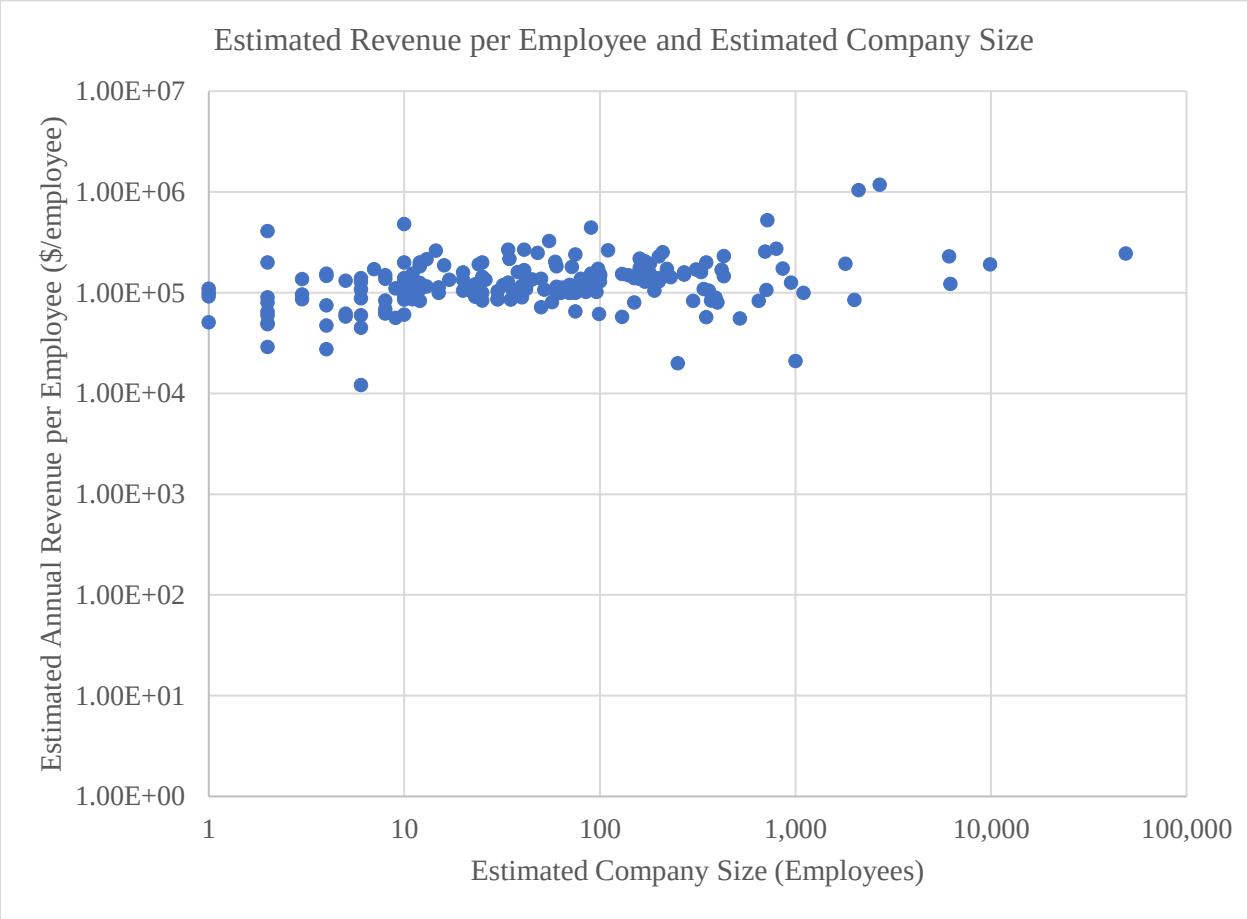


4.3 Estimated Revenue per Employee

When normalizing the estimated total revenue by company size, the range reduces significantly relative to company size and estimated revenue individually. The revenue per employee range for the sample was $12,000 per employee to $1,200,000 per employee. The median revenue per employee was $120,000 and the mean was $150,000. These values can vary

significantly depending on the respective company's line of business, as different services will have different cost and revenue structures. The revenue per employee and estimated company sizes for the sample can be seen in Figure 6. These values are once again plotted on a logarithmic scale due to significant outliers.

Figure 6: Plot of estimated total revenue per employee and estimated company size



4.4 Distribution of Commissioning Revenue in Terms of Company Category

Many of the companies included in the sample are not pure commissioning providers, and often include commissioning as a component of a broader selection of services and revenue streams. For example, engineering design and construction firms may offer building

commissioning services as a secondary or tertiary offering. However, there are also firms that focus on building commissioning as their primary line of business. This relationship was approximated using a set of general company categories with assigned commissioning revenue makeups, as outlined in the previous section, under which all included companies were assigned individually based on provided services and markets serviced. Table 23 shows the distribution of the company categories within the sample. Roughly one third of the sample was assigned to 'Building Commissioning', roughly one third of the sample was assigned to 'MEP Design/Engineering', while the final third of the sample made up the rest of the categories.

Table 23: Distribution of company categories

Company Category	**Commissioning Revenue Percentage**	**Count**
Building Commissioning	100%	67
MEP Design/Engineering	50%	66
Energy Services	40%	9
Building/Facilities Engineering and Architecture	20%	14
Architecture, Engineering, Environmental and Construction Services	5%	30
Construction, Utility, Misc.	2%	12

5. FINDINGS

The sample of revenue estimates for the 198 companies summarized in the section above was applied to the previously outlined calculations to compute estimates of total implementation and impact of existing building commissioning, as well as overall building commissioning, for the sample. Because these values are approximations, they have been rounded to two significant figures.

5.1 *Existing Building Commissioning*

The total estimated annual existing building commissioning revenue for the sample of companies was $270 million per year. In terms of estimated floor area commissioned in existing buildings, the total for the sample was approximated to be 780 million square feet per year of floor area. When looking at estimated cost savings from existing building commissioning, the average between the two calculation methods was $290 million per year. When calculating using typical cost savings per unit area, the total estimated cost savings was $270 million per year. Comparatively, when calculating using the typical simple payback, the total estimated cost savings was $300 million per year. Finally, in terms of estimated annual energy savings, the total for the sample was calculated to be 22 billion kBtu per year.

5.2 *Total Building Commissioning*

For existing building commissioning and new construction commissioning combined, the estimated total annual revenue for the sample was calculated to be $1.8 billion per year. In terms of floor area, the estimated total commissioned building space for both types of commissioning was roughly 2.0 billion square feet per year. The average estimated annual cost savings for the two types of commissioning was $540 million per year, with the simple payback-based calculation giving $650 million per year in estimated cost savings, and the cost savings per unit area-based calculation giving $430 million per year in estimated cost savings. These values for each calculation method display a significant difference because the assumed commissioning values, simple payback period and cost savings per unit area, were presented as median values in the

selected studies, and were therefore based on different sized samples depending on the study and value. Lastly, the estimated energy savings for the combined commissioning types was estimated to be around 48 billion kBtu of annual energy savings for the sample.

5.3 Comparison of Commissioning Types

When comparing the two sets of values, an interesting set of trends arises. In terms of total estimated annual revenue, existing building commissioning made up 15% of the total, which was predetermined based on the estimated revenue breakdown assumed for the calculations. However, in terms of total estimated floor area commissioned, existing building commissioning made up 39% of the total, while in terms of total estimated cost savings, existing building commissioning made up about 54% of the total. With regard to estimated annual energy savings, existing building commissioning accounts for 44% of the total. These differences emphasize the importance of the varying values associated with each type of commissioning, such as costs and savings per unit area. Additionally, this data suggests a larger impact from existing building commissioning relative to its portion of the total estimated commissioning revenue, due to higher typical savings values and lower typical cost values. Table 24 shows a summary of the presented findings for both existing building commissioning and the combination of new construction and existing building commissioning.

Table 24: Summary of EBCx and Cx results

	Existing Building Commissioning	**Total Commissioning**	**Percent EBCx**
Estimated Annual Revenue	$270,000,000/year	$1,800,000,000/year	15%
Estimated Annual Floor Area Commissioned	780,000,000 ft^2/year	2,000,000,000 ft^2/year	39%
Estimated Annual Cost Savings	$290,000,000/year	$540,000,000/year	54%
Estimated Annual Energy Savings	22,000,000,000 kBtu/year	50,000,000,000 kBtu/year	44%

5.4 Comparison of Results with Larger Market-Level Values

The estimated total annual commissioning revenue seems to be reasonable for the sample when compared to larger market projections. A market research report, performed by Navigant Research in 2015 for private clients, evaluated the global market for building commissioning, projecting revenue growth from 2015 to 2024. In this analysis, commissioning was broken out into 'Initial Commissioning', 'Retrocommissioning', and 'Monitoring-Based Commissioning'. In this case, 'Initial Commissioning' can be equated to new construction commissioning and 'Retrocommissioning' and 'Monitoring-Based Commissioning' can be equated to existing building commissioning. The global commissioning market was expected to exceed revenue of $6.6 billion by 2024, with a compound annual growth rate of 9.1% between 2014 and 2024. Based on the provided chart, 2017 revenue was projected to be around $3.7 billion. Looking at the projected total annual revenue for 2017 by commissioning type, existing building commissioning can be estimated at around $1.4 billion in annual revenue while new construction commissioning can be estimated at $2.3 billion in annual revenue[38]. It is important to note that this information is taken from a news article summarizing the report, and the methodology utilized by Navigant to generate these market projections was not mentioned or described.

When considering that this research report is a projection for the global commissioning market, and that the selection of studies included in this analysis does not make up the entirety of the U.S. market, the calculated Cx and EBCx revenue values, $1.8 billion and $270 million respectively, do seem reasonable. Based on the projections summarized above, the estimated annual existing building commissioning revenue for the sample accounts for around 56% of the projection. Comparatively, estimated total annual commissioning revenue for the sample makes up around 49% of the projected world market. Acknowledging some of the considerations to be discussed in the following section, the sample does not represent the entire U.S. commissioning market, and the constants used in the calculations could potentially be a combination of over and underestimates. When compared to the world market projections, the results for the sample generally appear to be reasonable with regard to overall magnitude of annual revenue, but should be viewed as approximations only.

In terms of annual energy savings, the totals for both existing building commissioning and total commissioning make up very small portions of commercial energy consumption. For example, the 2017 total energy consumption, which included all primary energy, electricity sales to the commercial sector, and electrical losses, totaled to around 18,000 trillion Btu[4]. Existing building commissioning savings, 22 trillion Btu, accounts for 0.12% of that total. Overall commissioning savings, 50 trillion Btu, made up about 0.28% of the total. When looking at just the 2017 primary energy consumption of the commercial sector, which was around 4,400 trillion Btu[4], existing building commissioning energy savings are roughly 0.50% of the total, while overall commissioning savings are around 1.1% of the total. Lastly, when looking at commercial energy consumption in terms of retail electricity sales and natural gas consumption, two of the major energy sources for the commercial sector, existing building commissioning energy savings only made up around 0.28%, while total commissioning savings made up about 0.63% of the consumption, which totaled to around 7,900 trillion Btu[4]. The percentage values, which are summarized in Table 25 seem to be significantly lower than expected, but bearing in mind that this is not a representation of the entire building commissioning market in the United States, and rather approximated values for a sample making up a portion of the total market, the values seem to be reasonable.

Table 25: Estimated annual commissioning energy savings as percentages of annual commercial energy consumption

U.S. Commercial Energy Consumption Type	**2017 Consumption (Trillion Btu)**	**EBCx Savings as Percent of Total**	**Cx Savings as Percent of Total**
Total Commercial Energy	18,000[4]	0.12%	0.28%
Total Retail Electricity Sales and Natural Gas	7,900[4]	0.28%	0.63%
Total Primary Energy	4,400[4]	0.50%	1.1%

Lastly, with regard to total commercial building floor area in the United States, the estimated total annual floor areas commissioned for the sample accounted for small portions of the total U.S. floor area. According to CBECS, the total U.S. commercial building floor area in 2012 was around 87 billion square feet, and the commercial building count totaled to around 5.6 million

buildings[39]. Comparatively, the total estimated existing building floor area commissioned for the sample was 790 million square feet, which made up 0.91% of the total U.S. commercial building floor area. Total estimated annual floor area commissioned for the sample totaled to 2.0 billion square feet, which made up around 2.3% of the total commercial building floor area. Although these percentage values, summarized in Table 26, are once again small, they also appear to be reasonable considering the sample is capturing a portion of the total U.S. building commissioning market.

Table 26: Estimated annual commissioned floor area as percentages of total U.S. commercial building floor area

Total U.S. Commercial Building Floor Area (ft^2)	**EBCx Floor Area as Percent of Total**	**Cx Floor Area as Percent of Total**
87,000,000,000[37]	0.91%	2.3%

5.5 Considerations and Caveats

It is crucial to view the results of this study with a bevy of considerations in mind. The values calculated in this study are meant to be approximations, rather than exact figures, for the sample of companies. Various considerations and caveats should be brought forward with regards to the sample of companies and respective data, as well as the calculation methodologies.

5.5.1 Sample and Company Data

Although the sample of companies included in the analysis spanned 198 total firms, the sample does not represent the entire market of commissioning firms. The sample consists only of registered BCxA member companies with a provided location in the United States. The BCxA member list provides a comprehensive data set, but it likely does not include every commissioning firm operating in the U.S., thus the sample itself underrepresents the commissioning market in terms of total number of companies. Additionally, some BCxA member companies did not have

any published estimates and were not included in the analysis. The implementation and impacts are representative of the sample of companies rather than the entire U.S. building commissioning market, and additional work must be conducted to make approximations for the whole market.

Values applied to the sample companies – such as percent commissioning revenue and percent existing building and new construction commissioning revenue – were approximations, and do not represent real values reflecting the individual companies. Due to time constraints, the initial data collection method, which was to sample the percentage values of total commissioning, existing building, and new construction commissioning from each of the included companies through the BCxA, was unable to be completed. As a result, the percentage values for total commissioning revenue were approximated using general company types and best estimates of typical revenue percentages.

Similarly, for percent makeup of revenue between commissioning types, anonymous BCxA survey data, collected prior to the beginning of this project, was analyzed to determine rough averages that were applied to every included company. These approximate values allowed for the calculation of the final estimates, however, the results would have more accurately reflected the sample if these values, estimated or actual, had come from the individual companies included in the study. This approach may have also helped to reduce the number of outliers within the sample, further improving the accuracy of the results. Because these assumed percentage values are a key component of the calculations, they have a considerable impact on the study results, and their level of approximation must be acknowledged when viewing the final calculated values.

