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Roadmap for Building Commissioning Research

Workshop Summary Report

September 2014

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U.S. Department of Commerce
Penny Pritzker, Secretary

National Institute of Standards and Technology
Willie May, Acting Under Secretary of Commerce for Standards and Technology and Acting Director

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ACKNOWLEDGMENTS

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Special thanks are extended to the members of the workshop planning committee, speakers, and others that assisted in this effort, listed below.

Planning Committee
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David Shipley, ICF International, ASHRAE TC 7.9 Research Chair
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Other Contributors
Additional thanks to Ryan Colker at the National Institute of Building Sciences (NIBS) and the Commissioning Leaders Council, as well as George Hernandez and Benjamin Goldstein of the Department of Energy for their assistance in creating this workshop.

Thanks are also due to the administrative and conference support staff, especially Michael Vaughn and Tara Thomas (ASHRAE), Jessica Knapstein and Rebecca Price (Energetics Incorporated) and Sandra Heckman (NIST) who made sure that the many important meeting details were handled properly and efficiently.

Hard copies of this report can be obtained by contacting Sandra Heckman at 301-975-4112 or sandra.heckman@nist.gov.

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PREFACE

This report summarizes the results of the *Building Commissioning Research and Measurement Science Needs Webinar Workshop* held on April 29, 2014, sponsored by the National Institute of Standards and Technology with assistance from ASHRAE. This effort supports ongoing research in building commissioning, a practice that has a significant potential for reducing energy consumption in existing and new buildings. This report documents an assessment of research needs in the commissioning industry to provide the information necessary for making informed research investment decisions. To that end, this report organizes and presents input from the building industry on the state of the building commissioning industry, the research priorities associated with it, and the measurement science necessary to support technological advances.

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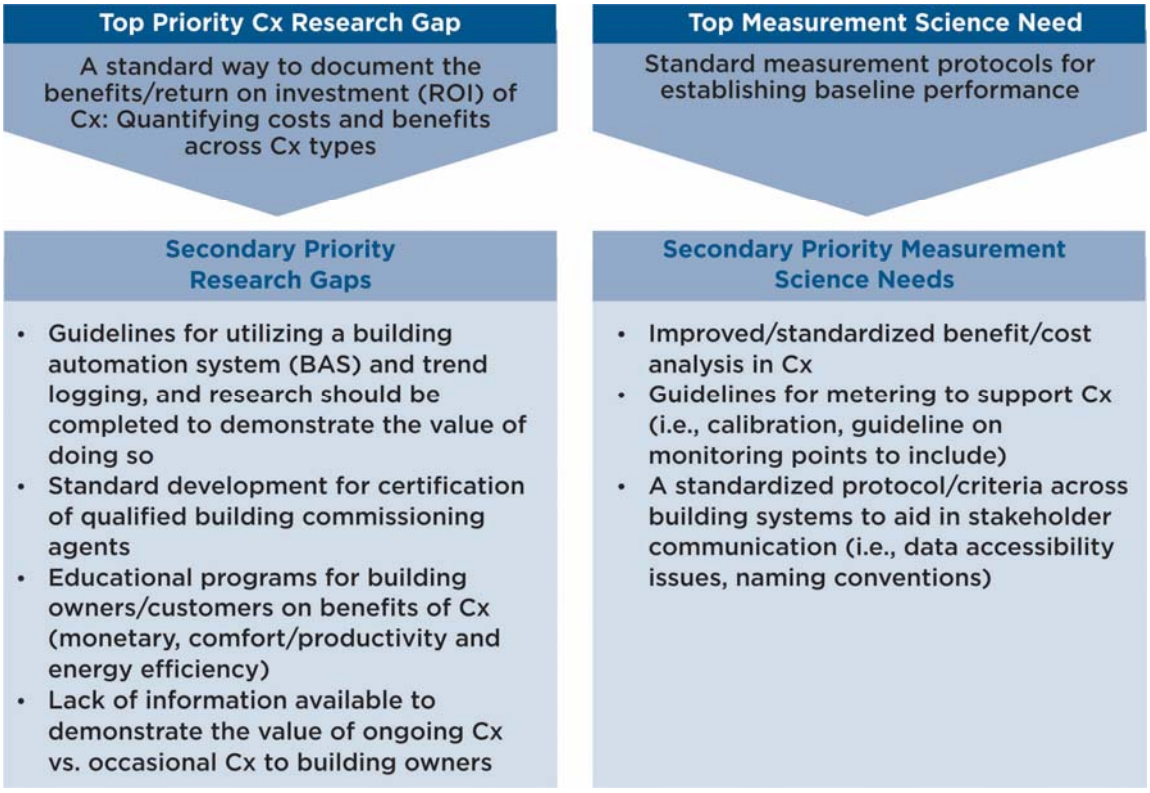
EXECUTIVE SUMMARY

