



STANDARDIZATION ROADMAP

Energy Efficiency in the Built Environment

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Prepared by the
Energy Efficiency Standardization
Coordination Collaborative of the
American National Standards Institute



BUILDING ENERGY AND WATER ASSESSMENT AND PERFORMANCE STANDARDS

SYSTEM INTEGRATION AND SYSTEMS COMMUNICATIONS

BUILDING ENERGY RATING, LABELING, AND SIMULATION

EVALUATION, MEASUREMENT, AND VERIFICATION

WORKFORCE CREDENTIALING



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TABLE OF CONTENTS

Table of Contents	3
Acknowledgments	7
Executive Summary	15
Introduction	17
Roadmap Goals	17
Power of Standardization: The Role of Standards and Conformity Assessment in the Market	19
Roadmap Audience	20
Roadmap Boundaries.....	21
Background on the EESCC Roadmap.....	22
Chapter One: Building Energy and Water Assessment and Performance Standards	23
1.0 Introduction.....	23
1.1 The Water–Energy Nexus.....	25
1.2 Building Envelope	26
1.3 Lighting	28
1.4 Cooling Systems.....	30
1.5 Heating Systems	32
1.6 Mechanical Systems	34
1.7 Energy Storage	37
1.8 Water Heating	40
1.9 Indoor Plumbing.....	41
1.10 Alternate Water Sources	44
1.11 Landscape Irrigation	46
1.12 Swimming Pools, Hot Tubs, Spas, Aquatic Features	48
1.13 Commissioning	49
1.14 Conformity Assessment.....	52
Chapter Two: System Integration and Systems Communications	57
2.0 Introduction.....	57
2.1 Coordination with the Smart Grid Interoperability Panel	58
2.2 A System Approach to Energy Management within a Building	60
2.3 Gap Analysis and Recommendations for System Integration and Systems Communications.....	62

Appendix 2A: Standards and Codes in the EESCC Inventory Database	67
Appendix 2B: Customer Interface Use Cases and Corresponding Information Elements.....	69
Appendix 2C: HVAC Case Study	70
Chapter Three: Building Energy Rating, Labeling, and Simulation.....	71
3.0 Introduction.....	71
3.1 Rating and Labeling Programs.....	71
3.1.1 Operational Ratings and Labels.....	71
3.1.2 Asset Ratings and Labels	73
3.1.3 Defining Characteristics of Building Rating Systems.....	74
3.1.4 The Current Market: Different Systems, Few Linkages.....	78
3.1.5 Gap Analysis and Recommendations: Rating and Labeling Programs.....	78
Table 3b, U.S. Rating Systems: Summary of Major Characteristics.....	81
3.2 Building Energy Simulation.....	90
3.2.1 Specific Use Cases of Whole Building Simulation	90
3.2.1.1 Energy Simulation for Code Compliance and Asset Rating.....	90
3.2.1.1.1 Commercial Buildings	91
3.2.1.1.2 Residential buildings	93
3.2.1.1.3 Multi-family buildings	94
3.2.1.1.4 Data Centers	94
3.2.1.2 Energy Simulation for Whole-Building Energy Efficiency Incentives	95
3.2.1.2.1 Commercial Buildings	95
3.2.1.2.2 Residential Buildings.....	96
3.2.1.2.3 Multi-family Buildings.....	99
3.2.1.3 Building Energy Simulation in Evaluation, Measurement, and Verification	100
3.2.1.3.1 Commercial Buildings	100
3.2.1.3.2 Residential Buildings.....	102
3.2.2 Energy Simulation Software Capabilities and Accuracy.....	103
3.2.2.1 Commercial and Residential Buildings.....	103
3.2.3 Energy Simulation Professionals	106
3.2.3.1 Commercial Buildings	106
3.2.3.2 Residential Buildings.....	107

Chapter Four: Evaluation, Measurement, and Verification (EM&V)	109
4.0	Introduction..... 109
4.1	Measurement and Verification Methodological Approaches..... 110
4.1.1	Baselines..... 111
4.1.2	Methods for Determining Annual Savings 116
4.1.2.1	Site-Specific Verification, IPMVP Option A, B, C, and D..... 117
4.1.2.2	Statistical Methodologies..... 118
4.1.2.3	Whole Building Metered Analysis 121
4.1.2.4	Methodologies Used for Large, Complex Retrofits..... 123
4.1.3	Duration of Savings: Effective Useful Life 125
4.1.4	Technical Reference Manuals (TRMs)..... 126
4.2	Reporting and Tracking Systems 130
4.2.1	Tracking Systems..... 130
4.2.2	Standardized Data Collection..... 131
4.2.3	Reporting..... 133
4.3	Other Evaluation Methodological Approaches 136
4.3.1	Top-Down and Bottom-Up Methodological Approaches 136
4.3.2	Use of Evaluation in Financial Risk Analysis 138
4.4	Emerging Issue Areas 140
4.4.1	Role of Conformity Assessment/Accreditation..... 140
4.4.2	Technology-Specific Areas 141
4.4.2.1	Behavior-Based Programs..... 142
4.4.2.2	Evaluating Emerging EE Technologies..... 145
4.4.2.3	Energy Performance Indicators (EnPIs)..... 147
	Appendix 4A: Listing of Technical Reference Manuals 148
	Appendix 4B: Categories of Behavior-Based Program and Evaluation Concerns..... 151
Chapter Five: Workforce Credentialing	153
5.0	Introduction..... 153
5.1	Terminology: Defining Workforce Credentialing 154
5.2	Indicators of Quality Credentialing Programs 156
5.3	Role of Registered Apprenticeships in Workforce Credentialing..... 158
5.4	Determining Market Value of Workforce Credentialing Programs..... 160

5.5	The Role of Conformity Assessment in Building Confidence in Credentialing Programs	161
5.6	Programmatic Accreditation for Training.....	162
5.7	Defining the Energy Efficiency Content of Occupations	163
5.8	Measuring Outcomes on the Performance of the Credentialed Workforce	164
5.9	Recommendations to Advance Credentialing for the Energy Efficiency Workforce	165
	Appendix 5A: Reference Documents for Terminology	167
	Appendix 5B: Reference Documents for Guidance on Credentialing Programs	169
	Appendix 5C: Additional Reference Documents and Initiatives	172
	Appendix 5D: Apprenticeships.....	174
	Appendix 5E: Defining the Occupation of Energy Efficiency	175
	Appendix 5F: Measuring Outcomes on the Performance of the Credentialed Workforce	178
	Next Steps for the EESCC Roadmap.....	179
	Roadmap Appendix A: Summary of Gaps/Recommendations.....	181
	Roadmap Appendix B: Additional Related Activities of Interest.....	213
	International (ISO, IEC) and Regional Standardization Activities.....	213
	U.S. Federal Government Agency Programs.....	214
	Other Standards-Related Cross-Sector Initiatives	216
	Roadmap Appendix C: Index of Acronyms and Abbreviations.....	219

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EXECUTIVE SUMMARY


Energy efficiency holds enormous promise to advance the nation's energy, economic, and environmental goals. A vast and cost-effective resource, its full potential remains yet untapped. Advancements in energy efficiency can help power the U.S. economy and job creation, boost energy security and independence, and bolster U.S. competitiveness by powering economic activity with less energy, at lower cost.

The more efficient use of energy in the buildings in which we live, work, study, and do business can significantly reduce the nation's energy costs, freeing up billions of dollars to invest in business growth, job creation, and building improvements. According to the U.S. Department of Energy (DOE), the nation's buildings account for more than 70 percent of total U.S. electricity use and 40 percent of the nation's total energy bill, at a cost of \$400 billion dollars per year.¹ With 20 percent or more of this energy wasted, comparable reductions in energy could save an estimated \$80 billion annually.²



Standards, codes, and conformity assessment programs offer significant opportunities for energy and cost savings, and improved energy efficiency capabilities for our nation's buildings. As the technical underpinning of products, services, and systems, standardization is an important tool that can be used to address market barriers, reduce costs, speed time-to-market, and accelerate the uptake of energy efficiency technologies and processes. Realizing the full potential that standardization has to offer demands a comprehensive and coordinated national approach, and close coordination between the public and private sectors.

This roadmap, developed by the American National Standard Institute's (ANSI) Energy Efficiency Standardization Coordination Collaborative (EESCC), is intended as a national framework for action and coordination on energy efficiency standardization, charting 125 actionable recommendations to advance energy efficiency in the built environment.


Greater awareness and coordination among the public and private sectors on standards, codes, and conformity assessment can help quicken the pace of energy efficiency technology development and deployment. To this end, this roadmap establishes a framework to which U.S. industry, government, standards developing organizations (SDOs), and other stakeholders can look to enable greater energy



A 20 percent reduction
in energy use in U.S. buildings
has the potential to save
\$80 billion annually



Standards, codes, and
conformity assessment offer
significant opportunities for
energy and cost savings, and
improved energy efficiency
capabilities for the long-term



¹ U.S. Department of Energy, "Securing America's Future with Energy Efficient Buildings," accessed May 5, 2014, <http://energy.gov/eere/buildings/securing-americas-future-energy-efficient-buildings>.

² Ibid.

efficiency capabilities for the nation's buildings. In the following chapters, the roadmap examines five inter-related yet distinct topics identified as areas where standardization could significantly impact deployment of energy efficiency in the built environment. The roadmap identifies standards, codes, and conformity assessment programs that are available or under development, gaps that exist, and additional standardization activities needed to advance energy efficiency in the United States.

In total, the roadmap details 125 recommendations and timelines for action, as appropriate:

- **Chapter One: Building Energy and Water Assessment and Performance Standards** outlines 46 recommendations to address identified standardization gaps in these areas
- **Chapter Two: System Integration and Systems Communications** details 9 recommendations examining how building sub-systems could be integrated in order to manage the energy use of a building or campus of buildings for maximum efficiency
- **Chapter Three: Building Energy Rating, Labeling, and Simulation** outlines 22 recommendations to address identified standardization gaps
- **Chapter Four: Evaluation, Measurement, and Verification (EM&V)** details 32 recommendations to advance the field of EM&V
- **Chapter Five: Workforce Credentialing** puts forth 16 overarching recommendations to advance workforce credentialing for the energy efficiency field

The roadmap's recommendations for closing standardization gaps in the near-term (0-2 years), mid-term (2-5 years), and long-term (5+ years) are intended to chart a strategic approach to energy efficiency standardization, and to assist SDOs in identifying priority areas for work, as well as opportunities for collaboration, coordination, and harmonization. A table summarizing all recommendations and relevant timelines is included in Roadmap Appendix A. This roadmap is supplemented by the ANSI EESCC Inventory Database³ – an online source of information on relevant standards, codes, guidelines, regulations, and conformity assessment programs.

Next Steps

While this roadmap represents a specific snapshot in time, it is envisioned as an ongoing effort that will evolve in tandem with market and standardization needs. The recommendations detailed in this roadmap are expected to see broad adoption and implementation. Following publication, the EESCC will monitor implementation of the roadmap's recommendations and follow updates on work to close identified gaps. The aim is to provide a living document that will help guide, coordinate, and enhance the standardization landscape to support energy efficiency in the United States.

Closing Standardization Gaps: A Call for Action

Organizations intending to carry out work to close an identified standardization gap are asked to **notify the EESCC**⁴ so that the collaborative can monitor the roadmap's implementation and assist with coordination of standardization activities, as appropriate.

³ The EESCC Inventory Database is available at: <http://toolwiki.ansi.org/tiki-index.php?page=EESCCTabs>.

⁴ Complete the online **EESCC Standardization Action Form** at www.ansi.org/eesc.

INTRODUCTION

Energy efficiency is a critical component of the nation’s clean energy agenda, and the opportunities that standardization offers to help achieve it are real. *The President’s Climate Action Plan* sets the goal of doubling the nation’s energy productivity by 2030,⁵ and promotes standards and practices that would cut energy waste equivalent to the energy produced by more than 650 mid-size power plants⁶ within the same time period.

Given the large-scale opportunity for increased energy efficiency within the built environment – and the benefits that can be achieved from the strategic use of supporting standards, codes, and conformity assessment solutions – this roadmap is intended to serve as a resource for U.S. industry, policymakers, and the broad energy efficiency market. This roadmap was developed by the Energy Efficiency Standardization Coordination Collaborative (EESCC), a cross-sector group of stakeholders convened by the American National Standards Institute (ANSI),⁷ with support from the U.S. Department of Energy and participating public- and private-sector organizations.

ROADMAP GOALS

The goals of this standardization roadmap are to:

- Serve as a resource for U.S. industry, government, and consumers on the range of standards, codes, and conformity assessment activities that can be leveraged to advance energy efficiency in the built environment
- Raise awareness and increase effective deployment of standardization activities among the public and private sectors
- Identify areas in the energy efficiency space where standardization gaps exist, so that the standardization community can respond with appropriate standards- and conformity assessment-based solutions
- Help federal agencies identify and prioritize areas where they may be able to direct assistance to the standardization community in responding to standardization needs

The collaborative recognizes that there are a number of important public- and private-sector initiatives currently underway to advance energy efficiency. This roadmap is intended to raise awareness of standardization activities, and to highlight areas where additional standardization is needed.

⁵ Executive Office of the President, “The Presidents Climate Action Plan,” June 2013, p9, <http://www.whitehouse.gov/sites/default/files/image/president27sclimateactionplan.pdf>.

⁶ Ibid, p19.

⁷ ANSI is a non-profit organization that coordinates the U.S. private-sector standards and conformity assessment system – a system that relies upon close collaboration and partnership between the public and private sectors. ANSI represents thousands of member companies, organizations, and individuals who rely upon standards and conformance to increase efficiency, create market acceptance, improve competitiveness, and foster international commerce. For more than ninety years, ANSI and its members have worked to demonstrate the strength of private-sector-led and public-sector-supported, market-driven, standards-based solutions that are characterized by consensus, openness, and balance. ANSI is the U.S. member of the International Organization for Standardization (ISO) and, via the U.S. National Committee, the International Electrotechnical Commission (IEC).

The EESCC is strictly a coordinating body and does not develop standards, nor does it assign responsibility for their development. The development of standards is carried out by various standards developing organizations.

Organizations intending to carry out work to close an identified standardization gap are asked to **notify the EESCC**⁸ so that the collaborative can monitor the roadmap's implementation and assist with coordination of standardization activities, as appropriate.

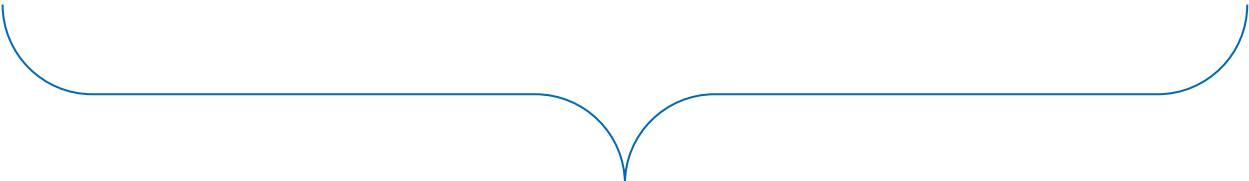


What Is a Gap?

In the context of this roadmap, **a gap** refers to a significant issue that has been identified and that should be addressed in a standard, code, regulation, or conformity assessment program, but for which currently none is published or known to exist. Gaps can be filled through the creation of entirely new standards, code provisions, regulations, or conformity assessment programs, or through revisions to existing ones. In some cases, work may already be in progress to fill the gap.

A partial gap refers to a situation where a significant issue has been identified that is partially addressed by an existing standard, code, regulation, or conformity assessment program.

No gap means there is no significant issue that has been identified at this time or that is not already adequately covered by an existing standard, code, regulation, or conformity assessment program.



⁸ Complete the online **EESCC Standardization Action Form** at www.ansi.org/eesc.

POWER OF STANDARDIZATION: THE ROLE OF STANDARDS AND CONFORMITY ASSESSMENT IN THE MARKET

Standards and conformity assessment activities – collectively referred to as “standardization” – are critically linked to all facets of our national economy and are vital to the global competitiveness of U.S. industry.

Impacting more than 80 percent of global commodity trade,⁹ standardization is essential to the success of U.S. products, personnel, and services in the marketplace. Standardization underpins global trade and commerce, supports technological innovation, and impacts the strength of the American workforce. As the technical underpinning of products, services, and systems, standards are key to helping U.S. industry tap into new and expanding technologies and bringing them to market.

In the energy efficiency space, standards and codes are critical tools for enabling greater efficiencies, reducing costs, and helping to accelerate the uptake of the next generation of energy efficiency technologies and processes. But just as important are conformity assessment activities like testing, inspection, certification, and accreditation.

Conformity assessment forms the vital link between standards – which define characteristics or requirements – and the products, systems, or personnel themselves.¹⁰ As energy efficiency technologies continue to evolve, the marketplace is becoming increasingly reliant on the methods used to ensure that products, personnel, and services comply with the requirements of those standards.

Conformity assessment programs play an important role in all of the topical areas discussed in this roadmap, and are an intrinsic part of determining the actual energy efficiency attributes of products and systems, as well as the credentialing of individuals working in specific energy efficiency fields. The task of assessing compliance to a standard may rest with the manufacturer, necessitate an independent third party like an auditor or a testing

What Are Standards?

Behind the scenes, standards make everyday life work. They establish the size, shape, or capacity of a product or system. They specify performance of products, processes, or personnel. They also define terms so that there is no misunderstanding among those using the standard.

What Is Conformity Assessment?

Conformity assessment is a demonstration that specified requirements (often via a standard or standards) relating to a product, process, system, person, or body are fulfilled. Conformance activities include accreditation, certification, inspection, registration, supplier’s declaration of conformity, and testing.

⁹ United States Department of Commerce, “Standards and Competitiveness – Coordinating for Results,” May 2004, p1, <http://ita.doc.gov/td/standards/pdf%20files/Standards%20and%20Competitiveness.pdf>.

¹⁰ For information on conformity assessment and related principles, see *The United States Conformity Assessment Principles*, <http://publicaa.ansi.org/sites/apdl/Documents/News%20and%20Publications/Brochures/USCAP%202011.pdf>.

lab, or be specified by an official like a building code inspector.

Certification bodies, testing laboratories, and inspection bodies have a critical role to play in assuring that products, personnel, and services comply with standards. Accreditation – an independent, third-party assessment of a certification body’s competency – is another key element that plays an important role in increasing marketplace confidence. Multilateral Recognition Agreements – like those established by the International Laboratory Accreditation Cooperation (ILAC) and the International Accreditation Forum (IAF) – reinforce the value of accreditation on an international scale, eliminating the need for costly multiple assessments and reducing technical barriers to trade.

Market-driven and highly diversified, the private-sector-led U.S. voluntary standardization system thrives on the active participation and engagement of all affected stakeholders, both public and private. Government use of standards has been reflected for over thirty years in federal policy, as outlined in the *National Technology Transfer and Advancement Act of 1995* (NTTAA),¹¹ the Office of Management and Budget (OMB) Circular A-119,¹² and most recently in a suite of recommendations from the Office of Science and Technology Policy in the White House (OSTP) encouraging federal engagement in standards activities addressing national priorities.¹³

Accordingly, the objective of this roadmap is to raise awareness and effective deployment of standardization activities among the public and private sectors in a manner consistent with the NTTAA, OMB Circular A-119, and the principles outlined in *The United States Standards Strategy* (USSS).¹⁴

ROADMAP AUDIENCE

This roadmap and the accompanying EESCC Inventory Database are intended as a resource to which U.S. industry, government, SDOs, and other stakeholders can look to improve energy efficiency capabilities for the nation’s buildings. Affected stakeholders include private industry; policymakers at the federal, state, and local levels; SDOs, building owners, operators, and purchasers; and architects and engineers.

Private industry: This roadmap can be used to identify the various standards, codes, and conformity assessment programs that can be used in the marketplace to enable greater efficiencies and energy cost savings. It can also help industry to target standards participation efforts, and aid in the development of energy-efficient technologies and related conformity assessment programs. It will also enable industry to identify commercial opportunities, and gain insights to support business strategies.

¹¹ Through the *National Technology Transfer and Advancement Act of 1995* (NTTAA), Public Law 104-113, the government affirmed its commitment to using standards developed by private-sector standards bodies to carry out policy objectives or activities, whenever possible. The NTTAA directs all federal government agencies to use, wherever feasible, standards and conformity assessment solutions, and directs them to do so in lieu of developing government-unique standards or regulations: <http://www.nist.gov/standardsgov/nttaa-act.cfm#>.

¹² OMB Circular A-119, *Federal Participation in the Development and Use of Voluntary Consensus Standards and in Conformity Assessment Activities*, establishes government policy on the use of and support for voluntary consensus standards. According to the circular, close interaction and cooperation between the public and private sectors is critical to developing and using standards that serve national needs and support innovation and competitiveness: http://www.whitehouse.gov/omb/circulars_a119/.

¹³ The Office of Science and Technology Policy, *Principles for Federal Engagement in Standards Activities to Address National Priorities*, Washington DC, January 2011, page 2: <http://www.whitehouse.gov/sites/default/files/omb/memoranda/2012/m-12-08.pdf>.

¹⁴ *The United States Standards Strategy* articulates the principles that guide how the U.S. develops standards and participates in international standards-setting: http://publicaa.ansi.org/sites/apdl/Documents/Standards%20Activities/NSSC/USSS_Third_edition/USSS%202010-sm.pdf.

U.S. federal, state, and municipal government: This roadmap is intended to raise awareness among policymakers of existing and forthcoming standards, codes, and conformity assessment programs, and to help support their implementation at the federal, state, and local levels. It can also assist federal and state government entities in supporting or tracking the progress of associated technical activities.


Standards developing organizations: This roadmap can assist SDOs in identifying priority areas, establishing boundaries, and identifying opportunities for collaboration, consolidation, and harmonization. With specific gaps identified in this roadmap, it will be easier for SDOs to prioritize their activities over the near-term (0-2 years), mid-term (2-5 years), and long-term (5+ years).

ROADMAP BOUNDARIES

Several high-level boundaries were established by the EESCC to guide the development of this roadmap, and the parameters for what was established as within and outside of scope are described below. Primary focus is given to U.S. standardization activities and the standards and conformity assessment activities that have direct applicability to the U.S. market.




WITHIN THE SCOPE OF THE EESCC:

- All types of energy use, from the service entry throughout the building, from the meter to the plug
 - Standards to enable communications between the building and “smart” individual devices or “smart” appliances
 - Energy storage and energy distribution within the building
 - Thermal heating and cooling building technologies that offset on-site energy use
 - Standards for on-site combined heat and power, given that thermal heat recovery is a type of energy efficiency
- 



OUTSIDE THE SCOPE OF THE EESCC:

- Individual product and appliance standards
 - Energy generation, transmission, and distribution
 - Distributed energy generation, including solar photovoltaic, small wind, methane capture and combustion, and fuel cells
- 

BACKGROUND ON THE EESCC ROADMAP

The ANSI EESCC was established to carry out the development of this standardization roadmap assessing energy efficiency within the built environment. In establishing the collaborative, ANSI sought input from a broad spectrum of stakeholders in a series of needs-focused meetings, including an April 2012 exploratory event,¹⁵ to assess how the collaborative could best help to catalyze energy efficiency for the United States. As a result, the decision was made to prioritize the five areas of focus discussed in this roadmap, and working groups were organized to conduct the standardization needs assessment for each area. More than 50 member organizations and 4 federal agencies, involving over 160 experts from industry, standards and code developing organizations, energy efficiency-focused organizations, educational institutions, and other groups took part in the effort.

The EESCC working groups began meeting via web conference in December 2012, and convened a January 2013 plenary to lay the essential groundwork for the roadmap. The working groups continued their standards needs assessment via biweekly web conferences and a series of in-person workshops in the summer of 2013. Working independently or in teams, working group members drafted sections of the roadmap, which were reviewed, edited, and discussed at working group web meetings. A draft of the roadmap was issued for public comment in January 2014 to provide an opportunity for broad review and feedback on the EESCC's findings and recommendations before final publication. The roadmap development process was characterized by open participation and consensus-based decision-making.

Assessing the Standardization Landscape – EESCC Inventory Database

As a key part of its efforts to assess the standardization landscape, the EESCC launched the EESCC Inventory Database¹⁶ and issued a broad call for input on existing and forthcoming standards, codes, guidelines, and conformity assessment programs related to energy efficiency in the built environment, as well as perceived gaps. Collecting input on more than 550 documents, 160 conformity assessment programs, and a dozen perceived gaps, the EESCC gathered input directly from the organizations responsible for the development of a document or conformity assessment program and from standards volunteers involved or highly knowledgeable of a program or tool. The documents and conformity assessment programs listed in the EESCC Inventory Database represent the best efforts of the EESCC to inventory the current standardization landscape, and may not be completely exhaustive.

Treatment of Standards in the Roadmap

The U.S. standardization system is market-driven and highly diversified; there are multiple standards developing organizations in this country, each working in response to a specific marketplace need. It is up to the marketplace to choose standards that best meet market needs. Accordingly, this roadmap is not intended to displace work that is being done, or to select “preferred” standards, codes, or conformity assessment programs. Rather, the intent is to augment and raise awareness of standardization activities. It should also be noted that different versions of a standard or code may be in use simultaneously in the market; likewise, various jurisdictions may have adopted different versions of a code or standard. For the purposes of this roadmap, the most recent version of a document is listed.

¹⁵ For the meeting event page, visit http://www.ansi.org/meetings_events/events/2012/eesp_meeting.aspx.

¹⁶ The EESCC Inventory Database is available at <http://www.ansi.org/eescc>.

CHAPTER ONE: BUILDING ENERGY AND WATER ASSESSMENT AND PERFORMANCE STANDARDS

1.0 Introduction

More than 40 percent of all energy use in the U.S. comes from residential and commercial buildings.¹⁷ By 2035, approximately three-quarters of the built environment will be new or renovated.¹⁸ This means that there are substantial opportunities for reducing energy use in buildings by optimizing systems for energy and water efficiency. Most of the standards identified in this roadmap are intended to improve the energy and water efficiency of systems in buildings, while continuing to ensure health, safety, and comfort of the occupants.

In determining the scope of topics covered in this roadmap, the EESCC decided to consider only the standards, codes, and guidelines that impact energy and water efficiency “between the meter and the plug” in a building. As a result, many standards and guidelines that pertain to energy and water use beyond the plug – or the water “supply stop,” to cite the correct plumbing equivalent of a plug – are not addressed in the roadmap even though they do impact the energy and water efficiency of a building after construction.

Product and appliance standards were also considered out of scope. A great deal of information pertaining to products and appliances is readily available, and significant advances in energy and water efficiency for products and appliances have already been achieved, in part as a result of initiatives such as the U.S. Environmental Protection Agency’s (EPA) ENERGY STAR® and WaterSense® programs.

This chapter focuses on systems in buildings that pertain to energy and water efficiency. Such systems are built into the building and can deliver various levels of energy and water efficiency, in most cases for the entire life of the structure. Because such systems have such a long-term impact, most of the codes, standards, and recommendations discussed

ESTABLISHED AS WITHIN SCOPE:

- Water-energy nexus
- Building envelope/enclosure
- Lighting
- Air conditioning/cooling systems
- Heating systems
- Mechanical systems
- Energy storage
- Water heating
- Indoor plumbing
- Alternate water sources
- Landscape irrigation
- Swimming pools, hot tubs, spas, aquatic features
- Commissioning
- Conformity assessment

ESTABLISHED AS OUTSIDE OF SCOPE:

- Appliance and product standards
- Indoor air quality standards
- Standards “outside the meter”
- Energy generation, transmission, and distribution
- Distributed energy generation

¹⁷ U.S. Energy Information Administration, “Electric Power Annual 2012,” December 2013, <http://www.eia.gov/electricity/annual/>.

¹⁸ Architecture 2030, “A Historic Opportunity,” accessed May 2014, http://architecture2030.org/the_solution/buildings_solution_how.

here best pertain to new construction and substantial renovations, and may not be appropriate for application to existing buildings or to minor alterations of buildings. This is not intended to minimize the importance of energy and water efficiency on the nation's existing building stock.

It is critical to consider water and energy together when looking at energy efficiency, as they are mutually dependent. The generation of energy often requires large volumes of water, while water distribution and treatment systems require high amounts of energy. Commissioning, maintenance, and conformity assessment also play a significant role in advancing energy and water efficiency, and therefore are also covered in this chapter.

Regardless of how much effort is put into the development of science-based codes and standards, or how efficient well-designed and -installed building systems are, society will not reap the full benefit of the resulting efficiencies unless buildings are also properly maintained as they age. Currently, no consensus standards are available that address building maintenance requirements. This is not viewed as a gap in standardization however, as maintenance requirements for buildings will vary greatly depending on the type, age, and location of the building, as well as on the type and age of the installed equipment and systems. In fact, deviating from manufacturer-recommended maintenance procedures can result in voiding warranties for building products and systems. Therefore, the development of a consensus-based standard on maintenance would be difficult and possibly counter-productive.

Commissioning, retro-commissioning, and ongoing commissioning, as discussed later in this chapter, are tools to assist building owners in assuring that the building and its systems operate as initially designed and provide the levels of performance (including energy and water) that the building owner desires. There are resources available for building owners and facility managers that offer building maintenance best practices. On the National Institute of Building Sciences (NIBS) website, the Whole Building Design Guide (WBDG) includes sections on "Facilities Operations and Maintenance"¹⁹ and "Sustainable Operations and Maintenance Practices."²⁰ In addition, the Federal Energy Management Program's (FEMP) *Operations and Maintenance Best Practices Guide*²¹ and the National Aeronautics and Space Administration's (NASA) *Reliability-Centered Maintenance Guide*²² are cited in the NIBS WBDG Operations and Maintenance sections as the "gold standard" in providing comprehensive guidance and best practices regarding building maintenance.

The gaps and recommendations outlined in this chapter provide an opportunity for legislators, regulators, standards developers, laboratories, engineers, contractors, and the general public to work on ways to fill the gaps in the energy and water efficiency standardization arena. The gaps can be filled by

¹⁹ National Institute of Building Sciences, "Facilities Operations and Maintenance," *Whole Building Design Guide*, October 2013, <http://wbdg.org/om/om.php>.

²⁰ National Institute of Building Sciences, "Sustainable O&M Practices," *Whole Building Design Guide*, July 2010, <http://wbdg.org/resources/sustainableom.php?r=om>.

²¹ U.S. Department of Energy Federal Energy Management Program, "Operations and Maintenance Best Practices: A Guide to Achieving Operational Efficiency, Release 3.0," August 2010, http://www1.eere.energy.gov/femp/pdfs/omguide_complete.pdf.