The final consideration to be given to the sample of companies and corresponding data is the collected revenue and company size estimates. A majority of these revenue and size estimates were taken from a Texas A&M Libraries database. It is unclear how these values are determined for private companies, or the degree of accuracy with which the values are presented. Similarly, for companies that did not have entries in the Business Source Ultimate database, revenue and company size estimates were sourced from other websites such as glassdoor.com, buzzfile.com, and manta.com. It is once again difficult to verify the accuracy of the values presented on these websites. Typically, when a range of values was presented, the average between the two was

recorded for the analysis. All revenue estimates were also rounded to two significant figures for use in calculations, as they are estimated values. In total, these values are meant to serve as approximations to facilitate initial estimates of the larger existing building and overall commissioning impacts for the sample of companies.

5.5.2 Calculations and Commissioning Values

As stated above, the values calculated in this study are meant to serve as broad initial estimates of the total existing building commissioning and overall commissioning impacts for the sample, using estimates and typical commissioning values.

Building commissioning is an inherently dynamic and variable process. Commissioning costs, savings, and payback periods can be impacted by a variety of factors, such as building use types, building size, commissioned system complexity, ASHRAE climate zone, building heating and cooling loads, baseline energy efficiency, savings degradation, and overall project goals. This means that values can vary significantly between projects. However, for calculations in this study, static commissioning values are broadly applied to the estimated revenues, which are theoretically made up of a collection of commissioning projects. The commissioning values were taken from the most comprehensive studies included in the literature review, Mills et al. 2004 and Mills 2011 through the LBNL, and averaged between the two studies, for both new construction and existing building commissioning. These values are meant to represent the typical numbers for commissioning projects, though it must be acknowledged that there is significant variability in these values when evaluating real commissioning projects individually. Ranges are provided in the tables summarizing these key commissioning values to provide additional context and comparison with regard to the calculated estimates and the degree to which they may change depending on the commissioning values used.

Additional assumptions were made when formulating the calculations for the study. For example, estimated commissioning revenue was assumed to be equivalent to the total commissioning costs when performing calculations to estimate commissioned floor area involving commissioning costs per unit area. In this case, commissioned floor areas may be underestimated

if each firm's commissioning revenue is only a portion of the overall commissioning cost per unit area. As mentioned previously, assumptions were also made when applying percentage values for commissioning revenue types. These values have the potential to be over or underestimates based on the individual company, and have the same impact on some of the underlying components of the final calculations.

For estimated energy savings, it was assumed that a general distribution of commissioned building types, by percent floor areas, was consistent across all firms included in the analysis. In actuality, firms may have differing areas of focus and specialization with regard to building types, and in turn there is no uniform distribution of commissioned building types across the entire market. Additionally, median EUIs from ENERGY STAR were assigned to the various building use types included in the analysis. In this case, it was assumed that these median values applied to the total calculated floor area commissioned for each building type, when in actuality EUIs can vary significantly depending on the building. Furthermore, these median EUIs were taken from a single building use type that best matched the building categories, whereas some of the categories included in the analysis spanned a variety of specific building types with differing individual EUIs. The EUIs selected were also source, rather than site, to better understand the overall impact of commissioning. However, site EUIs could have been utilized instead to better understand the energy savings strictly in terms of billed building energy consumption. In total, the calculated energy savings should be viewed as an approximation of the relative scale of sample-wide savings rather than a single detailed value. The same applies to the other final calculations contained in the study, such as revenue, cost savings, and total floor area commissioned.

6. CONCLUSIONS

6.1 Summary of Project Findings

In summary, this thesis has aimed to combine revenue estimates based on a selection of real commissioning providers, with values from comprehensive studies that represent typical commissioning characteristics in order to better understand the implementation and impact of existing building commissioning within the selection of providers.

The calculations performed in this study have successfully generated approximate values that can be useful in understanding the magnitude of the existing building commissioning impacts for the sample, as well as the larger building commissioning impacts. The most important calculated estimates for both existing building commissioning and general building commissioning can be seen below:

- Existing Building Commissioning
    - Total Estimated Annual Revenue: $270 million per year
    - Total Estimated Annual Floor Area Commissioned: 790 million ft^2 per year
    - Total Estimated Annual Cost Savings: $290 million per year
    - Total Estimated Annual Energy Savings: 22 billion kBtu per year
- Total Building Commissioning (EBCx and NCCx)
    - Total Estimated Annual Revenue: $1.8 billion per year
    - Total Estimated Annual Floor Area Commissioned: 2.0 billion ft^2 per year
    - Total Estimated Annual Cost Savings: $540 million per year
    - Total Estimated Annual Energy Savings: 50 billion kBtu per year

These values are underestimates of the true implementation and impact of the U.S. commissioning market, but adequately approximate the scale of revenue and savings within the sample. The values suggest a sizeable impact from the selection of commissioning firms in terms of general scale, however further updating and refining the methodology, particularly with regard to the commissioning constants, revenue percentages, and included providers may lead to improved results.

6.2 Future Research Considerations

The work completed in this thesis project can be expanded and refined in numerous ways to provide additional value as well as improved levels of confidence with regard to the final estimates. As noted in the previous section, the percentage values for commissioning revenue, existing building commissioning revenue, and new construction commissioning revenue had to be approximated and applied broadly to the selection of companies included in the study. To better represent the distribution of revenue throughout the selection of companies, individual surveyed data could be applied to each company, which would more accurately reflect overall revenue and improve the subsequent calculations. Similarly, additional work could be conducted to better reflect the variability of costs and savings values between companies, building types, or regions. This approach may also provide more accurate results when performing calculations. To better understand the extent of commissioning beyond what was included in this thesis, additional surveying could be conducted to comprehensively quantify the number of commissioning firms operating in the United States and approximate the entire commissioning market, as this study only accounted for a selection of BCxA member companies. An additional area of interest regarding commissioning impacts is the avoided carbon emissions associated with EBCx and NCCx energy savings. This is an additional impact of building commissioning that would be valuable to quantify. Lastly, to evaluate the impact of existing building commissioning in terms of energy savings over time, savings degradation models could be applied to calculated annual energy savings to approximate cumulative energy savings over a given period of time.

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APPENDIX A

Annual Revenue Estimates by Company (Total, Cx, EBCx, NCCx)

Company, i	Company Size	ER_i	$\%Cx_i$	CxR_i	%EBCx	$EBCxR_i$	%NCCx	$NCCxR_i$
1	103	$ 15,000,000	1	$ 15,000,000	0.15	$ 2,250,000	0.85	$ 12,750,000
2	90	$ 14,000,000	1	$ 14,000,000	0.15	$ 2,100,000	0.85	$ 11,900,000
3	72	$ 13,000,000	1	$ 13,000,000	0.15	$ 1,950,000	0.85	$ 11,050,000
4	41	$ 11,000,000	1	$ 11,000,000	0.15	$ 1,650,000	0.85	$ 9,350,000
5	41	$ 6,900,000	1	$ 6,900,000	0.15	$ 1,035,000	0.85	$ 5,865,000
6	63	$ 6,300,000	1	$ 6,300,000	0.15	$ 945,000	0.85	$ 5,355,000
7	42	$ 5,000,000	1	$ 5,000,000	0.15	$ 750,000	0.85	$ 4,250,000
8	75	$ 4,900,000	1	$ 4,900,000	0.15	$ 735,000	0.85	$ 4,165,000
9	24	$ 4,600,000	1	$ 4,600,000	0.15	$ 690,000	0.85	$ 3,910,000
10	34	$ 4,300,000	1	$ 4,300,000	0.15	$ 645,000	0.85	$ 3,655,000
11	36	$ 3,800,000	1	$ 3,800,000	0.15	$ 570,000	0.85	$ 3,230,000
12	26	$ 3,500,000	1	$ 3,500,000	0.15	$ 525,000	0.85	$ 2,975,000
13	20	$ 3,200,000	1	$ 3,200,000	0.15	$ 480,000	0.85	$ 2,720,000
14	35	$ 3,000,000	1	$ 3,000,000	0.15	$ 450,000	0.85	$ 2,550,000
15	16	$ 3,000,000	1	$ 3,000,000	0.15	$ 450,000	0.85	$ 2,550,000
16	13	$ 2,800,000	1	$ 2,800,000	0.15	$ 420,000	0.85	$ 2,380,000
17	20	$ 2,700,000	1	$ 2,700,000	0.15	$ 405,000	0.85	$ 2,295,000
18	30	$ 2,600,000	1	$ 2,600,000	0.15	$ 390,000	0.85	$ 2,210,000
19	30	$ 2,600,000	1	$ 2,600,000	0.15	$ 390,000	0.85	$ 2,210,000
20	12	$ 2,400,000	1	$ 2,400,000	0.15	$ 360,000	0.85	$ 2,040,000
21	22	$ 2,300,000	1	$ 2,300,000	0.15	$ 345,000	0.85	$ 1,955,000
22	12	$ 2,300,000	1	$ 2,300,000	0.15	$ 345,000	0.85	$ 1,955,000
23	17	$ 2,300,000	1	$ 2,300,000	0.15	$ 345,000	0.85	$ 1,955,000
24	23	$ 2,100,000	1	$ 2,100,000	0.15	$ 315,000	0.85	$ 1,785,000
25	15	$ 1,700,000	1	$ 1,700,000	0.15	$ 255,000	0.85	$ 1,445,000
26	11	$ 1,700,000	1	$ 1,700,000	0.15	$ 255,000	0.85	$ 1,445,000
27	15	$ 1,500,000	1	$ 1,500,000	0.15	$ 225,000	0.85	$ 1,275,000
28	12	$ 1,500,000	1	$ 1,500,000	0.15	$ 225,000	0.85	$ 1,275,000
29	13	$ 1,500,000	1	$ 1,500,000	0.15	$ 225,000	0.85	$ 1,275,000
30	10	$ 1,400,000	1	$ 1,400,000	0.15	$ 210,000	0.85	$ 1,190,000
31	12	$ 1,300,000	1	$ 1,300,000	0.15	$ 195,000	0.85	$ 1,105,000
32	10	$ 1,300,000	1	$ 1,300,000	0.15	$ 195,000	0.85	$ 1,105,000
33	10	$ 1,300,000	1	$ 1,300,000	0.15	$ 195,000	0.85	$ 1,105,000
34	7	$ 1,200,000	1	$ 1,200,000	0.15	$ 180,000	0.85	$ 1,020,000
35	12	$ 1,000,000	1	$ 1,000,000	0.15	$ 150,000	0.85	$ 850,000
36	10	$ 1,000,000	1	$ 1,000,000	0.15	$ 150,000	0.85	$ 850,000
37	9	$ 1,000,000	1	$ 1,000,000	0.15	$ 150,000	0.85	$ 850,000
38	11	$ 950,000	1	$ 950,000	0.15	$ 142,500	0.85	$ 807,500
39	10	$ 860,000	1	$ 860,000	0.15	$ 129,000	0.85	$ 731,000
40	6	$ 770,000	1	$ 770,000	0.15	$ 115,500	0.85	$ 654,500
41	8	$ 670,000	1	$ 670,000	0.15	$ 100,500	0.85	$ 569,500
42	6	$ 650,000	1	$ 650,000	0.15	$ 97,500	0.85	$ 552,500
43	4	$ 620,000	1	$ 620,000	0.15	$ 93,000	0.85	$ 527,000
44	10	$ 610,000	1	$ 610,000	0.15	$ 91,500	0.85	$ 518,500
45	4	$ 590,000	1	$ 590,000	0.15	$ 88,500	0.85	$ 501,500
46	8	$ 550,000	1	$ 550,000	0.15	$ 82,500	0.85	$ 467,500
47	6	$ 530,000	1	$ 530,000	0.15	$ 79,500	0.85	$ 450,500
48	9	$ 510,000	1	$ 510,000	0.15	$ 76,500	0.85	$ 433,500
49	8	$ 500,000	1	$ 500,000	0.15	$ 75,000	0.85	$ 425,000
50	2	$ 400,000	1	$ 400,000	0.15	$ 60,000	0.85	$ 340,000
51	6	$ 360,000	1	$ 360,000	0.15	$ 54,000	0.85	$ 306,000
52	5	$ 310,000	1	$ 310,000	0.15	$ 46,500	0.85	$ 263,500
53	4	$ 300,000	1	$ 300,000	0.15	$ 45,000	0.85	$ 255,000

APPENDIX A CONT.