Building commissioning (Cx) has a significant potential for reducing energy consumption in existing and new buildings. The last decade has seen a significant increase in market adoption of building commissioning but significant barriers remain to the widespread implementation (GBIG 2014, CaCx 2008), International Energy Agency Annex 40 presented an international assessment of research needs for commissioning (IEA 2004) and Frank et al. (2007) presented a state of the art review for commissioning low energy buildings in the U.S. but there has not been a more recent assessment of research needs in the commissioning industry to provide the information necessary for making informed research investment decisions. Consequently, the National Institute of Standards and Technology (NIST) and ASHRAE Technical Committee 7.9 on Building Commissioning (TC 7.9) sought input from key stakeholders to assess the state of the building commissioning industry, with the following objectives: to identify research priorities and identify measurement science needed to enable technological advances.

This report presents the outcomes of a facilitated discussion among building commissioning experts to identify gaps in building commissioning research and measurement science needs. These insights, which focus on energy, will provide guidance for future efforts that could facilitate adoption of more effective building commissioning practices.

The participating industry experts have made it clear that there are specific priorities in building commissioning research and measurement science that need to be addressed (see Figure E1). Specifically, research that demonstrates the benefits and return on investment (ROI) of commissioning to building owners is key in promoting mass adoption of building commissioning.

E1: Workshop Results



Building owners must be assured that changes in building design and operation for increased energy efficiency will not affect occupant health within the building. Education and certification components within building commissioning are also clearly important, according to experts. Building commissioning providers need methods to inform building owners about the building commissioning process, and how it can benefit their buildings and their bottom line. Strict certification requirements for building commissioning providers will help maintain uniformity in the industry and provide confidence to building owners that they will receive a service of consistent quality.

While several measurement science needs were identified, participants made one a clear priority; to develop a standardized measurement protocol for measuring actual building performance before and after building commissioning. This priority would effectively set a baseline for building commissioning evaluation. This priority will require the development of key performance metrics that are then integrated into the building design process and into operations. The three other secondary priorities in measurement science for building commissioning focus on standardizing cost/benefit analysis in the industry, proper guidelines for metering, and protocols for a standard criteria when evaluating buildings in building commissioning.

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I. INTRODUCTION

A. Overview

Building commissioning (Cx) is a quality control process for the design, construction and operation of buildings, in which requirements are determined while considering environmental effects, energy and facility usage. The commissioning process is executed in order to realize the performance of buildings' systems requested in the owner's project requirements through the life of the building. Commissioning of new and existing buildings has been shown to reduce energy usage and can also produce non-energy related benefits such as improved occupant comfort (Mills et al. 2009, Effinger et al. 2009, Friedman et al 2012,). When compared with other initiatives such as installation of high efficiency equipment or installing photovoltaic systems, commissioning can be highly cost-effective, resulting in short investment payback periods. Despite these proven benefits, commissioning is still not business as usual.