²² NASA, "RCM Guide – Reliability-Centered Maintenance Guide," September 2008, <http://www.hq.nasa.gov/office/codej/codejx/Assets/Docs/NASARCMGuide.pdf>.

requesting updates to current legislation, developing new documents, and/or providing necessary research to find ways to fill gaps where data is currently lacking.

It should be noted that the standards that were submitted for consideration by the EESCC, including those determined to be outside the scope, are included as reference in the EESCC Inventory Database²³ though they may not be addressed specifically in the roadmap. The standards and codes that are applicable to the sections in this chapter, and which were considered in determining the gaps and recommendations, can be found by performing a simple keyword search in the EESCC Inventory Database according to the relevant section heading (for example, “building envelope” or “lighting”).

1.1 The Water–Energy Nexus

The water–energy nexus is a term increasingly used to describe the interdependencies between water and energy resources. When considered at the highest levels, it is easy to understand that huge volumes of water are consumed in the energy sector for generating electricity, natural gas, and other fuels used in buildings. At the same time, significant energy is used to pump, treat, and use the water that is consumed in buildings to protect the health of its occupants.

The water–energy nexus extends beyond the generation of energy and the distribution of water, and its implications need to be better understood in order to provide guidance to standards developers on beneficial strategies for the efficient management of energy and water in our nation’s buildings. A better understanding of water–energy nexus implications on various building systems and products used in buildings would be instructive for standards developers when considering new provisions that address energy- and water-efficient building design. In this regard, the following issues are brought forward as gaps that should be addressed by standardization activities.

Gap Analysis and Recommendations

A. Standards that address supply chain- and product-embedded water–energy evaluations

There is a need for standards that address supply chain- and product-embedded water–energy evaluations that can inform consumers of the energy and water intensity of the building systems, products, or services they buy. There is currently no recognized consistent methodology for the way building systems, products, and services are evaluated for their overall water and energy footprint. Architects, engineers, consumers, and companies wishing to proactively reduce their water and energy intensity often receive mixed messages as a result.

Developing uniform standards that address the water and energy embedded in a system’s or product’s supply chain would: (1) provide a needed consistent method that would allow proper cross-comparison of options for products and services; (2) smooth out the duplicative and competing footprint methodologies, some of which unfairly favor certain companies, processes, or products, and most of which do not correctly count both water and energy interactions back through the supply chain; and (3) allow a deeper focus on systems, products,

²³ The EESCC Inventory Database is available at <http://www.ansi.org/eesc>.

and services in the commercial and industrial sectors where the combined water and energy savings potential is very high.

Recommended Timeline: While work should begin as soon as possible, this is a complex issue and is therefore a long-term effort: 5+ years.

B. Water and energy industry-accepted evaluation, measurement, and verification (EM&V) protocols

There is a need for water and energy industry-accepted evaluation, measurement, and verification (EM&V) protocols that can be utilized by standards developers to help make determinations on provisions where water and energy tradeoffs exist. Detailed EM&V protocols already exist for analyzing energy efficiency performance, but these protocols need to be revised to properly address the embedded energy savings emanating from water conservation and management programs. To date, only savings from hot water conservation programs have been included in these evaluation protocols. Interactive water and energy savings need to be properly documented where they occur, and greenhouse gas emission reduction calculation methodologies need to be revised to correctly recognize the contributions coming from the saved embedded energy in water supply, treatment, pumping, and consumer end-use consumption.

Recommended Timeline: While work should begin as soon as possible, this is a complex issue and is therefore a long-term effort: 5+ years.

1.2 Building Envelope

The building envelope – also referred to as the building enclosure – is the interface between the interior of the building and the outdoor environment, or between two environmentally distinct spaces within the same building. In the layer between the building interior and outdoor environment, the envelope of a building generally includes any building element that encloses conditioned spaces, including above-grade exterior walls, roofs, floors, doors, windows, and skylights, as well as below-grade foundation walls and floors. It serves as a building’s thermal barrier and plays the primary role in determining the amount of energy necessary to maintain a comfortable indoor environment relative to the outside environment. The original envelope decisions often remain unchanged for the life of the building.

Minimizing heat transfer across the building envelope is critical to reducing energy use in a building and the costs associated with space heating and cooling. In cold climates, the building envelope can reduce the amount of energy required for heating; in hot climates, the building can reduce the amount of energy required for cooling. This is important as heating, cooling, and ventilation account for the largest amount of end-use energy consumption in both commercial and residential buildings. In the commercial sector these account for more than one-third of energy used on site and more than one-third of primary energy use. Daylighting and the appropriate use of glazing can reduce the artificial light requirements for the building, which account for another significant portion of energy consumption. A discussion on lighting is provided in Section 1.3.

Building envelope design is a specialized area of architectural and engineering practice that draws from all areas of building science and indoor climate control, and must be very carefully considered. Site and building orientation, ratio of glass-to-opaque wall area, material selection, and detailing at interface conditions necessary to ensure the effective management of heat, air, and moisture transfer across the building envelope are critical to achieving fully integrated, whole building performance. The unique demands associated with the geographic region or climate in which the building will be located must also be considered. Climate-specific building envelope designs can significantly reduce the demand on the mechanical systems selected and sized for space heating and cooling, thereby improving energy efficiency and reducing operating costs and long-term cost of ownership. Climate-specific building envelope designs include efficient windows, doors, and skylights, spectrally-selective coatings on glass, appropriately positioned and detailed active and passive solar shading devices when used, super-insulated façades, walls and roofs, cool roofs, reflective roof membranes, and similar technologies.

Standards and codes are playing an increasingly important role in establishing both baseline and benchmark requirements for building envelope design, construction, and performance verification – a step intended to lead to higher performing, energy efficient buildings and structures. Existing standards such as ASTM E779, *Test Method for Determining Air Leakage Rate by Fan Pressurization*, and ASTM E1827, *Test Methods for Determining Airtightness of Buildings Using an Orifice Blower Door*, are being reviewed and new standard practices are being developed to improve whole building testing and its use as a compliance metric. The following discussion highlights areas where further standardization is needed.

Gap Analysis and Recommendations

A. Window installation guidance for effective energy, air, and moisture management

Within the building envelope, windows are often the most common source of heat loss, heat gain, and air leakage – often due to deficits in detailing and installation. Proper window installation is necessary to manage the heat transfer, air leakage, and water management in the building envelope. While activities are currently underway at ASTM and elsewhere, significant effort is needed to develop and deliver meaningful window installation guidance that could be adopted into voluntary programs as well as incorporated into building codes. In the field, training is needed with a specific focus on replacement window installation to deliver effective energy, air, and moisture management.

Recommended Timeline: These activities should be conducted in the near-term: 0-2 years.

B. Lifecycle valuation of envelope improvements

All energy efficiency options must be considered when evaluating portfolios of materials, technologies, and methods in construction. There is currently a deficit in service life considerations as applied to total energy efficiency, particularly with regard to the long-term durability and performance of the building envelope. The building envelope is often undervalued because its permanence in the structure is not reflected in immediate resource savings. As codes and standards evolve, a life cycle assessment (LCA) methodology for valuing options should be given further consideration and should be included, where possible.

Recommended Timeline: These activities should be conducted in the mid-term: 2-5 years.

C. Standards that evaluate insulation material performance in reducing heat flow under dynamic conditions

The current industry-accepted standard, ASTM C-518, is a static test (steady-state) at one temperature that does not represent actual in-field conditions and material performance. A dynamic test standard is needed that accounts for a material's resistance to heat transfer and a material's heat capacity at a range of temperatures, relative humidity (%RH), and air flow infiltration rates through a material.

Recommended Timeline: This work should be conducted in the near-term: 0-2 years.

1.3 Lighting

The U.S. Energy Information Administration (EIA) estimates that in 2011, about 461 billion kilowatt-hours (kWh) of electricity were used for lighting by the residential and commercial sectors. This was equal to roughly 17 percent of the total electricity used by both of these sectors and 12 percent of total U.S. electricity use. Residential lighting use was about 186 billion kWh, or 13 percent of all residential electricity used. The commercial sector, which includes commercial and institutional buildings as well as public street and highway lighting, used about 275 billion kWh for lighting, or 21 percent of commercial sector electricity use in 2011.²⁴

Many studies have shown that retrofitting the existing lighting from one type of illumination source to another can significantly reduce energy use. Most common is retrofitting incandescent or fluorescent to either fluorescent or LEDs (light emitting diodes). Linear fluorescent lighting is the most prevalent interior light source in commercial buildings, and thus, the most common retrofit is to change from T12 tubes to T8, which involves changing from magnetic ballasts to electronic ballasts. Incandescent is typically changed to either LED or compact fluorescent lighting (CFLs). Retrofit kits for luminaires need to be tested and certified for the application to ensure that the safety of the installation is not compromised.

While a typical incandescent lamp uses 60 watts of power to generate light, the current state of LED technology can produce the same light for less than 10 watts. However, interchangeability specifications are needed for LED light engines made by different manufacturers. This is a critical stepping stone toward devising practical field replacement systems for light engines comparable to those for Edison base lamps in traditional incandescent luminaires. Defined-fit systems need to define sufficient design parameters to ensure the interchangeability of modular components within a fit specification. The fit-systems would form the basis for developing safety and performance standards around predictable parameters for this class of products. These standards are under development by Zhaga,²⁵ a core group of lighting companies founded in 2010.

²⁴ U.S. Energy Information Administration, "How much electricity is used for lighting in the United States?," last modified January 2013, <http://www.eia.gov/tools/faqs/faq.cfm?id=99&t=3>.

²⁵ For information on Zhaga, visit www.zhagastandard.org.

The EPA recently released the updated ENERGY STAR® Luminaires Specification Version 1.2, and anticipates that the changes and clarifications will help simplify the use of the ENERGY STAR® Luminaire Specification and result in an increase in the number of ENERGY STAR® certified luminaires.

Lighting controls play an important role in reducing energy use and have become very sophisticated. More building automation systems now contain integrated lighting controls. Typical types of controls used are motion sensors, time switches, and daylighting controls. Compatibility of the dimmers with the type of illumination is critical for safety and to avoid the problems of the light not dimming all of the way or flickering. The illumination source also needs to be suitable for dimming. Additional savings on energy use can be realized by using special application controls for lighting, such as for hotel and motel guest rooms, display cases, tasks, food warming, and plants.

Daylighting – using natural light through skylights and windows – is becoming more popular, as it can reduce lighting and internal heat loads. Due to fluctuations on the amount of light that is transmitted, properly designed and calibrated automatic daylighting controls are necessary to operate artificial lighting to provide sufficient illumination for the area.

Any reduction or adjustments in illumination levels to address energy efficiency need to be tempered by the impact on safety and security. Reliable and proper illumination is critical for means of egress in order to ensure a safe and orderly evacuation of the building. Sufficient lighting is necessary to provide personal safety in areas such as streets and parking structures. Lighting is also used in theft prevention, such as in retail stores and car dealerships.

Gap Analysis and Recommendations

The lighting industry – including manufacturers, designers, and installers – has been diligent in addressing gaps in the applicable codes (the International Energy Conservation Code (IECC), the International Green Construction Code (IgCC), ASHRAE Standard 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings*, and ASHRAE Standard 189.1, *Standard for the Design of High-Performance, Green Buildings Except Low-Rise Residential Buildings*) through the normal code development process, as well as through clarifications or adjustments to LEED and ENERGY STAR®.

Technology has not produced anything significant that would cause the lighting industry to be able to increase efficiencies (power), with the one option of changing out existing installations to more efficient sources when possible. The other option is to reduce energy use with control systems, including daylighting controls. As such, a more “systems approach” is being used to address energy efficiency for lighting, rather than regulating individual lighting methods. This approach is focused on lighting controls, and standards are currently up to date with the latest technology. As for existing lighting installations, requirements have already been established to address retrofitting lighting to more efficient lighting methods.

No gap: At this time, existing standardization activities adequately address lighting. No known gaps currently exist.

1.4 Cooling Systems

The use of an air conditioning unit or cooling system allows for a building's temperature to be cooled and conditioned (removal or addition of moisture as needed) to a desired level, depending on the building's use and occupancy. In many instances, this is accomplished by allowing a working medium (e.g., liquid refrigerant, water, or mix of water and glycol) to act as a heat sink and remove thermal energy (heat) from the air that is being provided to the enclosed space.

Cooling systems can come in a variety of sizes, capacities, and configurations. In very large structures, such as high-rise multi-family housing or commercial buildings, cooling is typically provided from a centralized unit, where the cooled air is generated at discrete locations and distributed via ductwork, vents, and/or plenums. In applications such as these, the refrigeration equipment falls into two types of categories: vapor-compression refrigerant cycle chillers and absorption chillers. Both chiller types have unique advantages and disadvantages, which are largely dependent upon climate zones, end use, and lifecycle costs.

The cooling system may also come in the form of a decentralized system, which is common in residential heating, ventilation, and air conditioning (HVAC) systems, heat pumps, ductless mini-split systems, and evaporative coolers. Commonly, these units operate using the vapor-compression refrigerant cycle and consist of a condenser, compressor, evaporator, and expansion valve. In most areas of the United States, the primary system used to cool homes is the air conditioning portion of a residential HVAC system; however, in climates with mild winters, heat pumps can provide higher efficiency in both the heating and cooling seasons. For an efficient system capable of cooling a single room, ductless mini-split systems have become more popular in recent years. In very low humidity climates, evaporative coolers are ideal because they are able to significantly change the temperature of dry air via a phase change (transition of liquid water to water vapor), which requires much less energy than the vapor-compression refrigerant cycle.

The code requirements defined in documents such as the International Building Code (IBC), International Residential Code (IRC), and International Energy Conservation Code (IECC) specify minimum efficiency requirements for building cooling and air handling systems. ASHRAE Standard 90.1 and ASHRAE Standard 90.2, *Energy Efficient Design of Low-Rise Residential Buildings*, specify the minimum ratings and efficiency of the equipment. The Air Conditioning Contractors of America (ACCA) develops standards that are designed to assist professionals with the design, sizing, installation, and testing of HVAC systems. ACCA's Manual J, *Residential Load Calculation*; Manual D, *Residential Duct Systems*; and Manual S, *Equipment Selection*, have been adopted into code. For residential applications, and in partnership with ASHRAE for commercial applications, ACCA has developed uniform quality standards that provide effective maintenance, design, and installation guidance in documents such as ACCA Standard 6, *Restoring the Cleanliness of HVAC Systems*; ACCA Standard 4, *Maintenance for Residential HVAC Systems*; ACCA Standard 5, *HVAC Quality Installation Specification*; and ACCA Standard 180, *Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems*. These are intended to ensure that the systems are safe for occupants, service technicians, and the general public,

and to allow for cost-effective and innovative design, installation, owner education, and operations management.

Gap Analysis and Recommendations

The performance ratings and product method of testing standards for heating, ventilation, and air conditioning (HVAC) equipment are primarily developed by the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) and ASHRAE. These two entities provide a robust, dynamic standards development infrastructure that is vital in the advancement of residential, commercial, and industrial HVAC systems. Presently, the energy performance of individual air conditioning and cooling systems is well defined; however, a standardization gap does exist in the integration of these individual components to form a combined, integrated system²⁶ and for partial load efficiencies in variable speed equipment. Specific gaps related to integrated air conditioning and cooling systems are described below.²⁷

A. Standards for energy performance

The codes and standards pertaining to the energy performance of individual air conditioning and cooling systems are well defined. Establishing independently developed performance metrics that specify the cost and efficiency benefits of the overall performance of integrated air conditioning and cooling systems would enhance the basis in which architects, designers, engineers, and builders incorporate these systems in residential, commercial, and industrial applications. ASHRAE is looking at this issue for potential inclusion in Standard 90.1-2016 for commercial and multi-family residential buildings over three stories.

Recommended Timeline: This work should be conducted in the mid-term: 2-5 years.

B. Standards for integrated control

Control standards for integrated air conditioning and cooling systems are needed so that the performance and use of the systems can be optimally controlled. ASHRAE is looking at this issue for potential inclusion in Standard 90.1-2016 for commercial and multi-family residential buildings over three stories.

Recommended Timeline: This work should be conducted in the mid-term: 2-5 years.

C. Standards for building air leakage testing (unique for various building types)

Test methods for measuring the air leakage rates of a building envelope have been established for many years. In recent history, the level of interest associated with this area of building construction (e.g., green program requirements, commissioning requirements) has sizably grown due to the establishment and refinement of green, sustainable, and high performance

²⁶ An integrated system simultaneously operates and controls the systems that provide space heating (HVAC) and hot water.

²⁷ Technology research needs involving integrated systems for HVAC are discussed in the Bonneville Power Administration's (BPA) *National Energy Efficiency Technology Roadmap Portfolio*, March 2014 version. See sections on "Heating & Cooling Production and Delivery" (pp. 276-293); "Commercial Integrated Systems" (pp. 300-315); and "Residential HVAC" (pp. 316-325): http://www.bpa.gov/energy/n/emerging_technology/pdf/EE_Tech_RM_Portfolio.pdf.

energy codes and standards. The current methods only apply a single standard to all building categories and thus, do not address the complexities and difficulties that are present within the array of structure types. In order to recognize each structure's applicable limitations, it is recommended that unique standards be developed for the various building construction types.

Recommended Timeline: This work should be conducted in the mid-term: 2-5 years.

D. Partial load efficiencies for variable speed equipment

Air conditioning and cooling systems are sized to meet design conditions that occur at their rated, peak efficiencies (i.e., full load or capacity); however, in most instances, these systems only operate at partial load or capacity. For equipment that is able to vary its output capacity, efficiencies are needed that specify the systems' optimal conditions at partial load.

Recommended Timeline: This work should be conducted in the near-term: 0-2 years.

1.5 Heating Systems

Heating systems are used to maintain acceptable indoor temperatures, which can vary depending on the occupancy and use within a structure. For example, when comparing the operating conditions of a hospital's baby nursery to those of a warehouse storing general cleaning supplies, it is easy to believe that the heating set point of the nursery will be higher and more rigorously monitored as compared to the temperature of the warehouse.

The generation of heat is accomplished by converting one type of energy (chemical, electrical, energy) into thermal energy. A variety of fuels or heating mediums may be used to produce the desired heat; for example: fossil fuels (natural gas, coal, or fuel oil), renewable resources (solar or geothermal), electricity (electrical resistance or heat pumps), solid fuel (wood or pellets), or hydronics (water or steam). These systems are used in an array of applications. Due to their broad use, undertaking effective methods to more efficiently utilize this thermal energy has the potential to reduce the energy use and costs, and emissions associated with fuel use for heating medium.

In residential, commercial, and industrial applications, the heat provided is typically generated at a centralized unit and then distributed by forced air (or other methods) to other locations via ductwork, vents, and/or plenums. In the United States, furnaces and boilers are the primary means of heating structures for residential and commercial and industrial applications, respectively. However, the use of alternative heating systems varies greatly, depending on a number of key factors, including climate zones, end use, working medium, and lifecycle costs.

The standard requirements defined in documents such as the International Building Code (IBC), International Residential Code (IRC), and International Energy Conservation Code (IECC) specify minimum efficiency requirements for building heating and air handling systems. ASHRAE Standard 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings*, and ASHRAE 90.2, *Energy Efficient Design of Low-Rise Residential Buildings*, specify the minimum ratings and efficiency of the equipment to ensure that the new equipment provides superior quality that is appropriate for its application. ACCA develops standards that are designed to assist professionals with the quality design, sizing, installation,

and testing of HVAC systems. ACCA's Manual J, *Residential Load Calculation*; Manual D, *Residential Duct Systems*; and Manual S, *Equipment Selection*, have been adopted into code. For residential applications, and in partnership with ASHRAE for commercial applications, ACCA has developed quality standards that provide effective maintenance, design, and installation guidance in documents such as ACCA Standard 6, *Restoring the Cleanliness of HVAC Systems*; ACCA Standard 4, *Maintenance for Residential HVAC Systems*; ACCA Standard 5, *HVAC Quality Installation Specification*; and ACCA Standard 180, *Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems*. These are intended to ensure that the systems are safe for occupants, service technicians, and the general public, and to allow for cost-effective and innovative design, installation, owner education, and operations management.

Gap Analysis and Recommendations

ASHRAE and AHRI are two primary entities working to develop the performance ratings and product method of testing standards for HVAC equipment. They provide a robust, dynamic standards development infrastructure that is vital in the advancement of residential, commercial, and industrial HVAC systems. At the moment, the energy performance of individual heating systems is well defined; however, a standardization gap does exist in the integration of these individual components to form a combined, integrated system²⁸ and for partial load efficiencies in variable speed equipment. Specific gaps related to integrated heating systems are described below.²⁹

A. Standards for energy performance

Codes and standards related to the energy performance of individual heating systems are well defined. Establishing independently developed performance metrics that specify the cost and efficiency benefits of the overall performance of integrated heating systems would enhance the basis in which architects, designers, engineers, and builders incorporate these systems in residential, commercial, and industrial applications. ASHRAE is looking at this issue for potential inclusion in Standard 90.1-2016 for commercial and multi-family residential buildings over three stories.

Recommended Timeline: This work should be conducted in the mid-term: 2- 5 years.

B. Standards for integrated control

Control standards for integrated heating systems are needed so that the performance and use of the systems can be optimally controlled. ASHRAE is looking at this issue for potential inclusion in Standard 90.1-2016 for commercial and multi-family residential buildings over three stories.

Recommended Timeline: This work should be conducted in the mid-term: 2- 5 years.

²⁸ See note 43.

²⁹ See note 44.

C. Rating system for radiant windows

Radiant windows are increasingly being used for various heating applications in buildings. In addition to interior space heating applications, radiant windows are also being used to control the build-up of ice and snow on high-rise buildings. A standards development activity is needed to develop a consensus based rating system for radiant windows that will allow specifiers to compare the energy efficiency levels of various models.

Recommended Timeline: This activity should be conducted in the near-term: 0- 2 years.

D. Standards for building air leakage testing (unique for various building types)

Test methods for measuring the air leakage rates of a building envelope have been established for many years. In recent history, the level of interest associated with this area of building construction (e.g., green program requirements, commissioning requirements) has sizably grown due to the establishment and refinement of green, sustainable, and high performance energy codes and standards. The current methods only apply a single standard to all building categories and thus, do not address the complexities and difficulties that are present within the array of structure types. In order to recognize each structure's applicable limitations, it is recommended that unique standards be developed for the various building construction types.

Recommended Timeline: This activity should be conducted in the mid-term: 2-5 years.

E. Partial load efficiencies for variable speed equipment

Heating systems are sized to meet design conditions that occur at their rated, peak efficiencies (i.e., full load or capacity); however, in most instances, these systems only operate at partial load or capacity. For equipment that is able to vary its output speed, efficiencies are needed that specify the systems' optimal conditions at partial load.

Recommended Timeline: This work should be conducted in the near-term: 0-2 years.

1.6 Mechanical Systems

Mechanical systems are a vital component of most buildings. The term mechanical system generally applies to the equipment in a building along with the controllers of that equipment that regulate ventilation, heating, and cooling. Typically consisting of the HVAC system in residential, commercial, institutional, educational, and healthcare buildings, mechanical systems can also include process piping and equipment in commercial and industrial manufacturing and processing facilities. Energy is required to power mechanical systems, and many mechanical systems use water or steam to provide heating, cooling, or other functions. Thus, energy and water efficiency are very important considerations for mechanical systems.

Mechanical systems are designed and sized for efficiency based on the ventilation, heating, and cooling loads that the building is expected to encounter. These include both external loads relating to the influence of climate through the building envelope, as well as internal loads generated by the users of the building and the equipment contained within.

Primary standards for mechanical systems include the ASHRAE series and ACCA manuals. The ICC's International Mechanical Code (IMC) and the International Association of Plumbing and Mechanical Officials' (IAPMO) Uniform Mechanical Code (UMC) are widely used across the U.S. and provide baseline requirements for mechanical systems in the built environment. Both contain extensive references to additional standards that apply to mechanical systems. Additionally, the IAPMO Green Plumbing and Mechanical Code Supplement and ICC's International Green Construction Code (IgCC) provide a comprehensive set of code provisions for the installation of higher efficiency mechanical systems.

Gap Analysis and Recommendations

There are numerous codes and standards that address the design, installation, operation, and maintenance components of energy efficiency in both commercial and residential building mechanical systems. The model Mechanical, Electrical, and Plumbing (MEP) codes and standards all contain installation and/or maintenance-operation performance requirements, and recent editions of these codes and standards have resulted in considerable efficiencies being realized. Efforts to address specific standardization gaps are detailed below.

A. Heat energy as an underutilized resource

Thermal energy is a grossly underutilized resource in the United States relative to other developed countries. The development of an American National Standard for heat metering, led by ASTM International with cooperation from IAPMO, is currently underway. This standard will address a major gap in standardization, allowing for thermal technologies to be more easily utilized in residential and commercial buildings.

Geothermal and hydronic cooling and heating systems can provide significantly increased levels of efficiencies in both residential and commercial applications. Standards are required to help designers, engineers, and home builders better understand the long-term benefits of employing these technologies in buildings. CSA Group began the process of developing an ANSI/Standards Council of Canada bi-national standard, C448, *Design and Installation of Earth Energy Systems*, for the design and installation of geothermal ground heat pumps in response to needs that U.S. stakeholders identified.

Recommended Timeline: This work should be conducted in the mid-term: 2-5 years.

B. Duct leakage testing

i. Independently developed data pertaining to the practical levels of duct leakage testing

Forced-air heating and cooling systems use ducts to distribute conditioned air throughout the building. According to the EPA, about 20 percent of the air that moves through the duct system is lost due to leaks, holes, and poorly connected ducts in homes. Currently, there is considerable debate at codes and standards meetings in the industry regarding the minimum level of duct leakage testing that is required to improve efficiencies. Independently developed data pertaining to the practical levels of duct leakage testing is needed.

Recommended Timeline: This work should be conducted in the mid-term: 2-5 years.

ii. Testing protocols for whole HVAC duct system components

To improve energy efficiency, there is a need to develop testing protocols for whole HVAC duct system components. There is a high need for this as codes move toward requiring system testing prior to certificate of occupancy. There is also a need to standardize various techniques for measuring leakage in non-residential and multi-family air distribution and exhaust systems. Several standards developers are starting development on this topic, including ASHRAE, which is looking at this issue for potential inclusion in Standard 90.1-2016. Existing standards such as ASTM E1554/E1554M are being reviewed to improve understanding of precision and bias to aid in their use as code compliance tools.

Recommended Timeline: This work should be conducted in the mid-term: 2-5 years.

C. Employing nontraditional and emerging technologies

The potential to use nontraditional and emerging technologies for improving efficiencies in mechanical systems should be addressed by standards developers. Solar air conditioning, which can utilize several processes to cool buildings (e.g., open desiccant cooling, passive solar, photovoltaic solar cooling, and solar closed loop absorption systems); transcritical CO₂ systems, where improvements to system components may yield new efficiencies; and heat from energy-generating microturbines are technologies where standardization activities can help determine the potential for improved levels of efficiency.

Recommended Timeline: This work is a long-term effort: 5+ years.

D. Fault detection in HVAC systems

Research has shown that component faults in HVAC systems that significantly diminish efficiencies are common and go mostly undetected (see [Figure 1a](#)). Standards are needed to quantify the benefits of installing fault detection technologies on mechanical systems that can alert building and home owners to malfunctioning components.

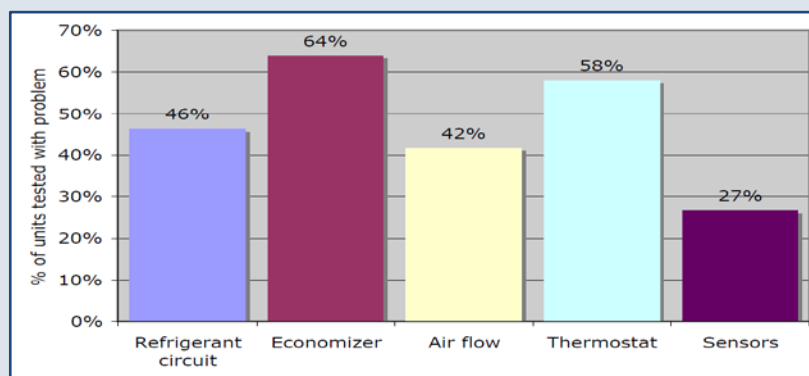


Figure 1a, Component Faults in HVAC Systems

Source: New Building Institute³⁰

Recommended Timeline: This work should be conducted in the mid-term: 2-5 years.

³⁰ New Building Institute, "Review of Recent Commercial Roof Top Unit Field Studies in the Pacific Northwest and California," October 2004, [http://rtf.nwccouncil.org/NWPCC_SmallHVAC_Report\(R3\)Final.pdf](http://rtf.nwccouncil.org/NWPCC_SmallHVAC_Report(R3)Final.pdf).

1.7 Energy Storage

Energy storage systems are critical for the realization of more energy efficient buildings, in part because they support the Smart Grid, microgrids, and other mechanisms to store energy that otherwise would be lost for future use. The development of codes and standards for such systems is complex because it involves a large range of capacities from residential implementations “behind the meter” – or on the “load side of the meter” – to larger grid-scale implementations on utility and non-utility installations associated with wind farms, large-scale solar photovoltaic installations, or campus-style microgrids.

Energy storage systems cover a range of technologies including, but not limited to: electric technologies, such as batteries; electric/thermal technologies, such as the storage of energy as heating or cooling (e.g., ice storage); and mechanical systems, such as pumped hydro, compressed air, and flywheels. These systems can be either shipped as a system near final assembly or constructed on site using a variety of components from multiple vendors or a matched assembly of components from one vendor.

At the moment, standardization is arguably in its infancy with respect to energy storage systems. For the purposes of this document, energy storage is considered the process of storing energy in any form such as chemical (batteries), thermal, mechanical (flywheel), electrical (capacitor), or another type of energy (in the form of compressed air, for instance) for use at another time. In light of these considerations, a few broad categories of needs in codes and standards can be easily identified:

- **Safety** – how to lower financial and operational risk and increase reliability
- **Communications and interconnection** – how to ensure interoperability
- **Performance** – how to express system characteristics and ratings

The safety of system installations behind the meter is generally codified in the National Electric Code® (NEC), NFPA 70. At the component level, UL and IEC standards specify safety criteria related to the design and construction of the elements that make up an energy storage system.

Standards for measuring and expressing the performance characteristics of energy storage systems are important to support the consideration of energy storage systems. They would allow different types of energy storage systems to be compared against one another in addition to comparing different systems of the same type, allowing a customer to select which system will best suit their needs. This issue is currently addressed through the DOE/Pacific Northwest National Laboratory (PNNL) *Protocol for Measuring and Expressing the Performance of Energy Storage Systems*. This document is organized by application, with each application specifying its own generic charge and discharge duty cycle, and the needed measurements to express the behavior of the system. Currently, peak shaving and frequency regulation applications are laid out, and ongoing work is focusing on thermal systems as well as systems for photovoltaic smoothing and microgrid applications. This activity can serve as a basis for future standards work associated with system rating and performance.