Company, i	Company Size	ER_i	$\%Cx_i$	CxR_i	%EBCx	$EBCxR_i$	%NCCx	$NCCxR_i$
54	3	$ 290,000	1	$ 290,000	0.15	$ 43,500	0.85	$ 246,500
55	6	$ 270,000	1	$ 270,000	0.15	$ 40,500	0.85	$ 229,500
56	3	$ 260,000	1	$ 260,000	0.15	$ 39,000	0.85	$ 221,000
57	4	$ 190,000	1	$ 190,000	0.15	$ 28,500	0.85	$ 161,500
58	2	$ 180,000	1	$ 180,000	0.15	$ 27,000	0.85	$ 153,000
59	2	$ 130,000	1	$ 130,000	0.15	$ 19,500	0.85	$ 110,500
60	2	$ 120,000	1	$ 120,000	0.15	$ 18,000	0.85	$ 102,000
61	4	$ 110,000	1	$ 110,000	0.15	$ 16,500	0.85	$ 93,500
62	1	$ 110,000	1	$ 110,000	0.15	$ 16,500	0.85	$ 93,500
63	1	$ 100,000	1	$ 100,000	0.15	$ 15,000	0.85	$ 85,000
64	2	$ 100,000	1	$ 100,000	0.15	$ 15,000	0.85	$ 85,000
65	1	$ 92,000	1	$ 92,000	0.15	$ 13,800	0.85	$ 78,200
66	2	$ 58,000	1	$ 58,000	0.15	$ 8,700	0.85	$ 49,300
67	1	$ 51,000	1	$ 51,000	0.15	$ 7,650	0.85	$ 43,350
68	363	$ 33,000,000	0.5	$ 16,500,000	0.15	$ 2,475,000	0.85	$ 14,025,000
69	145	$ 20,000,000	0.5	$ 10,000,000	0.15	$ 1,500,000	0.85	$ 8,500,000
70	135	$ 20,000,000	0.5	$ 10,000,000	0.15	$ 1,500,000	0.85	$ 8,500,000
71	225	$ 46,000,000	0.5	$ 23,000,000	0.15	$ 3,450,000	0.85	$ 19,550,000
72	130	$ 38,000,000	0.5	$ 19,000,000	0.15	$ 2,850,000	0.85	$ 16,150,000
73	350	$ 38,000,000	0.5	$ 19,000,000	0.15	$ 2,850,000	0.85	$ 16,150,000
74	195	$ 35,000,000	0.5	$ 17,500,000	0.15	$ 2,625,000	0.85	$ 14,875,000
75	220	$ 35,000,000	0.5	$ 17,500,000	0.15	$ 2,625,000	0.85	$ 14,875,000
76	170	$ 32,000,000	0.5	$ 16,000,000	0.15	$ 2,400,000	0.85	$ 13,600,000
77	180	$ 31,000,000	0.5	$ 15,500,000	0.15	$ 2,325,000	0.85	$ 13,175,000
78	400	$ 29,000,000	0.5	$ 14,500,000	0.15	$ 2,175,000	0.85	$ 12,325,000
79	365	$ 28,000,000	0.5	$ 14,000,000	0.15	$ 2,100,000	0.85	$ 11,900,000
80	114	$ 26,000,000	0.5	$ 13,000,000	0.15	$ 1,950,000	0.85	$ 11,050,000
81	180	$ 25,000,000	0.5	$ 12,500,000	0.15	$ 1,875,000	0.85	$ 10,625,000
82	200	$ 22,000,000	0.5	$ 11,000,000	0.15	$ 1,650,000	0.85	$ 9,350,000
83	300	$ 21,000,000	0.5	$ 10,500,000	0.15	$ 1,575,000	0.85	$ 8,925,000
84	172	$ 21,000,000	0.5	$ 10,500,000	0.15	$ 1,575,000	0.85	$ 8,925,000
85	190	$ 20,000,000	0.5	$ 10,000,000	0.15	$ 1,500,000	0.85	$ 8,500,000
86	75	$ 18,000,000	0.5	$ 9,000,000	0.15	$ 1,350,000	0.85	$ 7,650,000
87	98	$ 17,000,000	0.5	$ 8,500,000	0.15	$ 1,275,000	0.85	$ 7,225,000
88	100	$ 15,000,000	0.5	$ 7,500,000	0.15	$ 1,125,000	0.85	$ 6,375,000
89	96	$ 13,000,000	0.5	$ 6,500,000	0.15	$ 975,000	0.85	$ 5,525,000
90	48	$ 12,000,000	0.5	$ 6,000,000	0.15	$ 900,000	0.85	$ 5,100,000
91	59	$ 12,000,000	0.5	$ 6,000,000	0.15	$ 900,000	0.85	$ 5,100,000
92	150	$ 12,000,000	0.5	$ 6,000,000	0.15	$ 900,000	0.85	$ 5,100,000
93	60	$ 11,000,000	0.5	$ 5,500,000	0.15	$ 825,000	0.85	$ 4,675,000
94	87	$ 11,000,000	0.5	$ 5,500,000	0.15	$ 825,000	0.85	$ 4,675,000
95	86	$ 11,000,000	0.5	$ 5,500,000	0.15	$ 825,000	0.85	$ 4,675,000
96	85	$ 11,000,000	0.5	$ 5,500,000	0.15	$ 825,000	0.85	$ 4,675,000
97	86	$ 10,000,000	0.5	$ 5,000,000	0.15	$ 750,000	0.85	$ 4,250,000
98	34	$ 9,100,000	0.5	$ 4,550,000	0.15	$ 682,500	0.85	$ 3,867,500
99	85	$ 8,700,000	0.5	$ 4,350,000	0.15	$ 652,500	0.85	$ 3,697,500
100	70	$ 8,400,000	0.5	$ 4,200,000	0.15	$ 630,000	0.85	$ 3,570,000
101	74	$ 8,200,000	0.5	$ 4,100,000	0.15	$ 615,000	0.85	$ 3,485,000
102	72	$ 8,100,000	0.5	$ 4,050,000	0.15	$ 607,500	0.85	$ 3,442,500
103	125	$ 7,500,000	0.5	$ 3,750,000	0.15	$ 562,500	0.85	$ 3,187,500
104	34.5	$ 7,500,000	0.5	$ 3,750,000	0.15	$ 562,500	0.85	$ 3,187,500
105	65	$ 7,300,000	0.5	$ 3,650,000	0.15	$ 547,500	0.85	$ 3,102,500
106	63	$ 7,100,000	0.5	$ 3,550,000	0.15	$ 532,500	0.85	$ 3,017,500
107	70	$ 7,000,000	0.5	$ 3,500,000	0.15	$ 525,000	0.85	$ 2,975,000
108	60	$ 6,900,000	0.5	$ 3,450,000	0.15	$ 517,500	0.85	$ 2,932,500

APPENDIX A CONT.

Company, i	Company Size	ER_i	$\%Cx_i$	CxR_i	%EBCx	$EBCxR_i$	%NCCx	$NCCxR_i$
109	50	$ 6,900,000	0.5	$ 3,450,000	0.15	$ 517,500	0.85	$ 2,932,500
110	45	$ 6,100,000	0.5	$ 3,050,000	0.15	$ 457,500	0.85	$ 2,592,500
111	38	$ 6,100,000	0.5	$ 3,050,000	0.15	$ 457,500	0.85	$ 2,592,500
112	43	$ 5,700,000	0.5	$ 2,850,000	0.15	$ 427,500	0.85	$ 2,422,500
113	25	$ 5,000,000	0.5	$ 2,500,000	0.15	$ 375,000	0.85	$ 2,125,000
114	10	$ 4,800,000	0.5	$ 2,400,000	0.15	$ 360,000	0.85	$ 2,040,000
115	40	$ 4,700,000	0.5	$ 2,350,000	0.15	$ 352,500	0.85	$ 1,997,500
116	42	$ 4,600,000	0.5	$ 2,300,000	0.15	$ 345,000	0.85	$ 1,955,000
117	14.5	$ 3,800,000	0.5	$ 1,900,000	0.15	$ 285,000	0.85	$ 1,615,000
118	40	$ 3,600,000	0.5	$ 1,800,000	0.15	$ 270,000	0.85	$ 1,530,000
119	25	$ 3,600,000	0.5	$ 1,800,000	0.15	$ 270,000	0.85	$ 1,530,000
120	50	$ 3,600,000	0.5	$ 1,800,000	0.15	$ 270,000	0.85	$ 1,530,000
121	24	$ 2,900,000	0.5	$ 1,450,000	0.15	$ 217,500	0.85	$ 1,232,500
122	23	$ 2,800,000	0.5	$ 1,400,000	0.15	$ 210,000	0.85	$ 1,190,000
123	12	$ 2,200,000	0.5	$ 1,100,000	0.15	$ 165,000	0.85	$ 935,000
124	25	$ 2,100,000	0.5	$ 1,050,000	0.15	$ 157,500	0.85	$ 892,500
125	20	$ 2,100,000	0.5	$ 1,050,000	0.15	$ 157,500	0.85	$ 892,500
126	10	$ 2,000,000	0.5	$ 1,000,000	0.15	$ 150,000	0.85	$ 850,000
127	8	$ 1,200,000	0.5	$ 600,000	0.15	$ 90,000	0.85	$ 510,000
128	10	$ 1,100,000	0.5	$ 550,000	0.15	$ 82,500	0.85	$ 467,500
129	8	$ 1,100,000	0.5	$ 550,000	0.15	$ 82,500	0.85	$ 467,500
130	2	$ 820,000	0.5	$ 410,000	0.15	$ 61,500	0.85	$ 348,500
131	5	$ 660,000	0.5	$ 330,000	0.15	$ 49,500	0.85	$ 280,500
132	5	$ 290,000	0.5	$ 145,000	0.15	$ 21,750	0.85	$ 123,250
133	2	$ 160,000	0.5	$ 80,000	0.15	$ 12,000	0.85	$ 68,000
134	2	$ 98,000	0.5	$ 49,000	0.15	$ 7,350	0.85	$ 41,650
135	716	$ 380,000,000	0.4	$ 152,000,000	0.15	$ 22,800,000	0.85	$ 129,200,000
136	90	$ 40,000,000	0.4	$ 16,000,000	0.15	$ 2,400,000	0.85	$ 13,600,000
137	340	$ 37,000,000	0.4	$ 14,800,000	0.15	$ 2,220,000	0.85	$ 12,580,000
138	96	$ 9,800,000	0.4	$ 3,920,000	0.15	$ 588,000	0.85	$ 3,332,000
139	75	$ 7,500,000	0.4	$ 3,000,000	0.15	$ 450,000	0.85	$ 2,550,000
140	52	$ 5,600,000	0.4	$ 2,240,000	0.15	$ 336,000	0.85	$ 1,904,000
141	250	$ 5,000,000	0.4	$ 2,000,000	0.15	$ 300,000	0.85	$ 1,700,000
142	32	$ 3,800,000	0.4	$ 1,520,000	0.15	$ 228,000	0.85	$ 1,292,000
143	30	$ 3,100,000	0.4	$ 1,240,000	0.15	$ 186,000	0.85	$ 1,054,000
144	430	$ 63,000,000	0.2	$ 12,600,000	0.15	$ 1,890,000	0.85	$ 10,710,000
145	308	$ 53,000,000	0.2	$ 10,600,000	0.15	$ 1,590,000	0.85	$ 9,010,000
146	160	$ 35,000,000	0.2	$ 7,000,000	0.15	$ 1,050,000	0.85	$ 5,950,000
147	170	$ 23,000,000	0.2	$ 4,600,000	0.15	$ 690,000	0.85	$ 3,910,000
148	157	$ 22,000,000	0.2	$ 4,400,000	0.15	$ 660,000	0.85	$ 3,740,000
149	55	$ 18,000,000	0.2	$ 3,600,000	0.15	$ 540,000	0.85	$ 3,060,000
150	100	$ 15,300,000	0.2	$ 3,060,000	0.15	$ 459,000	0.85	$ 2,601,000
151	80	$ 11,000,000	0.2	$ 2,200,000	0.15	$ 330,000	0.85	$ 1,870,000
152	82	$ 9,800,000	0.2	$ 1,960,000	0.15	$ 294,000	0.85	$ 1,666,000
153	80	$ 8,900,000	0.2	$ 1,780,000	0.15	$ 267,000	0.85	$ 1,513,000
154	11	$ 1,300,000	0.2	$ 260,000	0.15	$ 39,000	0.85	$ 221,000
155	8	$ 500,000	0.2	$ 100,000	0.15	$ 15,000	0.85	$ 85,000
156	6	$ 73,000	0.2	$ 14,600	0.15	$	0.85	$ 12,410
157	49400	$ 12,000,000,000	0.05	$ 600,000,000	0.15	$ 90,000,000	0.85	$ 510,000,000
158	9852	$ 1,900,000,000	0.05	$ 95,000,000	0.15	$ 14,250,000	0.85	$ 80,750,000
159	6111	$ 1,400,000,000	0.05	$ 70,000,000	0.15	$ 10,500,000	0.85	$ 59,500,000
160	6200	$ 760,000,000	0.05	$ 38,000,000	0.15	$ 5,700,000	0.85	$ 32,300,000
161	1800	$ 350,000,000	0.05	$ 17,500,000	0.15	$ 2,625,000	0.85	$ 14,875,000
162	800	$ 220,000,000	0.05	$ 11,000,000	0.15	$ 1,650,000	0.85	$ 9,350,000
163	700	$ 180,000,000	0.05	$ 9,000,000	0.15	$ 1,350,000	0.85	$ 7,650,000

APPENDIX A CONT.

Company, i	Company Size	ER_i	$\%Cx_i$	CxR_i	%EBCx	$EBCxR_i$	%NCCx	$NCCxR_i$
164	2000	$ 170,000,000	0.05	$ 8,500,000	0.15	$ 1,275,000	0.85	$ 7,225,000
165	860	$ 150,000,000	0.05	$ 7,500,000	0.15	$ 1,125,000	0.85	$ 6,375,000
166	946	$ 120,000,000	0.05	$ 6,000,000	0.15	$ 900,000	0.85	$ 5,100,000
167	1056	$ 110,000,000	0.05	$ 5,500,000	0.15	$ 825,000	0.85	$ 4,675,000
168	425	$ 100,000,000	0.05	$ 5,000,000	0.15	$ 750,000	0.85	$ 4,250,000
169	420	$ 70,000,000	0.05	$ 3,500,000	0.15	$ 525,000	0.85	$ 2,975,000
170	350	$ 71,000,000	0.05	$ 3,550,000	0.15	$ 532,500	0.85	$ 3,017,500
171	650	$ 54,000,000	0.05	$ 2,700,000	0.15	$ 405,000	0.85	$ 2,295,000
172	330	$ 53,000,000	0.05	$ 2,650,000	0.15	$ 397,500	0.85	$ 2,252,500
173	269	$ 43,000,000	0.05	$ 2,150,000	0.15	$ 322,500	0.85	$ 1,827,500
174	270	$ 41,000,000	0.05	$ 2,050,000	0.15	$ 307,500	0.85	$ 1,742,500
175	164	$ 28,000,000	0.05	$ 1,400,000	0.15	$ 210,000	0.85	$ 1,190,000
176	195	$ 28,000,000	0.05	$ 1,400,000	0.15	$ 210,000	0.85	$ 1,190,000
177	189	$ 23,000,000	0.05	$ 1,150,000	0.15	$ 172,500	0.85	$ 977,500
178	1000	$ 21,000,000	0.05	$ 1,050,000	0.15	$ 157,500	0.85	$ 892,500
179	96	$ 13,000,000	0.05	$ 650,000	0.15	$ 97,500	0.85	$ 552,500
180	70	$ 7,000,000	0.05	$ 350,000	0.15	$ 52,500	0.85	$ 297,500
181	35	$ 6,500,000	0.05	$ 325,000	0.15	$ 48,750	0.85	$ 276,250
182	58	$ 5,900,000	0.05	$ 295,000	0.15	$ 44,250	0.85	$ 250,750
183	12	$ 1,300,000	0.05	$ 65,000	0.15	$ 9,750	0.85	$ 55,250
184	10	$ 1,300,000	0.05	$ 65,000	0.15	$ 9,750	0.85	$ 55,250
185	12	$ 1,200,000	0.05	$ 60,000	0.15	$ 9,000	0.85	$ 51,000
186	10	$ 950,000	0.05	$ 47,500	0.15	$ 7,125	0.85	$ 40,375
187	6	$ 840,000	0.05	$ 42,000	0.15	$ 6,300	0.85	$ 35,700
188	2700	$ 3,200,000,000	0.02	$ 64,000,000	0.15	$ 9,600,000	0.85	$ 54,400,000
189	2080	$ 2,200,000,000	0.02	$ 44,000,000	0.15	$ 6,600,000	0.85	$ 37,400,000
190	705	$ 76,000,000	0.02	$ 1,520,000	0.15	$ 228,000	0.85	$ 1,292,000
191	206	$ 53,000,000	0.02	$ 1,060,000	0.15	$ 159,000	0.85	$ 901,000
192	388	$ 35,000,000	0.02	$ 700,000	0.15	$ 105,000	0.85	$ 595,000
193	515	$ 29,000,000	0.02	$ 580,000	0.15	$ 87,000	0.85	$ 493,000
194	157	$ 22,000,000	0.02	$ 440,000	0.15	$ 66,000	0.85	$ 374,000
195	99	$ 6,100,000	0.02	$ 122,000	0.15	$ 18,300	0.85	$ 103,700
196	57	$ 4,600,000	0.02	$ 92,000	0.15	$ 13,800	0.85	$ 78,200
197	25	$ 2,500,000	0.02	$ 50,000	0.15	$ 7,500	0.85	$ 42,500
198	3	$ 410,000	0.02	$ 8,200	0.15	$ 1,230	0.85	$ 6,970