(Photo credit: Istock image #2353167)

B. Background

Building commissioning has a significant potential for reducing energy consumption in existing and new buildings and the last decade has seen a significant increase in market adoption, but significant barriers remain to the widespread implementation of these quality control processes. In 2000, the International Energy Agency conducted two international workshops to assess the research needs for commissioning. The international assessment of research needs for commissioning and to develop a work plan that would make progress in those areas. The result was IEA Annex 40, an international research project that was conducted between 2000 and 2004 (IEA 2004). In the U.S., Frank et al. (2007) presented a state of the art review for commissioning low energy buildings but there has not been a more recent, published assessment of research needs in the commissioning industry to provide the information necessary for making informed research investment decisions. Since 2007, there has not been a published assessment of research needs in the commissioning industry to provide the information is necessary for making informed research investment decisions. Prior to the workshop, the National Institute of Standards and Technology (NIST) and members of ASHRAE Technical Committee 7.9 Building Commissioning (TC 7.9) conducted a literature review and developed an initial list of gaps in research and measurement science for building commissioning. This list provided a seed for the workshop discussions and highlighted a number of commissioning barriers:

- Lack of information on the life cycle cost impacts of commissioning,
- Lack of knowledge and acceptance of commissioning,
- Technical knowledge gaps, and
- Lack of systems to support the commissioning process.

Workshop discussions also covered a full spectrum of measurement science needs, as shown in Figure 1. The availability of measurement science for building commissioning will be critical as the industry moves forward. For example, effective measurements and standards could:

- Provide a foundation for commerce,
- Enable interchangeability (hardware and software),
- Lower costs and simplify training,
- Provide a basis for agreement on deliverables and specifications, and
- Promote reliability and repeatability in investigations.

Figure1. Broad Aspect of Measurement Science:

- ✓ Reference Data
- ✓ Reference Materials
- ✓ Measurement Methods
- ✓ Methods of Test
- ✓ Test beds
- ✓ Predictive Tools
- ✓ Performance Metrics
- ✓ Comparison Studies
- ✓ Assessment of Technologies
- ✓ Information Models
- ✓ Protocols
- ✓ Technical Guidelines

C. Workshop Objectives and Scope

The overall objectives were to identify 1) critical gaps in building commissioning research; 2) needs for measurement science having the greatest potential impact for improving standard practice; and 3) where government funded (or co-funded) research would be of the most benefit to industry. All types of building commissioning were discussed, including new buildings, existing buildings, and retrofits, with a focus on energy commissioning.

Workshop organizers invited over 120 experts within the building commissioning field from 80 organizations, resulting in participation from over 50 individuals from over 40 organizations (The participants are listed in Appendix A of this report). During the two discussion periods of the workshop (research gaps and measurement science needs), participants were invited to share their ideas.

The outputs of the discussion were a set of research gaps and measurement science needs for building commissioning along with possible strategies to meet these challenges. Post-event, a survey was developed to enable stakeholders to prioritize the R&D gaps and needs in terms of urgency. More information on the survey can be found in Section V of this report.

This report presents the outcomes of the workshop, organized around the primary objectives of barriers, research gaps, and measurement science needs. It is anticipated that the priorities identified here will help to guide future research and development and related measurement science activities among those working in the building commissioning field.

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II. Barriers Facing Building Commissioning

Through a literature review, stakeholder discussion and in prior meetings of TC 7.9 (http://tc79.ashraetcs.org/research.html), several barriers were identified and presented during this workshop, as shown in Table 1. These have given rise to potential research concepts in the areas of: 1) Impact of commissioning on the life cycle cost of a building; 2) Awareness and acceptance of commissioning; 3) System support for commissioning, and 4) Measurement science needs.