Gap Analysis and Recommendations

There are various codes and standards that address the components that constitute the “black box” of energy storage, defined as all between the point of common coupling, but very few that address the

system. This does not fully take into account regulatory requirements or market-driven commercial requirements (e.g. customer specifications), but rather, those voluntary consensus codes and standards that address the technical or semi-technical needs associated with energy storage systems. Energy storage technology, compared to past experiences with lead-acid batteries, is very new; thus, almost all areas of standards for systems can be considered true gaps. In addition, the nascent rise of direct-current distribution should be considered within the scope of any future standards and updates.

A. Standards for system safety issues for energy storage systems

Safety is a crucial element for the success of energy storage systems. Issues including ratings, markings, personnel barriers/set backs, system access (e.g., entry and exit points), physical abuse, and temperature ratings come immediately to mind. These may be addressed by SDOs such as UL, IEC, and others. The standards should make use of previously identified standards in SAE International and UL for battery components, should the system use batteries as the storage medium.

Recommended Timeline: This should be conducted in the near-term: 0-2 years.

B. Standards for availability, reliability, and maintenance

Energy storage systems are envisioned to be controlled autonomously by a central energy management system or a building energy management system with little human interference on a regular basis. In order to make sure the energy storage systems are functioning as specified, standards need to be developed to determine:

- **Availability** – optimal times and levels of charge and discharge for the energy storage system based on physical location, historical patterns, and other relevant factors
- **Reliability** – determining the mean uptime and mean time to failure; the mean lifetime and cycle life of the energy storage system; and/or the storage medium component associated with the system
- **Maintenance** – determining what maintenance routines should be performed on the energy storage system and when

Recommended Timeline: This should be conducted in the mid-term: 2-5 years.

C. Standards for electromagnetic compatibility (EMC)

As information technology becomes layered over electrical components, it is essential that each smart grid component, including energy storage systems, is interoperable and that each component is appropriately shielded, insulated, or otherwise designed to reduce or prevent electromagnetic interference. Note that there are currently significant barriers to testing EMC in many instances.

Recommended Timeline: This work is a long-term effort: 5+ years.

D. Standards for load flow, protection coordination, automatic gain control

The need exists to limit or prevent electrical damage to the energy storage system through the development of standards for load flow, protection coordination, and automatic gain control.

Recommended Timeline: This should be conducted in the mid-term: 2-5 years.

E. (Partial Gap) Standards to identify representative duty cycles and performance metrics for each application and/or use case

Until recently, there was no methodology for comparing the performance attributes of energy storage systems. The DOE/PNNL *Protocol for Uniformly Measuring and Expressing the Performance of Energy Storage Systems*³¹ can provide a basis for addressing this issue. It can be applied across systems that employ different types of storage mediums because it establishes a representative duty cycle for each possible energy storage system application.

A starting point for developing such a list of applications and/or use cases is the California Public Utility Commission (CPUC) *Energy Storage Staff Proposal*.³² Figure 4 from that report is reproduced below. A series or family of standards specifying representative duty cycles and performance metrics applicable by representative duty cycle should be written that would foster the uniform and comparable measurement and expression of energy storage system performance. This series of standards would allow a customer or other end user to evaluate which product is best for their use, and to establish universal testing and reporting criteria.

Recommended Timeline: This should be conducted in the near-term: 0-2 years.

³¹ Pacific Northwest National Laboratory, "Protocol for Uniformly Measuring and Expressing the Performance of Energy Storage Systems," October 2012, http://www.pnl.gov/main/publications/external/technical_reports/PNNL-22010.pdf.

³² Elizaveta Malashenko et al., California Public Utility Commission, "Energy Storage Framework Staff Proposal," April 3, 2012, http://www.cpuc.ca.gov/NR/.../0/EnergyStorage_FinalStaffProposal.docx.

Energy Storage "End Use"		Scenarios			
		A. Renewables Support/ Dispatchability	B. Distributed Storage	C. Demand-side Management	D. Ancillary Services
1	Ancillary services: frequency regulation				X
2	Ancillary services: spin/ non-spin/ replacement reserves			x	X
3	Ancillary services: ramp			x	X
4	Black start				
5	Real time energy balancing				x
6	Energy price arbitrage		x		
7	Resource Adequacy		x		
8	Intermittent resource integration (ramp/voltage support)	X			
9	Intermittent resource integration (time shift, voltage sag, rapid demand support)	X			
10	Supply firming	X			
11	Peak shaving		x		
12	Transmission peak capacity support				
13	Transmission operation				
14	Transmission congestion relief				
15	Distribution peak capacity support (upgrade deferral)		X		
16	Distribution operation (voltage / VAR support)		X		
17	Outage mitigation: micro-grid		x	x	
18	TOU energy cost management			X	
19	Power quality			X	
20	Back-up power			X	

Figure 4: Energy Storage Deployment Scenarios

Source: California Public Utilities Commission Energy Storage Framework Staff Proposal (2012)

1.8 Water Heating

The heating and delivery of water for potable water applications in a building represents one of the key areas where energy and water efficiency concerns converge into what is referred to as the water–energy nexus. It represents a prime example of how system design and delivery mechanisms, combined with sound public health and safety³³ principles, can lead to a reduction in water use and energy consumption.

Debate over the energy and water efficiency benefits of point-of-use versus conventional tank storage water heaters continues. Research conducted to date indicates that the resulting efficiencies are related to use patterns in the home or building, rather than to the water heaters themselves. As a result, this may not be a gap that can be addressed by standards developers without additional research guidance.

Gap Analysis and Recommendations

A. Standards for heat metering and solar thermal systems

Consensus standards for heat metering and hot water solar thermal systems need to be completed to advance the use of thermal technologies for water heating applications. This represents a significant and very achievable advancement in energy efficiency.

Recommended Timeline: This work should be conducted in the mid-term: 2-5 years.

³³ A discussion of pathogens and Legionellosis are covered in Section 1.9, *Indoor Plumbing*.

B. Design standards for plumbing systems

Design standards for architects and home builders are needed to illustrate how efficient building and home design can provide for greater efficiencies in water heating applications.

Recommended Timeline: This work should be conducted in the mid-term: 2-5 years.

C. Standards that address the location of the heating source and end-use point³⁴

Standards are needed for water heating and delivery systems to address the location of the heating source and the end-of-use point to ensure that the most efficient system is installed while meeting consumers' hot water use expectations. Activity is currently under way within several codes and standards development venues, including the IgCC and IAPMO's Green Plumbing and Mechanical Code committees, to address the use of recirculation systems and length of pipe requirements, and to provide guidance on how to design the most efficient systems.

Recommended Timeline: This work should be conducted in the near-term: 0-2 years.

1.9 Indoor Plumbing

By definition, indoor plumbing systems are critical to ensuring efficient operations of the building, and have a potential impact on almost every aspect of building design and operation.³⁵ The United States has made good progress toward reducing the amount of potable water consumed in our homes and buildings, as demonstrated in **Figure 1b**, which shows that in spite of L.A.'s population growth, potable water consumption has remained relatively constant over the course of the past 20 years. Similar results have been reported across the country. This is attributed to utility-based public awareness campaigns that emphasize the need to conserve water, especially in times of shortages; incentive programs that foster the installation of water efficient plumbing fixtures and appliances; and efficiency provisions contained in standards, plumbing codes, and regulations such as the *Energy Policy Act of 1992*, which addressed plumbing products.

The design, installation, operation, and maintenance of plumbing systems provide significant additional opportunities for reducing water consumption and energy use. Examples of current initiatives that are impacting the design of plumbing systems are plumbing fixtures, fittings, and appliances that provide reduced flow rates and reduced flush volumes, as well as the increased use of water re-use and rainwater catchment systems. Due to the significant impact indoor plumbing can have on both water and energy efficiency, it is often the area most looked at to obtain certain and cost-effective improvements.

³⁴ Technology research needs related to water heating are discussed in the Bonneville Power Administration's (BPA) National Energy Efficiency Technology Roadmap Portfolio, March 2014 version. See section on "Commercial and Residential Water Heating" (pp. 222-239): http://www.bpa.gov/energy/n/emerging_technology/pdf/EE_Tech_RM_Portfolio.pdf.

³⁵ The American Society of Plumbing Engineers (ASPE) defines plumbing systems as the "fluid and/or gas (including medical gas) supply and distribution systems and associated waste disposal systems, including piping, plumbing fixtures and traps, and drainage and vent pipes, including their respective joints, connections, devices, receptacles, and appurtenances."

A significant amount of work has been completed or is in progress related to energy and water efficiency standardization for indoor plumbing systems. Nevertheless, there is a need to address through standardization issues related to: (1) the impact of reduced flows on the ability of plumbing systems to remove waste; (2) the ongoing maintenance of the plumbing systems; and (3) the balance of energy and water efficiency (see Section 1.1, *Water-Energy Nexus*).

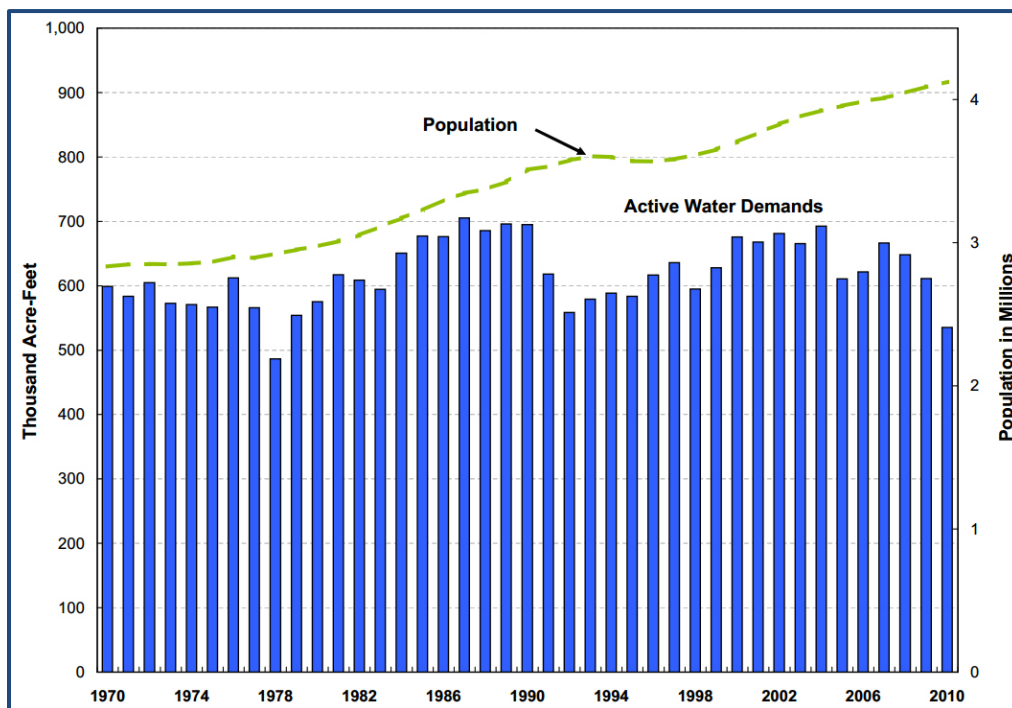


Figure 1b, Historical City of Los Angeles Water Use

Source: Los Angeles Department of Water and Power (LADWP) Urban Water Management Plan (2010)

Gap Analysis and Recommendations

The relationship between indoor plumbing systems and codes and standards is well established, and has provided the foundation for the design, installation, and maintenance of plumbing systems that deliver and remove liquid and gas media in a manner that protects public health and safety. Significant codes and standards work has been completed or is in progress to address the energy and water efficiency of the plumbing system itself and the components used in plumbing systems. While the efficiencies associated with components used in plumbing systems are outside of the “meter to plug” scope of this roadmap, the systemic nature of plumbing necessitates that the impact of these devices on the efficacy of the system be considered in this discussion.

Today, there are four standardization gaps in what currently exists and what will be needed in the future to ensure that plumbing systems are designed as efficiently as possible, while continuing to protect public health and safety.

A. Research evaluating the impact of efficient plumbing component design on the plumbing system's overall performance

Current codes and standards continue to provide significant improvements in water and energy efficiency requirements for plumbing components used in plumbing systems. However, there is considerable pressure to further increase the water savings by requiring decreased flows and flush volumes. It has been shown that further reduction in water use can be achieved through more efficient plumbing component design. However, there is little research available today evaluating the impact of those designs on the plumbing system's overall performance due to reduced flows in the system, and particularly the drainage system. There are research projects underway in the U.S., notably the Plumbing Efficiency Research Coalition, that will help to determine "how low we can go" without negatively impacting public health and safety.

Recommended Timeline: While some research, as noted above, will be conducted in the short term: 0-2 years, achieving optimum efficiency levels in plumbing systems through standardization efforts that consider the entire plumbing system will be an ongoing, long-term project: 5+ years.

B. Revised pipe sizing calculation methods that take modern lower flow rates and lower waste discharges into account along with use patterns associated with building types

Another question currently being addressed through research is the ability to design plumbing systems using smaller diameter piping due to the decreased water demand and decreased volumes needed to supply residential buildings. While it is anticipated that this research will be completed within the next 1-2 years for residential applications, similar research efforts that study water use patterns associated with increasingly complex commercial buildings needs to be conducted so that pipe size reductions that deliver energy and water efficiencies throughout the life of the building at lower construction costs can be realized.

Recommended Timeline: This work constitutes a long-term project: 5+ years.

C. The combined energy and water savings associated with the use of thermal insulation on hot water pipes

Hot water delivery systems routinely use thermal insulation (pipe insulation) to maintain the temperature of the water as it travels from the source (the water heater) to the destination (the faucet at the sink). All current energy codes and standards require some degree of thermal insulation on potable hot water piping. However, the requirements between codes vary, and most requirements are normally considered minimum levels.

Existing research has not considered the value of water when making the business case for putting additional pipe insulation on hot water piping, increasing the thickness of insulation, or identifying a scope of work for insulation installation. While studies have looked at energy efficiency, they have not addressed the short-term economics, which depend on frequency,

duration, and pattern of use, and remain the overriding consideration for most building owners.³⁶

Recommended Timeline: This work should be conducted in the near-term: 0-2 years.

D. Reducing the potential for Legionellosis and other pathogenic outbreaks

Reducing hot water temperatures in plumbing systems has been proven to both reduce scalding incidences and to save energy. However, hot water temperature reductions also provide a perfect environment for opportunistic pathogens to grow in hot water pipes. ASHRAE is currently in the process of completing BSR/ASHRAE Standard 188P, *Prevention of Legionellosis Associated with Building Water Systems*, and the accompanying Guideline 12. When published, these guidance documents will provide facility managers with techniques that can be employed to mitigate Legionellosis outbreaks, as well as a set of best practices for when outbreaks occur.

Recommended Timeline: This work should be conducted in the near-term: 0-2 years.

1.10 Alternate Water Sources

Energy is used to pump potable drinking water at all phases: from its initial source to water treatment plants, to buildings for domestic and process uses to wastewater treatment, and finally, back into a lake, river, or ocean. Currently underutilized in the United States, the effective use of alternate water supplies has the potential to significantly improve water and energy efficiency by reducing the demand for energy laden, treated potable water. Fortunately, the use of alternative water supply sources is growing. Common types of alternative water supply sources include municipally-treated wastewater, graywater, rainwater harvesting, stormwater harvesting, HVAC system condensate collection (including cooling tower blowdown sources), on-site wastewater treatment systems, and desalination.

The primary consideration regarding the use of an alternate water source is the intended end use of the water; the level of treatment must match the application. For example, an alternate water source intended for sub-surface mulch bed irrigation requires less treatment than water intended to be used indoors for flushing toilets. Most alternate water sources are well suited for non-potable applications; however, some alternate water sources, such as rainwater, can also be safely used for potable purposes with adequate and consistent treatment.

Alternate water systems vary greatly in size and complexity, ranging from small, passive domestic rainwater barrel systems used exclusively for residential irrigation purposes to complex, multi-building “campus” systems that collect several types of alternate water sources and treat the water for various uses. Municipally-treated wastewater, often referred to as reclaimed or recycled water, is treated to drinking water purity levels and is only available when a municipality or utility supplies both the

³⁶ For a discussion on the need for research toward improved pipe sizing methods and the use of thermal insulation, refer to the National Institute of Building Sciences’ (NIBS) 2012 report: *Moving Forward: In-Depth Findings and Recommendations from the Consultative Council*: http://c.ymcdn.com/sites/www.nibs.org/resource/resmgr/CC/NIBS_2012_CC_Report.pdf?hhSearchTerms=2012+and+moving+and+forward.

infrastructure and the treated water. At this time, municipally-supplied wastewater is used for non-potable applications only, such as for landscape irrigation or flushing toilets and urinals.

Currently, the 2012 Uniform Plumbing Code contains extensive installation and use provisions for alternate water source systems contained within the body of that code. The 2012 International Plumbing Code also has provisions contained in the appendix. Additionally, NSF International has published NSF 350, *Onsite Residential and Commercial Reuse Treatment Systems*. The American Rainwater Catchment Systems Association (ARCSA) and the American Society of Plumbing Engineers (ASPE) are currently developing a design standard for rainwater catchment systems, an effort sponsored by IAPMO and NSF International. ICC and CSA are also developing a standard for rainwater catchment systems.

Gap Analysis and Recommendations

A. “Fit for use” standards that provide appropriate treatment requirements for the intended use of the water

The biggest challenge facing the expanded use of water from alternate water sources is the need for agreed-upon “fit for use” standards that provide appropriate treatment and water quality requirements for the intended use of the water regardless of the source, and that ensure health and safety. Several codes and standards organizations have made excellent progress toward creating classifications of alternate water sources and corresponding applications, as well as treatment strategies. However, a one-size-fits-all approach to design and treatment may be unachievable. For example, rainwater in one area of the country may have higher heavy metals contamination than rainwater in other areas, therefore requiring different treatment measures. Standards developers need to continue to expand their knowledge base and consider provisions that will foster increased use of alternate water sources.

Recommended Timeline: Improvements to alternate water use standards should be an ongoing process with advancements made by consensus and achieved in the short-, mid-, and long-term.

B. Comprehensive stormwater standard

There is a need to develop a comprehensive stormwater standard. There is great potential for stormwater to be better utilized as an important alternate water source. Current stormwater infrastructure serves only to carry stormwater away from developed areas as quickly as possible. However, stormwater is a valuable resource that, when utilized properly, can buffer runoff and combined sewer overflows and replenish aquifers through irrigation, soak-away pits, rain gardens, and other designed stormwater features. ASPE, ARCSA, and ICC are currently developing a stormwater harvesting design standard, which may address this gap. A national standard for green infrastructure/low impact design has been provided for federal facilities by implementation of the *Energy Independence and Security Act of 2007*, Section 438.

Recommended Timeline: Development of these standards will necessitate collaboration between water use experts, civil engineers, and other stakeholders. This is a long-term effort: 5+ years.

1.11 Landscape Irrigation

In many parts of the country, especially arid areas, supplemental irrigation is relied upon to maintain healthy plants and turf grasses used in the managed landscape. A healthy landscape provides many functional benefits, including cooling, erosion control, pollution mitigation (air and noise), habitat for wildlife, recreational areas, safety zones, and fire protection. A well-designed and managed landscape can help mitigate the impacts of buildings and the associated traffic on a site, as well as create a healthy and pleasant environment for the community. While plants do not require potable water, they do need water of sufficient quality to not cause harm. Developing alternate water sources on site, such as rainwater harvesting, collecting and using stormwater, recycling or reusing water, or using reclaimed water, can ease the burden on the potable water system, including energy inputs for treatment and pumping.

Existing standards and codes that address energy and water efficiency of landscape irrigation include ASHRAE Standard 189.1, the IAPMO Green Plumbing and Mechanical Supplement, and the IgCC. The model codes have provisions to reduce or eliminate the use of potable water for landscape irrigation and have provisions for the use of alternate water sources for landscape irrigation. Additionally, some codes strive to reduce the use of water for landscapes with provisions about the type of plants used in the landscape or the amount of area used for lawns.

While the green codes have provisions to address some aspects of landscape irrigation, each has some unique criteria for the same issue (such as the maximum application rate for sloped areas). The model codes related to energy- or water-use efficiency do not reference any standards for landscape irrigation because they do not exist. The irrigation industry has relied upon the competitive forces within the marketplace for product development. The products have been innovative and the quality and performance of the products have had to meet market demands. This gap was identified several years ago, and American National Standards for landscape irrigation are currently being developed by ICC and the American Society of Agricultural and Biological Engineers (ASABE).

Gap Analysis and Recommendations

A. Standards for design practices and validating product performance

Additional standards for landscape irrigation systems would be useful in establishing minimum safety requirements and validating performance claims of products. Standards facilitate the comparison of different products to aid the consumer in making a selection for a particular application. PINS³⁷ have been filed with ANSI for controllers and rain sensors, but no committees have been formed to develop the standards. ICC is currently developing an irrigation emission device standard, which may address this gap.

³⁷ At the initiation of a project to develop or revise an American National Standard, notification is transmitted to ANSI using the Project Initiation Notification System (PINS) form.

The following gaps are becoming apparent as competing green codes are being developed with regard to landscape irrigation. Because landscape irrigation is the assembly of various components to create a system, the system needs to be designed, installed, and maintained properly.

While there are documents that have been created by industry to identify best practices for each of these areas, the potential exists to create standards out of the identified best practices that could be referenced in the codes. Such standards could eliminate conflicting or differing provisions, and thus minimize confusion in the marketplace. This would allow the green codes to be less prescriptive in nature and move more toward performance-based outcomes in managing resources. Some prescriptive irrigation provisions within the green codes conflict with implementing best practices that should be used to address the unique challenges of individual landscapes. Standards should enhance the development of a quality irrigation system that would be based on well-developed best practices for:

- Designing an irrigation system
- Installing/commissioning an irrigation system
- Long-term maintenance of an irrigation system for optimal performance

One challenge of developing standards for design, installation, and maintenance is the perceived notion that by following a standard, an untrained person can achieve the desired results, the same as a qualified professional. The reality is that each landscape project is unique, and the professional applies standards to achieve the desired outcome. Care should be taken so that standards do not become training manuals for design, installation, or maintenance.

Recommended Timeline: This work should be conducted in the mid-term: 2-5 years.

B. Standards for landscape sustainability and ecosystem services

Other gaps in standards for landscape irrigation are interrelated, but currently not enough information or research has been done to provide guidance for standards development.

1. A standard is needed for evaluating all water sources so that the most sustainable water source(s) would be used for irrigation. This standard would address the water-energy nexus and would be useful in evaluating the embedded energy in all potential irrigation water sources.
2. A standard is needed that would address the benefits derived from an irrigated landscape compared to the resources used to maximize the ecosystem services from the managed urban landscape.

Recommended Timeline: If standards are developed, they should address the process to follow in making the evaluation. This work constitutes a long-term effort: 5+years.

1.12 Swimming Pools, Hot Tubs, Spas, Aquatic Features

People use swimming pools, hot tubs, and spas regularly for recreation and leisure, so safety is properly regarded by codes and standards developers as the main concern. However, as a result, energy and water efficiency is often overlooked. Several codes and standards set requirements for products used in aquatic facilities. The diversity and complexity of these components make it challenging to understand the compliance process that ensures both safety *and* efficiency. This discussion is intended to provide an understanding of the issues that codes and standards developers are currently addressing to ensure safety as well as energy and water efficiency.

The main factors that are considered when evaluating energy and water efficiency of recreational water facilities are water pumps,³⁸ piping systems, filtration systems, temperature control measures, means of heating and cooling the water, and preventative maintenance and operational best practices. For indoor pools, ventilation and de-humidification systems are additional considerations. The type of filtration system used and the use of pool covers and liquid barriers can also significantly impact water use and energy loss by minimizing backwashing and preventing evaporation.

Aquatic features³⁹ also require evaluation when considering energy and water efficiency. The main components described for evaluating the energy and water efficiency of recreational water facilities are also applicable to aquatic features. In addition to the conservation actions noted above, UV light disinfection systems and solar water heating systems can also significantly impact energy use.

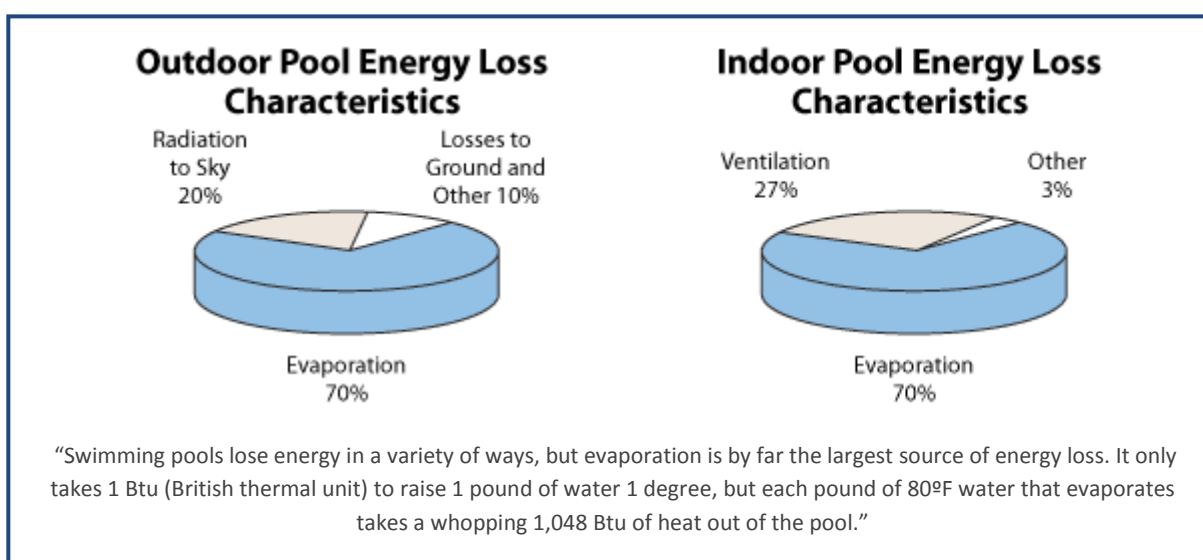


Figure 1c, Pool Energy Loss Characteristics
Image Courtesy of the U.S. Department of Energy⁴⁰

³⁸ Several model and state building codes highlight the need for using pumps with ENERGY STAR® classification.

³⁹ Aquatic features include indoor or outdoor fountains, waterfalls, water jets, or water sprays that are solely intended to wet the individual playing in the spray stream, as well as fountains or other water installations, such as decorative or interactive installations in which only incidental water contact occurs.

⁴⁰ U.S. Department of Energy, “Pool Covers,” accessed May 2014, <http://energy.gov/energysaver/articles/swimming-pool-covers>.

Gap Analysis and Recommendations

Various codes and standards address public health and safety of the above-listed water features; however, few also address water and energy efficiency issues.

A. Standards for filters and filter media testing that address water efficiency

Standards are needed to evaluate the water consumption of a pool and spa filtration system. The efficiency of a filter's backwash ability is critical to its water consumption. The industry often uses the backwash to help eliminate contaminants in the pool. The backwash water is sent to waste and new water – “make up water” – is added to dilute contaminants. This industry best practice will need to be addressed, but the need for backwash efficiency still exists.

Recommended Timeline: This should be done in the near-term: 0-2 years.

B. Standards for UV systems that address energy efficiency

Currently there are no existing standards to cover the energy efficiency for UV light generators. Standards are needed to evaluate the energy efficiency through analysis of the power delivery level and flow rates.

Recommended Timeline: This should be done in the near-term: 0-2 years.

C. Standards for testing the energy efficiency of disinfection systems (ozone generators, electrolytic chlorinators, and copper and silver ionizers)

Standards are needed to test the energy efficiency of these disinfection systems to determine the energy use at integral power levels of chemical output.

Recommended Timeline: This should be done in the near-term: 0-2 years.

D. Standards for testing the efficiency of pool covers and liquid barriers

Pool covers and liquid barriers represent a significant opportunity to minimize pool energy use by reducing heat loss and evaporation. However, they cannot provide efficiencies if they are not utilized. Research is needed to investigate the behavioral aspects of pool cover use by homeowners and facility managers, and to determine realistic potential for efficiency gains. Where research shows that efficiency gains can be reasonably expected from the use of pool covers or liquid barriers, regional construction codes and best practice maintenance guidelines should be developed that require their use.

Recommended Timeline: This should be done in the mid-term: 2-5 years.

1.13 Commissioning

Commissioning is a quality assurance process for achieving, verifying, and documenting that the performance of facilities, systems, and assemblies meets defined objectives and criteria (namely, the owner's project requirements). Depending on when the commissioning activities occur in a building's lifecycle, they may be called commissioning (new facilities and additions); retro-commissioning

(commissioning of an existing building that has not been commissioned previously), re-commissioning (the commissioning of an existing building that has undergone prior commissioning), and ongoing commissioning (a process of commissioning a building on a regular basis, including the frequent evaluation of certain building components). Commissioning serves as the linkage between the design or project team, the building owner, and the facility operation team. It provides building or project documentation, as well as training of operations and maintenance personnel and occupants.

The use of commissioning has grown as building owners and policymakers look for increased assurance of building performance. ASHRAE Guideline 0, *The Commissioning Process*, and ASHRAE Standard 202, *Commissioning Process for Buildings and Systems*, establish the overall process for conducting commissioning activities. For individual building systems, commissioning criteria are defined by relevant SDOs, with most referring back to the process defined in ASHRAE Guideline 0. At a building system level, commissioning guidelines and standards have been or are being developed by SDOs including ASTM (building enclosures), ASHRAE (HVAC, building envelope, and smoke control), ASPE (plumbing), IES (lighting), NFPA (fire and life safety systems), SMACNA (HVAC), and NECA (electrical). Additional guidance, including personnel certification programs, are provided by organizations that support the achievement of building and system performance, such as AABC Commissioning Group (ACG), ACCA, the Building Commissioning Association (BCxA), ICC, the National Environmental Balancing Bureau (NEBB), RCI Engineering, and TABB Commissioning.

Many codes and standards, including ASHRAE Standard 189.1, the IgCC, ASTM E2813, *Standard Practice for Building Enclosure Commissioning*, and the IAPMO Green Plumbing and Mechanical Code Supplement, along with green building rating systems, are currently incorporating commissioning requirements. However, it is important to note that commissioning as a process is not intended to be a surrogate for verification of code compliance.

Given the relatively new practice of building commissioning, the adherence to minimum commissioning process requirements and the identification of qualified providers has been a challenge. DOE, NIBS, and the International Accreditation Service are in the process of developing methods for recognizing competent providers.