ER_i: estimated annual revenue for each i company, $/year;
$\%Cx_i$: estimated percent of annual revenue from commissioning for each i company, %;
CxR_i: estimated annual commissioning revenue for each i company, $/year;
%EBCx: assumed percent of commissioning revenue from existing building commissioning, %;
$EBCxR_i$: estimated annual existing building commissioning revenue for each i company, $/year;
%NCCx: assumed percent of commissioning revenue from new construction commissioning, %
$NCCxR_i$: estimated annual new construction commissioning revenue for each i company, $/year;

APPENDIX B

EBCx Estimates by Company (Commissioned Floor Area, Cost Savings, Energy Savings)

Company, i	CxR_i	%EBCx	$EBCxR_i$	$GFA_{EBCx,i}$	$TCS_{EBCx,i}$ (SPB)	$TCS_{EBCx,i}$ (CxS)	$TES_{EBCx,i}$
1	$ 15,000,000	0.15	$ 2,250,000	6,428,571	$ 2,500,000	$ 2,185,714	182,287,142
2	$ 14,000,000	0.15	$ 2,100,000	6,000,000	$ 2,333,333	$ 2,040,000	170,134,666
3	$ 13,000,000	0.15	$ 1,950,000	5,571,429	$ 2,166,667	$ 1,894,286	157,982,189
4	$ 11,000,000	0.15	$ 1,650,000	4,714,286	$ 1,833,333	$ 1,602,857	133,677,237
5	$ 6,900,000	0.15	$ 1,035,000	2,957,143	$ 1,150,000	$ 1,005,429	83,852,085
6	$ 6,300,000	0.15	$ 945,000	2,700,000	$ 1,050,000	$ 918,000	76,560,600
7	$ 5,000,000	0.15	$ 750,000	2,142,857	$ 833,333	$ 728,571	60,762,381
8	$ 4,900,000	0.15	$ 735,000	2,100,000	$ 816,667	$ 714,000	59,547,133
9	$ 4,600,000	0.15	$ 690,000	1,971,429	$ 766,667	$ 670,286	55,901,390
10	$ 4,300,000	0.15	$ 645,000	1,842,857	$ 716,667	$ 626,571	52,255,647
11	$ 3,800,000	0.15	$ 570,000	1,628,571	$ 633,333	$ 553,714	46,179,409
12	$ 3,500,000	0.15	$ 525,000	1,500,000	$ 583,333	$ 510,000	42,533,666
13	$ 3,200,000	0.15	$ 480,000	1,371,429	$ 533,333	$ 466,286	38,887,924
14	$ 3,000,000	0.15	$ 450,000	1,285,714	$ 500,000	$ 437,143	36,457,428
15	$ 3,000,000	0.15	$ 450,000	1,285,714	$ 500,000	$ 437,143	36,457,428
16	$ 2,800,000	0.15	$ 420,000	1,200,000	$ 466,667	$ 408,000	34,026,933
17	$ 2,700,000	0.15	$ 405,000	1,157,143	$ 450,000	$ 393,429	32,811,686
18	$ 2,600,000	0.15	$ 390,000	1,114,286	$ 433,333	$ 378,857	31,596,438
19	$ 2,600,000	0.15	$ 390,000	1,114,286	$ 433,333	$ 378,857	31,596,438
20	$ 2,400,000	0.15	$ 360,000	1,028,571	$ 400,000	$ 349,714	29,165,943
21	$ 2,300,000	0.15	$ 345,000	985,714	$ 383,333	$ 335,143	27,950,695
22	$ 2,300,000	0.15	$ 345,000	985,714	$ 383,333	$ 335,143	27,950,695
23	$ 2,300,000	0.15	$ 345,000	985,714	$ 383,333	$ 335,143	27,950,695
24	$ 2,100,000	0.15	$ 315,000	900,000	$ 350,000	$ 306,000	25,520,200
25	$ 1,700,000	0.15	$ 255,000	728,571	$ 283,333	$ 247,714	20,659,209
26	$ 1,700,000	0.15	$ 255,000	728,571	$ 283,333	$ 247,714	20,659,209
27	$ 1,500,000	0.15	$ 225,000	642,857	$ 250,000	$ 218,571	18,228,714
28	$ 1,500,000	0.15	$ 225,000	642,857	$ 250,000	$ 218,571	18,228,714
29	$ 1,500,000	0.15	$ 225,000	642,857	$ 250,000	$ 218,571	18,228,714
30	$ 1,400,000	0.15	$ 210,000	600,000	$ 233,333	$ 204,000	17,013,467
31	$ 1,300,000	0.15	$ 195,000	557,143	$ 216,667	$ 189,429	15,798,219
32	$ 1,300,000	0.15	$ 195,000	557,143	$ 216,667	$ 189,429	15,798,219
33	$ 1,300,000	0.15	$ 195,000	557,143	$ 216,667	$ 189,429	15,798,219
34	$ 1,200,000	0.15	$ 180,000	514,286	$ 200,000	$ 174,857	14,582,971
35	$ 1,000,000	0.15	$ 150,000	428,571	$ 166,667	$ 145,714	12,152,476
36	$ 1,000,000	0.15	$ 150,000	428,571	$ 166,667	$ 145,714	12,152,476
37	$ 1,000,000	0.15	$ 150,000	428,571	$ 166,667	$ 145,714	12,152,476
38	$ 950,000	0.15	$ 142,500	407,143	$ 158,333	$ 138,429	11,544,852
39	$ 860,000	0.15	$ 129,000	368,571	$ 143,333	$ 125,314	10,451,129
40	$ 770,000	0.15	$ 115,500	330,000	$ 128,333	$ 112,200	9,357,407
41	$ 670,000	0.15	$ 100,500	287,143	$ 111,667	$ 97,629	8,142,159
42	$ 650,000	0.15	$ 97,500	278,571	$ 108,333	$ 94,714	7,899,109
43	$ 620,000	0.15	$ 93,000	265,714	$ 103,333	$ 90,343	7,534,535
44	$ 610,000	0.15	$ 91,500	261,429	$ 101,667	$ 88,886	7,413,010
45	$ 590,000	0.15	$ 88,500	252,857	$ 98,333	$ 85,971	7,169,961
46	$ 550,000	0.15	$ 82,500	235,714	$ 91,667	$ 80,143	6,683,862
47	$ 530,000	0.15	$ 79,500	227,143	$ 88,333	$ 77,229	6,440,812
48	$ 510,000	0.15	$ 76,500	218,571	$ 85,000	$ 74,314	6,197,763
49	$ 500,000	0.15	$ 75,000	214,286	$ 83,333	$ 72,857	6,076,238
50	$ 400,000	0.15	$ 60,000	171,429	$ 66,667	$ 58,286	4,860,990
51	$ 360,000	0.15	$ 54,000	154,286	$ 60,000	$ 52,457	4,374,891
52	$ 310,000	0.15	$ 46,500	132,857	$ 51,667	$ 45,171	3,767,268

APPENDIX B. CONT

Company, i	CxR_i	%EBCx	$EBCxR_i$	$GFA_{EBCx,i}$	$TCS_{EBCx,i}$ (SPB)	$TCS_{EBCx,i}$ (CxS)	$TES_{EBCx,i}$
53	$ 300,000	0.15	$ 45,000	128,571	$ 50,000	$ 43,714	3,645,743
54	$ 290,000	0.15	$ 43,500	124,286	$ 48,333	$ 42,257	3,524,218
55	$ 270,000	0.15	$ 40,500	115,714	$ 45,000	$ 39,343	3,281,169
56	$ 260,000	0.15	$ 39,000	111,429	$ 43,333	$ 37,886	3,159,644
57	$ 190,000	0.15	$ 28,500	81,429	$ 31,667	$ 27,686	2,308,970
58	$ 180,000	0.15	$ 27,000	77,143	$ 30,000	$ 26,229	2,187,446
59	$ 130,000	0.15	$ 19,500	55,714	$ 21,667	$ 18,943	1,579,822
60	$ 120,000	0.15	$ 18,000	51,429	$ 20,000	$ 17,486	1,458,297
61	$ 110,000	0.15	$ 16,500	47,143	$ 18,333	$ 16,029	1,336,772
62	$ 110,000	0.15	$ 16,500	47,143	$ 18,333	$ 16,029	1,336,772
63	$ 100,000	0.15	$ 15,000	42,857	$ 16,667	$ 14,571	1,215,248
64	$ 100,000	0.15	$ 15,000	42,857	$ 16,667	$ 14,571	1,215,248
65	$ 92,000	0.15	$ 13,800	39,429	$ 15,333	$ 13,406	1,118,028
66	$ 58,000	0.15	$ 8,700	24,857	$ 9,667	$ 8,451	704,844
67	$ 51,000	0.15	$ 7,650	21,857	$ 8,500	$ 7,431	619,776
68	$ 16,500,000	0.15	$ 2,475,000	7,071,429	$ 2,750,000	$ 2,404,286	200,515,856
69	$ 10,000,000	0.15	$ 1,500,000	4,285,714	$ 1,666,667	$ 1,457,143	121,524,761
70	$ 10,000,000	0.15	$ 1,500,000	4,285,714	$ 1,666,667	$ 1,457,143	121,524,761
71	$ 23,000,000	0.15	$ 3,450,000	9,857,143	$ 3,833,333	$ 3,351,429	279,506,951
72	$ 19,000,000	0.15	$ 2,850,000	8,142,857	$ 3,166,667	$ 2,768,571	230,897,046
73	$ 19,000,000	0.15	$ 2,850,000	8,142,857	$ 3,166,667	$ 2,768,571	230,897,046
74	$ 17,500,000	0.15	$ 2,625,000	7,500,000	$ 2,916,667	$ 2,550,000	212,668,332
75	$ 17,500,000	0.15	$ 2,625,000	7,500,000	$ 2,916,667	$ 2,550,000	212,668,332
76	$ 16,000,000	0.15	$ 2,400,000	6,857,143	$ 2,666,667	$ 2,331,429	194,439,618
77	$ 15,500,000	0.15	$ 2,325,000	6,642,857	$ 2,583,333	$ 2,258,571	188,363,380
78	$ 14,500,000	0.15	$ 2,175,000	6,214,286	$ 2,416,667	$ 2,112,857	176,210,904
79	$ 14,000,000	0.15	$ 2,100,000	6,000,000	$ 2,333,333	$ 2,040,000	170,134,666
80	$ 13,000,000	0.15	$ 1,950,000	5,571,429	$ 2,166,667	$ 1,894,286	157,982,189
81	$ 12,500,000	0.15	$ 1,875,000	5,357,143	$ 2,083,333	$ 1,821,429	151,905,951
82	$ 11,000,000	0.15	$ 1,650,000	4,714,286	$ 1,833,333	$ 1,602,857	133,677,237
83	$ 10,500,000	0.15	$ 1,575,000	4,500,000	$ 1,750,000	$ 1,530,000	127,600,999
84	$ 10,500,000	0.15	$ 1,575,000	4,500,000	$ 1,750,000	$ 1,530,000	127,600,999
85	$ 10,000,000	0.15	$ 1,500,000	4,285,714	$ 1,666,667	$ 1,457,143	121,524,761
86	$ 9,000,000	0.15	$ 1,350,000	3,857,143	$ 1,500,000	$ 1,311,429	109,372,285
87	$ 8,500,000	0.15	$ 1,275,000	3,642,857	$ 1,416,667	$ 1,238,571	103,296,047
88	$ 7,500,000	0.15	$ 1,125,000	3,214,286	$ 1,250,000	$ 1,092,857	91,143,571
89	$ 6,500,000	0.15	$ 975,000	2,785,714	$ 1,083,333	$ 947,143	78,991,095
90	$ 6,000,000	0.15	$ 900,000	2,571,429	$ 1,000,000	$ 874,286	72,914,857
91	$ 6,000,000	0.15	$ 900,000	2,571,429	$ 1,000,000	$ 874,286	72,914,857
92	$ 6,000,000	0.15	$ 900,000	2,571,429	$ 1,000,000	$ 874,286	72,914,857
93	$ 5,500,000	0.15	$ 825,000	2,357,143	$ 916,667	$ 801,429	66,838,619
94	$ 5,500,000	0.15	$ 825,000	2,357,143	$ 916,667	$ 801,429	66,838,619
95	$ 5,500,000	0.15	$ 825,000	2,357,143	$ 916,667	$ 801,429	66,838,619
96	$ 5,500,000	0.15	$ 825,000	2,357,143	$ 916,667	$ 801,429	66,838,619
97	$ 5,000,000	0.15	$ 750,000	2,142,857	$ 833,333	$ 728,571	60,762,381
98	$ 4,550,000	0.15	$ 682,500	1,950,000	$ 758,333	$ 663,000	55,293,766
99	$ 4,350,000	0.15	$ 652,500	1,864,286	$ 725,000	$ 633,857	52,863,271
100	$ 4,200,000	0.15	$ 630,000	1,800,000	$ 700,000	$ 612,000	51,040,400
101	$ 4,100,000	0.15	$ 615,000	1,757,143	$ 683,333	$ 597,429	49,825,152
102	$ 4,050,000	0.15	$ 607,500	1,735,714	$ 675,000	$ 590,143	49,217,528
103	$ 3,750,000	0.15	$ 562,500	1,607,143	$ 625,000	$ 546,429	45,571,785
104	$ 3,750,000	0.15	$ 562,500	1,607,143	$ 625,000	$ 546,429	45,571,785
105	$ 3,650,000	0.15	$ 547,500	1,564,286	$ 608,333	$ 531,857	44,356,538
106	$ 3,550,000	0.15	$ 532,500	1,521,429	$ 591,667	$ 517,286	43,141,290

APPENDIX B CONT.