Table 1. Barriers Identified for Building Commissioning

Barrier	Details on Gaps
Lack of information on the life cycle cost impacts of commissioning	• Accurate upfront estimates of commissioning costs • Effects of commissioning on subsequent owning and operating costs • Data on the performance impacts of faults that commissioning would be expected to fix • Data on the comfort impacts of faults that commissioning would be expected to fix • Field data on the impact of commissioning on the performance of specific pieces of equipment, such as rooftop units, variable air volume boxes, and direct digital control systems • Data on the persistence of commissioning savings • Limited understanding of how technology can be used for maximum benefit • Quantifying true value of Cx • Demonstrating return on investment (ROI) of Cx
Lack of knowledge and acceptance of commissioning on the part of various stakeholders	• Convincing building owners to invest in the Cx process • Convincing operators to act on building commissioning opportunities
Lack of Cx stakeholder coordination	• Ineffective teams (including building operators, design practitioners, contractors and subcontractors, code officials) • Need to capture the relevant building design information from the design phase and make that available for use in improving building operations
Lack of systems to support the commissioning process	• Building design information needed during the commissioning process and subsequent building operation • Standard of practice for functional testing • User interfaces to building energy management systems that enable

	operators to perform ongoing commissioning • Agreed upon naming conventions • Data accessibility • Issues with metadata
Measurement Science Needs	• Lack of a metric for "goodness" of control loop tuning • Applicability of sampling techniques in commissioning • Metrics to evaluate the performance of automated tools/ expert tools • Improved measurement and verification of commissioning impacts • Lack of tools for evaluating the performance of mechanical systems such as automated fault detection and diagnostic systems • Identifying monitoring points in control systems to support the commissioning process

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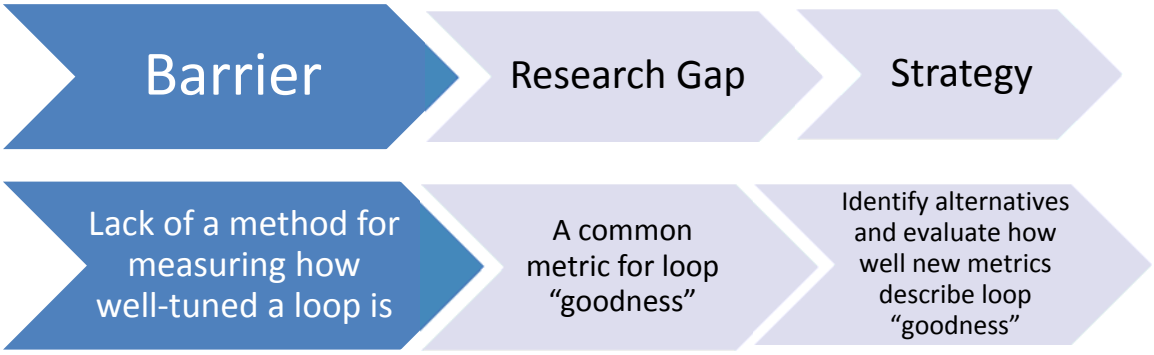
III. Building Commissioning Research Gaps

Building commissioning experts were asked to provide input to the following focus question to identify gaps and priorities in building commissioning research:

"What are the gaps in building commissioning research outside of those identified by ASHRAE Technical Committee 7.9 on Building Commissioning and pre-workshop literature review?"

Participants were provided with an example answer which included a barrier, a research gap, and a strategy to overcome that barrier/gap:



A number of important themes emerged from this discussion as summarized in Table 2.

Table 2. Building Commissioning Research Barriers, Gaps and Strategies

Building Commissioning Barrier	Building Commissioning Research Gap	Proposed Strategies
Lack of information on the life cycle cost impacts of commissioning	• No standard way to document the benefits/ROI of Cx: Quantifying costs and benefits across Cx types. • The need for and the benefits of having data measurement tools in the field.	• Research to determine best way to share the benefits of commissioning and the drivers that affect an owner's approach to the Cx process. • A continuous building performance monitoring system that allows for intermittent review, and involves all stakeholders would help demonstrate the value of Cx. • Research to quantify occupant comfort and air quality vs. energy efficiency/savings.