Gap Analysis and Recommendations

A. Commissioning practices

Currently, there appears to be much confusion on what constitutes quality commissioning practices, how it can be incorporated into codes and other standards, and the identification of quality commissioning providers. Many of these questions have been addressed by commissioning industry organizations, but not in an organized fashion. Addressing these issues in the short-term will be essential to the widespread and productive use of commissioning, and the achievement of the anticipated levels of building system and utility cost performance. Many of the organizations identified above have agreed to work collectively to address these issues. ICC is currently developing a standard to address these issues as they relate to the International Codes, which may address this gap. Additionally, ASTM and the National Institute of Building Sciences (NIBS) have begun the process of

developing a set of standards and guidelines that may help to address this concern through a process referred to as building enclosure commissioning (BECx).⁴¹

Recommended Timeline: These activities should be conducted in the near-term: 0-2 years.

B. Education and training on commissioning process

There is a lack of understanding of the commissioning process among many commissioning users, such as building owners, facility managers, and personnel. There needs to be education, documentation, and training developed for commissioning users on the commissioning process, deliverables, and expected results. Having educated consumers is equally important to a quality process and providers. ASTM and NIBS have begun development of a Building Enclosure Certification and Training Program, which may help to address this need. The program⁴² will be developed in accordance with ISO 17024, *Conformity assessment – General requirements for bodies operating certification of persons*, which will be a requirement of the new ICC 1000, *Standard for Commissioning*, and the Better Buildings Workforce Guidelines project, an initiative led by NIBS and the U.S. Department of Energy.

Recommended Timeline: These activities should be conducted in the near-term: 0-2 years.

C. Methods for third-party provider conformity assessment and accreditation

Research, guidance, and common agreement are needed regarding the methods for third-party provider conformity assessment and accreditation. Additionally, data is needed on commissioning results and how the practices can enhance building performance and safety.⁴³

Recommended Timeline: This work should be conducted in the mid-term: 2-5 years.

D. Commissioning standards and guidelines for building systems

While standards and guidelines now exist for the commissioning process and many building systems have been included as identified above, several additional building systems can and should be commissioned. Standards and guidelines will need to be developed or adapted in these areas, including irrigation and decorative water systems; on-site renewable energy systems; integrated energy systems; indoor environmental quality systems; building enclosures; fire alarm, security systems, and IT systems; vertical conveyance (elevators); and integrated building automation/energy management systems.

⁴¹ The first of those standards to be published was ASTM E2813, *Standard Practice for Building Enclosure Commissioning (BECx)*. ASTM is scheduled to publish a new ASTM Standard Guide for BECx that will replace NIBS GL-3 and be available to the industry as a complement to ASTM E2813.

⁴² Certification levels and the pre-requisites required to achieve certification will be based on the minimum “core competencies” outlined in ASTM E2813, which include: Building and Materials Science, Procurement and Project Delivery, Contract Documents and Construction Administration, and Performance Test Standards and Methodology.

⁴³ The core competencies outlined in ASTM E2813 are included by reference in the recently published IAS/IEC AC476, *Accreditation Criteria for Organizations Providing Training and/or Certification of Commissioning Personnel*, and the standard is currently under consideration for inclusion in ICC 1000, *Standard for Commissioning*. Both documents will be available to local jurisdictions and code enforcement officials through the International Code Council (ICC) for adoption, and will require personnel certification of commissioning and building enclosure commissioning service-providers in conformance with ISO 17024. The U.S. Department of Energy will also include similar requirements for ISO 17024 accreditation under its Better Buildings Workforce Guidelines project.

The gap that currently exists with regard to building enclosure commissioning includes the development of a consensus guide for the implementation of the building enclosure commissioning process, which differs slightly from ASHRAE Guideline 0 and ASHRAE Standard 202, in that it speaks specifically to commissioning of the materials, components, systems, and assemblies that comprise the exterior enclosure of a building or structure. ASTM, in cooperation with NIBS, will address this gap in the Spring/Summer of 2014 with the publication of a new ASTM Standard Guide for Building Enclosure Commissioning, which will replace NIBS Guideline 3, *Building Enclosure Commissioning Process BECx*.

Recommended Timeline: These activities should be conducted in the mid-term: 2-5 years.

E. Communications from and to building equipment, sensors, and security protocols

Ongoing commissioning will depend on monitoring of all building systems in order to assure that the systems are operating in a manner consistent with the owner's current facility performance requirements. This will require the standardization of communications from and to building equipment and sensors and security protocols to allow any alteration of building systems electronically. Commissioning practices that ensure proper communication with energy providers and energy efficient operation in a smart grid environment will need to be developed. Increased understanding of the linkages between building systems and their contributions to total building performance will be necessary. This includes the development of metrics and methods to support whole building assessments and existing building commissioning process.

Recommended Timeline: These activities should be completed in the long-term: 5+ years.

1.14 Conformity Assessment

Energy and water performance standards play a key role in advancing energy efficiency and enabling industry and consumers to adopt more energy efficient technologies. These standards communicate the expectations of the marketplace regarding safety, performance, compatibility, sustainability, and efficiency. But the proper implementation of these standards is fundamental to achieve ultimate energy efficiency results. Conformity assessment plays an important role in the proper and consistent compliance and implementation of standards, and is therefore instrumental in the enforcement of these standards when they become regulations. The tenets outlined in the *United States Conformity Assessment Principles* (USCAP) can be applied to any of the different types of conformity assessment activities (accreditation, certification, inspection, registration, supplier's declaration of conformity, and testing), and can be beneficial to first, second, or third parties,⁴⁴ or to government users of conformity assessment.

⁴⁴ As defined by the USCAP, "The first party is generally the person or organization that provides the object, such as the supplier. The second party is usually a person or organization that has a user interest in the product, such as the customer. The third party is a person or body that is recognized as being independent of the person or organization that provides the object, as well as the user or customer of the object."

Accreditation – an independent, third-party assessment or verification of a program’s or institution’s competency to meet established quality standards – plays a critical role in increasing marketplace confidence and proper enforcement of codes and regulations.

The most appropriate and cost-effective mix of these approaches should be used for each conformity assessment activity. This mix will be different for different types of conformity programs performed by conformity assessment bodies. Conformity assessment activities that pose a higher risk of incurring significant costs of failure (i.e., producing harm to human safety, health, or environment) generally will need greater assurance of conformity and thus, second- or third-party forms of conformity assessment are most appropriate.

The standards used to determine conformity that have a general application in verifying energy efficiency can be found in the International Organization for Standardization’s (ISO) Conformity Assessment Committee (CASCO) Toolbox and the EESCC Inventory Database, and include:

1. **ISO/IEC 17021:2011**, *Conformity assessment – Requirements for bodies providing audit and certification of management systems*
2. **ISO/IEC 17025:2005**, *Conformity assessment – General requirements for the competence of testing and calibration laboratories*
3. **ISO/IEC 17024:2012**, *Conformity assessment – General requirements for bodies operating certification of persons*
4. **ISO/IEC 17020:2012**, *Conformity assessment – Requirements for the operation of various types of bodies performing inspection*
5. **ISO/IEC 17065:2012**, *Conformity assessment – Requirements for bodies certifying products, processes and services*

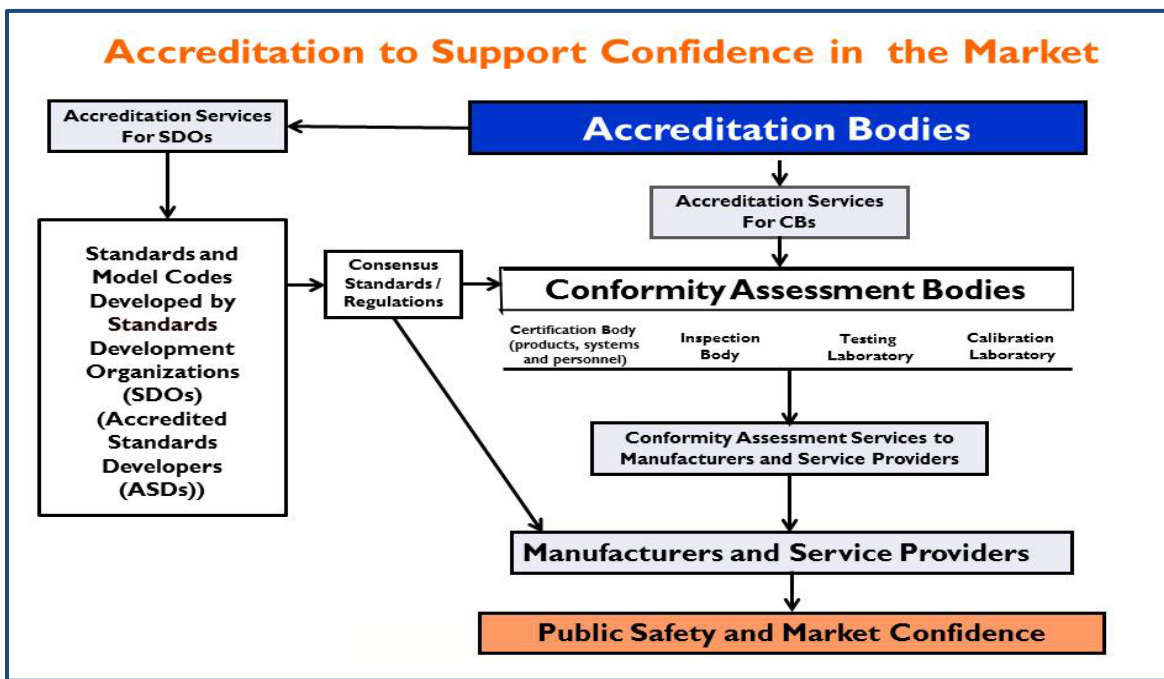


Figure 1d, Accreditation to Support Confidence in the Market
Image courtesy of the American Association for Laboratory Accreditation (A2LA)

Gap Analysis and Recommendations

The following represents a gap analysis for conformity assessment accreditation in the energy efficiency field. Two perspectives have been considered to identify the gaps:

A. Gaps in the actual accreditation standards

There are various standards such as the ISO/IEC 17000 series that are designed to work together with technical standards in the energy efficiency field. The 17000 standards have systematic reviews that take place five years after publication. If they are reaffirmed, the standards are reviewed five years later unless a new work item proposal (NWIP) is proposed earlier by a CASCO member and approved by CASCO for a compelling need. The gaps from this perspective are addressed through the systematic reviews.

Recommended Timeline: This depends on ISO's systematic review process; however, some of these standards such as ISO/IEC 17011 and ISO/IEC 17000 are in need of update as soon as possible. This should be conducted in the near-term: 0-2 years.

B. Gaps in the implementation of accreditation

Accreditation is a tool for decision makers/regulators to assist in risk reduction. Some product characteristics are vital for safe and effective performance; however, many of these characteristics cannot be reasonably evaluated simply by observation or examining the product in the marketplace. Such characteristics need to be determined and assessed, and assurance needs to be provided to the buyer (or other interested party) that the product conforms to requirements and that conformance is consistent from product to product.

Regulators may be unaware of internationally-recognized accreditation bodies such as those recognized by the International Laboratory Accreditation Cooperation (ILAC) and the International Accreditation Forum (IAF), such as the American National Standards Institute (ANSI), the American Association for Laboratory Accreditation (A2LA), the International Accreditation Service (IAS), and the National Voluntary Laboratory Accreditation Program (NVLAP), among others. Third-party accreditation of testing and calibration laboratories, inspection bodies, and product certification bodies is an option that is sometimes overlooked.

The most appropriate and cost-effective mix of these approaches should be used for each conformity assessment activity. This mix will be different for different types of conformity programs performed by the conformity assessment bodies. Conformity assessment activities that pose a higher risk of incurring significant costs of failure (i.e., producing harm to human safety, health, or environment) generally will need greater assurance of conformity and thus, second- or third-party forms of conformity assessment are most appropriate.

The following are specific areas to be addressed:

- Need of consensus standards in the different areas of energy efficiency: this is being addressed in this roadmap by identifying areas where standardization is needed to advance energy efficiency.

- Research on applications and emerging technologies related to inspection, testing, and monitoring of energy efficiency devices and equipment.
- Research on traceability measurement for energy efficiency. Traceable measurements must have both the correct equipment and be used in the correct ways in a valid method. Questions that should be considered include: *Are the current testing methods appropriate to the test, and are the compliance specifications appropriate for the current technologies and market needs?*
- Research on the application of calibration of energy efficiency equipment.
- Documentation of accreditation best practices to demonstrate to regulators and other stakeholders the increase to the bottom-line.
- Documentation of how accreditation increases market value and confidence, and how governments can be involved and use accreditation to increase their confidence.
- Documentation of how accreditation increases market value in international trade.
- Reinforcement of the body of knowledge related to the implementation of accreditation standards such as laboratory accreditation (17025), product certification (17065), and inspection bodies (17020).

Recommended Timeline: This should be conducted in the mid-term: 2-5 years.



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CHAPTER TWO: SYSTEM INTEGRATION AND SYSTEMS COMMUNICATIONS

2.0 Introduction

Today, various sub-systems⁴⁵ within buildings operate in a mostly fractured environment. Building sub-systems – such as heating, ventilation, and lighting – use energy, but they do not communicate their energy use with each other. In the future, system integration will be key to enabling more cost-effective operations. Future gains in energy efficiency require an understanding of the total system energy profile of the sub-systems in a building or campus of buildings.

Building designers, constructors, service providers, as well as contractors, owners, operators, and managers are all impacted by the integration of systems that may control and/or report information relative to the building's operational systems. In this chapter, the system integration and systems communications working group examines how building sub-systems could be integrated in order to manage the energy use of a building or campus of buildings for maximum efficiency.

The system approach to addressing energy efficiency of a building makes use of terms that can have different meanings depending on the context in which they are used. For example, the term energy management system could be understood as a Smart Grid automation technology, a real-time control system designed to automate operations (i.e., a building automation system), a set of elements of an organization establishing energy policy and objectives, or as a process of continuous improvement, such as that defined by ISO 50001.⁴⁶

In the context of this document, the building energy management system (EnMS) is the set of hardware and software that performs the inventory of all energy flows, users, and uses, and determines the building operating parameters based on a set of prescribed optimization factors.

ESTABLISHED AS WITHIN SCOPE:

- Machine-to-machine communications
- Standards for the integration of products and/or appliances within a building structure or with the energy management system
- Standards that impact the design, operation, or energy management of a building
- Telecommunications wiring infrastructure that affects how much energy a system uses, and the related telecommunications standards for connectivity of networks

ESTABLISHED AS OUTSIDE OF SCOPE:

- Appliance and product standards
- Human-to-human communications
- Vehicle-to-building-to-grid communications
- Industrial floor automation

⁴⁵ Alternate terms for sub-systems in buildings are functions, building activities, and end use.

⁴⁶ Developed by the International Organization for Standardization (ISO), ISO 50001, *Energy management systems - Requirements with guidance for use*, specifies requirements for establishing, implementing, maintaining, and improving an energy management system. For more information, visit <http://webstore.ansi.org/RecordDetail.aspx?sku=ISO+50001%3A2011>.

As defined by this working group, **system integration and systems communications** encompasses communications between building automation/operation systems and equipment/appliances within a single building and/or between buildings, such as across facilities and campuses. Additional boundaries around scope are detailed in the text box on the previous page. To carry out its assessment and develop the recommendations outlined in this chapter, the EESCC system integration and systems communications working group conducted a review of applicable standards and codes with the aim of identifying what additional standardization is needed to advance this area.⁴⁷ Wherever possible, standards development and revision should be done in the context of existing internationally-recognized building automation protocol standards development.

2.1 Coordination with the Smart Grid Interoperability Panel

While the EESCC system integration and systems communications working group is focused specifically on energy efficiency and energy management within a building or group of buildings (i.e., facilities and campuses), a complementary coordination effort – the Smart Grid Interoperability Panel (SGIP) – is focused on standards, testing, and certification efforts that enable interoperable communications between internal building EnMS with external grid service providers. Throughout its assessment, the EESCC system integration and systems communications working group coordinated with the SGIP to ensure that the respective efforts would remain complementary and not overlap in scope.

The SGIP was established to support the National Institute of Standards and Technology (NIST) in fulfilling its responsibilities under the *Energy Independence and Security Act of 2007* (EISA). SGIP’s mission is to provide a framework for coordinating Smart Grid stakeholders to accelerate standards harmonization and advance the interoperability of Smart Grid devices and systems. The NIST Smart Grid Conceptual Model shown in **Figure 2a** illustrates the SGIP’s core areas of technological focus – or “domains” – and is a tool for visualizing the structure and operation of the power system.

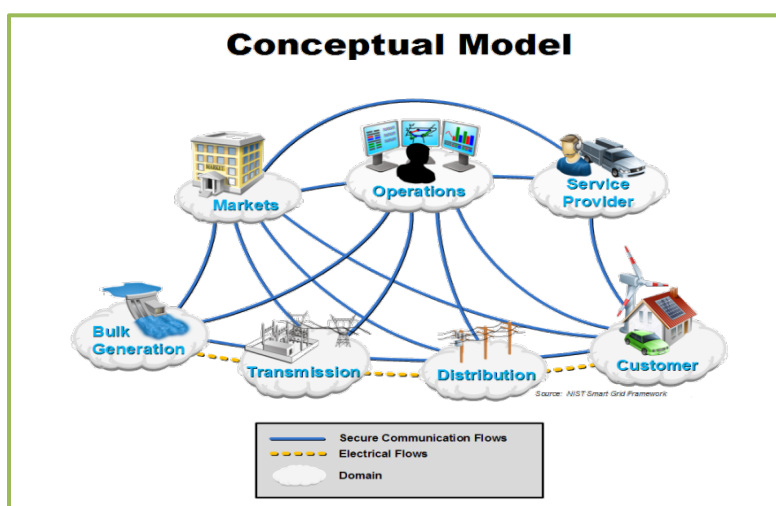


Figure 2a, NIST Smart Grid Conceptual Model⁴⁸

⁴⁷ Results from the working group’s review are included in the chapter appendices.

⁴⁸ Source: NIST Special Publication 1108R2, “NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 2.0,” February 2012, p. 42, http://www.nist.gov/smartgrid/upload/NIST_Framework_Release_2-0_corr.pdf.

Of particular importance to the EESCC system integration and systems communications working group is the SGIP “customer domain,” shown in **Figure 2b**, where electricity is consumed. Actors⁴⁹ in the customer domain enable customers to manage their energy use and generation. Some actors also provide control and information flow between the customer and the other domains. The boundaries of the customer domain are typically considered to be the utility meter and the energy services interface (ESI). The ESI provides a secure interface for utility-to-consumer interactions, and can act as a bridge to facility-based systems such as a building automation system (BAS). As illustrated in Figure 2b, the SGIP customer domain is segmented into sub-domains: home, building/commercial, and industrial. Each sub-domain has a diverse set of actors, applications, and technology. This diversity results in a challenge for grid-side service providers to engage with a range of customer systems and devices managed for different purposes, using a wide variety of communication protocols. The customer interface needs to accept and adapt to this customer diversity in order to achieve scalability and a high level of acceptance.

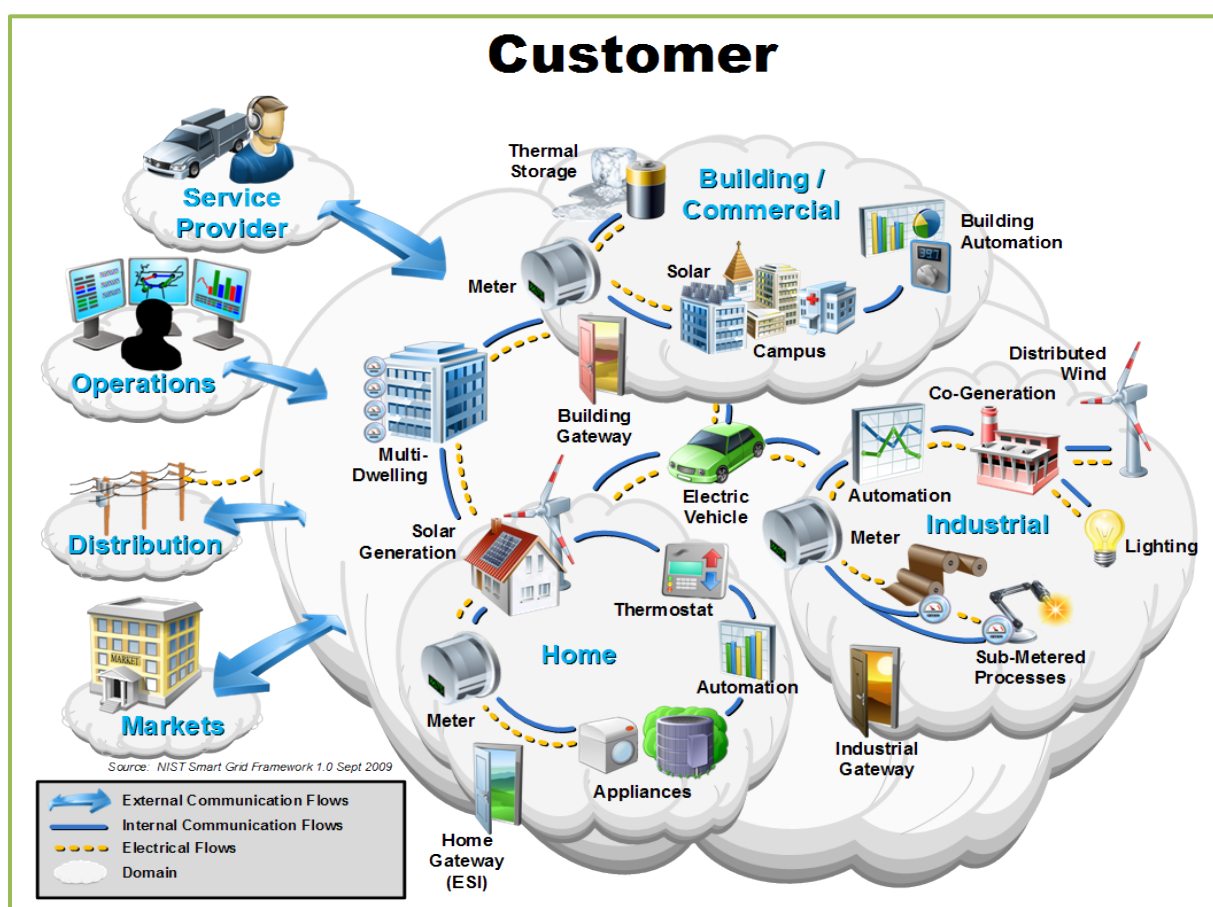


Figure 2b, Customer Domain⁵⁰

⁴⁹ As defined by the “NIST Framework and Roadmap for Smart Grid Interoperability Standards, “actors” may be devices, computer systems, or software programs and/or the organizations that own them. Actors have the capability to make decisions and exchange information with other actors through interfaces: NIST Special Publication 1108R2, “NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 2.0,” February 2012, page 40, http://www.nist.gov/smartgrid/upload/NIST_Framework_Release_2-0_corr.pdf.

⁵⁰ Source: NIST Special Publication 1108R2, “NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 2.0,” February 2012, p. 211, http://www.nist.gov/smartgrid/upload/NIST_Framework_Release_2-0_corr.pdf.

As demonstrated in **Figure 2c**, the ESI supports the exchange of data and information elements between the grid and customers required to enable a grid-interactive building by satisfying a set of SGIP use cases, detailed in Appendix 2B. Some of these SGIP use cases, such as Facility Energy Management (FEM), are supported by applications that also support energy efficiency. Demand response also involves external inputs that affect the management of internal facility loads.

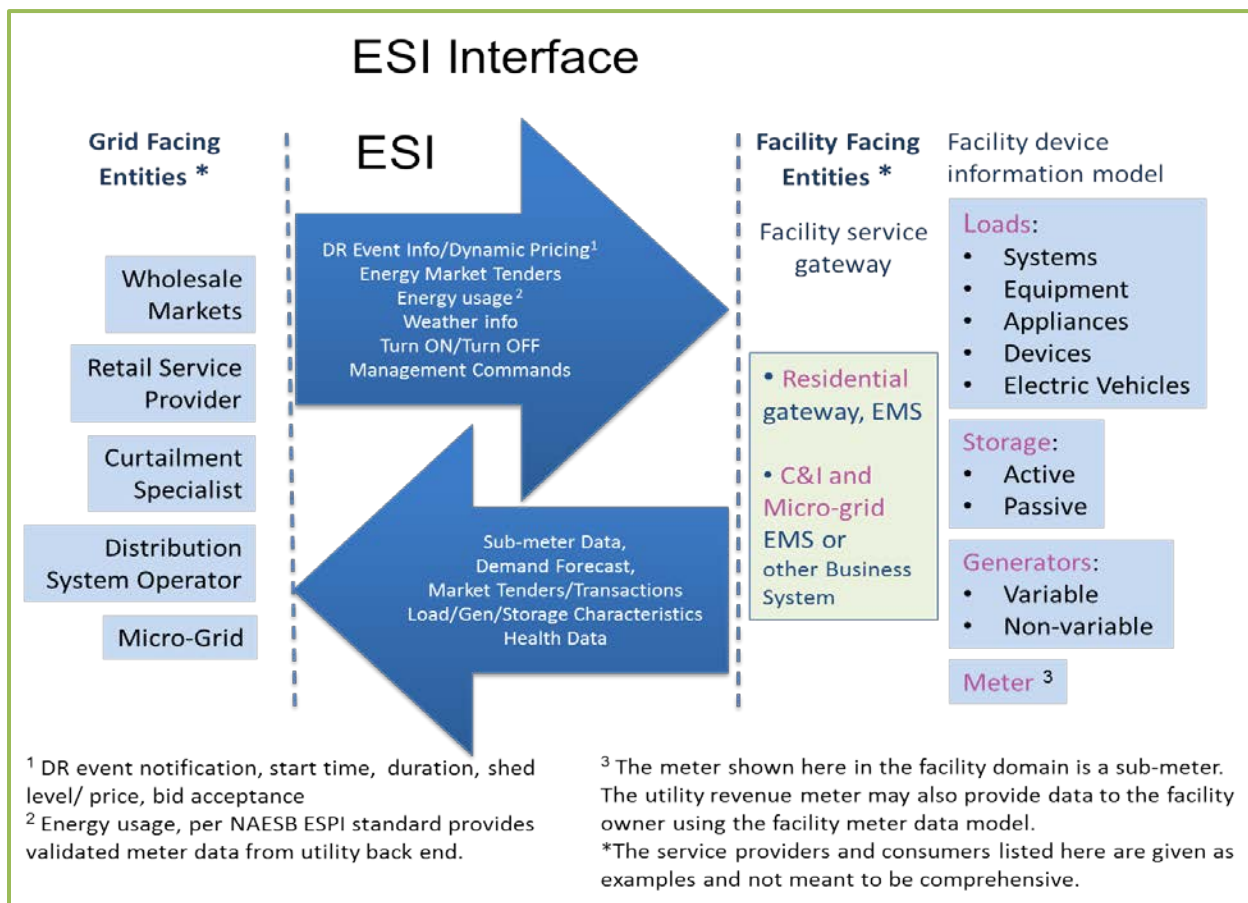


Figure 2c, ESI Interface

While the scopes of the SGIP and the EESCC system integration and systems communications working group are distinct, there are instances of potential connection points that impact both and may require the coordination of new standards or extensions to existing standards. One example of a potential connection point is the modeling of building or facility energy information used to monitor energy for demand response (SGIP use).

2.2 A System Approach to Energy Management within a Building

As discussed above, the Smart Grid seeks to reduce energy losses during electric power transmission and distribution. Residential and commercial buildings use nearly 75 percent of the nation’s electricity,

and are thus the major energy users connected to the grid.⁵¹ Reducing those losses would require large investments in reactive power compensation, phase shifting transformer, and power electronics steering and control. And yet, these investments may not be recovered from reduced losses alone during the lifetime of the system. Alternatively, two-way communication between the Smart Grid and buildings could better control the reactive power and ensure an even loading of transmission and distribution connections.

For the Smart Grid, energy management is a bidirectional flow of information and electricity. Energy management within a building on the other hand is more complex. Energy flows through the building in a variety of forms, including heat, steam, compressed air, and electricity. Even if two buildings have identical structure and envelope, the system energy profile will be unique due to variances in tenant use and occupancy. The Smart Grid determines a demand response strategy based on data from the building that lead to the reduction of losses during electric power transmission and distribution. Other strategies, such as the transactive approach, can be used as well.

A building system is made up of a number of different sub-systems, such as HVAC, lighting, electric power, or security. Each sub-system has a defined function, importance, and a set of energy performance indicators. A 'system approach' to a building considers how the sub-systems influence each other within the building system as a whole, and can determine whether an improvement in one area may adversely affect another area of the building system.

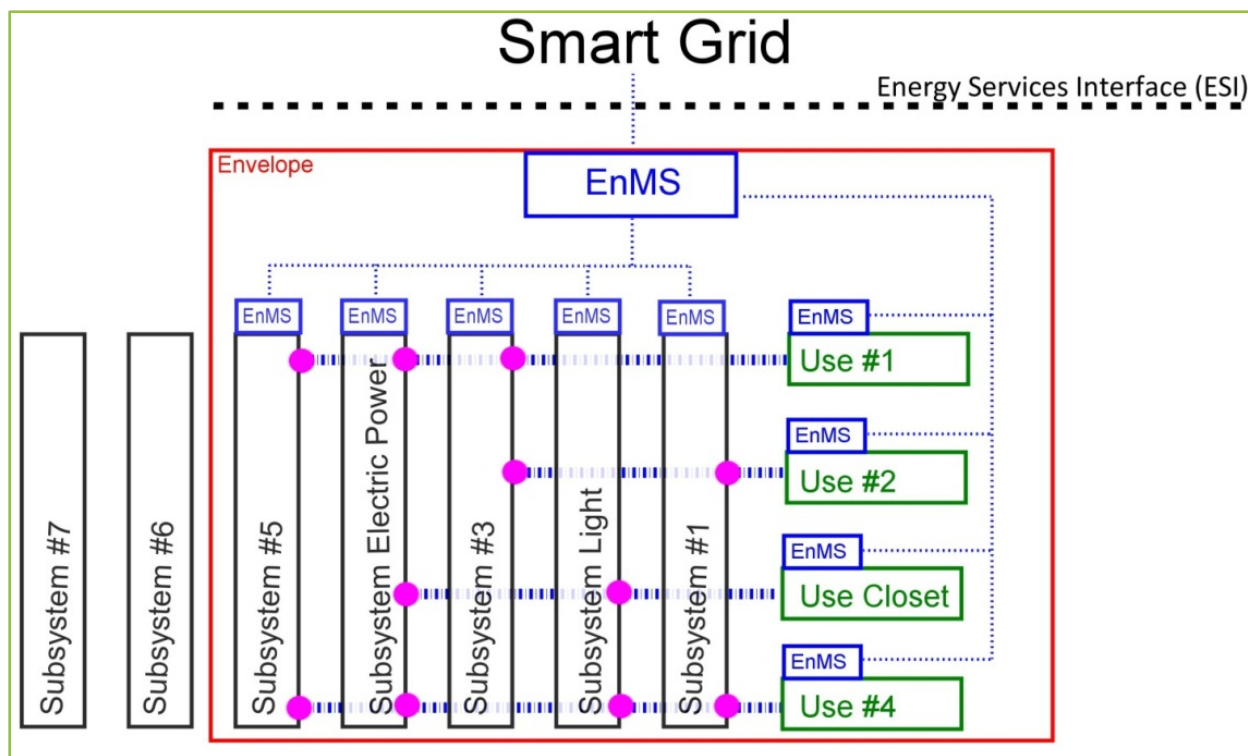


Figure 2d, A Model of the Building Energy System

⁵¹ In 2011, the residential sector constituted 38.2 percent of retail sales; the commercial sector constituted 35.4 percent. Source: DOE/EIA, "Annual Energy Review 2011," September 2012, Table 8.9., page 253: <http://www.eia.gov/totalenergy/data/annual/index.cfm>.