Company, i	CxR_i	%EBCx	$EBCxR_i$	$GFA_{EBCx,i}$	$TCS_{EBCx,i}$ (SPB)	$TCS_{EBCx,i}$ (CxS)	$TES_{EBCx,i}$
107	$ 3,500,000	0.15	$ 525,000	1,500,000	$ 583,333	$ 510,000	42,533,666
108	$ 3,450,000	0.15	$ 517,500	1,478,571	$ 575,000	$ 502,714	41,926,043
109	$ 3,450,000	0.15	$ 517,500	1,478,571	$ 575,000	$ 502,714	41,926,043
110	$ 3,050,000	0.15	$ 457,500	1,307,143	$ 508,333	$ 444,429	37,065,052
111	$ 3,050,000	0.15	$ 457,500	1,307,143	$ 508,333	$ 444,429	37,065,052
112	$ 2,850,000	0.15	$ 427,500	1,221,429	$ 475,000	$ 415,286	34,634,557
113	$ 2,500,000	0.15	$ 375,000	1,071,429	$ 416,667	$ 364,286	30,381,190
114	$ 2,400,000	0.15	$ 360,000	1,028,571	$ 400,000	$ 349,714	29,165,943
115	$ 2,350,000	0.15	$ 352,500	1,007,143	$ 391,667	$ 342,429	28,558,319
116	$ 2,300,000	0.15	$ 345,000	985,714	$ 383,333	$ 335,143	27,950,695
117	$ 1,900,000	0.15	$ 285,000	814,286	$ 316,667	$ 276,857	23,089,705
118	$ 1,800,000	0.15	$ 270,000	771,429	$ 300,000	$ 262,286	21,874,457
119	$ 1,800,000	0.15	$ 270,000	771,429	$ 300,000	$ 262,286	21,874,457
120	$ 1,800,000	0.15	$ 270,000	771,429	$ 300,000	$ 262,286	21,874,457
121	$ 1,450,000	0.15	$ 217,500	621,429	$ 241,667	$ 211,286	17,621,090
122	$ 1,400,000	0.15	$ 210,000	600,000	$ 233,333	$ 204,000	17,013,467
123	$ 1,100,000	0.15	$ 165,000	471,429	$ 183,333	$ 160,286	13,367,724
124	$ 1,050,000	0.15	$ 157,500	450,000	$ 175,000	$ 153,000	12,760,100
125	$ 1,050,000	0.15	$ 157,500	450,000	$ 175,000	$ 153,000	12,760,100
126	$ 1,000,000	0.15	$ 150,000	428,571	$ 166,667	$ 145,714	12,152,476
127	$ 600,000	0.15	$ 90,000	257,143	$ 100,000	$ 87,429	7,291,486
128	$ 550,000	0.15	$ 82,500	235,714	$ 91,667	$ 80,143	6,683,862
129	$ 550,000	0.15	$ 82,500	235,714	$ 91,667	$ 80,143	6,683,862
130	$ 410,000	0.15	$ 61,500	175,714	$ 68,333	$ 59,743	4,982,515
131	$ 330,000	0.15	$ 49,500	141,429	$ 55,000	$ 48,086	4,010,317
132	$ 145,000	0.15	$ 21,750	62,143	$ 24,167	$ 21,129	1,762,109
133	$ 80,000	0.15	$ 12,000	34,286	$ 13,333	$ 11,657	972,198
134	$ 49,000	0.15	$ 7,350	21,000	$ 8,167	$ 7,140	595,471
135	$ 152,000,000	0.15	$ 22,800,000	65,142,857	$ 25,333,333	$ 22,148,571	1,847,176,369
136	$ 16,000,000	0.15	$ 2,400,000	6,857,143	$ 2,666,667	$ 2,331,429	194,439,618
137	$ 14,800,000	0.15	$ 2,220,000	6,342,857	$ 2,466,667	$ 2,156,571	179,856,646
138	$ 3,920,000	0.15	$ 588,000	1,680,000	$ 653,333	$ 571,200	47,637,706
139	$ 3,000,000	0.15	$ 450,000	1,285,714	$ 500,000	$ 437,143	36,457,428
140	$ 2,240,000	0.15	$ 336,000	960,000	$ 373,333	$ 326,400	27,221,546
141	$ 2,000,000	0.15	$ 300,000	857,143	$ 333,333	$ 291,429	24,304,952
142	$ 1,520,000	0.15	$ 228,000	651,429	$ 253,333	$ 221,486	18,471,764
143	$ 1,240,000	0.15	$ 186,000	531,429	$ 206,667	$ 180,686	15,069,070
144	$ 12,600,000	0.15	$ 1,890,000	5,400,000	$ 2,100,000	$ 1,836,000	153,121,199
145	$ 10,600,000	0.15	$ 1,590,000	4,542,857	$ 1,766,667	$ 1,544,571	128,816,247
146	$ 7,000,000	0.15	$ 1,050,000	3,000,000	$ 1,166,667	$ 1,020,000	85,067,333
147	$ 4,600,000	0.15	$ 690,000	1,971,429	$ 766,667	$ 670,286	55,901,390
148	$ 4,400,000	0.15	$ 660,000	1,885,714	$ 733,333	$ 641,143	53,470,895
149	$ 3,600,000	0.15	$ 540,000	1,542,857	$ 600,000	$ 524,571	43,748,914
150	$ 3,060,000	0.15	$ 459,000	1,311,429	$ 510,000	$ 445,886	37,186,577
151	$ 2,200,000	0.15	$ 330,000	942,857	$ 366,667	$ 320,571	26,735,447
152	$ 1,960,000	0.15	$ 294,000	840,000	$ 326,667	$ 285,600	23,818,853
153	$ 1,780,000	0.15	$ 267,000	762,857	$ 296,667	$ 259,371	21,631,407
154	$ 260,000	0.15	$ 39,000	111,429	$ 43,333	$ 37,886	3,159,644
155	$ 100,000	0.15	$ 15,000	42,857	$ 16,667	$ 14,571	1,215,248
156	$ 14,600	0.15	$ 2,190	6,257	$ 2,433	$ 2,127	177,426
157	$ 600,000,000	0.15	$ 90,000,000	257,142,857	$ 100,000,000	$ 87,428,571	7,291,485,669
158	$ 95,000,000	0.15	$ 14,250,000	40,714,286	$ 15,833,333	$ 13,842,857	1,154,485,231
159	$ 70,000,000	0.15	$ 10,500,000	30,000,000	$ 11,666,667	$ 10,200,000	850,673,328
160	$ 38,000,000	0.15	$ 5,700,000	16,285,714	$ 6,333,333	$ 5,537,143	461,794,092

APPENDIX B CONT.

Company, i	CxR_i	%EBCx	$EBCxR_i$	$GFA_{EBCx,i}$	$TCS_{EBCx,i}$ (SPB)	$TCS_{EBCx,i}$ (CxS)	$TES_{EBCx,i}$
161	$ 17,500,000	0.15	$ 2,625,000	7,500,000	$ 2,916,667	$ 2,550,000	212,668,332
162	$ 11,000,000	0.15	$ 1,650,000	4,714,286	$ 1,833,333	$ 1,602,857	133,677,237
163	$ 9,000,000	0.15	$ 1,350,000	3,857,143	$ 1,500,000	$ 1,311,429	109,372,285
164	$ 8,500,000	0.15	$ 1,275,000	3,642,857	$ 1,416,667	$ 1,238,571	103,296,047
165	$ 7,500,000	0.15	$ 1,125,000	3,214,286	$ 1,250,000	$ 1,092,857	91,143,571
166	$ 6,000,000	0.15	$ 900,000	2,571,429	$ 1,000,000	$ 874,286	72,914,857
167	$ 5,500,000	0.15	$ 825,000	2,357,143	$ 916,667	$ 801,429	66,838,619
168	$ 5,000,000	0.15	$ 750,000	2,142,857	$ 833,333	$ 728,571	60,762,381
169	$ 3,500,000	0.15	$ 525,000	1,500,000	$ 583,333	$ 510,000	42,533,666
170	$ 3,550,000	0.15	$ 532,500	1,521,429	$ 591,667	$ 517,286	43,141,290
171	$ 2,700,000	0.15	$ 405,000	1,157,143	$ 450,000	$ 393,429	32,811,686
172	$ 2,650,000	0.15	$ 397,500	1,135,714	$ 441,667	$ 386,143	32,204,062
173	$ 2,150,000	0.15	$ 322,500	921,429	$ 358,333	$ 313,286	26,127,824
174	$ 2,050,000	0.15	$ 307,500	878,571	$ 341,667	$ 298,714	24,912,576
175	$ 1,400,000	0.15	$ 210,000	600,000	$ 233,333	$ 204,000	17,013,467
176	$ 1,400,000	0.15	$ 210,000	600,000	$ 233,333	$ 204,000	17,013,467
177	$ 1,150,000	0.15	$ 172,500	492,857	$ 191,667	$ 167,571	13,975,348
178	$ 1,050,000	0.15	$ 157,500	450,000	$ 175,000	$ 153,000	12,760,100
179	$ 650,000	0.15	$ 97,500	278,571	$ 108,333	$ 94,714	7,899,109
180	$ 350,000	0.15	$ 52,500	150,000	$ 58,333	$ 51,000	4,253,367
181	$ 325,000	0.15	$ 48,750	139,286	$ 54,167	$ 47,357	3,949,555
182	$ 295,000	0.15	$ 44,250	126,429	$ 49,167	$ 42,986	3,584,980
183	$ 65,000	0.15	$ 9,750	27,857	$ 10,833	$ 9,471	789,911
184	$ 65,000	0.15	$ 9,750	27,857	$ 10,833	$ 9,471	789,911
185	$ 60,000	0.15	$ 9,000	25,714	$ 10,000	$ 8,743	729,149
186	$ 47,500	0.15	$ 7,125	20,357	$ 7,917	$ 6,921	577,243
187	$ 42,000	0.15	$ 6,300	18,000	$ 7,000	$ 6,120	510,404
188	$ 64,000,000	0.15	$ 9,600,000	27,428,571	$ 10,666,667	$ 9,325,714	777,758,471
189	$ 44,000,000	0.15	$ 6,600,000	18,857,143	$ 7,333,333	$ 6,411,429	534,708,949
190	$ 1,520,000	0.15	$ 228,000	651,429	$ 253,333	$ 221,486	18,471,764
191	$ 1,060,000	0.15	$ 159,000	454,286	$ 176,667	$ 154,457	12,881,625
192	$ 700,000	0.15	$ 105,000	300,000	$ 116,667	$ 102,000	8,506,733
193	$ 580,000	0.15	$ 87,000	248,571	$ 96,667	$ 84,514	7,048,436
194	$ 440,000	0.15	$ 66,000	188,571	$ 73,333	$ 64,114	5,347,089
195	$ 122,000	0.15	$ 18,300	52,286	$ 20,333	$ 17,777	1,482,602
196	$ 92,000	0.15	$ 13,800	39,429	$ 15,333	$ 13,406	1,118,028
197	$ 50,000	0.15	$ 7,500	21,429	$ 8,333	$ 7,286	607,624
198	$ 8,200	0.15	$ 1,230	3,514	$ 1,367	$ 1,195	99,650

CxR_i: estimated annual commissioning revenue for each i company, $/year;
%EBCx: assumed percent of commissioning revenue from existing building commissioning, %;
$EBCxR_i$: estimated annual existing building commissioning revenue for each i company, $/year;
$GFA_{EBCx,i}$: estimated annual existing building floor area commissioned for each i company, ft^2/year;
$TCS_{EBCx,i}$ (SPB): estimated annual existing building commissioning cost savings for each i company, using simple payback method, $/year;
$TCS_{EBCx,i}$ (CxS): estimated annual existing building commissioning costs savings for each i company, using cost savings per unit area method, $/year;
$TES_{EBCx,i}$: estimated annual existing building commissioning energy savings for each i company kBtu/year;

APPENDIX C

NCCx Estimates by Company (Commissioned Floor Area, Cost Savings, Energy Savings)