Lack of knowledge and acceptance of commissioning on the part of various stakeholders	Lack of information available to demonstrate the value of ongoing Cx vs. occasional Cx to building owners.	Ensuring Cx providers possess the proper tools to educate building owners of ongoing Cx benefits and necessity. Develop Ongoing Cx toolbox for Cx providers, and sufficient proof of benefits of ongoing Cx.
	Lack of educational programs for building owners/customers on benefits of Cx (monetary, comfort/productivity and energy efficiency).	Training curricula to help guide building owners through the Cx process while demonstrating the benefits of Cx actions.
	Lack of guidance for integrated building operations in Cx.	Guidance for the commissioning of multiple building systems and their interactions (HVAC, enclosure, security, water systems).
	Lack of industry standards for the certification of qualified building commissioning agents to improve consistency in Cx processes (minimum required core competencies).	Leveraging industry efforts to identify core competencies that support industry best practices: • American Society for Testing and Materials (ASTM) E2813 Support work to establish accreditation criteria and to harmonize personal certification processes: • International Code Council (AC476), to be used to accredit organizations that train and/or certify commissioning personnel. • International Organization for Standardization (ISO) 17024 • National Institute of Building Sciences (NIBS) • NIBS/Department of Energy (DOE) Commercial Workforce Credentialing program

Lack of Cx stakeholder coordination	Guidelines to ease communications between Cx stakeholders.	Develop tools for standard process flow that makes it easy for developers to collaborate, utilizing a building systems manual and developed standards. Standardized forms/reports in Cx for statements of work, functional testing protocols, and other documents.
	Bridging the gap between building efficiency and overall design, e.g., how Cx works in differing building design/delivery models.	Licensed design professionals to set facility and condition goals and set performance requirements and identify ways to reach them. There must be a feedback loop to designers and ongoing Cx as a benefit to improve design.
Lack of systems to support the commissioning process	Guidelines for utilizing a building automation system (BAS) and trend logging.	Hardware and operational sequences for self-checks in BAS could remedy this issue. Big data and analytics can be utilized to provide feedback on continuous basis to owners and operators. Research should be completed to demonstrate the value of using the BAS and trend logging.
	Lack of research to support Cx of the building enclosure.	Support for industry efforts to address this gap: ASTM standards and guidelines for Building Envelope Cx (BECx) – developed in collaboration with NIBS. ASHRAE partnering with ASTM, NIBS (and federal agencies through NIBS) to propose instrumentation for building enclosures in the GSA inventory (e.g., for data acquisition and analysis).

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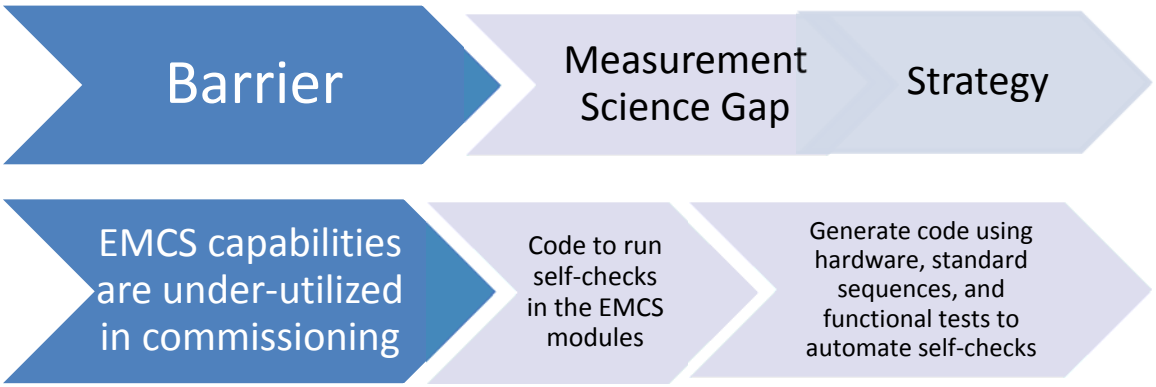
IV. Building Commissioning Measurement Science Needs

Building commissioning experts were asked to provide input to the following focus question to identify gaps and priorities in measurement science for building commissioning:

"What are the measurement science needs that would likely have the greatest potential impact for improving standard building commissioning practice?"