Figure 2d provides a model of a commercial building with a building automation system. This model is used to illustrate the interaction among building system components and the interaction between the building and the Smart Grid. The terms and interactions described in relation to this model can also be applied to smaller commercial buildings that do not have building automation systems.

The building envelope, also referred to as the building fabric or structure, is also discussed in Section 1.2 of this roadmap. Basic functions of the building envelope include adding structural support, controlling moisture and humidity, regulating temperature, and controlling air pressure changes. By serving these different functions, the envelope also affects ventilation and energy use within the building. The sub-systems installed in a building depend on the building's function; for example, whether it is a hospital or a library.

The spaces in the building modeled in Figure 2d can have various 'uses.'⁵² Commercial buildings enable a wide variety of 'uses,' from providing a space to work or be educated, to places for health care, storage, shopping, and lodging. A 'use' exchanges energy with a combination of sub-systems necessary for its activity. Figure 2d illustrates the example for a storage closet 'use' that exchanges energy with only two sub-systems: light and electric power. In Figure 2d, two sub-systems (#6 and #7) are not part of a specific building system.

An EnMS can be implemented in order to optimize the energy profile for each 'use' in Figure 2d. Data exchanged by the 'use' is very valuable to the building EnMS because it contains information about the 'use' type and energy use profile. The standard, ISO 50001, provides a comprehensive methodology for energy management systems. The ISO 50001 methodology can be applied at the building system level or it can be scaled down and applied at the 'use' level. The energy data exchanged within the building system can be used for compiling the building system's energy profile in a format compatible with the Smart Grid communication protocols and transaction strategies. The energy data exchanged among the building sub-systems and 'uses' can be used for generating ISO 50001 reports.

The building system model represented in Figure 2d also illustrates (via the dotted blue lines) the energy data exchanged among the building sub-systems and 'uses.' A building sub-system can exchange energy data with other sub-systems, with the 'use,' and with the building EnMS. The building EnMS has access to a database of reference data containing the energy profile of the building envelope (e.g., physical properties, building codes constraints), and energy data exchanged among the building sub-systems and the 'uses.' Finally, communication with the Smart Grid is managed by the building EnMS.

2.3 Gap Analysis and Recommendations for System Integration and Systems Communications

To improve energy efficiency within the built environment, it is important to establish metrics to measure and evaluate energy use and the methods used to achieve efficiency, while assuring the

⁵² Alternate terms for 'use' in buildings are application, building type, use case, use type, business type, and use class. The U.S. Energy Information Administration (EIA) characterizes and defines these commercial building 'uses' as 'building types,' and they are regularly used in DOE and EIA analyses. For more information, see EIA's "Building Type Definitions" at <http://www.eia.gov/consumption/commercial/building-type-definitions.cfm>.

methods employed do not hamper occupant comfort, productivity, or business operations. While there are a multitude of programs used to collect energy data and to manage energy use, most are proprietary in nature and may not communicate across multiple data sets. Because of the complexity of this communication, there is a need to establish standards for information exchange, eliminate duplicative collection efforts, and provide for a system of information sharing within a building, facility, or group of facilities, as well as with the grid.

Data can serve different needs within a building, including for example, energy management, occupant comfort, and facility operations. Standards are needed in these areas to ensure that different data sets are not duplicative or exclusionary. These data sets should also be compatible with the information transfer to the grid without the need for duplicative collection efforts.

Part of the data that is collected within the building may be needed for energy management from a grid perspective. Building operational data may be used to inform grid operators, alerting them to the larger possibilities of energy use control across a grid based on building or facility operational needs.

A. Common information models and taxonomies

Standards are needed around common information models and taxonomies using common protocols to transmit data between the building and the Smart Grid, so that Smart Grid service providers can utilize data in a consistent way.

Recommended Timeline: This work should be conducted in the near-term: 0-2 years.

B. Communication between building energy management systems and the grid

As standards are implemented to support communication between building energy management systems and the grid, there will be an ongoing need for standards to support communication.

Recommended Timeline: This work should be conducted in the mid-term: 2-5 years, with ongoing attention to evolving needs.

The utility can acquire energy data from a commercial building by directly monitoring building power meters or by communicating with the building's EnMS and building automation system. Energy data collection is used in several applications, including measurement of building performance and grading analysis of buildings. Acquired energy data can be processed by statistical tools to identify and quantify specific energy uses in the building that affect Smart Grid performance. Subsequently, the Smart Grid can provide to the building EnMS recommendations to adjust its energy use profile.

Two factors influence the accuracy and effectiveness of the recommendations provided by the Smart Grid to the building: (1) the consistency and accuracy of the energy data acquired from the building; and (2) the availability of relevant building energy use information that can indicate the potential of the building to modify its energy demand in order to meet the Smart Grid's energy supply (e.g., the specific energy-using equipment that the EnMS could shut down or have its energy use modulated).

C. Consistent data communication

Standards are needed to support more consistent data communication back to the utility or service provider.

Recommended Timeline: This work should be conducted in the near-term: 0-2 years.

Often, building operational data is used for access control, productivity increases, and maintenance functions. These data sets can be used to inform building operators about how energy use impacts the overall operation of a building and grid operators about energy distribution limitations or timing that might be counterproductive to a building owner's comfort, operational, or business needs.

Advancing the increased use of data collection and utilization to improve energy efficiency will require a robust cost benefit/return on investment assessment to inform building owners, operators, and tenants about the value of such systems that capture, communicate, and evaluate energy use information within buildings. Potential building investors, owners, and operators will demand more market information to provide evidence that these systems can produce more efficient buildings, resulting in a better business investment.

In addition to numerous industrial process and automation communication protocols, there are more than thirty commonly used communication network protocols for building automation, substation automation, and automatic meter reading.⁵³ It would seem to follow that there is a large amount of data being exchanged in a building, depending on the level of building automation.

The U.S. Department of Energy supports ISO 50001 broad implementation to achieve benefits to U.S. businesses and to the nation.⁵⁴ However, ISO 50001 can be perceived by some to be difficult to implement because of a lack of available data. Implementation of other energy management systems may also pose difficulty in accessing data exchanged among the devices operating in the building.

D. Methodology and identification of energy data formats and attributes

There is a need for standards that provide for the development of the methodology and identification of the commonly exchanged device, asset, process, and system integration parameters and specifications (data formats and attributes) related to significant energy uses or objectives of an energy management system.

Recommended Timeline: This work should be conducted in the near-term: 0-2 years.

E. Measurement and monitoring protocols for energy data

There is a need for standards to establish measurement and monitoring protocols, including the recognition of security protocols, to support energy data.

Recommended Timeline: This work should be conducted in the near-term: 0-2 years.

⁵³ Wikipedia, "List of automation protocols," last modified April 28, 2014, http://en.wikipedia.org/wiki/List_of_automation_protocols.

⁵⁴ U.S. Department of Energy, "About DOE and ISO 50001," accessed May, 2014, <http://www1.eere.energy.gov/energymanagement/about.html>.

F. Methodology for energy information sharing

There is a need for standards that provide a methodology for energy information sharing within a building, facility, or group of facilities, as well as with the grid.⁵⁵

Recommended Timeline: This work should be conducted in the mid-term: 2-5 years.

An energy management system standard like ISO 50001 is a framework for industrial plants, commercial facilities, or entire organizations to manage energy. Even after collecting and processing data, organizations still need to know what the different building sub-systems need to perform and how to manage those sub-systems. Integration and communication among building sub-systems could dramatically reduce the cost of energy efficiency or energy performance assessments. Where possible, design and product performance standards should be “forward-thinking” and attuned to smart communications and system integration and operation.

G. Methodology of integrating the building sub-systems into an energy system

There is a need for a technical guide that provides for the development of a methodology for integrating building sub-systems into an energy system in a manner that serves the mutual interests of each sub-system to perform and the overall building energy efficiency.⁵⁶

Recommended Timeline: This should be conducted in the near-term: 0-2 years.

Recommendations D and G indicate methodologies that enable the industry to close specific gaps. Those methodologies refer to data exchange formats and attributes and to sub-systems that are integral parts of the building energy system. It could be worth replicating the success of SGIP PAP17 NEMA/ASHRAE SPC201 in developing the Facility Smart Grid Information Model (FSGIM).

ASHRAE SPC201 identifies the data types and attributes exchanged in relevant use cases. Though different than an energy management system framework, the ASHRAE SPC201 use cases indicate how devices can be controlled for the benefit of managing the energy efficiency on the grid side of the building. Those use cases are complex because of modeling information collected by the Smart Grid from meters, devices, and components in a building. A building energy information model is expected to be simpler because it serves only the needs of the building. By the same token, a building energy information model will not take into account data security and integrity issues specific to communications outside of the building and within the energy distribution infrastructure.

⁵⁵ In this usage, "building" refers to the structure of building envelope. For details on building energy information, visit http://www.wbdg.org/bim/nibs_bim.php.

⁵⁶ Technology research needs related to this discussion are highlighted in the Bonneville Power Administration's (BPA) *National Energy Efficiency Technology Roadmap Portfolio*, March 2014 version. See section on "Enterprise and Maintenance Management Systems (1 of 9)" (pp. 394-394): http://www.bpa.gov/energy/n/emerging_technology/pdf/EE_Tech_RM_Portfolio.pdf.

H. Standards to provide for a building energy information model

There is a need for standards to provide for a building energy information model, consisting of a series of use cases, to shape future standards related to building energy performance and management, and to test that the content of the standard provides for all of the information needed to optimize the energy performance of the building.

Recommended Timeline: This should be conducted in the near-term: 0-2 years.

Currently, there is workforce expertise to design, build, maintain, and manage each building sub-system; however, the sub-systems' integration and configuration into a system – as well as managing the system's energy as a whole – requires intelligent devices and therefore a workforce with advanced skills in automation and controls.

I. Workforce training and certification programs

A better integration of automation and controls into the skills standards underlying workforce training and certification programs is needed.

Recommended Timeline: This should be conducted in the mid-term: 2-5 years.

Appendix 2A: Standards and Codes in the EESCC Inventory Database

Table 2A, Breakdown of Applicable Standards and Codes in the EESCC Inventory Database

Type	Number of documents
Energy efficiency within a specific sub-system	11
Communication with a building system, including communication with SGIP	37
Energy performance reporting from a system point of view (a minimum of two sub-systems or 'uses')	6
Energy management methodology from a system point of view (a minimum of two sub-systems or 'uses')	1
Envelope, sub-system, and 'use' design specifications	41
Installation and maintenance	17

Table 2B, Standards Addressing Energy Efficiency in Buildings

Organization	Records	Focus
International Association of Plumbing and Mechanical Officials (IAPMO)	5	Buildings
International Code Council, Inc. (ICC)	8	Buildings
National Electrical Contractors Association (NECA)	2	Buildings
National Fire Protection Association (NFPA)	3	Buildings
Society of Cable Telecommunications Engineers (SCTE)	2	Buildings
American Society of Mechanical Engineering (ASME)	9	Energy
California Energy Commission (CEC)	4	Energy
International Electrotechnical Commission (IEC)	19	Energy and Interfaces
The International Organization for Standardization (ISO)	5	Energy Management
Air Conditioning Contractors of America (ACCA)	19	HVAC
ASHRAE	9	HVAC&R and Buildings
Alliance for Telecommunications Industry Solutions (ATIS)	17	Telecommunications
Telecommunications Industry Association (TIA)	4	Telecommunications
American Welding Society (AWS)	1	Buildings
United States Code	2	Energy
The Sustainable Technology Environments Program (STEP) Foundation	1	Energy

Organization	Records	Focus
Deputy Under Secretary of Defense for Installations and Environment, Business Enterprise Integration Directorate (DUSD(I&E)-BEI)	1	Energy Management
InfoComm International	1	Telecommunications
Project-Haystack.org	1	Telecommunications

Appendix 2B: Customer Interface Use Cases and Corresponding Information Elements⁵⁷

Use Case Classes	Description	Customer Interface Required Information Elements
Energy Market Transactions	Balancing and trading power, externally with electricity, gas and other energy markets, and internally balancing energy sources	Energy supply cost data (including electricity price forecasts), market transactions (indications of interest, bids, and transactions). Demand forecasts also require weather forecast data.
Demand Response	Demand Response: Day ahead capacity DR and Day-of DR; Fast-DR (ancillary services); and price communications. Includes event communications, supporting services, feedback, and measurement and verification.	DR event information (start time, duration, and level/amount), price and product, event status, market context, resource ID, and service location. Support information includes: registration, opt in/out, availability, event response, and meter data for M&V.
Direct Load Control (DLC)	Direct control of facility loads	Commands to turn on/turn off end node, or more sophisticated generator/storage control signals
Facility Energy Management (FEM)	Energy management of facility loads, storage and generation for monitoring and planning of facility energy use	Validated meter data, energy cost data (including electric price forecasts), weather forecasts
Transaction-based Controls	Techniques for managing the generation, consumption or flow of electric power within an electric power system through the use of economic or market based constructs while considering grid reliability constraints. The term "transactive" comes from considering that decisions are made based on a value. These decisions may be analogous to or literally economic transactions. ⁵⁸	Market signals (price, payments, carbon intensity) enabling end-use customers to transact with the Smart Grid and realize value from doing so; means of financial settlement; and elements from DR
FEM Measurement and Validation	Internal measurement and validation: display of facility energy usage for tracking energy consumption, allocating energy costs, monitoring emissions and power quality, and benchmarking	Validated energy usage data, emissions data, and energy cost data
Remote System Monitoring and Management	Monitoring and management of system health by service providers to allow system diagnostics and remote energy management	High-frequency meter data, power quality data, and sub-system status. Remote FEM may require additional building system data (occupancy schedules, process schedules, business planning, etc.).
Integration of Distributed Energy Resources⁵⁹	Exchange of grid and distributed energy resource (DER) status	Grid power voltage and quality forecasts, generation and storage status (available power, charge level, ramp rates, availability schedule, priority, present demand, forecast demand, etc.). Alternatively, DER integration may be enabled via market transactions or DR signals.

⁵⁷ This table is based on the uses cases outlined the *Customer Energy Services Interface White Paper*, published in 2011 by the SGIP B2G/I2G/H2G Domain Expert Working Groups: http://www.gridwiseac.org/pdfs/forum_papers11/hardin_paper_gi11.pdf.

⁵⁸ Gridwise Architecture Council, "Transactive Energy," accessed May 2014, http://www.gridwiseac.org/about/transactive_energy.aspx.

⁵⁹ Distributed energy resources are outside the scope of the EESCC, but have been added as part of this table for the sake of completeness.

Appendix 2C: HVAC Case Study

The following case study demonstrates the need for standards on data exchange. The HVAC sub-system can be used as a simple example of exchanged energy data used by the sub-system EnMS. The EnMS in this example is a computerized control system and the energy data includes inputs to the computerized controllers, output from the computerized controllers, and software points used within the computerized controllers. This specific example has been chosen for the purpose of indicating the variety, quantity, and type of energy data exchanged within a sub-system. It is important to realize that a small commercial building may not have more energy data to record than the reading from the meter on the wall and the AC thermostat setting. The following lists are not meant to be all-inclusive, but rather to offer examples of analog and binary inputs and outputs.

Input points can be of the analog type obtained from transducers and measurement devices.

Analog inputs (AI) include:

- Temperature sensors
- Humidity sensors
- Pressure sensors
- Flow meters
- CO₂ sensors

Input points can also be of the binary type, typically correlated to the status of a switch or relay.

Binary inputs (BI) include:

- Status – on/off
- Level switch
- Low temperature limit switch (freeze-stat)
- High pressure limit switch
- Fault

Output points are commands sent to system components and can be binary or analog.

Binary output (BO) points include:

- Start/stop
- Open/closed

Analog output (AO) points typically modulate a component/device, for example:

- Valve position
- Damper position
- Variable frequency drive (VFD)

The above AI points, BI points, AO points, and BO points are hardware points; they physically exist and consist of wires from the BAS to some physical device. Software points reside within the BAS and consist of the set-points, time delays, and intermediate values either calculated or used in calculations. For the purpose of using automated fault diagnostics (AFD) tools and for energy management, the object models defined in the BACnet standard need to be associated with semantic data.

CHAPTER THREE: BUILDING ENERGY RATING, LABELING, AND SIMULATION

3.0 Introduction

Buildings use about 40 percent of all energy in the United States. In order to reduce the amount of energy used in residential, commercial, and industrial buildings, energy rating and labeling programs have been developed to make the energy use and/or energy performance of a building more visible. Building energy simulation tools have been created to help engineers, architects, and building professionals model the performance of a building to optimize the building design and energy use.

This chapter examines both building rating and labeling and building energy simulation with an eye toward identifying where additional standardization activities may be needed to advance energy efficiency.

3.1 Rating and Labeling Programs

Energy rating and labeling programs provide an analysis of a building's energy use or energy features and allow comparison to similar buildings. The comparison may be to a median building, specific reference points (e.g., built to specific code, technical potential rating), or to a distribution of building performance (percentile rating), generally by building type. The ability to compare buildings can help place a premium on energy efficient buildings, thereby encouraging building owners to implement energy efficient measures in existing buildings and design future buildings to be more energy efficient.

Building energy rating and labeling programs are generally classified as either **operational ratings** or **asset ratings**, and can apply to residential, commercial, and industrial buildings. Operational ratings usually rely on the actual, metered energy use of the building to establish the rating. Asset ratings typically use energy simulation tools to estimate the energy performance of the building's envelope, mechanical systems, and electrical systems independent of the behavior of the building occupants. With both types of ratings, a qualified professional may be required to collect, review, or submit data, assess the building, and/or carry out other quality assurance procedures as required by the rating system.

Both operational and asset ratings may be used as the foundation for labeling and recognition programs. In such cases, the rating system usually establishes criteria or levels associated with one or more levels of recognition.

3.1.1 Operational Ratings and Labels

Operational rating programs evaluate building energy performance using actual, metered energy data and other characteristics to reflect both the structure of the building and how it is operated. Normally used for assessing existing buildings, operational rating programs focus on the performance of a building as a single system, although subsystem information may also be provided. The rating's baseline,⁶⁰ which

⁶⁰ For the purposes of this section, the term "baseline" describes the reference used for comparing the energy performance of the facility being rated. This reference can be defined in multiple ways.

provides the reference for evaluating performance, may be based on internal data from a single building, or external data from peer groups or national populations of similar space types. While operational ratings typically evaluate a twelve-month period of past performance, the rating's baseline may be based on data from multiple years.

Operational ratings may use statistical models to normalize for significant variables that affect energy use, such as weather, production rates, or occupancy rates, depending on the space type or sector. Ratings that compare buildings against an external peer group or national population may conduct further normalization for differences in physical characteristics, such as size or specific building features (e.g., indoor pool), and operational characteristics, such as operating or production hours, occupant density, or product mix.

To rate performance, operational ratings establish criteria or a benchmark⁶¹ that defines performance relative to the baseline. This criteria or benchmark may also provide the basis for determining eligibility for labeling programs that are based on the rating system. For example, performance might be indexed on a scale of 1 to 100, and the specific benchmark for efficiency pegged at 75 or greater. Alternatively, the scale might use letter grades from A to F, with A indicating the highest possible efficiency at zero net energy use.

Operational ratings are typically used on a recurring basis to monitor performance. Information learned through subsequent years of operational ratings and labels can provide building owners, managers, and maintenance staff with insight into how the building performs and opportunities for improving the building systems and operation. For owners with portfolios of multiple buildings, operational ratings can help to prioritize investment in energy efficiency improvements across multiple buildings.

Labeling programs based on operational ratings have been used to recognize top performing buildings, and motivate building owners to make energy efficiency investments. More recently, operational ratings and labeling programs have been required as part of many building energy use disclosure regulations.

A number of state and local jurisdictions have enacted benchmarking and disclosure policies that require covered building types to measure and report their energy usage. The requirements vary in what types and sizes of buildings are covered, and what specifically must be done to comply with the regulations. Most policies require some sort of audit or assessment and disclosure of the energy information

If It Looks Like a Label, Is It a Label?

Terminology used in this arena is often unclear. One rating system's baseline may be another's reference point or benchmark.

The term "label" in most cases is used to describe a plaque or other physical sign generated by a rating system. Labels usually designate some type of achievement (reaching a certain level of efficiency, number of points, etc.) as defined by the particular rating system.

⁶¹ A benchmark is a specific level of energy performance relative to the baseline. It can be used to define energy efficiency or to calibrate a rating scale.

identified during those audits, either to the government or as part of a real estate transaction. In some cases, rating programs are identified as a means to meet the auditing and disclosure requirements.

3.1.2 Asset Ratings and Labels

Asset rating programs evaluate a building based on the physical characteristics and major energy-using systems independent of operational and occupancy factors. Asset ratings can be used to assess both new (less than twelve months of operation) and existing buildings, and allow building owners to compare buildings on an equal basis by applying standard assumptions about occupant behavior, location, and operational factors. Asset ratings typically require an on-site assessment of a building's physical characteristics and major energy using systems (as built or as designed) – including mechanical systems, building envelope, orientation, lighting, and daylighting.

Asset ratings are generally calculated using energy simulation tools. The simulation tool uses data about the building's assets (e.g., envelope, lighting, mechanical systems), applies standard operating assumptions based on building type (e.g., office, retail, multi-family, single family), and translates the result of the simulation into a rating. Some asset ratings are based on a single energy simulation of the candidate building as compared to a fixed or calculated baseline; others are derived by comparing energy simulations of both the candidate building and a baseline building. Just as with operational rating programs, the fixed or calculated baseline may be based on internal data from a single building, or external data from peer groups or national populations of similar space types.

Asset ratings can encourage building owners and operators to value the potential energy efficiency of a building and/or property, whether at the time of purchase or during ownership and operation. Since they apply standard assumptions about operations and other transitory factors, asset rating programs can be used to value building performance within a financial transaction, and could be a basis for energy efficiency code compliance or beyond-code new construction incentive programs. Some asset ratings programs can provide insight into the efficiency of a building's individual systems by disaggregating energy information and identifying inefficient systems and potential opportunities for upgrade.

Table 3a highlights the major distinctions between asset and operational ratings, and suggests when each is most likely applicable in informing decisions.

Table 3a, Different Ratings for Different Purposes

Rating Type	Purpose	Likely Time to Use It
Asset	<ul style="list-style-type: none"> Allows a building owner, buyer, lessee, or other stakeholder to understand how a building is likely to perform based on its physical characteristics and systems compared to similar building types under standard operating conditions 	<ul style="list-style-type: none"> During ownership, an asset rating can guide investment in capital improvements and efficiency upgrades At point of sale, lease, or purchase of a building, an asset rating can be useful in highlighting the efficiency of a building’s principal energy-related assets (e.g., envelope, heating, cooling) apart from current operations As an alternative path to code compliance
Operational	<ul style="list-style-type: none"> Allows a building owner, operator, buyer, or lessee to evaluate a building’s actual energy performance over time and/or against similar building types 	<ul style="list-style-type: none"> During the operation of the building, operational ratings help guide energy management decisions, particularly those related to improving operations and maintenance At point of sale, rental, or purchase, operational ratings provide information on how a building performs under current operating conditions

3.1.3 Defining Characteristics of Building Rating Systems

Each rating system applies a specific approach to calculating and displaying a building’s rating. The diversity of current rating systems reflects, in part, the applicability of any given system to specific circumstances, needs, and market demand. The following discussion describes the defining characteristics of rating systems and how they vary. Table 3b shown at the end of this rating and labeling section provides greater detail on the defining characteristics of each of the major U.S. building rating systems.

- **Building Type Applicability**

Rating systems are usually broadly applicable to residential, commercial, or industrial buildings. Within these broad categories, most rating systems make further distinctions based on physical aspects of the building or its primary use. For example, in the residential arena, multi-family buildings are frequently divided into two groups – those with four or more stories, and those with less than four stories. In the commercial building arena, ratings distinguish between building types based on use and design intent, such as office buildings, schools, or warehouses. Industrial rating system applicability is usually defined by sector North American Industry Classification System (NAICS) codes and/or the products that are produced. A further distinction is also made between the applicability for new construction, while others are designed for existing buildings.

- **Calculation Method**

Rating systems use a variety of methods for calculating ratings. Most asset rating systems rely on energy modeling to estimate energy use, while most operational rating systems use utility bill or metered data to generate a rating. Some asset rating systems require the use of one specific energy simulation tool, while others allow a variety of simulation tools to be used to calculate energy use and other values required to generate the rating. Operational ratings typically use statistical models to normalize for significant variables that affect energy use. These variables usually vary depending on the space type being rated.
- **Performance Measurement**

Many ratings use an energy use metric (e.g., energy use per building; energy use per square foot) to measure or express energy performance. These metrics may be a simple ratio or may be based on multiple variables. However, some labeling programs use a combination of performance metrics and other criteria to determine eligibility for labeling. For example, the U.S. Green Building Council's (USGBC) LEED rating and the Green Building Initiative's (GBI) Green Globes are both calculated by adding up points related to a variety of different metrics (e.g., indoor air quality, energy performance, location).
- **Use of Site or Source Energy**

Some rating systems convert energy used on site to "source" energy. Source or total primary energy adjusts for generation and distribution losses of purchased energy, namely electricity. However, other rating systems use only "site" energy which reflects the energy used on site.
- **Baseline Definition**

To evaluate performance, rating systems usually rely on a baseline as the reference point for conducting comparisons. However, the methods used to establish or calculate the baseline vary significantly between operational and asset ratings, as well as within these categories of rating systems. Consequently, the term "baseline" can mean different things depending on the rating system being used. For example, some rating systems use specific energy code as the "baseline" for rating the building in question, while other ratings systems use a distribution of energy performance to establish a sector-wide baseline.
- **Relationship to Energy Code**

Some rating systems assess buildings relative to a particular energy code. Most of these rating systems consider a building that meets the specific energy code as the "baseline" for rating the building in question. The rating then reflects how well the building (as built or designed) performs or is likely to perform relative to that baseline. Systems that rely on energy code as the basis for ratings are usually intended to inform new construction. Even rating systems that do not use energy code as a basis for calculating the rating may indicate where a typical building built to a specific code is likely to rate as a reference point.

- **Relationship to Existing Building Data**

A number of rating systems rely on data collected by the federal government. Commonly used data sets include the Commercial Building Energy Consumption Survey (CBECS), Residential Energy Consumption Survey (RECS), and Manufacturing Energy Consumption Survey (MECS). These surveys, carried out every several years by the U.S. Energy Information Administration (EIA), collect energy use, building characteristic information, and production data for facilities across the United States. This data is used by some rating systems to generate ratings by comparing the measured or modeled energy use of the building in question against a subset of the buildings in CBECS or RECS. The reference point may be the median performance of that specific subset of data. For example, after taking into account building location, size, type, and other factors, ENERGY STAR® Portfolio Manager scores the building in comparison to building data derived from CBECS. While many systems do not directly compare a building to CBECS or RECS data, these data sources are frequently used to help set the endpoints on rating scales, generate reference points, create baselines, or provide other valuable input into the development of rating systems.

- **Scale**

Ratings usually fit along some type of scale, whether absolute, relative, numeric, graduated, or another type. Some scales are pegged to zero energy use or net zero energy use. In these cases, the rating system usually provides some type of credit for on-site renewable energy generation. Other scales focus solely on energy utilization and efficiency and index performance on a numerical scale or grading system.

Scales also vary in terms of their levels of granularity. More granular systems are able to distinguish between buildings with relatively similar energy performance levels; consequently, these scales frequently require a greater level of data inputs. Some programs award a rating for buildings that exceed a certain threshold value using a pass/fail approach or have a limited number of delineations in the scale, thus grouping performance into broad “buckets.” Other programs employ more levels or a continuous scale in order to more precisely distinguish building performance. Whether continuous or delineated, the scales may employ a non-linear function that rewards absolute differences in performance differently, depending on where on the scale those differences occur. This approach helps to better distinguish the top levels of performance.

- **Rater/Assessor Certification Requirements**

Some systems have specific requirements for individuals who generate the ratings. In other words, only a qualified individual can conduct the analysis for rating a facility under some systems. Other rating systems have requirements for those verifying performance for labeling applications. Requirements can range from specific certifications recognized in the field to testing administered by the specific rating program. Some programs require a combination of certification and testing. The objective of requiring a certificated professional at some point in the rating and labeling process is to ensure that the integrity of the rating and labeling programs is maintained.

- **Quality Assurance Requirements**

Quality assurance (QA) in the rating arena is distinct from quality assurance performed to verify installation of energy improvements. This roadmap is concerned with quality assurance in the rating arena which covers two distinct areas. The first is the QA of the rating development process and the second is the QA of the rating submission for the building being rated.

Quality assurance during the rating development process is conducted to verify that the rating process provides a reasonable, fair, and accurate rating process for the building type and rating process. Repeatability is one factor that must be considered when verifying the fairness and accuracy of a rating program. The verification process generally includes some sort of statistical analysis or simulation process, pilot testing, round robin style evaluations, and/or a review by industry experts or practitioners.

Quality assurance for rating submissions is conducted to verify that the information being submitted accurately portrays and captures the data for that building. Requirements may include a certified professional to perform the rating process, a paper review of ratings and documentation, and/or in-person, third-party review of the rated building. Where an in-person review is required, the program typically does not require 100 percent review, but rather a sampling of buildings rated. Some programs require that the person conducting the quality assurance be from a third-party organization.