Company, i	CxR_i	%NCCx	$NCCxR_i$	$GFA_{NCCx,i}$	$TCS_{NCCx,i}$ (SPB)	$TCS_{NCCx,i}$ (CxS)	$TES_{NCCx,i}$
1	$ 15,000,000	0.85	$ 12,750,000	9,807,692	$ 2,833,333	$ 1,373,077	225,266,069
2	$ 14,000,000	0.85	$ 11,900,000	9,153,846	$ 2,644,444	$ 1,281,538	210,248,331
3	$ 13,000,000	0.85	$ 11,050,000	8,500,000	$ 2,455,556	$ 1,190,000	195,230,593
4	$ 11,000,000	0.85	$ 9,350,000	7,192,308	$ 2,077,778	$ 1,006,923	165,195,117
5	$ 6,900,000	0.85	$ 5,865,000	4,511,538	$ 1,303,333	$ 631,615	103,622,392
6	$ 6,300,000	0.85	$ 5,355,000	4,119,231	$ 1,190,000	$ 576,692	94,611,749
7	$ 5,000,000	0.85	$ 4,250,000	3,269,231	$ 944,444	$ 457,692	75,088,690
8	$ 4,900,000	0.85	$ 4,165,000	3,203,846	$ 925,556	$ 448,538	73,586,916
9	$ 4,600,000	0.85	$ 3,910,000	3,007,692	$ 868,889	$ 421,077	69,081,595
10	$ 4,300,000	0.85	$ 3,655,000	2,811,538	$ 812,222	$ 393,615	64,576,273
11	$ 3,800,000	0.85	$ 3,230,000	2,484,615	$ 717,778	$ 347,846	57,067,404
12	$ 3,500,000	0.85	$ 2,975,000	2,288,462	$ 661,111	$ 320,385	52,562,083
13	$ 3,200,000	0.85	$ 2,720,000	2,092,308	$ 604,444	$ 292,923	48,056,761
14	$ 3,000,000	0.85	$ 2,550,000	1,961,538	$ 566,667	$ 274,615	45,053,214
15	$ 3,000,000	0.85	$ 2,550,000	1,961,538	$ 566,667	$ 274,615	45,053,214
16	$ 2,800,000	0.85	$ 2,380,000	1,830,769	$ 528,889	$ 256,308	42,049,666
17	$ 2,700,000	0.85	$ 2,295,000	1,765,385	$ 510,000	$ 247,154	40,547,892
18	$ 2,600,000	0.85	$ 2,210,000	1,700,000	$ 491,111	$ 238,000	39,046,119
19	$ 2,600,000	0.85	$ 2,210,000	1,700,000	$ 491,111	$ 238,000	39,046,119
20	$ 2,400,000	0.85	$ 2,040,000	1,569,231	$ 453,333	$ 219,692	36,042,571
21	$ 2,300,000	0.85	$ 1,955,000	1,503,846	$ 434,444	$ 210,538	34,540,797
22	$ 2,300,000	0.85	$ 1,955,000	1,503,846	$ 434,444	$ 210,538	34,540,797
23	$ 2,300,000	0.85	$ 1,955,000	1,503,846	$ 434,444	$ 210,538	34,540,797
24	$ 2,100,000	0.85	$ 1,785,000	1,373,077	$ 396,667	$ 192,231	31,537,250
25	$ 1,700,000	0.85	$ 1,445,000	1,111,538	$ 321,111	$ 155,615	25,530,155
26	$ 1,700,000	0.85	$ 1,445,000	1,111,538	$ 321,111	$ 155,615	25,530,155
27	$ 1,500,000	0.85	$ 1,275,000	980,769	$ 283,333	$ 137,308	22,526,607
28	$ 1,500,000	0.85	$ 1,275,000	980,769	$ 283,333	$ 137,308	22,526,607
29	$ 1,500,000	0.85	$ 1,275,000	980,769	$ 283,333	$ 137,308	22,526,607
30	$ 1,400,000	0.85	$ 1,190,000	915,385	$ 264,444	$ 128,154	21,024,833
31	$ 1,300,000	0.85	$ 1,105,000	850,000	$ 245,556	$ 119,000	19,523,059
32	$ 1,300,000	0.85	$ 1,105,000	850,000	$ 245,556	$ 119,000	19,523,059
33	$ 1,300,000	0.85	$ 1,105,000	850,000	$ 245,556	$ 119,000	19,523,059
34	$ 1,200,000	0.85	$ 1,020,000	784,615	$ 226,667	$ 109,846	18,021,286
35	$ 1,000,000	0.85	$ 850,000	653,846	$ 188,889	$ 91,538	15,017,738
36	$ 1,000,000	0.85	$ 850,000	653,846	$ 188,889	$ 91,538	15,017,738
37	$ 1,000,000	0.85	$ 850,000	653,846	$ 188,889	$ 91,538	15,017,738
38	$ 950,000	0.85	$ 807,500	621,154	$ 179,444	$ 86,962	14,266,851
39	$ 860,000	0.85	$ 731,000	562,308	$ 162,444	$ 78,723	12,915,255
40	$ 770,000	0.85	$ 654,500	503,462	$ 145,444	$ 70,485	11,563,658
41	$ 670,000	0.85	$ 569,500	438,077	$ 126,556	$ 61,331	10,061,884
42	$ 650,000	0.85	$ 552,500	425,000	$ 122,778	$ 59,500	9,761,530
43	$ 620,000	0.85	$ 527,000	405,385	$ 117,111	$ 56,754	9,310,998
44	$ 610,000	0.85	$ 518,500	398,846	$ 115,222	$ 55,838	9,160,820
45	$ 590,000	0.85	$ 501,500	385,769	$ 111,444	$ 54,008	8,860,465
46	$ 550,000	0.85	$ 467,500	359,615	$ 103,889	$ 50,346	8,259,756
47	$ 530,000	0.85	$ 450,500	346,538	$ 100,111	$ 48,515	7,959,401
48	$ 510,000	0.85	$ 433,500	333,462	$ 96,333	$ 46,685	7,659,046
49	$ 500,000	0.85	$ 425,000	326,923	$ 94,444	$ 45,769	7,508,869
50	$ 400,000	0.85	$ 340,000	261,538	$ 75,556	$ 36,615	6,007,095
51	$ 360,000	0.85	$ 306,000	235,385	$ 68,000	$ 32,954	5,406,386
52	$ 310,000	0.85	$ 263,500	202,692	$ 58,556	$ 28,377	4,655,499

APPENDIX C CONT.

Company, i	CxR_i	%NCCx	$NCCxR_i$	$GFA_{NCCx,i}$	$TCS_{NCCx,i}$ (SPB)	$TCS_{NCCx,i}$ (CxS)	$TES_{NCCx,i}$
53	$ 300,000	0.85	$ 255,000	196,154	$ 56,667	$ 27,462	4,505,321
54	$ 290,000	0.85	$ 246,500	189,615	$ 54,778	$ 26,546	4,355,144
55	$ 270,000	0.85	$ 229,500	176,538	$ 51,000	$ 24,715	4,054,789
56	$ 260,000	0.85	$ 221,000	170,000	$ 49,111	$ 23,800	3,904,612
57	$ 190,000	0.85	$ 161,500	124,231	$ 35,889	$ 17,392	2,853,370
58	$ 180,000	0.85	$ 153,000	117,692	$ 34,000	$ 16,477	2,703,193
59	$ 130,000	0.85	$ 110,500	85,000	$ 24,556	$ 11,900	1,952,306
60	$ 120,000	0.85	$ 102,000	78,462	$ 22,667	$ 10,985	1,802,129
61	$ 110,000	0.85	$ 93,500	71,923	$ 20,778	$ 10,069	1,651,951
62	$ 110,000	0.85	$ 93,500	71,923	$ 20,778	$ 10,069	1,651,951
63	$ 100,000	0.85	$ 85,000	65,385	$ 18,889	$ 9,154	1,501,774
64	$ 100,000	0.85	$ 85,000	65,385	$ 18,889	$ 9,154	1,501,774
65	$ 92,000	0.85	$ 78,200	60,154	$ 17,378	$ 8,422	1,381,632
66	$ 58,000	0.85	$ 49,300	37,923	$ 10,956	$ 5,309	871,029
67	$ 51,000	0.85	$ 43,350	33,346	$ 9,633	$ 4,668	765,905
68	$ 16,500,000	0.85	$ 14,025,000	10,788,462	$ 3,116,667	$ 1,510,385	247,792,676
69	$ 10,000,000	0.85	$ 8,500,000	6,538,462	$ 1,888,889	$ 915,385	150,177,380
70	$ 10,000,000	0.85	$ 8,500,000	6,538,462	$ 1,888,889	$ 915,385	150,177,380
71	$ 23,000,000	0.85	$ 19,550,000	15,038,462	$ 4,344,444	$ 2,105,385	345,407,973
72	$ 19,000,000	0.85	$ 16,150,000	12,423,077	$ 3,588,889	$ 1,739,231	285,337,021
73	$ 19,000,000	0.85	$ 16,150,000	12,423,077	$ 3,588,889	$ 1,739,231	285,337,021
74	$ 17,500,000	0.85	$ 14,875,000	11,442,308	$ 3,305,556	$ 1,601,923	262,810,414
75	$ 17,500,000	0.85	$ 14,875,000	11,442,308	$ 3,305,556	$ 1,601,923	262,810,414
76	$ 16,000,000	0.85	$ 13,600,000	10,461,538	$ 3,022,222	$ 1,464,615	240,283,807
77	$ 15,500,000	0.85	$ 13,175,000	10,134,615	$ 2,927,778	$ 1,418,846	232,774,938
78	$ 14,500,000	0.85	$ 12,325,000	9,480,769	$ 2,738,889	$ 1,327,308	217,757,200
79	$ 14,000,000	0.85	$ 11,900,000	9,153,846	$ 2,644,444	$ 1,281,538	210,248,331
80	$ 13,000,000	0.85	$ 11,050,000	8,500,000	$ 2,455,556	$ 1,190,000	195,230,593
81	$ 12,500,000	0.85	$ 10,625,000	8,173,077	$ 2,361,111	$ 1,144,231	187,721,724
82	$ 11,000,000	0.85	$ 9,350,000	7,192,308	$ 2,077,778	$ 1,006,923	165,195,117
83	$ 10,500,000	0.85	$ 8,925,000	6,865,385	$ 1,983,333	$ 961,154	157,686,248
84	$ 10,500,000	0.85	$ 8,925,000	6,865,385	$ 1,983,333	$ 961,154	157,686,248
85	$ 10,000,000	0.85	$ 8,500,000	6,538,462	$ 1,888,889	$ 915,385	150,177,380
86	$ 9,000,000	0.85	$ 7,650,000	5,884,615	$ 1,700,000	$ 823,846	135,159,642
87	$ 8,500,000	0.85	$ 7,225,000	5,557,692	$ 1,605,556	$ 778,077	127,650,773
88	$ 7,500,000	0.85	$ 6,375,000	4,903,846	$ 1,416,667	$ 686,538	112,633,035
89	$ 6,500,000	0.85	$ 5,525,000	4,250,000	$ 1,227,778	$ 595,000	97,615,297
90	$ 6,000,000	0.85	$ 5,100,000	3,923,077	$ 1,133,333	$ 549,231	90,106,428
91	$ 6,000,000	0.85	$ 5,100,000	3,923,077	$ 1,133,333	$ 549,231	90,106,428
92	$ 6,000,000	0.85	$ 5,100,000	3,923,077	$ 1,133,333	$ 549,231	90,106,428
93	$ 5,500,000	0.85	$ 4,675,000	3,596,154	$ 1,038,889	$ 503,462	82,597,559
94	$ 5,500,000	0.85	$ 4,675,000	3,596,154	$ 1,038,889	$ 503,462	82,597,559
95	$ 5,500,000	0.85	$ 4,675,000	3,596,154	$ 1,038,889	$ 503,462	82,597,559
96	$ 5,500,000	0.85	$ 4,675,000	3,596,154	$ 1,038,889	$ 503,462	82,597,559
97	$ 5,000,000	0.85	$ 4,250,000	3,269,231	$ 944,444	$ 457,692	75,088,690
98	$ 4,550,000	0.85	$ 3,867,500	2,975,000	$ 859,444	$ 416,500	68,330,708
99	$ 4,350,000	0.85	$ 3,697,500	2,844,231	$ 821,667	$ 398,192	65,327,160
100	$ 4,200,000	0.85	$ 3,570,000	2,746,154	$ 793,333	$ 384,462	63,074,499
101	$ 4,100,000	0.85	$ 3,485,000	2,680,769	$ 774,444	$ 375,308	61,572,726
102	$ 4,050,000	0.85	$ 3,442,500	2,648,077	$ 765,000	$ 370,731	60,821,839
103	$ 3,750,000	0.85	$ 3,187,500	2,451,923	$ 708,333	$ 343,269	56,316,517
104	$ 3,750,000	0.85	$ 3,187,500	2,451,923	$ 708,333	$ 343,269	56,316,517
105	$ 3,650,000	0.85	$ 3,102,500	2,386,538	$ 689,444	$ 334,115	54,814,744
106	$ 3,550,000	0.85	$ 3,017,500	2,321,154	$ 670,556	$ 324,962	53,312,970

APPENDIX C CONT.