Participants were provided with an example answer which included a barrier, a research gap, and a strategy to overcome that barrier/gap:



A number of important themes emerged about gaps in measurement science needed to advance building commissioning. Strategies were also developed to address gaps and issues identified. Both are summarized in Table 3.

Table 3. Measurement Science Barriers, Gaps and Strategies related to Building Commissioning

Building Commissioning Measurement Science Barrier	Building Commissioning Measurement Science Need	Proposed Strategies
Missing metrics for Building Commissioning	Identification of proper sampling techniques and the impact of sampling rate on cost and completeness.	• Establish metrics associated with the sampling rate. • Develop guidelines on the proper use of sampling in Cx.
Missing Measurement Tools	Accurate measurement/calibration of fluid flow and power consumption.	Utilize equipment with built in sensors that are self-calibrating to measure flow & power.

	Measurements to support building automation systems for trend logs and other related Cx analysis.	
Missing standard measurement protocols	Lack of standardized protocol/criteria across building systems to aid in stakeholder communication (i.e. data accessibility issues, naming conventions).	Develop a standard that accounts for different building system types and evaluation criteria that provides a predictive model of performance. This model should consider occupant productivity, impact to the planet, and a financial perspective.
	Lack of standard measurement protocols for establishing baseline performance.	Develop an evaluation model and a predictive model for performance.
	Whole building air leakage measurement to support Cx of building enclosure.	Develop a strategy for making use of existing methods for conducting whole building air leakage testing before/during construction. A proxy measurement should be required for finished construction.
	Lack of standards to utilize metering in Cx.	Guidelines for metering to support Cx (i.e. calibration, guideline on monitoring points to include).
	Standard way to document the benefits/ROI of Cx: Quantifying costs and benefits across Cx types.	Improved/ standardized benefit/cost analysis in Cx.

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V. Building Commissioning Prioritization Survey

A. Description

Following the workshop webinar, meeting organizers identified various themes within both discussions: building commissioning research gaps, and measurement science needs. These themes, found in sections III and IV of this report, were added to an online prioritization survey, conducted by ASHRAE. The following questions were included in the survey:

Table 4. Building Commissioning Prioritization Survey Questions

Question #1	Please review the following research areas that would be beneficial to the Building Commissioning industry. These research areas are based on input from a recent webinar that identified gaps in building commissioning research. Please rank your top four (4) choices, one (1) being the most important/impactful piece of research for the building commissioning community.
Question #2	Please explain your building commissioning research gap selections.
Question #3	What building commissioning research gaps are we missing? Is this missing piece a top four (4) priority research gap?
Question #4	Please review the following measurement science needs within the Building Commissioning industry. These measurement science needs are based on input from a recent webinar that identified such needs in building commissioning. Please rank your top three (3) choices, one (1) being the most important/impactful piece of research for the building commissioning community.
Question #5	Please explain your building commissioning measurement science need selections.
Question #6	What measurement science needs in building commissioning are we missing? Is this missing piece a top three (3) priority research gap?

Following development of this online survey, invitations with a link to the survey were shared with all 122 invitees, with 31 experts filling out the survey. Below are the results of their input.

B. Prioritization Survey Results

After reviewing the total votes for the various research gap and measurement science need themes, scores were determined with the following values:

- Research Gaps scoring
  - 1st ranked theme (the most important theme) = 4 points
  - 2nd = 3 points
  - 3rd = 2 points
  - 4th = 1 points
  - All other themes = 0 points
- Measurement Science scoring
  - 1st ranked theme (the most important theme) = 3 points
  - 2nd = 2 points
  - 3rd = 1 point
  - All other themes = 0 points

With this scoring in mind, the following themes were identified as priorities:

Table 5. Workshop Results

Priority	Description	Survey Score
Top Priority Cx Research Gaps	A standard way to document the benefits/ROI of Cx: Quantifying costs and benefits across Cx types	79
Secondary Priority Research Gaps	Guidelines for utilizing a building automation system (BAS) and trend logging, and research should be completed to demonstrate the value of doing so.	37
	Standard development for certification of qualified building commissioning agents	35
	Educational programs for building owners/customers on benefits of Cx (monetary, comfort/productivity and energy efficiency)	32
	Lack of information available to demonstrate the value of ongoing Cx vs. occasional Cx to building owners	26
Top Measurement Science Need	Standard measurement protocols for establishing baseline performance	42
Secondary Priority Measurement Science Needs	Improved/standardized benefit/cost analysis in Cx	33
	Guidelines for metering to support Cx (i.e. calibration, guideline on monitoring points to include)	33
	A standardized protocol/criteria across building systems to aid in stakeholder communication (i.e. data accessibility issues, naming conventions)	24

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VI. Summary of Findings

Reviewing the results of the workshop and the resulting prioritization survey, industry experts have made it clear that there are specific priorities in building commissioning research and measurement science that need to be addressed. Figure 2 illustrates the top priority research and measurement science needs identified. By a considerable margin, stakeholders indicated research that demonstrates the benefits and ROI of commissioning to building owners is a high priority, as it is key in promoting mass adoption of building commissioning. Building owners must be assured that changes in building design and operation for increased energy efficiency will not affect occupant health within the building, and if/how it can benefit their bottom line. Building commissioning stakeholders have identified strategies to combat this priority research gap: new research to determine best methods to quantify the benefits/costs of building commissioning, as well as to determine the drivers that affect an owner's approach to the building commissioning process.

Demonstrating the value of ongoing building commissioning vs. occasional building commissioning was also voted as important to advancing the field. Building commissioning providers need reliable, quantitative data to educate building owners and enable them to make an informed investment decision.