- **Supplemental Information Provided**

In addition to ratings, some programs provide supplemental information, such as recommendations for energy improvements; a building's potential rating; evaluations of specific energy sub-systems; energy estimates by system; utility cost estimates; savings estimates; and indoor environmental quality screening/assessment. Some programs allow raters or assessors to generate their own recommendations or other information separate from the rating. In these cases, the final report may or may not identify how the rater's recommended improvements would affect the building's potential rating.

- **Other Features**

A number of other components vary among rating systems and may affect the degree to which they meet the objectives of those interested in a rating. These factors include, but are not limited to:

- **Ease and Cost of Generating the Rating**

Data requirements, user interface, and other factors all affect the time and resources needed to generate a rating. Some systems also charge fees to access required software or to generate a rating. Some rating systems offer application programming interfaces (APIs) to simplify transfer and use of data required for the rating. APIs are particularly useful if the individual rating the building uses other software to collect and/or analyze data. In some cases, APIs can be licensed free of charge or require a one-time or recurring fee.

While cost and ease of use may not be primary criteria for determining which system is most appropriate for a particular use, they do vary from system to system and are therefore worth noting.

- **Public or Property Ratings**
Some ratings have been created by public entities, and submissions to that system are free. Others systems are proprietary and require a submission fee and/or a license to operate.
- **Transparency**
Some rating systems provide significant documentation concerning calculation methods, underlying assumptions, data sources, and other information regarding the algorithms used to calculate the rating. Documentation may also describe how the rating system was developed and tested prior to implementation.
- **Clarity**
In order for a rating system to be effective, it must clearly communicate what the building rating means, and ideally motivate the user to invest in energy efficient buildings and/or improvements. While different approaches and systems are likely to appeal to different users, it is important that the rating be clear and meaningful to most users and to the public.

3.1.4 The Current Market: Different Systems, Few Linkages

As previously stated, a variety of rating systems have developed in part because different circumstances or objectives for the ratings systems exist. Furthermore, labeling or disclosure regulations drive the use of specific rating systems.

Few linkages are readily available between existing systems, and where linkages are possible, the information is complementary, not comparable. Because the underlying calculation methods, scales, and other system characteristics are not equivalent, one rating cannot be readily converted into another type of rating.

In the commercial building market, the ENERGY STAR® rating system offered through the Portfolio Manager tool has achieved the greatest market penetration, with more than 45 percent of U.S. commercial building space using this system. ENERGY STAR® industrial energy rating systems have achieved widespread market penetration in certain sectors. A few other rating systems dominate certain smaller markets (e.g., specific locations, new homes); however, none of the currently available rating systems are ubiquitous.

3.1.5 Gap Analysis and Recommendations: Rating and Labeling Programs

To evaluate the current landscape of operational rating and labeling programs, an inventory was conducted to identify different rating and labeling systems currently in the market or in the later stages of development. The EESCC working group on building energy rating, labeling, and simulation then developed a matrix to further analyze the responses collected through the inventory and to provide a

starting point for discussion. This matrix is shown in Table 3b. From reviewing existing rating and labeling systems, the working group identified the following issues, gaps, and opportunities.⁶²

A. Data availability

Operational ratings and labeling programs rely on data that is representative of the existing building and industrial plant stock. As noted earlier, data sources such as the Residential Energy Consumption Survey (RECS), Commercial Building Energy Consumption Survey (CBECS), Manufacturing Energy Consumption Survey (MECS), and the Census of Manufacturing are commonly used for operational rating development. However, these data sets are frequently limited in the number and types of buildings included in the surveys, the granularity of building characteristics, robustness of the sample, and timeliness of the data.

There are many issues due to limited data sets. One critical issue is that limitations in the amount and quality of data in the CBECS and RECS studies can impact the consistency within a rating system. CBECS results for specific building types can vary significantly from survey to survey. This creates changes in the rating scores for buildings with no action taken by the owner. A high scoring building may become a low scoring building. Investment in additional data collection will reduce this noise and increase trust in the ratings.

In addition, many building types have insufficient data on which to base a rating program. This is most evident in the commercial building arena, but also affects mixed use and multi-family building types. An expansion in the types of buildings included in the consumption surveys listed above would help to remedy this situation. Additional data sets could also benefit asset ratings by providing more robust information on which to base standard occupancy assumptions.

In recent years, funding for building energy surveys has been questioned, and in some cases, reduced. If further development or refinement of existing operational ratings is to take place, additional steps should be taken to expand or establish new data sets that can be used to create operational ratings. Additionally, steps could be taken to establish criteria or standards for guiding data collection by organizations seeking to collect building performance data for operational rating development.

Recommended Timeline: Existing efforts underway need to be accelerated in the near-term: 0-2 years. However, this is an ongoing need that is going to exist in the long-term. Those organizations in charge of collecting data (e.g., U.S. Energy Information Administration, Census) should continue to solicit feedback from stakeholders with each iteration of their surveys in order to improve the data collected and the collection process.

⁶² A similar analysis has been conducted by the Building Energy Efficiency Taskgroup (BEET) of the International Partnership for Energy Efficiency Cooperation (IPEEC). Their report, *Building Energy Rating Schemes: Assessing Issues and Impacts*, is available at <http://www.buildingrating.org/ipeec>.

B. Taxonomy and terminology

Currently, different systems use different definitions for common terms such as baseline, benchmark, label, reference, etc. As a result, it can be difficult to compare or quickly understand the structure and design of various rating systems. Further dialogue (and consensus where possible) is needed to clarify terminology used in this field. There is at least one standard under development that might be able to address this.⁶³

Recommended Timeline: This should be conducted in the near-term: 0-2 years.

C. Rating and labeling directory

Through the process of inventorying operational rating and labeling systems, it became clear that there is no central resource or catalogue that outlines existing programs and their focus. There is an opportunity for the establishment of a consistently updated “rating and labeling directory” that catalogues different programs and discusses each program’s design and focus in a systematic format.

Recommended Timeline: This should be conducted in the near-term: 0-2 years; however, it will require update over time.

⁶³ The scope and purpose of the proposed standard, ASHRAE 214P, *Standard for Measuring and Expressing Building Energy Performance in a Rating Program*, is available at <https://www.ashrae.org/standards-research--technology/standards--guidelines/titles-purposes-and-scopes#spc214p>.

Table 3b, U.S. Rating Systems: Summary of Major Characteristics⁶⁴

Rating System	Rating Type	Applicability	Calculation Method	Performance Metric Used to Rate Building	Scale	Certification Requirements	Quality Assurance (QA) Requirements	Supplemental Information Provided	Additional Information
ASHRAE Building Energy Quotient (bEQ) Asset	Asset	New (constructed) and existing commercial buildings	Allows multiple simulation tools to estimate energy use intensity (EUI)	Standardized as-built building EUI divided by standard/median EUI multiplied by 100. Result is compared to a scale.	A+ thru F, with A+ representing a zero net energy building	Certified practitioner	All submissions are reviewed by ASHRAE staff	Building receives approved workbook, dashboard, certificate, and label graphic file for plaque creation. Workbook includes all calculations and modeling inputs used to generate the rating.	Proprietary workbook
ASHRAE Building Energy Quotient (bEQ) Operational	Operational	Existing commercial buildings	Uses metered data and ENERGY STAR® Portfolio Manager	Metered building EUI divided by median EUI for that building type multiplied by 100. Result is compared to a scale.	A +thru F, with A+ representing a zero net energy building	Certified practitioner	All submissions are reviewed by ASHRAE staff	Building receives approved workbook, dashboard, certificate, and label graphic file for plaque creation. Workbook includes all calculations and measurements used to generate a rating, as well as the information from the ASHRAE Level 1 Energy Audit, which provides suggestions to improve energy efficiency in the building and the IEQ screening.	Proprietary workbook

⁶⁴ Unless otherwise noted, all of these systems use standard calculations and scoring methods and are applicable nationally.

Rating System	Rating Type	Applicability	Calculation Method	Performance Metric Used to Rate Building	Scale	Certification Requirements	Quality Assurance (QA) Requirements	Supplemental Information Provided	Additional Information
BOMA 360 Performance Program	Hybrid focused on building operation and maintenance performance	Existing occupied commercial office buildings and industrial buildings		ENERGY STAR® Portfolio Manager scores	Pass/Fail with minimum score for each section evaluated. The sections are: building operations and maintenance; life safety/security/risk management; training and education; energy; environmental/sustainability; tenant relations/community involvement.		Third-party data evaluation and random on-site evaluation		Combines ENERGY STAR® ratings with best practice check lists
ENERGY STAR® Certified Homes	Asset	New construction single family detached homes; townhouses; duplexes, triplexes, quadplexes; dwelling units in multi-family buildings with 3 stories or fewer above-grade; and certain dwelling units in multi-family buildings with 4 or 5 stories above-grade that have their own heating, cooling, and hot water systems.	Homes certified using the ENERGY STAR® Performance Path must achieve similar performance as the reference design using the RESNET Home Energy Rating System (HERS)	A specified HERS index, called the ENERGY STAR® HERS Index Target, combined with mandatory requirements essential to the home's performance	ENERGY STAR® establishes a reference design, against which performance is compared using the ENERGY STAR® HERS index targets and other criteria. Regional requirements have been established for specific jurisdictions and regions.	Certified practitioner/ auditor accredited through RESNET	RESNET QA procedures and software tests supplemented by additional RESNET QA procedures specific to the ENERGY STAR® program and HVAC Quality Installation and Oversight Organization		The ENERGY STAR® Certified Homes program has certified over 1.5 million homes to date

Rating System	Rating Type	Applicability	Calculation Method	Performance Metric Used to Rate Building	Scale	Certification Requirements	Quality Assurance (QA) Requirements	Supplemental Information Provided	Additional Information
ENERGY STAR® Commercial Energy Performance Ratings/Labels	Operational	Existing commercial buildings	Portfolio Manager uses building-specific statistical models derived from Commercial Building Energy Consumption Survey (CBECS) data to calculate a normalized annual EUI from measured energy use data submitted by users. This EUI is then compared to national distribution of energy performance of similar buildings, which serves as the baseline and is indexed on the ENERGY STAR® performance scale of 1 to 100.	Source EUI	1 to 100; a score of 75 is used as the benchmark for top performance. Buildings that score 75 or higher are in the top quartile of performance relative to their peers.	Professional Engineers (PE) or Registered Architects (RA) conduct a verification process for buildings applying for ENERGY STAR® certification. If all criteria are met, the PE or RA certifies a Statement of Energy Performance document.			Free web-based tool called Portfolio Manager. There is no fee for usage, but there can be costs for certification.
ENERGY STAR® Industrial Energy Performance Ratings/Labels	Operational	Existing industrial buildings	ENERGY STAR® Plant energy performance indicators (EPIs) use sector-specific statistical models to calculate a normalized annual EUI from data submitted by users. This EUI is then compared to national distribution of energy performance of industrial plants, which serves as the baseline and is indexed on the ENERGY STAR® performance scale of 1 to 100.	Normalized EUI, such as MMBTU/unit of production	1 to 100; plants that score a 75 or higher are eligible for the ENERGY STAR® label	Professional Engineers (PE) conduct a verification process for plants applying for ENERGY STAR® certification. If all criteria are met, the PE certifies a Statement of Energy Performance document.	Statistical models used to generate ENERGY STAR® scores are tested and reviewed by energy managers from the sectors benchmarked. Once U.S. EPA and the sector believe the models accurately measure performance, the rating is released.		Distribution of performance of similar industrial plants. Baseline data based on U.S. Census data and data volunteered by industrial sectors.

Rating System	Rating Type	Applicability	Calculation Method	Performance Metric Used to Rate Building	Scale	Certification Requirements	Quality Assurance (QA) Requirements	Supplemental Information Provided	Additional Information
ENERGY STAR® Home Energy Yardstick	Operational	Existing single family detached homes, mobile homes, townhouses, rowhouses, and duplexes	The Home Energy Yardstick uses statistical models to calculate a normalized annual EUI from data submitted by users. This EUI is then compared to national distribution of energy performance, which serves as the baseline and is indexed on a scale of 1 to 10.		1 to 10	None	None		Free online tool
Green Globes for Continual Improvement of Existing Buildings (CIEB)	Hybrid focused on green building and sustainability	Existing buildings (offices, multi-residential, retail, health care, light industrial) and commercial interiors (i.e., office fit ups)	Points in six categories. For energy category, uses EPA ENERGY STAR® Portfolio Manager.		Certification is awarded based on 1,000 possible points across six categories. The six categories are: environmental management; energy; water; materials and resources; emissions; indoor environment. There are four levels of certification – 1 to 4 Green Globes.	A Green Globes certified third-party assessor is required to review documentation and visit the facility, with opportunities to interact with owner's representatives and staff. The assessor completes a final report and provides a final score.	Third-party assessor – a professional with credentials – professional judgment exercised		

Rating System	Rating Type	Applicability	Calculation Method	Performance Metric Used to Rate Building	Scale	Certification Requirements	Quality Assurance (QA) Requirements	Supplemental Information Provided	Additional Information
Green Globes New Construction	Hybrid focused on green building and sustainability	New construction/ significant renovations for commercial, institutional, and multi-residential buildings	Points in seven categories. For energy category, EPA ENERGY STAR® Target Finder.		Certification is awarded based on 1,000 possible points across seven categories. The seven categories are: project management; site; energy; water; materials and resources; emissions; indoor environment. There are 4 levels of certification – 1 to 4 Green Globes.	A Green Globes certified third-party assessor is required to review documentation and visit the facility, with opportunities to interact with owner's representatives and staff. The assessor completes a final report and provides a final score.			
International Living Future Institute Living Building Challenge™	Hybrid focused on green building and sustainability	Existing	Evaluates performance in seven areas. For energy category, building must be net zero energy.		Certification is awarded based on performance in seven areas: site; water; energy; health; materials; equity; and beauty. There are three types of certification: Full Certification, Petal Recognition, or Net Zero Energy Building Certification.	Auditors must attend auditor training prior to being assigned to a project	All projects are reviewed by a trained auditor who conducts a site visit		Multiple buildings or projects can operate in a cooperative state and share green infrastructure through the program's scale jumping overlay

Rating System	Rating Type	Applicability	Calculation Method	Performance Metric Used to Rate Building	Scale	Certification Requirements	Quality Assurance (QA) Requirements	Supplemental Information Provided	Additional Information
Leadership in Energy and Environmental Design (LEED) - v4	Hybrid focused on green building and sustainability	New commercial buildings, core and shell development, single family and multi-family residential buildings	Points in seven categories. For energy category, uses either EPA ENERGY STAR® score or a demonstrated level of performance per a prescribed method. Allows multiple simulation tools to estimate EUI.		Certification is awarded based on credits earned in five main categories (sustainable sites; water efficiency; energy and atmosphere; materials and resources; indoor environmental quality) and two bonus categories (innovation in operations; regional priority credits). There are four levels of certification: Certified, Silver, Gold, and Platinum.	Green Building Certification Institute (GBCI)-approved project reviewers and certified professionals			Prerequisites must be met in order to apply for certification
LEED for Existing Buildings: Operations & Maintenance (LEED EB: O&M)	Hybrid focused on green building and sustainability	Existing commercial buildings, single family, and multi-family residential buildings	Points in seven categories. For energy category, uses ENERGY STAR® Portfolio Manager.	LEED requires an ENERGY STAR® score of 69. If the space type is not eligible, data must still be input into Portfolio Manager, but there are alternative compliance paths.	Certification is awarded based on credits earned in five main categories (sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality) and two bonus categories (innovation in operations; regional priority credits). There are four levels of certification: Certified, Silver, Gold, and Platinum.	GBCI-approved project reviewers and certified professionals	Independent third-party reviewers are used		Prerequisites must be met in order to apply for certification

Rating System	Rating Type	Applicability	Calculation Method	Performance Metric Used to Rate Building	Scale	Certification Requirements	Quality Assurance (QA) Requirements	Supplemental Information Provided	Additional Information
Massachusetts Department of Energy Resources (DOER) "Raising the BAR (Building Asset Rating)" Pilot	Asset	Existing commercial office buildings	Allows multiple simulation tools to estimate EUI	Site energy EUIs (kBTU/sq. ft.)	Absolute scale with EUI as the unit of measure	Third-party			Web-based tool; proprietary software. State specific.
Multifamily Building Energy Performance Scoring Tool	Operational	Existing multi-family buildings	Actual energy use per apartment is divided by "average" generated from scoring model for four specific characteristics; this ratio is mapped to a scale of 1 - 100. Uses Residential Energy Consumption Survey (RECS) 2005 multi-family data as point of comparison.	Total energy use per dwelling unit	1 to 100			Limited testing in Wisconsin has verified apparent ability to indicate likely energy savings potential for retrofits	
RESNET/HERS	Asset	New and existing residential buildings	Approved software used to model energy use for the home, then compared to modeled energy use of the home if built to IECC 2006 code.	Energy use per square foot	HERS Index Scale, with zero equating to zero energy	Certified practitioner/ auditor	RESNET QA procedures and software tests		Proprietary software (several allowed)
Superior Energy Performance (SEP)	Operational	Existing industrial facilities	Statistical/regression based	EUI	Silver, Gold, Platinum	Certified Practitioner must verify performance			SEP EM&V provides a calculation method for determining energy savings from baseline; proprietary software

Rating System	Rating Type	Applicability	Calculation Method	Performance Metric Used to Rate Building	Scale	Certification Requirements	Quality Assurance (QA) Requirements	Supplemental Information Provided	Additional Information
U.S. DOE Commercial Building Energy Asset Score	Asset	New and existing commercial buildings	A standard scoring tool estimates energy use by modeling the building given user-entered data and standard operational assumptions	Source energy per square foot	1 to 100, with 100 representing most efficient buildings	TBD for verified score	TBD for verified score	Provides preliminary upgrade recommendations	There is no fee for usage, but there can be costs for verification. This rating system is currently under development .
						No requirements for preliminary score	No QA requirements for preliminary score		U.S. DOE administered
U.S. DOE Home Energy Score	Asset	Existing residential buildings	A standard scoring tool estimates energy use by modeling the building given user-entered data and standard operational assumptions	Source energy for entire home (excluding baseload)	1 to 10, with 10 representing most efficient buildings	Must be certified as a BPI Building Analyst or HERS Rater	Requires that 5% of all homes scored must be rescored by another qualified assessor	Provides preliminary upgrade recommendations	Free tool; no fee for usage, but there can be costs for certification
						Must pass free DOE online exam			
						NOTE Certification requirements are currently under review and may be modified in Summer 2014			

Rating System	Rating Type	Applicability	Calculation Method	Performance Metric Used to Rate Building	Scale	Certification Requirements	Quality Assurance (QA) Requirements	Supplemental Information Provided	Additional Information
U.S. DOE Zero Energy Ready Home (formerly DOE Challenge Home)	Asset	Primarily new construction (one and two family homes and multi-family)	RESNET/HERS Index	DOE Zero Energy Ready Home sets a HERS target called the DOE Challenge Home Target Home (adjusted for house size) and adds mandatory items, including ENERGY STAR® New Homes Certification, advanced insulation/window requirements, EPA's Indoor airPlus program, hot water distribution requirements, ducts in conditioned space, and renewable ready features. Prescriptive compliance is also allowed (as is CA Title 24 rating).	Binary certification, but uses the HERS Index to set the target	Certified practitioner/auditor	RESNET QA procedures and software tests supplemented by additional RESNET QA procedures specific to the ENERGY STAR® program, HVAC Quality Installation and Oversight Organization, and additional inspections for indoor air quality, renewable ready features, and hot water delivery		

3.2 Building Energy Simulation

Building energy simulation is the physics-based software calculation of a building’s energy use, given a description of its physical assets, its occupancy and operation, and prevailing conditions.⁶⁵ A powerful tool for comparing design and operation alternatives, building energy simulation underpins many aspects of the building energy efficiency enterprise, including:

- Integrated architectural, lighting, and mechanical system design for new construction and retrofits
- Design of building control algorithms and model-predictive dynamic control
- Building system commissioning, fault-detection, and diagnosis
- Development of prescriptive energy efficiency codes, standards, and guidelines
- Compliance with energy efficiency codes and standards
- Building energy efficiency rating and labeling
- Qualification for building energy efficiency rebates, tax credits, and other financial incentives
- Evaluation, measurement, and verification

3.2.1 Specific Use Cases of Whole Building Simulation

This section focuses on two specific use cases: (1) energy simulation for code compliance and asset rating; and (2) energy simulation for evaluation, measurement, and verification. Energy simulation has a unique experimental capability that makes it valuable in these use cases; it can effectively isolate the impact of a building’s physical assets from those of its occupancy and operation.

In order to serve as a sound basis for both regulatory and market-based programs and transactions, building energy simulation and its use cases must be standardized to establish comparative frameworks, and regulated to prevent abuse of those frameworks. This section of the roadmap addresses standards for the use cases, for energy simulation software capabilities and data exchanges, and for energy simulation professionals.

Building energy simulation is most commonly used to address issues in the residential and commercial sectors. It can be used to address the building energy (primarily HVAC and envelope) aspects of industrial use, but it does not address process uses such as motors, pumping, and compressed air.

3.2.1.1 Energy Simulation for Code Compliance and Asset Rating

Building energy efficiency codes typically provide multiple compliance paths. A “prescriptive” path supports line-by-line compliance with minimum prescriptive requirements. A “performance” path builds on the prescriptive path; it allows the use of simulation to demonstrate equivalent or better performance to a hypothetical “code baseline” version of the same building that meets the prescriptive requirements. The performance path is more involved but gives the designer-builder-owner greater flexibility in meeting code. Specifically, it accepts a building that fails to meet one or more prescriptive

⁶⁵ Building energy can also be modeled using metered data analysis—that approach is discussed in Chapter Four, EM&V.

requirements, but compensates for them elsewhere. Performance compliance paths generally have minimum prescriptive requirements that restrict arbitrary tradeoffs, which can sometimes have unintended consequences. Performance path code compliance enables both artistic, “signature” designs (e.g., glazing ratios of close to 100 percent) and more cost-effective buildings. Performance compliance paths will become more important as codes become more stringent, and greater flexibility is needed to meet them in a cost-effective manner.

The mechanics of performance-path code compliance are often used as the basis for rating a building’s inherent or asset energy efficiency; the rating is determined by the amount by which the building’s performance exceeds that of a would-be code-minimum baseline. Ratings can also use simulation in a more direct, absolute fashion by standardizing operational parameters and comparing buildings directly on the basis of simulated energy use intensity (EUI).

3.2.1.1.1 Commercial Buildings

In the commercial building space, multiple standards exist for simulation-based code compliance and beyond-code performance calculations. ASHRAE Standard 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings*, has parallel methods for each of these – the Chapter 11, *Energy Cost Budget* (ECB) procedure for code compliance, and the Appendix G, *Performance Rating Method* (PRM) for beyond-code performance calculations. PRM prescribes and standardizes the baseline building more thoroughly than ECB; PRM standardizes constructions and glazing ratios whereas ECB does not, effectively giving the nominal building flexibility along additional design dimensions. ASHRAE Standard 189.1, *Standard for the Design of High-Performance, Green Buildings Except Low-Rise Residential Buildings*, and the International Code Council’s (ICC) International Green Construction Code (IgCC) have performance-path compliance methods that are similar to PRM, while the International Energy Conservation Code (IECC) has a method that is similar to ECB. The COMNET Modeling Guidelines and Procedures (MGP) provide additional details that can be used with these rule sets, as well as an elaborated baseline building methodology based on ASHRAE’s PRM. Starting in 2014, COMNET MGP will serve as the basis for California’s Title 24 Alternative Calculation Method (ACM).

For asset ratings, LEED’s Energy and Atmosphere Credit 1 is based on ASHRAE Standard 90.1 Appendix G, while the Green Building Initiative’s (GBI) Green Globes Energy Performance Credit provides multiple calculation paths, several of which are based on ASHRAE Standard 90.1 Appendix G. DOE’s Commercial Building Asset Score does not use a baseline building approach. Instead, it isolates the effect of the building’s physical assets from those of its occupants and operators by using standard operating assumptions, including occupancy schedules and thermostat set-points, and then rates buildings based on calculated EUI.

Gap Analysis and Recommendations

A goal of any modeling procedure should be that given a specific building design, applying the rules should yield the same result (i.e., code pass/fail or building rating), regardless of the modeler or software used. This is a lofty but worthy goal. Realizing it will require standardization and consensus on modeling inputs and protocols, and subsequent implementation of those standards in software.

To achieve consistency in application, a rule set needs to be sufficiently detailed to cover all significant model inputs; for a commercial building these may number in the hundreds. California's Title 24 ACM details its code compliance modeling assumptions in a 250 page document.⁶⁶ On the other end of the spectrum, some modeling procedures do not have this level of detail and leave many inputs to the discretion of the modeler or the modeling software developer. For example, the 2012 IECC and the 2010 ASHRAE Standard 90.1 ECB describe their respective code compliance performance-approach procedures in seven and nine pages, and do not cover inputs such as HVAC equipment part-load curves, infiltration, and daylighting.

The COMNET Modeling Guidelines and Procedures (MGP) attempt to standardize the modeling procedures of several of the rule sets mentioned above.⁶⁷ COMNET has established detailed energy simulation input assumptions that address multiple simulation end uses, including establishing eligibility for federal tax deductions per §179D of the Internal Revenue Service (IRS), calculating percent savings for point eligibility for green building rating systems, and estimating annual energy use for a building in the design phase for the purpose of energy labeling. COMNET MGP is referenced by the 2013 update of the Title 24 ACM; however, because it was developed outside the established procedures for enhancing ASHRAE or LEED standards, it has not yet been accepted by ASHRAE Standard 90.1 or the IECC.

Equally significant is the issue created by the multiplicity of performance path compliance methods and the prescriptive changes that accompany updates. Not only are simulation results using ASHRAE Standard 90.1 Appendix G not directly comparable to those using California's Title 24 ACM, but results using ASHRAE Standard 90.1-2004 Appendix G are not directly comparable to those using ASHRAE Standard 90.1-2007 Appendix G. This Balkanization creates problems and confusion in practice. It is not clear how buildings certified under different versions of LEED compare to one another. Another problem is the extreme load on software development, the resultant lack of availability of compliance and rating software, and the ultimate impact this has on compliance rates and building energy efficiency. Because of the care and tedium involved, automation of performance procedures is critical to their widespread and effective use. However, because performance procedures are based on continually moving prescriptive baselines, the software that implements them must be continually updated.

A. Single rule set

All codes and beyond-code programs should use a single rule set for performance-path modeling.

Recommended Timeline: This process should be initiated in the near-term: 0-2 years, but may not be fully implemented for 2-5 years.

B. Prescriptive baselines

The prescriptive baseline should not change with improvements to codes and standards. Rather than ratcheting up prescriptive baselines, standards should advance by ratcheting up

⁶⁶ California Energy Commission, "2013 Title 24 California Nonresidential ACM Reference Manual," Draft version, accessed May 2014, http://www.energy.ca.gov/title24/2013standards/implementation/documents/2013_nonres_ACM_reference/2012-10-26_2013_Nonres_ACM_Reference_manual.pdf.

⁶⁷ COMNET, "Buildings Energy Modeling Guidelines and Procedures (MGP)," accessed May 2014, <http://www.comnet.org/mgp/?purpose=0>.

performance increases over a fixed prescriptive baseline. In this setup, different standards could continue to set and advance performance increments independently and even set minimum prescriptive responses independently.

Recommended Timeline: This should be conducted in the near-term: 0-2 years.

C. Comprehensive, robust rule sets

Rule sets need to be better defined, more comprehensive, and more robust.

Recommended Timeline: This should be conducted in the near-term: 0-2 years.

Some of these recommendations are already being pursued. The proposed ASHRAE Standard 90.1 Addendum bm would create a unified code compliance/beyond-code path. This path would be based on ASHRAE Standard 90.1-2004 Appendix G and require 45 percent performance improvements for compliance. The implication is that subsequent code updates would take a more top-down approach where the performance goal is developed first and prescriptive requirements – possibly in the form of building-specific packages – are created to match the performance goals. Eventually, prescriptive options may disappear entirely, making simulation-driven, performance-based compliance mandatory.

On the side of rule set detail, the COMNET MGP prescribes additional modeling assumptions and could eventually be adopted or referenced by ASHRAE standards.

3.2.1.1.2 Residential buildings

Unlike the commercial space, the use of energy modeling tools for demonstrating code compliance, calculating asset ratings, and awarding certificates within the residential space is characterized by a plurality of methods implicitly embodied in tools. Many of these methods are software program and end- use specific, and do not build on, reference, or reuse one another.

Some residential rating systems provide a method for accreditation of simulation tools for generating their specific ratings. The software tool accreditation process usually involves submitting formal documentation demonstrating the proposed software’s effectiveness. In the case of a HERS rating, approved software tools must generate a code-compliant reference home; pass HERS BESTEST⁶⁸ Tier 1 tests; produce acceptable outputs for HVAC, duct distribution efficiency, and DHW (domestic hot water) predictions; and calculate a HERS rating within some acceptable margin of error.

The software accreditation process does not address minimum standards defining the capabilities of the underlying physics engines that generate energy use predictions. Other residential rating systems require that a single physics engine be used, eliminating the need for software accreditation entirely. Multiple end user applications can be used to access the same rating engine. For example, the DOE Home Energy Score requires use of their centralized rating engine, but allows multiple software systems to access it. Existing residential ratings systems also have naturally evolved to serve the different

⁶⁸ Developed by the National Renewable Energy Laboratory (NREL) and adapted as Section 7 of ASHRAE Standard 140-2011, the Home Energy Rating System (HERS) Building Energy Simulation Test (BESTEST) is a method of test for building energy analysis computer software.

transactions that occur within a building’s lifetime; for example, time of construction, time of retrofit, and time of sale.

Gap Analysis and Recommendations

Given the variety of rating systems in the marketplace, a standard or standards may be needed to ensure minimum technical rigor for software tools used to develop ratings for specific uses. For example, minimum software tool feature requirements for generating a rating for a newly constructed, highly efficient home could include the ability to model hourly thermal mass effects and/or external shading devices using the rigor defined above, while minimum software tool feature requirements for time of retrofit ratings of existing homes may be relaxed with respect to thermal mass, but include the ability to correctly model the part-load operation of existing HVAC systems or to model a specific range of retrofit options.

Furthermore, testing and administrative procedures may be useful in ensuring that software tools that produce certain types of ratings are tested using defined procedures whenever a new version of the software is released.

A. Standards for different rating purposes

Recognizing that increased cost effectiveness of rating delivery can be improved by data and process integration, it is recommended that standards be identified and developed that consider different rating purposes (e.g., real estate transaction, posting on multiple listing service (MLS) or commercial listing service, energy audit, new home, financial incentive applications).

Recommended Timeline: This should be conducted in the near-term: 0-2 years. Identification could be completed within 1 year and standards could be developed within 2 years.