Company, i	CxR_i	%NCCx	$NCCxR_i$	$GFA_{NCCx,i}$	$TCS_{NCCx,i}$ (SPB)	$TCS_{NCCx,i}$ (CxS)	$TES_{NCCx,i}$
107	$ 3,500,000	0.85	$ 2,975,000	2,288,462	$ 661,111	$ 320,385	52,562,083
108	$ 3,450,000	0.85	$ 2,932,500	2,255,769	$ 651,667	$ 315,808	51,811,196
109	$ 3,450,000	0.85	$ 2,932,500	2,255,769	$ 651,667	$ 315,808	51,811,196
110	$ 3,050,000	0.85	$ 2,592,500	1,994,231	$ 576,111	$ 279,192	45,804,101
111	$ 3,050,000	0.85	$ 2,592,500	1,994,231	$ 576,111	$ 279,192	45,804,101
112	$ 2,850,000	0.85	$ 2,422,500	1,863,462	$ 538,333	$ 260,885	42,800,553
113	$ 2,500,000	0.85	$ 2,125,000	1,634,615	$ 472,222	$ 228,846	37,544,345
114	$ 2,400,000	0.85	$ 2,040,000	1,569,231	$ 453,333	$ 219,692	36,042,571
115	$ 2,350,000	0.85	$ 1,997,500	1,536,538	$ 443,889	$ 215,115	35,291,684
116	$ 2,300,000	0.85	$ 1,955,000	1,503,846	$ 434,444	$ 210,538	34,540,797
117	$ 1,900,000	0.85	$ 1,615,000	1,242,308	$ 358,889	$ 173,923	28,533,702
118	$ 1,800,000	0.85	$ 1,530,000	1,176,923	$ 340,000	$ 164,769	27,031,928
119	$ 1,800,000	0.85	$ 1,530,000	1,176,923	$ 340,000	$ 164,769	27,031,928
120	$ 1,800,000	0.85	$ 1,530,000	1,176,923	$ 340,000	$ 164,769	27,031,928
121	$ 1,450,000	0.85	$ 1,232,500	948,077	$ 273,889	$ 132,731	21,775,720
122	$ 1,400,000	0.85	$ 1,190,000	915,385	$ 264,444	$ 128,154	21,024,833
123	$ 1,100,000	0.85	$ 935,000	719,231	$ 207,778	$ 100,692	16,519,512
124	$ 1,050,000	0.85	$ 892,500	686,538	$ 198,333	$ 96,115	15,768,625
125	$ 1,050,000	0.85	$ 892,500	686,538	$ 198,333	$ 96,115	15,768,625
126	$ 1,000,000	0.85	$ 850,000	653,846	$ 188,889	$ 91,538	15,017,738
127	$ 600,000	0.85	$ 510,000	392,308	$ 113,333	$ 54,923	9,010,643
128	$ 550,000	0.85	$ 467,500	359,615	$ 103,889	$ 50,346	8,259,756
129	$ 550,000	0.85	$ 467,500	359,615	$ 103,889	$ 50,346	8,259,756
130	$ 410,000	0.85	$ 348,500	268,077	$ 77,444	$ 37,531	6,157,273
131	$ 330,000	0.85	$ 280,500	215,769	$ 62,333	$ 30,208	4,955,854
132	$ 145,000	0.85	$ 123,250	94,808	$ 27,389	$ 13,273	2,177,572
133	$ 80,000	0.85	$ 68,000	52,308	$ 15,111	$ 7,323	1,201,419
134	$ 49,000	0.85	$ 41,650	32,038	$ 9,256	$ 4,485	735,869
135	$152,000,000	0.85	$129,200,000	99,384,615	$ 28,711,111	$ 13,913,846	2,282,696,168
136	$ 16,000,000	0.85	$ 13,600,000	10,461,538	$ 3,022,222	$ 1,464,615	240,283,807
137	$ 14,800,000	0.85	$ 12,580,000	9,676,923	$ 2,795,556	$ 1,354,769	222,262,522
138	$ 3,920,000	0.85	$ 3,332,000	2,563,077	$ 740,444	$ 358,831	58,869,533
139	$ 3,000,000	0.85	$ 2,550,000	1,961,538	$ 566,667	$ 274,615	45,053,214
140	$ 2,240,000	0.85	$ 1,904,000	1,464,615	$ 423,111	$ 205,046	33,639,733
141	$ 2,000,000	0.85	$ 1,700,000	1,307,692	$ 377,778	$ 183,077	30,035,476
142	$ 1,520,000	0.85	$ 1,292,000	993,846	$ 287,111	$ 139,138	22,826,962
143	$ 1,240,000	0.85	$ 1,054,000	810,769	$ 234,222	$ 113,508	18,621,995
144	$ 12,600,000	0.85	$ 10,710,000	8,238,462	$ 2,380,000	$ 1,153,385	189,223,498
145	$ 10,600,000	0.85	$ 9,010,000	6,930,769	$ 2,002,222	$ 970,308	159,188,022
146	$ 7,000,000	0.85	$ 5,950,000	4,576,923	$ 1,322,222	$ 640,769	105,124,166
147	$ 4,600,000	0.85	$ 3,910,000	3,007,692	$ 868,889	$ 421,077	69,081,595
148	$ 4,400,000	0.85	$ 3,740,000	2,876,923	$ 831,111	$ 402,769	66,078,047
149	$ 3,600,000	0.85	$ 3,060,000	2,353,846	$ 680,000	$ 329,538	54,063,857
150	$ 3,060,000	0.85	$ 2,601,000	2,000,769	$ 578,000	$ 280,108	45,954,278
151	$ 2,200,000	0.85	$ 1,870,000	1,438,462	$ 415,556	$ 201,385	33,039,023
152	$ 1,960,000	0.85	$ 1,666,000	1,281,538	$ 370,222	$ 179,415	29,434,766
153	$ 1,780,000	0.85	$ 1,513,000	1,163,846	$ 336,222	$ 162,938	26,731,574
154	$ 260,000	0.85	$ 221,000	170,000	$ 49,111	$ 23,800	3,904,612
155	$ 100,000	0.85	$ 85,000	65,385	$ 18,889	$ 9,154	1,501,774
156	$ 14,600	0.85	$ 12,410	9,546	$ 2,758	$ 1,336	219,259
157	$600,000,000	0.85	$510,000,000	392,307,692	$ 113,333,333	$ 54,923,077	9,010,642,770
158	$ 95,000,000	0.85	$ 80,750,000	62,115,385	$ 17,944,444	$ 8,696,154	1,426,685,105
159	$ 70,000,000	0.85	$ 59,500,000	45,769,231	$ 13,222,222	$ 6,407,692	1,051,241,657
160	$ 38,000,000	0.85	$ 32,300,000	24,846,154	$ 7,177,778	$ 3,478,462	570,674,042

Company, i	CxR_i	%NCCx	$NCCxR_i$	$GFA_{NCCx,i}$	$TCS_{NCCx,i}$ (SPB)	$TCS_{NCCx,i}$ (CxS)	$TES_{NCCx,i}$
161	$ 17,500,000	0.85	$ 14,875,000	11,442,308	$ 3,305,556	$ 1,601,923	262,810,414
162	$ 11,000,000	0.85	$ 9,350,000	7,192,308	$ 2,077,778	$ 1,006,923	165,195,117
163	$ 9,000,000	0.85	$ 7,650,000	5,884,615	$ 1,700,000	$ 823,846	135,159,642
164	$ 8,500,000	0.85	$ 7,225,000	5,557,692	$ 1,605,556	$ 778,077	127,650,773
165	$ 7,500,000	0.85	$ 6,375,000	4,903,846	$ 1,416,667	$ 686,538	112,633,035
166	$ 6,000,000	0.85	$ 5,100,000	3,923,077	$ 1,133,333	$ 549,231	90,106,428
167	$ 5,500,000	0.85	$ 4,675,000	3,596,154	$ 1,038,889	$ 503,462	82,597,559
168	$ 5,000,000	0.85	$ 4,250,000	3,269,231	$ 944,444	$ 457,692	75,088,690
169	$ 3,500,000	0.85	$ 2,975,000	2,288,462	$ 661,111	$ 320,385	52,562,083
170	$ 3,550,000	0.85	$ 3,017,500	2,321,154	$ 670,556	$ 324,962	53,312,970
171	$ 2,700,000	0.85	$ 2,295,000	1,765,385	$ 510,000	$ 247,154	40,547,892
172	$ 2,650,000	0.85	$ 2,252,500	1,732,692	$ 500,556	$ 242,577	39,797,006
173	$ 2,150,000	0.85	$ 1,827,500	1,405,769	$ 406,111	$ 196,808	32,288,137
174	$ 2,050,000	0.85	$ 1,742,500	1,340,385	$ 387,222	$ 187,654	30,786,363
175	$ 1,400,000	0.85	$ 1,190,000	915,385	$ 264,444	$ 128,154	21,024,833
176	$ 1,400,000	0.85	$ 1,190,000	915,385	$ 264,444	$ 128,154	21,024,833
177	$ 1,150,000	0.85	$ 977,500	751,923	$ 217,222	$ 105,269	17,270,399
178	$ 1,050,000	0.85	$ 892,500	686,538	$ 198,333	$ 96,115	15,768,625
179	$ 650,000	0.85	$ 552,500	425,000	$ 122,778	$ 59,500	9,761,530
180	$ 350,000	0.85	$ 297,500	228,846	$ 66,111	$ 32,038	5,256,208
181	$ 325,000	0.85	$ 276,250	212,500	$ 61,389	$ 29,750	4,880,765
182	$ 295,000	0.85	$ 250,750	192,885	$ 55,722	$ 27,004	4,430,233
183	$ 65,000	0.85	$ 55,250	42,500	$ 12,278	$ 5,950	976,153
184	$ 65,000	0.85	$ 55,250	42,500	$ 12,278	$ 5,950	976,153
185	$ 60,000	0.85	$ 51,000	39,231	$ 11,333	$ 5,492	901,064
186	$ 47,500	0.85	$ 40,375	31,058	$ 8,972	$ 4,348	713,343
187	$ 42,000	0.85	$ 35,700	27,462	$ 7,933	$ 3,845	630,745
188	$ 64,000,000	0.85	$ 54,400,000	41,846,154	$ 12,088,889	$ 5,858,462	961,135,229
189	$ 44,000,000	0.85	$ 37,400,000	28,769,231	$ 8,311,111	$ 4,027,692	660,780,470
190	$ 1,520,000	0.85	$ 1,292,000	993,846	$ 287,111	$ 139,138	22,826,962
191	$ 1,060,000	0.85	$ 901,000	693,077	$ 200,222	$ 97,031	15,918,802
192	$ 700,000	0.85	$ 595,000	457,692	$ 132,222	$ 64,077	10,512,417
193	$ 580,000	0.85	$ 493,000	379,231	$ 109,556	$ 53,092	8,710,288
194	$ 440,000	0.85	$ 374,000	287,692	$ 83,111	$ 40,277	6,607,805
195	$ 122,000	0.85	$ 103,700	79,769	$ 23,044	$ 11,168	1,832,164
196	$ 92,000	0.85	$ 78,200	60,154	$ 17,378	$ 8,422	1,381,632
197	$ 50,000	0.85	$ 42,500	32,692	$ 9,444	$ 4,577	750,887
198	$ 8,200	0.85	$ 6,970	5,362	$ 1,549	$ 751	123,145

CxR_i: estimated annual commissioning revenue for each i company, $/year;
%NCCx: assumed percent of commissioning revenue from new construction commissioning, %;
$NCCxR_i$: estimated annual new construction commissioning revenue for each i company, $/year
$GFA_{NCCx,i}$: estimated annual new construction floor area commissioned for each i company, ft^2/year;
$TCS_{NCCx,i}$ (SPB): estimated annual new construction commissioning cost savings for each i company, using simple payback method, $/year;
$TCS_{NCCx,i}$ (CxS): estimated annual new construction commissioning cost savings for each i company, using cost savings per unit area method, $/year;
$TES_{NCCx,i}$: estimated annual new construction commissioning energy savings for each i company, kBtu/year;

APPENDIX D

Total Cx Estimates by Company (Commissioned Floor Area, Cost Savings, Energy Savings)

Company, i	CxR_i	$GFA_{Cx,i}$	$TCS_{Cx,i}$ (SPB)	$TCS_{Cx,i}$ (CxS)	$TES_{Cx,i}$
1	$ 15,000,000	16,236,264	$ 5,333,333	$ 3,558,791	407,553,211
2	$ 14,000,000	15,153,846	$ 4,977,778	$ 3,321,538	380,382,997
3	$ 13,000,000	14,071,429	$ 4,622,222	$ 3,084,286	353,212,783
4	$ 11,000,000	11,906,593	$ 3,911,111	$ 2,609,780	298,872,355
5	$ 6,900,000	7,468,681	$ 2,453,333	$ 1,637,044	187,474,477
6	$ 6,300,000	6,819,231	$ 2,240,000	$ 1,494,692	171,172,349
7	$ 5,000,000	5,412,088	$ 1,777,778	$ 1,186,264	135,851,070
8	$ 4,900,000	5,303,846	$ 1,742,222	$ 1,162,538	133,134,049
9	$ 4,600,000	4,979,121	$ 1,635,556	$ 1,091,363	124,982,985
10	$ 4,300,000	4,654,396	$ 1,528,889	$ 1,020,187	116,831,920
11	$ 3,800,000	4,113,187	$ 1,351,111	$ 901,560	103,246,813
12	$ 3,500,000	3,788,462	$ 1,244,444	$ 830,385	95,095,749
13	$ 3,200,000	3,463,736	$ 1,137,778	$ 759,209	86,944,685
14	$ 3,000,000	3,247,253	$ 1,066,667	$ 711,758	81,510,642
15	$ 3,000,000	3,247,253	$ 1,066,667	$ 711,758	81,510,642
16	$ 2,800,000	3,030,769	$ 995,556	$ 664,308	76,076,599
17	$ 2,700,000	2,922,527	$ 960,000	$ 640,582	73,359,578
18	$ 2,600,000	2,814,286	$ 924,444	$ 616,857	70,642,557
19	$ 2,600,000	2,814,286	$ 924,444	$ 616,857	70,642,557
20	$ 2,400,000	2,597,802	$ 853,333	$ 569,407	65,208,514
21	$ 2,300,000	2,489,560	$ 817,778	$ 545,681	62,491,492
22	$ 2,300,000	2,489,560	$ 817,778	$ 545,681	62,491,492
23	$ 2,300,000	2,489,560	$ 817,778	$ 545,681	62,491,492
24	$ 2,100,000	2,273,077	$ 746,667	$ 498,231	57,057,450
25	$ 1,700,000	1,840,110	$ 604,444	$ 403,330	46,189,364
26	$ 1,700,000	1,840,110	$ 604,444	$ 403,330	46,189,364
27	$ 1,500,000	1,623,626	$ 533,333	$ 355,879	40,755,321
28	$ 1,500,000	1,623,626	$ 533,333	$ 355,879	40,755,321
29	$ 1,500,000	1,623,626	$ 533,333	$ 355,879	40,755,321
30	$ 1,400,000	1,515,385	$ 497,778	$ 332,154	38,038,300
31	$ 1,300,000	1,407,143	$ 462,222	$ 308,429	35,321,278
32	$ 1,300,000	1,407,143	$ 462,222	$ 308,429	35,321,278
33	$ 1,300,000	1,407,143	$ 462,222	$ 308,429	35,321,278
34	$ 1,200,000	1,298,901	$ 426,667	$ 284,703	32,604,257
35	$ 1,000,000	1,082,418	$ 355,556	$ 237,253	27,170,214
36	$ 1,000,000	1,082,418	$ 355,556	$ 237,253	27,170,214
37	$ 1,000,000	1,082,418	$ 355,556	$ 237,253	27,170,214
38	$ 950,000	1,028,297	$ 337,778	$ 225,390	25,811,703
39	$ 860,000	930,879	$ 305,778	$ 204,037	23,366,384
40	$ 770,000	833,462	$ 273,778	$ 182,685	20,921,065
41	$ 670,000	725,220	$ 238,222	$ 158,959	18,204,043
42	$ 650,000	703,571	$ 231,111	$ 154,214	17,660,639
43	$ 620,000	671,099	$ 220,444	$ 147,097	16,845,533
44	$ 610,000	660,275	$ 216,889	$ 144,724	16,573,831
45	$ 590,000	638,626	$ 209,778	$ 139,979	16,030,426
46	$ 550,000	595,330	$ 195,556	$ 130,489	14,943,618
47	$ 530,000	573,681	$ 188,444	$ 125,744	14,400,213
48	$ 510,000	552,033	$ 181,333	$ 120,999	13,856,809
49	$ 500,000	541,209	$ 177,778	$ 118,626	13,585,107
50	$ 400,000	432,967	$ 142,222	$ 94,901	10,868,086
51	$ 360,000	389,670	$ 128,000	$ 85,411	9,781,277
52	$ 310,000	335,549	$ 110,222	$ 73,548	8,422,766

APPENDIX D CONT.