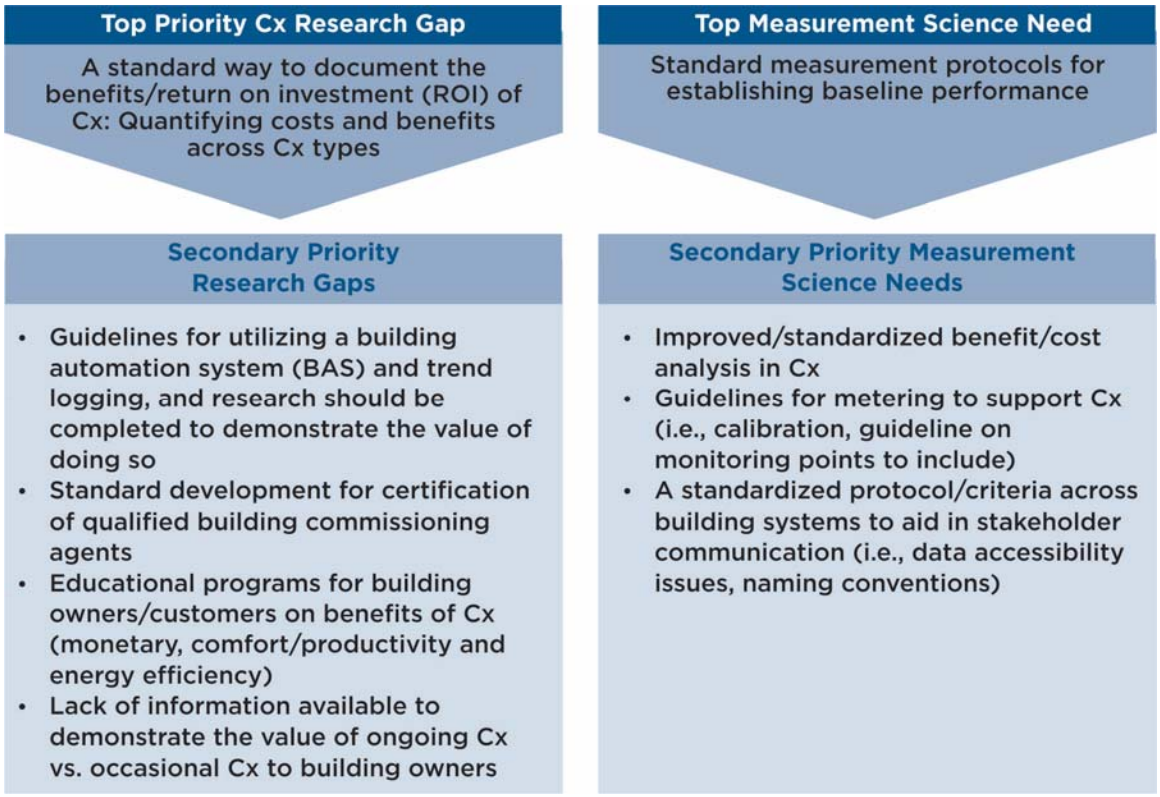

Figure 2: Top Commissioning (Cx) Research and Measurement Science Needs

Education and certification components within building commissioning are clearly important as ascertained by both survey voting and workshop discussions. Building commissioning officials working with building owners must meet strict certification requirements in order to maintain uniformity in the industry. ASTM E2813 (Standard Practice for Building Enclosure

Commissioning) is working toward addressing this gap in the context of BECx through minimum required core competencies and is developing with NIBS, a BECx Personnel Certification and Training Program to support those requirements in accordance with ISO 17024 (sets out criteria for an organization's certification program for individual persons). ASHRAE is already participating in this effort, which will also align with the requirements of the NIBS/DOE Commercial Workforce Credentialing program. Further steps can be taken to help in the education process of building owners, such as creating a common lexicon for communicating, determining scope, and meeting objectives for building projects.

Other strategies included developing guidelines for utilizing a BAS and trend logging, as well as the research to prove its value to buildings owners. By developing hardware and sequences for self-checks in BAS, value could become readily apparent to building commissioning stakeholders. Building data and analytics can also be utilized to provide feedback on a continuous basis to owners and operators.

While several measurement science needs were identified, participants made one a clear priority; to develop a standardized measurement protocol for measuring actual building performance before and after building commissioning. This priority would effectively set a baseline for building commissioning evaluation, and will require the development of key performance metrics that are then integrated into the design process and into operations. By developing an evaluation model and a predictive model for performance, this need can be met.

The three secondary priorities in measurement science for building commissioning focus on standardizing cost/benefit analysis in the industry, proper guidelines for metering, and protocols for a standard criteria when evaluation buildings in building commissioning. By developing a standard criteria that accounts for different building system types and evaluation criteria that provides a predictive model of performance, the building commissioning industry can achieve further uniformity. In addition, this model should consider occupant productivity, impact to the planet, and a financial perspective.

This report and assessment of research needs in the commissioning industry is already being utilized to prioritize building commissioning research by NIST and ASHRAE. It is anticipated that this report can serve as a benchmark for industry needs and to highlight critical barriers to broader deployment of commissioning as a means to achieve improved building system performance and improved environmental quality.

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APPENDICES

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APPENDIX A: List of Contributors

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APPENDIX B: Workshop Agenda

Webinar Workshop Agenda		
1:00 pm	***Introductory Remarks***: Webinar Overview	Walt Zalis, Facilitator
1:05 pm	**Welcoming Remarks**	Natascha Milesi Ferretti, NIST
1:15 pm	***Presentation***: ASHRAE Building Commissioning Research	David Shipley, ASHRAE and Reinhard Seidl, Taylor Engineering
1:30 pm	***Facilitated Discussion Part 1***: Identify the gaps in building commissioning research outside of those identified by ASHRAE Technical Committee 7.9 on Building Commissioning.	
2:15 pm	***Presentation***: Measurement Science	Natascha Milesi Ferretti, NIST
2:30 pm	***Facilitated Discussion Part 2***: Identify the needs for measurement science that would likely have the greatest potential impact for improving standard practice.	
3:15 pm	***Prioritization:*** Identify research areas that would be of the most benefit to industry for both building commissioning research gaps, and measurement science needs in building commissioning through a survey.	
3:25 pm	**Closing Remarks**	Natascha Milesi Ferretti, NIST and David Shipley, ASHRAE
3:30pm	**Adjourn**	