3.2.1.1.3 Multi-family buildings

A discussion on multi-family buildings can be found in Section 3.2.1.2, *Energy Simulation for Whole-Building Energy Efficiency Incentives*.

3.2.1.1.4 Data Centers

While mostly handled in the past by commercial building energy codes and labels, data centers are now splitting off into a separate category. In part because of their extreme internal load characteristics and thermal comfort requirements, data centers need to keep computers – rather than human occupants – “comfortable.”

Gap Analysis and Recommendations

ASHRAE Standard 90.1 currently covers all computer rooms, but a new standard which is currently under development, ASHRAE Standard 90.4, will cover larger data centers. When Standard 90.4 is complete, those data centers will likely be removed from the scope of Standard 90.1. Informed by ASHRAE Technical Committee (TC) 9.9, Standard 90.4 is still in its early formation stages, and the Standard Project Committee (SPC) is still debating foundational decisions regarding both efficiency standards and a path to those standards. For instance, SPC has not decided whether 90.4 will set

absolute power use efficiency (PUE)⁶⁹ targets – or if it will pursue a path similar to that of ASHRAE Standard 90.1 with minimum PUEs determined by prescriptive requirements. In the case of the latter, simulation will be a critical element. TC 9.9 is looking to answer some of these questions using ASHRAE-sponsored research projects.

A. Standard for data centers

If possible, ASHRAE should seek to publish the first version of the 90.4 standard by the next update cycle in 2016. This first version should, to the extent possible, align with the protocols and methodologies of the 90.1 standard.

Recommended Timeline: This should be conducted in the mid-term: 2-5 years.

3.2.1.2 Energy Simulation for Whole-Building Energy Efficiency Incentives

Energy simulation is often used to generate predictions for awarding performance-based incentives. Incentives can be grouped into two broad categories: (1) funding provided by utility-sponsored energy efficiency programs in the form of rebates; and (2) subsidies provided by federal, state, or local governments in the form of tax credits or deductions.

In particular, performance-based programs can benefit from the standardization of simulation process and the use of data transfer standards. Performance-based programs are burdened by increased overhead from lack of simulation standards and the review. The lack of data transfer standards also interferes with the ability of service providers (contractors, engineers, raters, and others) to extend their business into other geographic incentive territories, and prevents long-term investments in data management solutions because of frequent changes in program data reporting standards and required software. These data transfer standards will have application outside of performance-based programs.

3.2.1.2.1 Commercial Buildings

Model-based energy efficiency incentives for commercial buildings consist of the §179D federal tax deduction, utility Energy Design Assistance (EDA) for new construction programs, and a single pilot program for deep retrofits.

The §179D federal deduction, enacted by the *Energy Policy Act of 2005*, offers monetary incentives for new and retrofitted buildings achieving 50 percent savings beyond code. The statute specifies simulation as the savings calculation method and ASHRAE Standard 90.1-2004 PRM (i.e., Appendix G) as the calculation protocol, with additional modeling requirements for occupancy, infiltration, and lighting power borrowed from California's Title 24-2005 ACM. The Internal Revenue Service has certified a number of simulation engines for use, requiring testing with ASHRAE Standard 140-2007, *Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs*. This list is sometimes referenced by other programs. §179D requires only a professional engineering certificate of the modeler. With the help of the National Renewable Energy Laboratory (NREL), DOE has developed a screening tool for §179D that uses regression-based estimates derived from EnergyPlus simulations for DOE/NREL reference buildings.

⁶⁹ PUE, the ratio of total data center energy use to computer equipment energy use, is the de facto standard efficiency metric for data centers.

Many utilities operate EDA programs either directly or indirectly, using in-house modeling staff or contractors. Program details vary, but a representative program is one run by Xcel Energy in Colorado. Baseline performance is established by ASHRAE Standard 90.1-2007, although sub-jurisdictions can adopt more stringent standards. Xcel EDA targets new commercial buildings over 50,000 square feet in size, and sets a performance target of 15 percent above code. The modeling protocol is ASHRAE Standard 90.1-2007 Appendix G, modified to reflect Colorado-specific conditions, as well as the early stage design nature of the program. On a case-by-case basis, projects can apply for exemptions from various aspects of the modeling protocol, including allowances for plug and process loads. Xcel mandates the use of hourly simulation software. Participating consultants must have a Building Energy Modeling Professional (BEMP)⁷⁰ or a Building Energy Simulation Analyst (BESA™)⁷¹ credentialed modeler on the team and meet additional project and software experience requirements.

Gap Analysis and Recommendations

Energy design assistance program implementation details vary, but most programs confront the same standards gaps. Specifically, simulation methodologies and protocols need to be included in published standards so that they can be referenced in contracts for design work. ASHRAE has proposed a standard on simulation-driven design assistance, but publication of that standard is several years away. While there are a number of sophisticated simulation tools on the market, it is less clear which tools are appropriate for use with different design elements, especially HVAC system types. The current ASHRAE Standard 140 is not sufficiently comprehensive for this purpose at this time.

A. Simulation methodologies and protocols⁷²

The proposed standard, ASHRAE Standard 209P, *Energy Simulation Aided Design for Buildings Except Low-Rise Residential Buildings*, is designed to fill the modeling protocol gap above. A reasonable goal is for a first version of the standard to be published along with the next update to ASHRAE Standard 90.1 in 2016. ASHRAE Standard 140 will eventually address the simulation tool suitability gap, but the effort to bring the standard to the necessary level will require a significant volume of detailed measured data, and therefore may evolve slowly. Accelerating the development of the standard – specifically on the data gathering and model reconciliation activities that underlie the standard – will require substantial resources.

Recommended Timeline: This should be conducted in the mid-term: 2-5 years.

3.2.1.2.2 Residential Buildings

Utility-sponsored whole-house energy efficiency programs often adopt the EPA/DOE Home Performance with ENERGY STAR® (HPwES) or a similar “whole-house” program model. While energy simulation is not

⁷⁰ Information on ASHRAE’s Building Energy Modeling Professional (BEMP) certification is available at: <https://www.ashrae.org/education--certification/certification/building-energy-modeling-professional-certification>.

⁷¹ Information on the Association of Energy Engineers’ Building Energy Simulation Analyst (BESA™) certification is available at <http://www.aeecenter.org/j4a/pages/index.cfm?pageid=3479>.

⁷² Technology research needs related to this discussion are highlighted in the Bonneville Power Administration’s (BPA) *National Energy Efficiency Technology Roadmap Portfolio*, March 2014 version. See the reference to the R&D Program “More variability, determined automatically in simulation for more realistic systems modeling” in the section “Modeling, Lab and Field Testing (1 of 9)” (pp. 326-327): http://www.bpa.gov/energy/n/emerging_technology/pdf/EE_Tech_RM_Portfolio.pdf.

a specific program requirement of HPwES compliance, when a program offers a whole-house incentive pathway, energy simulation – both building-specific and using prototype buildings more generally – is sometimes used to generate the incentive. An existing standard, BPI 2400-S-2012, *Standard Practice for Standardized Qualification of Whole-House Energy Savings Predictions by Calibration to Energy Use History*, was developed as a methodology for determining a qualifying baseline for determining energy savings. Efforts (led primarily by Efficiency First) to educate and promote the standard to influential stakeholders continue. RESNET has developed a variation of their energy rating tool accreditation process for use in existing home retrofits.⁷³ This test procedure uses all the rating test requirements except the rating score test, and adds a requirement to test the interaction of proposed improvements to the baseline model.

BPI 2200-S-2013, *Standard for Home Performance-Related Data Collection*, defines a standard vocabulary of data elements necessary to provide a general description of a whole-house energy efficiency upgrade for reporting, rebate, and basic QA purposes. The data elements defined in BPI 2200 are the foundation of the home performance extensible mark-up language (HPXML) schema defined in BPI 2100-S-2013, *Standard for Home Performance-Related Data Transfer*. HPXML provides a way to structure and communicate information about whole-house energy efficiency upgrades. DOE's Building Energy Data Exchange Specification (BEDES) includes standard descriptors for energy conservation measures (ECMs) for both commercial and residential buildings; the precise definition of each measure will be set by a technical working group. Simulation guidance can be developed for these descriptors. Where there is overlap in the definition of residential data elements, efforts have been made to align BEDES (formerly the Building Energy Performance Taxonomy) with BPI Standards 2100 and 2200.

Recent work by Rocky Mountain Institute (RMI) is developing such guidance in the form of measure simulation cutsheets that specify simulation methodologies, required inputs, and related benchmarking and analysis. NREL's National Residential Efficiency Measures Database (NREMDB) is a publicly available, centralized resource of residential building retrofit measures and costs for the U.S. building industry. The measures database contains standardized definitions for residential energy conservation measures. Efforts are underway to incorporate aspects of the NREMDB into NREL's Building Component Library (BCL), an online repository of simulation model data objects (including scripts for transforming simulation input models) that includes public, auditable, citable implementations of common ECMs for the OpenStudio platform. OpenStudio is currently specific to the EnergyPlus simulation engine, but can be generalized to other engines.

Gap Analysis and Recommendations

Several standardization gaps hamper adoption of whole-house performance-based rebates. For example, BPI Standards 2100 and 2200, RMI's ECM cutsheets, and NREL's NREMD and BCL would benefit from increased coordination. In the residential arena, there is a lack of standard protocols for simulating energy conservation measures. Currently, different simulation programs implement these differently. For example, some simulation tools model the addition of an attic fan using empirically-derived equations that calculate annual electrical load and an associated change in thermostat set-point to

⁷³ For details, see http://www.resnet.us/professional/programs/taxcredit_software_existing_application.

represent the thermal load changes. Other tools model this measure by increasing infiltration/ventilation rates during summer nighttime periods. Even within a single tool, there are often multiple ways to model the same measure. Where there are different approaches, there is no basis for choosing among them based on accuracy. This is addressed more specifically in Section 3.2.2, *Energy Simulation Software Capabilities and Accuracy*.

A related gap is a lack of well-defined, accepted uncertainty ranges in savings calculations. Uncertainty can be due to the simulation method approximations or the simulation model inputs. Additionally, service providers lack software tools that can easily generate uncertainty estimates. In residential whole-house projects, homeowners often choose to make different investments based on different risk tolerances. When risk tolerances are not exposed, investments are often not made.

A standardized procedure for simulation model review is also missing. Currently, models are reviewed by individuals of varying competence using ad hoc procedures often associated with specific simulation tools. The lack of standardized model review protocols creates inconsistent results and degrades confidence in the modeling enterprise. The RMI measure cutsheets include model review protocols, including benchmarking, for individual measures. The BCL can be used as a proactive model review tool. Models created using pre-approved BCL content and measures are in some sense “good by construction.” Xcel Energy’s Energy Design Assistance Program uses OpenStudio and the BCL in this precise way to reduce model review costs; it should be noted that this is a pilot application.

A. Develop standardized definitions for energy conservation measures, standard protocols for simulation, and standard implementations of those protocols

The recommendation is to cascade the BEDES, BPI 2100/2200, measure cutsheet, NREMDB, and BCL projects, potentially using ASHRAE Standard 209P as a standards vehicle for the simulation protocols. HERS BESTEST, BPI 2400, and the RESNET extensions to HERS BESTEST for heating plant, distribution system, DHW (domestic hot water), and improvement measure interaction need to be expanded, especially in the HVAC space, to support this effort. This is a cascading, multi-step effort that could take 5-10 years to complete.

Recommended Timeline: This is a long-term work effort and should be completed in 5+years.

B. Develop a standardized procedure for simulation model review

Model review, including benchmarking, can be built into the modeling, but the entire review and acceptance framework needs to be agreed upon. An initial framework can likely be put together in about 2 years.

Recommended Timeline: This is a near-term priority and should be conducted in 0-2 years.

C. Develop standard methods for estimating uncertainty in energy-savings calculations as well as acceptability ranges for uncertainty

Ad hoc tools for uncertainty analysis are very close and should help. However, there is some research to be done before a sound, useful, comprehensive framework is put in place 3-5 years from now.

Recommended Timeline: This is an urgent priority; however, it will not likely be fully resolved in the near-term. Conversations should begin immediately, and work should be completed in the mid-term: 2-5 years.

3.2.1.2.3 Multi-family Buildings

Both ASHRAE and ICC consider multi-family buildings having three or fewer stories (above grade) to be low-rise, and they are mostly covered under residential standards. Those having greater than three stories (above grade) are considered high-rise residential, and are covered under commercial standards. As such, the reader can refer to descriptions of existing standards, gaps, and recommendations in the commercial and residential sections above to describe multi-family buildings appropriately. Generally, the multi-family label is applied to buildings with more than four housing units.

Energy efficiency standards that apply across the wide variation in multi-family building types have been difficult to develop. The range of construction types in multi-family buildings is considerable, ranging from smaller low-rise wood frame construction with individual apartment heating and cooling units to high-rise buildings with major central mechanical systems. Standards for multi-family buildings may be applied to the whole building or to the individual residential living units. Multi-family buildings in metropolitan areas may be mixed use with commercial use spaces in the lower floors and residential apartments in the upper floors. Multi-family buildings can also be managed by their owners as part of larger properties. Properties may also be master metered for one or more fuels, resulting in no energy metering at the individual building level.

Gap Analysis and Recommendations

Utility requirements for reporting energy savings from incentive programs by customer rate class are another significant barrier to a consolidated handling of multi-family energy efficiency standards. Individually-metered apartments in a multi-family building are considered residential meters eligible for residential incentives. Common space meters in the same building are considered to be commercial meters eligible for commercial incentives. This interferes with the ability of utilities to offer whole building programs. Frequently, utilities do not have a strong mapping of meters to building addresses, and variations in the addresses in accounts can make mapping and aggregating individually-metered apartment accounts in a building to a common address difficult. This problem is beginning to be resolved as utilities make greater use of energy usage data and participate in benchmarking initiatives.

There are important variations in the combination of who pays for different end uses in multi-family buildings. This a barrier to private investment in multi-family efficiency, when investments by the owner in efficiency measures that impact the apartment meter return savings to the tenant and not to the owner, the so-called split incentive issue. A related problem is energy usage data privacy in multi-family buildings with individually-metered apartments. In some utility regulatory jurisdictions, whole building data, including information from individually-metered apartments, can be provided in aggregate to the building owner. In other regulatory jurisdictions, privacy concerns require obtaining a data release from each individual tenant. Difficulty in obtaining whole building data in multi-family buildings is a major barrier to benchmarking, to the development of calibrated models, and to the development of feedback systems on energy savings predictions in this building type.

Whole building programs for multi-family and commercial buildings are developing program designs that support comprehensive retrofit using energy model predictions potentially followed by tracking and incentives for actual measured performance. Using energy model predictions for the award of incentives on existing buildings requires the application of a range of quality control and quality assurance measures, including model calibration, establishment of bounds for inputs and outputs, etc., to avoid the risk that baseline energy usage will be inflated and incentive awards inappropriately increased. Integration of actual performance tracking into program design and incentives also increases the motivation to make accurate savings predictions. This approach is also being explored in residential whole building retrofits.

There is a general movement toward performance-based programs, such as the Multifamily Performance Program (MPP) from the New York State Energy Research and Development Authority (NYSERDA).⁷⁴ The issue of rate class is a barrier toward utilities implementing whole building programs using simulation tools for multi-family programs.

A. Standardized modeling requirements for multi-family buildings

New work on multi-family modeling should be done to develop standardized modeling requirements.

Recommended Timeline: Work to address this should gap begin immediately and should be completed in the mid-term: 2-5 years.

3.2.1.3 Building Energy Simulation for Use in Evaluation, Measurement, and Verification

This section is focused specifically on building energy simulation for use in evaluation, measurement, and verification (EM&V). Beyond this, EM&V is covered in Chapter Four. Complex, time-dependent interactions between building envelope loads, occupancy, and HVAC space conditioning equipment are best captured by quasi-steady state energy simulation tools. As deep retrofits reach beyond simply replacing equipment with more efficient equipment, simulation tools allow users to estimate first-cost savings from the use of smaller equipment and annual savings from operating the smaller equipment.

3.2.1.3.1 Commercial Buildings

Building energy simulation is a commonly used tool for the evaluation of energy efficiency programs and for the measurement and verification of projects (EM&V). It is identified as Option D in the International Performance Measurement and Verification Protocols (IPMVP).⁷⁵ Calibrated energy simulation can be used for both retrofits and new construction. Energy use is typically simulated for components or the whole facility. The simulations may be of either specific or representative buildings.

⁷⁴ For more information on the MPP, visit <http://www.nyseda.ny.gov/Energy-Efficiency-and-Renewable-Programs/Multifamily-Performance-Program/Multifamily-Performance-Program.aspx>.

⁷⁵ Efficiency Valuation Organization, "International Performance Measurement and Verification Protocol: Concepts and Options for Determining Energy and Water Savings, Volume I," March 2002, www.ipmvp.org

Simulation is most useful for estimating savings from commercial or industrial measures affecting HVAC energy use. This includes HVAC efficiency and envelope improvement measures. Applications for industrial facilities tend to be more like commercial applications. Simulation is also commonly used to estimate the effects of HVAC interaction with lighting efficiency measures. It may also be used to estimate equivalent full load hours for HVAC equipment. It is useful where:

- Pre-retrofit energy data do not exist or are unavailable
- Post-retrofit energy use data are unavailable or obscured by factors whose influence will be difficult to quantify
- The expected energy savings are not large enough to be separated from the facility's utility meter using IPMVP Option C
- The savings associated with individual ECMs need to be determined, but IPMVP Options A or B isolation and measurements are too difficult or costly⁷⁶

The DOE Uniform Methods Project (UMP) protocols call for simulation for commercial and industrial lighting interactive effects, small commercial and residential unitary and split system HVAC cooling equipment-efficiency upgrade, peak demand, and time-differentiated energy savings.⁷⁷ The protocols are referenced by public utility commissions responsible for revising evaluations of utility programs.

Reference buildings are frequently used in commercial modeling. This application is most common with prescriptive rather than custom measures. Standard commercial reference building models are available from NREL⁷⁸ and Pacific Northwest National Laboratory (PNNL).⁷⁹

Calibration is a critical element of accurate simulation. Models must be calibrated to utility billing data and/or end-use metered data so that the model reasonably matches actual use and demand from either pre- or post-retrofit conditions. ASHRAE Guideline 14, *Measuring Energy and Demand Savings*, addresses calibration of building simulation models, as does BPI 2400-S-2011, *Standardized Qualification of Whole-House Energy Savings Estimate* and the California Evaluation Framework and Protocols.^{80,81}

⁷⁶ American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), "ASHRAE Guideline 14, Measuring Energy and Demand Savings," 2002, <https://www.ashrae.org/standards-research--technology/standards--guidelines/titles-purposes-and-scopes#Gdl14>.

⁷⁷ Jayaweera, T., Haeri, H., Bruchs, D., Keeling, J., Khawaja, S., Rushton, J., et al., "The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures," April 2013, National Renewable Energy Laboratory, <http://www.nrel.gov/docs/fy13osti/53827.pdf>.

⁷⁸ Deru, M., Field, K., Studer, D., Benne, K., Griffith, B., Torcellini, P., et al., "U.S. Department of Energy Commercial Reference Building Models of the National Building Stock," February 2011, National Renewable Energy Laboratory, <http://www.nrel.gov/docs/fy11osti/46861.pdf>.

⁷⁹ Thornton, B., Rosenberg, M., Richman, E., Wang, W., Xie, Y., Zhang, J., et al., "Achieving the 30% Goal: Energy and Cost Savings Analysis of ASHRAE Standard 90.1-2010," May 2011, Pacific Northwest National Laboratory, https://www.energycodes.gov/sites/default/files/documents/BECP_Energy_Cost_Savings_STD2010_May2011_v00.pdf.

⁸⁰ TecMarket Works, "The California Evaluation Framework," June 2004, http://www.calmac.org/publications/California_Evaluation_Framework_June_2004.pdf.

⁸¹ TecMarket Works, "California Energy Efficiency Program Evaluation Protocols: Technical, Methodological, and Reporting Requirements for Evaluation Professionals," April 2006, http://www.calmac.org/events/EvaluatorsProtocols_Final_AdoptedviaRuling_06-19-2006.pdf.

Gap Analysis and Recommendations

A. Explicit linkages for standards specifying building simulation

Standards specifying building simulation software should provide explicit linkages to other standards providing specifics related to calibration, training, and certification of software, including ASHRAE Guideline 14 (calibration), ASHRAE Standard 140 (software certification), BPI 2400-S-2011 (calibration), and the California Evaluation Framework and Protocols (training).⁸²

Recommended Timeline: This should be conducted in the near-term: 0-2 years.

3.2.1.3.2 Residential Buildings

Simulation is most useful for estimating savings from residential measures affecting HVAC energy use. This includes HVAC efficiency and envelope improvement measures. Simulation is also commonly used to estimate the effects of HVAC interaction with lighting efficiency measures. It may also be used to estimate equivalent full load hours for HVAC equipment. It is useful where:

- Pre-retrofit energy data do not exist or are unavailable
- Post-retrofit energy use data are unavailable or obscured by factors whose influence will be difficult to quantify
- The expected energy savings are not large enough to be separated from the facility's utility meter using IPMVP Option C
- The savings associated with individual ECMs are needed, but IPMVP Options A or B isolation and measurements are too difficult or costly⁸³

The California Evaluation Framework identifies building simulation as robustly applicable for residential air leakage sealing, cool roofs, duct leakage, exterior shading, natural ventilation, passive solar heat, radiant barriers, refrigerant charge and airflow, sunspaces/atria, thermal mass, and zonal HVAC systems.⁸⁴

Building simulation is not currently identified in DOE's Uniform Methods Project protocols for residential buildings. The next edition, due in 2014, may specify building simulation. Simulation models may be used to calculate parameters for use in default energy savings values in technical reference manuals (TRMs) issued by public utility commissions. For example, the Pennsylvania TRM⁸⁵ uses per-unit energy and demand savings estimates based on prior building simulations of windows.

Reference buildings are typically used in residential modeling, as the populations of participants tends to be in the thousands and individual building modeling is not cost-effective.

⁸² Software certification is discussed in Section 3.2.2, *Energy Simulation Software Capabilities and Accuracy*.

⁸³ American Society of Heating, Ventilating, and Air Conditioning Engineers, "ASHRAE Guideline 14, Measuring Energy and Demand Savings," 2002, Atlanta, Georgia.

⁸⁴ TecMarket Works, "The California Evaluation Framework," June 2004.

⁸⁵ Public Utilities Commission, "Technical Reference Manual: State of Pennsylvania Act 129: Energy Efficiency and Conservation Program and Act 213: Alternative Energy Portfolio Standards," June 2012.

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Recommended Timeline: This should be addressed in the near-term: 0-2 years.

B. EM&V simulation standards are needed for multi-family buildings

BPI 2400 applies to 1-4 unit residential buildings, but no standards currently exist for larger multi-family buildings.

Recommended Timeline: This should be addressed in the near-term: 0-2 years.

3.2.2 Energy Simulation Software Capabilities and Accuracy

Energy simulation software is certified for specific purposes (e.g., rating calculations, code compliance) on the basis of the scope of its simulation capabilities and the “accuracy” of its calculations within that scope.

3.2.2.1 Commercial and Residential Buildings

For commercial building energy simulation software there is no single absolute acceptance standard for energy simulation software. Instead, ASHRAE Standard 140 contains suites of test cases – including sensitivity studies on major parameters – along with associated reference results. The intent is that individual programs set use-specific acceptance criteria based on deviation from these reference results. The Internal Revenue Service (IRS) uses ASHRAE Standard 140 to approve software for calculating commercial building energy efficiency tax deductions.⁸⁸ The IRS has approved a large number of simulation engines using this method including EnergyPlus and DOE2.2.⁸⁹ In Section 2.2, ASHRAE Standard 90.1 Appendix G requires energy simulation software to submit to ASHRAE Standard 140

⁸⁶ TecMarket Works, “The California Evaluation Framework,” June 2004.

⁸⁷ TecMarket Works, “California Energy Efficiency Program Evaluation Protocols: Technical, Methodological, and Reporting Requirements for Evaluation Professionals,” April 2006.

⁸⁸ Qualified computer software for calculating commercial building energy and power cost savings that meet federal tax incentive requirements are listed at: <http://energy.gov/eere/buildings/qualified-software-calculating-commercial-building-tax-deductions>.

⁸⁹ Henninger, R., & Witte, M., “EnergyPlus Testing with ANSI/ASHRAE Standard 140-2001 (BESTEST),” 2003, U.S. Department of Energy, http://simulationresearch.lbl.gov/dirpubs/epl_bestest_ash.pdf.

testing, but includes no acceptance criteria per se. It also includes a list of required software capabilities including the ability to account for thermal mass and to simulate part-load equipment performance. USGBC's LEED program references Appendix G 2.2, and the Green Building Certification Institute (GBCI) publishes a list of commonly used and recommended software. USGBC and GBCI do not publish or reference a list of *approved* software. It is not clear how many other programs require approved energy simulation software and how many of those simply reference Appendix G and/or the IRS-approved software list.

For the purposes of complying with Title 24-2013, the California Energy Commission requires that approved software "pass" ASHRAE Standard 140 tests (*note*: passing ASHRAE Standard 140 consists of executing the tests and reporting the results). It has also published additional tests that cover sensitivity to parameters like insulation, infiltration, fenestration U-value and solar heat gain coefficient, and internal loads.⁹⁰ Some programs – DOE's Commercial Building Asset Score, for example – sidestep the capability and accuracy-based engine approval issue by using a single-engine implementation.

In addition to basic physics simulation capabilities, there are scattered tests for other software procedures that are frequently used in various simulation end-use cases. The two most important related capabilities are: (1) the generation of a code-baseline building from a proposed building for code-compliance and beyond-code performance level calculations; and (2) the calibration of simulation-model inputs. ASHRAE Standard 90.1 Appendix G requires simulation software that can handle both the proposed and code-baseline building, but does not specifically address the automated creation of the code-baseline building from the proposed building. The fact that LEED does not publish or reference approved software is at least partly due to the common misinterpretation that Appendix G 2.2 approval extends to the procedure for creating the code-baseline building. In contrast, California's Title 24 software approval tests explicitly cover the generation of a Title 24 code-baseline building. RESNET is currently working on adapting the BESTEST-EX procedure for testing of model-input calibration as the current procedure requires an expensive "one-time" test.

ASHRAE Standard 140 has growing test coverage, and some of the older tests are being refurbished with new specifications and/or new reference result sets using more modern and sophisticated simulation software. An important goal for ASHRAE Standard 140 is increasing the number of tests that have reference results obtained from test facility measurement. The current tests are either simple enough to have known analytical solutions, or are consensus results generated by multiple simulation engines that have each implemented the analytical tests. Additional measured data reference result sets will increase confidence in both simulation tools and the ASHRAE Standard 140 methodology. They will also point to shortcomings in simulation capabilities and coverage gaps in the testing standard. Another goal is to establish robust, comprehensive, and easy to administer tests for other software capabilities, beginning with generation of code-baseline buildings and model-input calibration.

For residential buildings, RESNET has published procedures for accrediting simulation programs for various purposes. These include RESNET Publication 06-002, *Procedures for Verification of RESNET*

⁹⁰ California Energy Commission, "Nonresidential Alternative Calculation Method Reference Manual," June 2013, <http://energy.ca.gov/2013publications/CEC-400-2013-004/CEC-400-2013-004-CMF.pdf>.

Accredited HERS Software Tools, RESNET Publication 2006-001, *Procedures for Certifying Residential Energy Efficiency Tax Credits*, and RESNET Publication 07-003, *Procedures for Verification of International Energy Conservation Code Performance Path Calculation Tools*. Publication 06-002 is referenced in the Mortgage Industry National Home Energy Rating Standards as well. HERS BESTEST, developed by NREL and adapted as Section 7 of ASHRAE Standard 140-2011, is a method of test that assesses calculation capabilities for residential simulation software. Some of the HERS BESTEST physics tests have been updated and extended in BESTEST-EX. The non-BESTEST RESNET tests differ from the BESTEST and ASHRAE Standard 140 tests in that they define acceptance ranges alongside the reference result sets.

In addition to physics-based tests that target individual home configurations and parameter sensitivities around them, new tests are being developed that directly target the application of energy-efficiency measures. These tests are empirical in that their reference results are generated using “before-and-after” measurements on homes that have undergone the corresponding upgrade. These tests are being developed and administered at the program level. Examples include California’s Energy Upgrade California whole-building program and the New York State Home Performance with ENERGY STAR® sponsored by NYSERDA.

The residential energy simulation software industry, and the home performance industry that depends on it, are currently afflicted by a proliferation of software tests with unarticulated, incomplete, and partially overlapping coverage. The result is that software that passes one set of tests designed to serve a specific use case is automatically approved for any purpose. For instance, software that passes an empirical test for savings estimates for one set of energy efficiency measures in one geographic location is subsequently used to estimate savings for any energy efficiency measure in any geographic location.

Gap Analysis and Recommendations

The following recommendations are put forward for commercial and residential buildings:

A. Roadmap for improving the coverage and physical fidelity of energy simulation engine tests

The recommendation is to develop a roadmap for improving the coverage and physical fidelity of energy simulation engine tests, including expanding the range of tests for existing buildings and potentially including reference results from empirical measurements. This activity would use the growing collection of test facility data to characterize and benchmark the simulated accuracy of major building-physics phenomena and common HVAC system types, and create a prioritized list of missing or lagging simulation capabilities combined with measurement experiments needed to resolve or upgrade them.⁹¹

Recommended Timeline: This should be completed in the mid-term: 2-5 years.

B. Tests for energy simulation software and supporting software

There is a need to develop and reference suites of tests for energy simulation software and supporting software – potentially with accuracy guidelines – that are appropriate for specific

⁹¹ Technology research needs related to this discussion are highlighted in the Bonneville Power Administration’s (BPA) *National Energy Efficiency Technology Roadmap Portfolio*, March 2014 version. See the section on “Modeling, Lab and Field Testing” (pp. 326-345): http://www.bpa.gov/energy/n/emerging_technology/pdf/EE_Tech_RM_Portfolio.pdf.

use cases. Each suite should be designed to: (1) be applicable to market uses and/or connected to standard program types such as residential, commercial, new, existing, whole building, retro-commissioning, code compliance, ratings, incentives; and (2) where appropriate, explicitly test before- and after-simulation of efficiency measures associated with these use cases.

Such test suites should be designed to: (a) assess accuracy and coverage of software capabilities; (b) standardize the level of effort required by software vendors to test software; and (c) foster development and implementation of third-party validation methods/systems.

In regulated contexts, credentials for the accuracy of savings calculations are extremely valuable. Utility programs rely on state-level technical reference manuals to approve calculation methodologies. The manuals, which often include references to standards as opposed to specific tools, could cite these standard suites of tests along with acceptability/accuracy criteria that meet the programs' needs.