Company, i	CxR_i	$GFA_{Cx,i}$	$TCS_{Cx,i}$ (SPB)	$TCS_{Cx,i}$ (CxS)	$TES_{Cx,i}$
53	$ 300,000	324,725	$ 106,667	$ 71,176	8,151,064
54	$ 290,000	313,901	$ 103,111	$ 68,803	7,879,362
55	$ 270,000	292,253	$ 96,000	$ 64,058	7,335,958
56	$ 260,000	281,429	$ 92,444	$ 61,686	7,064,256
57	$ 190,000	205,659	$ 67,556	$ 45,078	5,162,341
58	$ 180,000	194,835	$ 64,000	$ 42,705	4,890,639
59	$ 130,000	140,714	$ 46,222	$ 30,843	3,532,128
60	$ 120,000	129,890	$ 42,667	$ 28,470	3,260,426
61	$ 110,000	119,066	$ 39,111	$ 26,098	2,988,724
62	$ 110,000	119,066	$ 39,111	$ 26,098	2,988,724
63	$ 100,000	108,242	$ 35,556	$ 23,725	2,717,021
64	$ 100,000	108,242	$ 35,556	$ 23,725	2,717,021
65	$ 92,000	99,582	$ 32,711	$ 21,827	2,499,660
66	$ 58,000	62,780	$ 20,622	$ 13,761	1,575,872
67	$ 51,000	55,203	$ 18,133	$ 12,100	1,385,681
68	$ 16,500,000	17,859,890	$ 5,866,667	$ 3,914,670	448,308,532
69	$ 10,000,000	10,824,176	$ 3,555,556	$ 2,372,527	271,702,141
70	$ 10,000,000	10,824,176	$ 3,555,556	$ 2,372,527	271,702,141
71	$ 23,000,000	24,895,604	$ 8,177,778	$ 5,456,813	624,914,923
72	$ 19,000,000	20,565,934	$ 6,755,556	$ 4,507,802	516,234,067
73	$ 19,000,000	20,565,934	$ 6,755,556	$ 4,507,802	516,234,067
74	$ 17,500,000	18,942,308	$ 6,222,222	$ 4,151,923	475,478,746
75	$ 17,500,000	18,942,308	$ 6,222,222	$ 4,151,923	475,478,746
76	$ 16,000,000	17,318,681	$ 5,688,889	$ 3,796,044	434,723,425
77	$ 15,500,000	16,777,473	$ 5,511,111	$ 3,677,418	421,138,318
78	$ 14,500,000	15,695,055	$ 5,155,556	$ 3,440,165	393,968,104
79	$ 14,000,000	15,153,846	$ 4,977,778	$ 3,321,538	380,382,997
80	$ 13,000,000	14,071,429	$ 4,622,222	$ 3,084,286	353,212,783
81	$ 12,500,000	13,530,220	$ 4,444,444	$ 2,965,659	339,627,676
82	$ 11,000,000	11,906,593	$ 3,911,111	$ 2,609,780	298,872,355
83	$ 10,500,000	11,365,385	$ 3,733,333	$ 2,491,154	285,287,248
84	$ 10,500,000	11,365,385	$ 3,733,333	$ 2,491,154	285,287,248
85	$ 10,000,000	10,824,176	$ 3,555,556	$ 2,372,527	271,702,141
86	$ 9,000,000	9,741,758	$ 3,200,000	$ 2,135,275	244,531,927
87	$ 8,500,000	9,200,549	$ 3,022,222	$ 2,016,648	230,946,820
88	$ 7,500,000	8,118,132	$ 2,666,667	$ 1,779,396	203,776,605
89	$ 6,500,000	7,035,714	$ 2,311,111	$ 1,542,143	176,606,391
90	$ 6,000,000	6,494,505	$ 2,133,333	$ 1,423,516	163,021,284
91	$ 6,000,000	6,494,505	$ 2,133,333	$ 1,423,516	163,021,284
92	$ 6,000,000	6,494,505	$ 2,133,333	$ 1,423,516	163,021,284
93	$ 5,500,000	5,953,297	$ 1,955,556	$ 1,304,890	149,436,177
94	$ 5,500,000	5,953,297	$ 1,955,556	$ 1,304,890	149,436,177
95	$ 5,500,000	5,953,297	$ 1,955,556	$ 1,304,890	149,436,177
96	$ 5,500,000	5,953,297	$ 1,955,556	$ 1,304,890	149,436,177
97	$ 5,000,000	5,412,088	$ 1,777,778	$ 1,186,264	135,851,070
98	$ 4,550,000	4,925,000	$ 1,617,778	$ 1,079,500	123,624,474
99	$ 4,350,000	4,708,516	$ 1,546,667	$ 1,032,049	118,190,431
100	$ 4,200,000	4,546,154	$ 1,493,333	$ 996,462	114,114,899
101	$ 4,100,000	4,437,912	$ 1,457,778	$ 972,736	111,397,878
102	$ 4,050,000	4,383,791	$ 1,440,000	$ 960,874	110,039,367
103	$ 3,750,000	4,059,066	$ 1,333,333	$ 889,698	101,888,303
104	$ 3,750,000	4,059,066	$ 1,333,333	$ 889,698	101,888,303
105	$ 3,650,000	3,950,824	$ 1,297,778	$ 865,973	99,171,281
106	$ 3,550,000	3,842,582	$ 1,262,222	$ 842,247	96,454,260

APPENDIX D CONT.

Company, i	CxR_i	$GFA_{Cx,i}$	$TCS_{Cx,i}$ (SPB)	$TCS_{Cx,i}$ (CxS)	$TES_{Cx,i}$
107	$ 3,500,000	3,788,462	$ 1,244,444	$ 830,385	95,095,749
108	$ 3,450,000	3,734,341	$ 1,226,667	$ 818,522	93,737,239
109	$ 3,450,000	3,734,341	$ 1,226,667	$ 818,522	93,737,239
110	$ 3,050,000	3,301,374	$ 1,084,444	$ 723,621	82,869,153
111	$ 3,050,000	3,301,374	$ 1,084,444	$ 723,621	82,869,153
112	$ 2,850,000	3,084,890	$ 1,013,333	$ 676,170	77,435,110
113	$ 2,500,000	2,706,044	$ 888,889	$ 593,132	67,925,535
114	$ 2,400,000	2,597,802	$ 853,333	$ 569,407	65,208,514
115	$ 2,350,000	2,543,681	$ 835,556	$ 557,544	63,850,003
116	$ 2,300,000	2,489,560	$ 817,778	$ 545,681	62,491,492
117	$ 1,900,000	2,056,593	$ 675,556	$ 450,780	51,623,407
118	$ 1,800,000	1,948,352	$ 640,000	$ 427,055	48,906,385
119	$ 1,800,000	1,948,352	$ 640,000	$ 427,055	48,906,385
120	$ 1,800,000	1,948,352	$ 640,000	$ 427,055	48,906,385
121	$ 1,450,000	1,569,505	$ 515,556	$ 344,016	39,396,810
122	$ 1,400,000	1,515,385	$ 497,778	$ 332,154	38,038,300
123	$ 1,100,000	1,190,659	$ 391,111	$ 260,978	29,887,235
124	$ 1,050,000	1,136,538	$ 373,333	$ 249,115	28,528,725
125	$ 1,050,000	1,136,538	$ 373,333	$ 249,115	28,528,725
126	$ 1,000,000	1,082,418	$ 355,556	$ 237,253	27,170,214
127	$ 600,000	649,451	$ 213,333	$ 142,352	16,302,128
128	$ 550,000	595,330	$ 195,556	$ 130,489	14,943,618
129	$ 550,000	595,330	$ 195,556	$ 130,489	14,943,618
130	$ 410,000	443,791	$ 145,778	$ 97,274	11,139,788
131	$ 330,000	357,198	$ 117,333	$ 78,293	8,966,171
132	$ 145,000	156,951	$ 51,556	$ 34,402	3,939,681
133	$ 80,000	86,593	$ 28,444	$ 18,980	2,173,617
134	$ 49,000	53,038	$ 17,422	$ 11,625	1,331,340
135	$ 152,000,000	164,527,473	$ 54,044,444	$ 36,062,418	4,129,872,538
136	$ 16,000,000	17,318,681	$ 5,688,889	$ 3,796,044	434,723,425
137	$ 14,800,000	16,019,780	$ 5,262,222	$ 3,511,341	402,119,168
138	$ 3,920,000	4,243,077	$ 1,393,778	$ 930,031	106,507,239
139	$ 3,000,000	3,247,253	$ 1,066,667	$ 711,758	81,510,642
140	$ 2,240,000	2,424,615	$ 796,444	$ 531,446	60,861,280
141	$ 2,000,000	2,164,835	$ 711,111	$ 474,505	54,340,428
142	$ 1,520,000	1,645,275	$ 540,444	$ 360,624	41,298,725
143	$ 1,240,000	1,342,198	$ 440,889	$ 294,193	33,691,065
144	$ 12,600,000	13,638,462	$ 4,480,000	$ 2,989,385	342,344,697
145	$ 10,600,000	11,473,626	$ 3,768,889	$ 2,514,879	288,004,269
146	$ 7,000,000	7,576,923	$ 2,488,889	$ 1,660,769	190,191,498
147	$ 4,600,000	4,979,121	$ 1,635,556	$ 1,091,363	124,982,985
148	$ 4,400,000	4,762,637	$ 1,564,444	$ 1,043,912	119,548,942
149	$ 3,600,000	3,896,703	$ 1,280,000	$ 854,110	97,812,771
150	$ 3,060,000	3,312,198	$ 1,088,000	$ 725,993	83,140,855
151	$ 2,200,000	2,381,319	$ 782,222	$ 521,956	59,774,471
152	$ 1,960,000	2,121,538	$ 696,889	$ 465,015	53,253,620
153	$ 1,780,000	1,926,703	$ 632,889	$ 422,310	48,362,981
154	$ 260,000	281,429	$ 92,444	$ 61,686	7,064,256
155	$ 100,000	108,242	$ 35,556	$ 23,725	2,717,021
156	$ 14,600	15,803	$ 5,191	$ 3,464	396,685
157	$ 600,000,000	649,450,549	$ 213,333,333	$ 142,351,648	16,302,128,439
158	$ 95,000,000	102,829,670	$ 33,777,778	$ 22,539,011	2,581,170,336
159	$ 70,000,000	75,769,231	$ 24,888,889	$ 16,607,692	1,901,914,985
160	$ 38,000,000	41,131,868	$ 13,511,111	$ 9,015,604	1,032,468,134

APPENDIX D CONT.

Company, i	CxR_i	$GFA_{Cx,i}$	$TCS_{Cx,i}$ (SPB)	$TCS_{Cx,i}$ (CxS)	$TES_{Cx,i}$
161	$ 17,500,000	18,942,308	$ 6,222,222	$ 4,151,923	475,478,746
162	$ 11,000,000	11,906,593	$ 3,911,111	$ 2,609,780	298,872,355
163	$ 9,000,000	9,741,758	$ 3,200,000	$ 2,135,275	244,531,927
164	$ 8,500,000	9,200,549	$ 3,022,222	$ 2,016,648	230,946,820
165	$ 7,500,000	8,118,132	$ 2,666,667	$ 1,779,396	203,776,605
166	$ 6,000,000	6,494,505	$ 2,133,333	$ 1,423,516	163,021,284
167	$ 5,500,000	5,953,297	$ 1,955,556	$ 1,304,890	149,436,177
168	$ 5,000,000	5,412,088	$ 1,777,778	$ 1,186,264	135,851,070
169	$ 3,500,000	3,788,462	$ 1,244,444	$ 830,385	95,095,749
170	$ 3,550,000	3,842,582	$ 1,262,222	$ 842,247	96,454,260
171	$ 2,700,000	2,922,527	$ 960,000	$ 640,582	73,359,578
172	$ 2,650,000	2,868,407	$ 942,222	$ 628,720	72,001,067
173	$ 2,150,000	2,327,198	$ 764,444	$ 510,093	58,415,960
174	$ 2,050,000	2,218,956	$ 728,889	$ 486,368	55,698,939
175	$ 1,400,000	1,515,385	$ 497,778	$ 332,154	38,038,300
176	$ 1,400,000	1,515,385	$ 497,778	$ 332,154	38,038,300
177	$ 1,150,000	1,244,780	$ 408,889	$ 272,841	31,245,746
178	$ 1,050,000	1,136,538	$ 373,333	$ 249,115	28,528,725
179	$ 650,000	703,571	$ 231,111	$ 154,214	17,660,639
180	$ 350,000	378,846	$ 124,444	$ 83,038	9,509,575
181	$ 325,000	351,786	$ 115,556	$ 77,107	8,830,320
182	$ 295,000	319,313	$ 104,889	$ 69,990	8,015,213
183	$ 65,000	70,357	$ 23,111	$ 15,421	1,766,064
184	$ 65,000	70,357	$ 23,111	$ 15,421	1,766,064
185	$ 60,000	64,945	$ 21,333	$ 14,235	1,630,213
186	$ 47,500	51,415	$ 16,889	$ 11,270	1,290,585
187	$ 42,000	45,462	$ 14,933	$ 9,965	1,141,149
188	$ 64,000,000	69,274,725	$ 22,755,556	$ 15,184,176	1,738,893,700
189	$ 44,000,000	47,626,374	$ 15,644,444	$ 10,439,121	1,195,489,419
190	$ 1,520,000	1,645,275	$ 540,444	$ 360,624	41,298,725
191	$ 1,060,000	1,147,363	$ 376,889	$ 251,488	28,800,427
192	$ 700,000	757,692	$ 248,889	$ 166,077	19,019,150
193	$ 580,000	627,802	$ 206,222	$ 137,607	15,758,724
194	$ 440,000	476,264	$ 156,444	$ 104,391	11,954,894
195	$ 122,000	132,055	$ 43,378	$ 28,945	3,314,766
196	$ 92,000	99,582	$ 32,711	$ 21,827	2,499,660
197	$ 50,000	54,121	$ 17,778	$ 11,863	1,358,511
198	$ 8,200	8,876	$ 2,916	$ 1,945	222,796

CxR_i: estimated annual commissioning revenue for each i company, $/year;
$GFA_{Cx,i}$: estimated annual floor area commissioned for each i company, ft^2/year;
$TCS_{Cx,i}$ (SPB): estimated annual commissioning cost savings for each i company, using simple payback method, $/year;
$TCS_{Cx,i}$ (CxS): estimated annual commissioning cost savings for each i company, using cost savings per unit area method, $/year;
$TES_{Cx,i}$: estimated annual commissioning energy savings for each i company, kBtu/year;