This would parallel the simulation accuracy benchmarking activity described above. It could be led by a standards organization whose published scope covers this type of activity.

Recommended Timeline: This should be completed in the mid-term: 2-5 years.

C. Develop a robust and low-cost testing procedure for model-input calibration

This is a 1-2 year activity already undertaken by RESNET, which has formed a working group to generalize and codify the BESTEST-EX methodology for calibrating energy model inputs using measured data, e.g., utility bill data.

Recommended Timeline: This should be completed in the near-term: 0-2 years.

3.2.3 Energy Simulation Professionals

Appropriate use of simulation tools may require understanding of engineering principles and specific training in the use of the tools. Some simulation end use instances – including instances of code compliance and asset rating – require credentialed simulation professionals.

3.2.3.1 Commercial Buildings

As of 2014, there are two energy simulator certificates available in the marketplace: ASHRAE's Building Energy Modeling Professional (BEMP) and the Association of Energy Engineers' (AEE) Building Energy Simulation Analyst (BESA™). The number of professionals holding each certificate is small (under 300). It is also not clear which programs require these certificates.

ASHRAE specifies in Guideline 14 that five years of simulation experience is required for use of calibrated simulation for measurement and verification. Standards addressing simulation do not always address this issue.^{92,93}

Beginning in 2013, DOE and the National Institute of Building Sciences (NIBS) began developing voluntary national workforce guidelines under the Better Buildings Workforce Guidelines project, for five initial commercial energy-related jobs: Building Energy Auditors, Building Commissioning Professionals, Building Operations Professionals, Energy Managers, and Facilities Managers. The effort is designed to promote the adoption and utilization of national guidelines across the commercial buildings community, particularly in support of issuing interim credentials in accordance with 29 CFR Part 29.5(b)(16). DOE and NIBS expect adoption and implementation of guidelines across the commercial buildings community beginning in 2015. DOE/NIBS workforce guidelines addressing the commercial energy modeling community are anticipated to be addressed during a second round of activities, with a timeline to be determined.

Gap Analysis and Recommendations

A. Harmonize – or at least differentiate – the BESA™ and BEMP certificates

The relationship between the BEMP and BESA™ certificates is not clear, although the BESA™ certificate requires less experience for qualification.

Recommended Timeline: Differentiation is a near-term goal: 0-2 years. Harmonization is a long-term goal: 5+ years

B. Any simulation used for code compliance or asset rating should be overseen by a credentialed simulation professional

Beginners should not be responsible for simulations that explicitly support regulatory or financial transactions. However, they do have to learn somewhere, and furthermore, to learn by doing. The apprenticeship and responsibility structure should track that which is used in other engineering fields. An engineer in training may do the work, but a credentialed engineer (i.e., a PE) reviews it, stamps it, and is ultimately responsible for it. A timeframe for enforcing this requirement generally should be at least five years, because the number of credentialed simulation professionals is currently small.

Recommended Timeline: This is a long-term work effort and should be completed in 5+ years.

3.2.3.2 Residential Buildings

RESNET offers a HERS rater credentialing system. The Home Energy Score – DOE's residential asset rating program – certifies users for use of the Home Energy Scoring Tool, but this is a program/rating-specific credential. BPI has a software-agnostic residential modeling credential in development.

⁹² Jayaweera, T., Haeri, H., Bruchs, D., Keeling, J., Khawaja, S., Rushton, J., et al. "The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures," April 2013, National Renewable Energy Laboratory.

⁹³ Efficiency Valuation Organization, "International Performance Measurement and Verification Protocol: Concepts and Options for Determining Energy and Water Savings, Volume 1," 2012.

Gap Analysis and Recommendations

A standardized process for credentialing qualified users of residential energy simulation software currently does not exist.

A. Standardized methods for credentialing

Standardized methods of credentialing qualified users of residential energy simulation software should be created to address this gap.

Recommended Timeline: This should be conducted in the near-term: 0-2 years.

CHAPTER FOUR: EVALUATION, MEASUREMENT, AND VERIFICATION (EM&V)

4.0 Introduction

Evaluation, measurement, and verification (EM&V) within energy efficiency (EE) covers a wide range of practices that are undertaken to quantify the effects of EE measures, projects, and program activities, as well as methods to assess EE's potential effects and assess the performance of measures, projects, programs, and portfolios.⁹⁴ The quantification of energy savings for a particular measure or project is known as measurement and verification (M&V). From this broad landscape, the EESCC working group on EM&V chose to focus on energy efficiency savings, specifically in buildings, and issues closely associated with those savings (e.g., reporting). The working group identified a broad array of issues in the determination of electricity savings and selected those deemed most ready for roadmapping in the direction of refined guidelines, identification of best practices, and ultimately, standards. Energy savings are the fundamental connection between energy efficiency activity and understanding what that activity accomplished to inform business, economic, and policy analysis or decisions. Some approaches are applicable to industrial processes as well, though these are not the focus of the described issues.

The “evaluation” component in EM&V captures implementation and programmatic impacts such as measure savings persistence and market transformation. Further, an important aspect of evaluation captures the cost benefit aspects of programmatic EE, identifying net savings by assessing free rider⁹⁵ and spillover⁹⁶ rates. Lastly, the methods to quantify EE program savings through evaluation inform the development, deployment, and improvement of programs. This chapter captures several levels of EM&V, while focusing on M&V as the technical basis for determining energy reduction values resulting from EE investment.⁹⁷

EM&V savings calculations are used to support electrical industry resource planning by utilities and electrical system operators. Their use also applies to natural gas resource planning, though to a lesser extent. This chapter focuses on the use of EM&V methods to determine energy savings as essential information in its own right, and as a critical component that underlies many of the other EM&V activities. This includes the assessment of value of EE, particularly of EE programs, in comparison to other energy resources or approaches to satisfying energy demand.

⁹⁴ Programmatic activity covers activities conducted by utility and non-utility program administrators, often funded by electric or natural gas utility rates (third-party sources), and overseen by public authorities such as public utility commissions, municipal or independent boards.

⁹⁵ Free riders are EE program participants that utilize rebate or incentives offered in cases where they would have made the investment without these economic stimuli.

⁹⁶ Spillover accounts for EE investment that occurs as a result of the presence of programmatic stimuli, but where a participant does not utilize a rebate or incentive in order to make the EE investment.

⁹⁷ Standardization in the area of building energy use as well as other utilities (e.g. water) is an ongoing process, as reflected in other sections of this document and in work elsewhere. These efforts may concern themselves with issues at a more granular or higher level than addressed in this section. As that works develops, it may provide standardized inputs for EM&V, facilitating EM&V procedures. For example, ECMA International has recently developed standards for a data center's building communication taxonomy (ECMA-400), allowing integrated control of the building and equipment within it (servers).

The field of EM&V evolved from the original EE programs in the mid-to-late 1970s and has built up a wide array of tools and methods to determine savings in many contexts. This chapter builds on that extensive body of work to identify standardization activities that would help the industry move toward more consistent and rigorous savings determination. There are more than 250 entries in the EESCC Inventory Database tagged for EM&V. Among those most commonly used in the EM&V field are:⁹⁸

- International Performance Measurement and Verification Protocol (IPMVP)
- State and regional protocols such as California, Pacific Northwest, and Independent System Operators (ISOs) in the Northeast
- U.S. Department of Energy (DOE) documents, including the State and Local Energy Efficiency Action Network (SEE Action) publications⁹⁹ and the Uniform Methods Project (UMP)
- ASHRAE Standard 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings*, and ASHRAE Guideline 14, *Measurement of Energy and Demand Savings*
- North American Energy Standards Board (NAESB) Model Business Practice Standards

Review of these references reveals the almost universal practice of considering savings as the difference between what occurred and what *would have* occurred had no energy efficiency action been taken. This perspective underlies most, if not all, of the development of methods up to this point, and frequently guided the EM&V working group in its prioritization of various topics. Over time, modifications of existing protocols or development of new EM&V methods may be needed to capture other potential uses of EM&V results, for example (private) EE finance and the closely related area of metrics for energy management.

Even with this history, continued expansion of EE and its potential use in new areas (e.g., air quality improvement) has given rise to a need to increase the level of transparency and rigor, and at the same time quicken the availability of results at lower costs. Underscoring this are several studies that indicate that there is progress to be made in increasing consistency and comparability as savings from similar activities are assessed in different venues. These provided a major impetus for this working group's efforts. The other impetus is the perception of the increasing availability of rich data in the form of higher resolution usage information for the buildings and individual pieces of equipment, and for the additional program information that plays a critical role in EM&V.

4.1 Measurement and Verification Methodological Approaches

As discussed in the chapter introduction, significant elements of EM&V are the measurements and calculations used to determine the reductions in energy use due to energy efficiency measures. The combination of methodological approaches, engineering calculations, and adjustments factors are captured in EM&V activities, to which this section is dedicated. Many of these measuring and verification approaches also apply to specific sites.

⁹⁸ A comprehensive listing of relevant EM&V documents can be found in the EESCC Inventory Database, available at <http://www.ansi.org/eesc>.

⁹⁹ For information on various SEE Action publications, visit the website: <http://www1.eere.energy.gov/seeaction/evaluation.html>.

The general approach to measuring reductions from EE measures and projects are presented in the IPMVP description of M&V approaches. The activities that ensue once an approach is selected may include direct measurements before and after, indirect measurements using proxy variables or statistical methods on sample populations of measures or billing data, engineering analysis, or simulation models. Numerous resources have been developed over the past three decades that capture and standardize a broad range of engineering details for the express purpose of simplifying and standardizing the process of measurement and verification. This section addresses methodological approaches that capture savings at the project level and those methods that allow for estimation of savings at the program level. These include baseline criteria, statistical methods, whole building meter, and large, complex retrofit analysis. In addition to measurement approaches, methods for assessing variability in gross savings are addressed through measure life and persistence studies, which help to reflect the lifecycle impacts of EE.

The use of technical reference manuals (TRMs) is often viewed as a means to standardize approaches and to conserve evaluation resources. TRMs provide data and information on specific EE measures and program types that can be applied in appropriate similar settings without incurring the additional cost of specific site measurement when not needed to achieve a desired level of accuracy. A number of efforts underway to standardize processes for EM&V, including the DOE Uniform Methods Project, also seek to consider how increased standardization of methods will not only produce comparable results, but also conserve resources. Depending on how the EE savings data will be used (i.e., energy services company (ESCO) settlement purposes, system planning, or ISO markets) there may be different value placed on specific aspects of the data. The governing conditions will impact decisions made by those overseeing evaluation activities regarding the value of specific information versus the cost of gathering and analyzing data to provide the most appropriate information.

It should be noted that M&V is a tool used in many program impact evaluations. M&V is also used in other arenas, including evaluating compliance with guaranteed savings claims in performance contracts between energy consumers and ESCOs. Much of the early work in standardization of M&V methods and terminology was driven by the ESCO community's needs. Today, a primary driver for standardization and increased rigor springs from ratepayer-funded state utility programs and the 25 or more states with EE Portfolio Standards or EE policy goals. M&V is also used to estimate the savings from projects undertaken by organizations so that they can determine the achieved financial impact of projects or progress toward internal sustainability goals. The ISO 50001 energy management system standard currently supports such activities. Throughout the rest of this chapter, the focus is on EM&V of programmatic energy efficiency and on M&V as a tool used within EM&V.

4.1.1 Baselines

Determining the impact of energy efficiency measures, projects, or programs requires a comparison of the amount of energy used after the energy efficiency action was taken to the energy use that *would have* occurred in the absence of the measure, project, or program. In describing what would have occurred in the absence of the intervention, the term “baseline” can refer to the equipment that would have existed, the set of conditions that define the operation of the systems, or the estimated energy use

or demand of the systems. Baselines can be defined at a measure level, project level, program level, or portfolio level.¹⁰⁰

A key evaluation responsibility is to determine the proper baseline for a project, measure, or program. Improper baseline definition in the *ex ante* (pre-project or program implementation) calculations is a common cause for differences between verified and *ex ante* savings. Differences in baseline definition can result in significant differences in savings reductions estimates for the same EE implementation activity. This can result from use of algorithms and variables in savings calculations that are incorrectly applied to the location, facility, or measure. State jurisdictions defining different baselines for the same measure type may also result in different net savings from year to year, or in localized regions. However, in some cases these differences may be justified due to differences in building stocks and more or less mature markets for specific products.

Increasing consistency and comparability in the practice of EM&V will raise confidence in EM&V results. The various evaluation guidelines are consistent in describing baseline development for the main project categories. Several evaluation guidelines and standards define baselines at a high level:

EESCC Inventory Database Record	Title of Document	Developer/Organization
SD-568	Energy Efficiency Program Impact Evaluation Guide	State and Local Energy Efficiency Action Network (SEE Action)
SD-557	PA Evaluation Framework	Pennsylvania Public Utility Commission
SD-558	Decision 11.07.030 Attachment B101	California Public Utility Commission
SD-14	ISO-New England M&V Manuals	ISO New England
SD-46	PJM Manual 18B: Energy Efficiency Measurement and Verification	PJM
SD-75	NAESB Business Practice Standards	North American Energy Standards Board (NAESB)
SD-76	NAESB Model Business Practice Standards	NAESB
SD-53	Guideline 14, Measurement of Energy and Demand Savings	ASHRAE

¹⁰⁰ A **measure** is defined as equipment replacement or an operational/maintenance change to the way equipment is expected to produce a measurable, verifiable, or estimable improvement in energy use. A **project** may consist of a number of measures implemented in a building. A **program** is typically a set of measures and/or projects grouped to facilitate delivery to the market, and a **portfolio** is a group of programs funded and delivered via a single entity or collaborative.

¹⁰¹ Attachment B provides more detailed instruction related to the provisional energy savings determination of site-specific retrofit projects.

The SEE Action *Energy Efficiency Program Impact Evaluation Guide* includes extensive material on selecting baselines. This guidance may be sufficient to meet the needs for many if not most programs and measures. While the theoretical constructs for baseline estimation are fairly straightforward and are commonly defined in the literature, there are several areas in which more structured guidance could be used: (1) in selecting between existing conditions baselines and common practice baselines;¹⁰² (2) in the use of “dual” or two-part baselines and baseline categories; and (3) in creating baselines in industrial settings (production-related or using an energy use index).

Gap Analysis and Recommendations

A. Selecting between existing conditions baselines and common practice baselines

While the documents above indicate “best practice” in determining a baseline, one area that could use further clarification is when there are two possible approaches to determining the baseline. This occurs when a code or legal standard (e.g., for new construction) or industry common practice could be used to determine a baseline, or a baseline could be determined using the specific circumstances at the retrofit site (existing conditions baseline).

Determining if a project or measure triggers a Code/ISP baseline or an existing conditions baseline is often determined through governing rules, as in the NAESB standards and ISO markets, or may require a degree of evaluator judgment.

Except in the case when there are governing rules (e.g., the NAESB case), existing literature provides little guidance in these areas. These considerations necessarily require a degree of evaluator judgment and do not lend themselves to a fully prescriptive approach. The best option may be to address these types of occurrences through nonbinding guidance documents rather than formal standards in unregulated environments.

Recommended Timeline: This should be conducted in the long-term: 5+ years.

B. Treatment of dual baselines

When an EE program induces the replacement of equipment before it would otherwise have been replaced, an issue arises as to whether the applicable baseline should be based on the efficiency of the replaced equipment, or on an applicable standard or industry best practice at the time of replacement. According to the Pennsylvania TRM, *“Retrofit measures have a dual baseline: for the estimated remaining useful life of the existing equipment the baseline is the existing equipment; afterwards the baseline is the applicable code, standard, and standard practice expected to be in place at the time the unit would have been naturally replaced.”*

While this theoretical construct has always been well understood, it has been common practice in impact evaluation to determine the first year energy savings from energy efficiency

¹⁰² As described by the SEE Action *Energy Efficiency Program Impact Evaluation Guide*, **existing conditions baselines** are what is in place (e.g., equipment, controls, procedures) at the project site before the energy efficiency measures are implemented. **Common practice baselines** are estimates of what a typical consumer would have done at the time of the project implementation. Essentially, what is “commonly done” becomes the basis for baseline energy consumption. For more information on these terms, see pp. 7-1 and 7-2 of the SEE Action *Energy Efficiency Program Evaluation Guide*: http://www1.eere.energy.gov/seeaction/pdfs/emv_ee_program_impact_guide.pdf.

measures and, then to multiply this savings by the effective useful life of the measure to obtain lifetime savings. If the existing equipment would have failed in five years, a more reasonable estimate of the lifetime impact of the measure is obtained by using an existing conditions baseline for the remaining years of useful life, and then using a code or industry common practice baseline for the remainder of the measure life. This approach is not required by most jurisdictions outside of California, though there is some indication that other jurisdictions are beginning to adopt it. Finally, the use of dual baselines only applies to measures with early replacement.

The gap is that there are no unequivocal methods for determining how long the functioning equipment would have operated. Inconsistent application of this approach hinders comparability of savings across jurisdictions. However, as the treatment of baselines are often embedded in jurisdiction-specific protocols, such as state TRMs and state evaluation frameworks, treating the issue in a national or international standard is recommended.

Recommended Timeline: This should be conducted in the mid-term: 2-5 years.

C. Industrial baselines

In industrial retrofits, when production levels change, there has been inconsistent guidance on establishing a baseline. In California and New York, the baseline accounts for production increases differently if the measure allowed production to increase versus if the production increase occurred due to market forces only. If market forces drove the increase, the lifetime impacts are based on post-installation production levels. If the measure allowed production to increase, pre-installation levels are the basis of the savings. Other jurisdictions are largely silent on baseline estimation given externalities that impact savings. Given the standard evaluation practice of establishing energy savings based on post-intervention operating conditions, most jurisdictions may not be consistent with California and New York in the treatment of projects that allow for production increases.

Inconsistent definitions for baseline production levels hinder comparability of savings across jurisdictions. Since the treatments of baselines are often embedded in jurisdiction-specific protocols, it is recommended that the issue be treated in a national or international standard.

Recommended Timeline: This should be conducted in the mid-term: 2-5 years.

D. Non-direct dependence on production levels

Baselines are sometimes defined in terms of a metric that is a form of energy use per unit of production. This energy use index is then applied to the post-installation production levels, or to a typical production level, in order to obtain an estimate of the baseline energy use. The implicit assumption is that the energy use is linearly related to production, and that the energy use tends toward “0” when production is “0.” This assumption is almost never explicitly stated, and the assumption may be incorrect. A relationship between energy input and production output can typically be determined, but it is rarely of a form that is both linear and is zero with no production.

A number of documents provide guidance on developing baselines for industrial facilities, including the Northwest Energy Efficiency Alliance’s *Energy Baselines Methodologies for Industrial Facilities*,¹⁰³ the *Superior Energy Performance Measurement and Verification Protocol for Industry*,¹⁰⁴ and DOE’s *Steps to Developing a Baseline: A Guide to Developing an Energy Use and Energy Intensity Baseline and the Reporting Requirements for the Save Energy Now LEADER Pledge*.¹⁰⁵

Practice in this area should be examined, and to the extent possible, standardized. If that proves infeasible, standards should be developed to describe the method or procedure used so that there is transparency.

Recommended Timeline: This should be conducted in the mid-term: 2-5 years.

E. Automatic benchmarking of commercial and residential buildings

The advent of higher resolution data and more complete data sets describing buildings has opened the possibility of building energy management systems (EMSs) themselves “automatically” benchmarking a building by recording energy use and being programmed to estimate equations describing building energy use.¹⁰⁶ The advantages are that the EMS would have a basis for diagnosing building performance. For EM&V, a “baseline” of pre-upgrade performance would automatically be available. If many buildings in a given program had this capability, EM&V approaches could be modified to use larger samples (of self-benchmarking buildings), but at potentially different accuracy at each individual building. While this is an interesting possibility for developing faster, less costly EM&V, it relies on the quality of the benchmark the building’s EMSs are creating. The gap is that metrics or testing procedures to assess the accuracy of these self-created benchmarks do not exist. Some initial work in this regard has been done,¹⁰⁷ but more must be done for self-benchmarking buildings to provide a reliable basis for EM&V. Organizations with access to high-resolution building energy usage should research automatic benchmarking approaches to determine suitable metrics for the accuracy of self-benchmarking algorithms. This should be done with industry input regarding the purpose and use of the self-benchmarking capability.

Recommended Timeline: This should be conducted in the mid-term: 2-5 years.

¹⁰³ Northwest Energy Efficiency Alliance, “Energy Baselines Methodologies for Industrial Facilities,” October 17, 2013, <http://neea.org/docs/default-source/reports/energy-baseline-methodologies-for-industrial-facilities.pdf?sfvrsn=7>.

¹⁰⁴ The Regents of the University of California, “Superior Energy Performance Measurement and Verification Protocol for Industry,” November 19, 2012, http://www.superiorenergyperformance.net/pdfs/SEP_MV_Protocol.pdf.

¹⁰⁵ U.S. Department of Energy, “Steps to Develop a Baseline: A Guide to Developing an Energy Use and Energy Intensity Baseline and the Reporting Requirements for the Save Energy Now LEADER Pledge,” <http://www1.eere.energy.gov/manufacturing/resources/pdfs/leaderbaselinestepsguideline.pdf>.

¹⁰⁶ The Bonneville Power Administration’s (BPA) *National Energy Efficiency Technology Roadmap Portfolio*, March 2014 version, highlights technology research needs related to energy management. See the section “Real-time Smart Electric Power Measurement of Facilities (1 of 3)” (pp. 388-389): http://www.bpa.gov/energy/n/emerging_technology/pdf/EE_Tech_RM_Portfolio.pdf.

¹⁰⁷ A fact sheet with links to published results can be found at <http://www.etcc-ca.com/reports/commercial-building-energy-baseline-modeling-software-performance-metrics-and-method-testing>.

4.1.2 Methods for Determining Annual Savings

The previous section described the starting point for the determination of energy savings for any piece of equipment, building, or complex – defining and measuring the baseline energy use. Once a baseline is established, a variety of methods to analyze the impacts of energy savings actions to reduce energy use may be used. Energy savings activities may include equipment replacement, maintenance, commissioning, or retro-commissioning. It could also include operational changes affected by end user behavior. The following sections describe the most commonly used approaches for developing estimates of energy savings for these various energy-saving activities; gaps in standardization are also identified.

Gap Analysis and Recommendations

Recently, comparisons of annual¹⁰⁸ saving methodologies, technical assumptions, and input variables for estimating savings used for the same measures in different jurisdictions suggest the possibility of a lack of consistency or “gap” in measurement approaches. One study calculated annual savings for commonly installed measures using the methodologies and assumptions from different jurisdictions.¹⁰⁹ Variance in these savings estimates were not fully explained by differences in weather. In some cases, it was determined that different engineering approaches had been used to calculate the savings of the same measure, but the rationale for the difference in methods had not been documented. The basis for calculation should be well documented, including activities such as weather normalization techniques.

The lack of complete consistency in algorithms, technical assumptions, and default values for input variables across jurisdictions may be a challenge to the comparison or aggregation of those measurements. This is important for a regional or national perspective on energy savings that relies on comparability or even summation of those savings. This identifies an area to be explored and potential gaps in the methods of their presentation and reporting for savings calculations based on those methods (see Section 4.2.3, *Reporting*).

The U.S. Department of Energy began the Uniform Methods Project (UMP) to partially address this situation, but the UMP only addresses certain measures in particular applications (or use cases¹¹⁰) by identifying a commonly used approach to calculate “gross” savings. Further, it is not known if the UMP approach will in fact resolve the issue of potential inconsistency due to its limited application to date. Finally, in selecting a method for each use case, UMP was guided by industry practice. It sought to identify the method used by most EM&V professionals in that particular situation. It took this approach, validated by the long experience of the profession, in the absence of any objective standard for assessing one method over another.

¹⁰⁸ In this context, annual savings means the energy savings from the first full year after the energy efficiency installation.

¹⁰⁹ Comparisons can be found in Jayaweera, Tina, et al. “Scoping Study to Evaluate Feasibility of National Databases of EM&V document and Measure Savings: Appendices,” June 2011, SEE Action, web, accessed at http://www1.eere.energy.gov/seeaction/pdfs/emvscoping_databasefeasibility_appendices.pdf. Also see Martinez, Sierra, et al. “Tremendous Potential Benefits from Improving Energy Savings Estimates Across the Country,” August 2012, Proceeding of the ACEEE Summer Study on Buildings, web, accessed at <http://http://aceee.org/files/proceedings/2012/start.htm>.

¹¹⁰ A use case is an energy efficiency measure installed in a particular type of building in a particular application.

A. Potentially inconsistent savings estimates

1. The issue of consistency requires that the data and a description of the methodology be available to replicate the savings calculation. As a first step, the information required for replication of the energy savings result should routinely be available. This has the advantage of allowing annual savings calculations to be auditable.
2. Another important step would be to analyze and provide guidance on how a comparison of two annual savings results could be done, provided that all the information needed to replicate each is available. For example, starting with UMP use cases, a study could be conducted to consider whether it is possible to develop a transparent, standard approach to comparing the savings estimates in different locations. This could be a step-wise change of one location's data and measurement approach to the other, with each step following a logical progression, and the change in the annual savings figure provided and compared to previous and subsequent values. The analysis could also indicate when a logical, transparent comparison was not feasible. After the UMP use cases were explored, other annual savings calculation approaches could be examined. The objective would be to define a comparison methodology that is as broad as possible. The result would be that when a comparison is undertaken, the method employed by the comparison would not be a source of difference between the two compared results.
3. A final step would be to consider the development of standardized testing procedures for energy savings determination methodologies. The California Emerging Technologies Coordinating Council (ETCC) details initial work in this direction,¹¹¹ in which standard datasets are used to compare different energy savings approaches. This approach or another could be examined, including the development of criteria for assessing savings approaches, model or sample test procedures, etc. The goal would be to understand from an objective, quantifiable perspective the qualities of a given method. This could be first undertaken with the more simple annual savings calculation methodologies, and could take advantage of the increasing availability of larger datasets and computing power.

Recommended Timeline: This should be conducted in the near-term: 0-2 years.

4.1.2.1 Site-Specific Verification, IPMVP Option A, B, C, and D

Common methods for evaluating specific projects within a program use on-site verification of the installation in combination with collection of site-specific data in order to implement one of the four options described in the IPMVP. These methods can be applied to fully custom projects, or they can be used in conjunction with partially deemed values from a TRM.

- Options A and B focus on measuring the performance parameters that define the energy use of the installed energy conservation measures (ECMs), with Option A requiring measurement of key parameters and Option B requiring direct measurement of all parameters.

¹¹¹ For more information, visit the ETCC website: <http://www.etcc-ca.com/reports/energy-management-and-information-system-software-technology-assessment-considerations> .

- Option C calculates savings by comparing pre- and post-ECM installation energy use of the whole facility (or a sub-facility), adjusting for identifiable factors that also impact energy use (e.g., weather).
- Option D calculates savings using calibrated simulation approaches at the facility or sub-facility level, typically using public domain or proprietary building energy models calibrated to that particular facility's energy use. The technical development of simulation models is discussed in Chapter Three of this roadmap, in Section 3.2.1.3, *Building Energy Simulation for Use in Evaluation, Measurement, and Verification*.

Gap Analysis and Recommendations

The gap analysis and recommendations described in Section 4.1.2, *Methods for Determining Annual Savings*, could include all of these approaches, along with other annual savings approaches discussed below. In addition, Martinez, *et al.*,¹¹² indicate that there may be issues with misapplication of Option D in that the results presented as Option D may not be compliant with Option D's full requirements, particularly calibration.

A. Explore and refine the calibration requirements of Option D

Exploring additional standardization of calibration requirements used in Option D could increase understanding of the usefulness of EM&V results obtained with this method.¹¹³ Areas to be explored could include a description of how and why the simulation model was modified to achieve calibration, as well as graphical or other approaches to comparing the calculated energy use values and the actual energy use values. The goal is for users of the method to fully understand the accuracy and applicability of the calibrated model. Standardized documentation of the calibration process and data should include sufficient information so that a qualified third party could verify the results.¹¹⁴

Recommended Timeline: This should be conducted in the near-term: 0-2 years.

4.1.2.2 Statistical Methodologies

A number of nationwide and regional documents provide standards or guidelines on M&V that include the use of statistical techniques. These include the DOE Uniform Methods Project, the California Standard Practice Manual, NAESB standards, and detailed guidelines such as those from ASHRAE and ISO/RTOs, the Regional Technical Forum (RTF), and the Northeast Energy Efficiency Partnerships (NEEP). The bulk of these documents address sample design and analysis, as many regulating bodies have requirements for the precision of savings estimates, given a stipulated confidence level.

¹¹² Martinez, Sierra, et al., "Tremendous Potential Benefits from Improving Energy Savings Estimates Across the Country," Paper presented at the 2012 ACEEE Summer Study on Buildings, Pacific Grove, California, August 12-17, 2012, <http://aceee.org/files/proceedings/2012/start.htm>.

¹¹³ Technology research needs related to this discussion are discussed in the Bonneville Power Administration's (BPA) *National Energy Efficiency Technology Roadmap Portfolio*, March 2014 version. See the section "Low-Cost Savings Verification Techniques (1 of 7)" (pp. 374-375): http://www.bpa.gov/energy/n/emerging_technology/pdf/EE_Tech_RM_Portfolio.pdf.

¹¹⁴ ASHRAE's Proposed Guideline 14P for Measurement of Energy and Demand, in Proceedings of the First International Conference for Enhanced Building Operations, Austin, Texas, July 16-19, 2001.

EM&V of savings from energy efficiency involves a number of sources of uncertainty in the estimation of energy savings. In the case of EM&V of utility or government-sponsored programs, it is often impractical to collect data on every project in the participant population. This leads to the introduction of sampling error to energy savings estimates. EM&V projects often require either direct measurement of changes in energy use or of some intermediate parameters used in engineering algorithms. These parameters may be subject to some degree of measurement error from metering equipment or survey instruments. Additionally, statistical and simulation models are a common part of many EM&V efforts. This can introduce specification error as omitted variables, improper functional form, or prediction outside the range of observed values, resulting in inaccurate estimates.

Many jurisdictions have requirements on the maximum confidence levels for reported results, typically expressed in terms of relative precision, given a stipulated confidence level. Reported precision requirements vary by parameter, measure, project, program, or portfolio.

Statistical methods can also be used to help direct EM&V funding. Increasingly, jurisdictions managing large EM&V budgets, such as the California Public Utilities Commission, are using uncertainty analysis to help plan and manage their EM&V activities.¹¹⁵ The goal of this work would be to draft standard methods of quantifying uncertainty at the project and portfolio level.

Current State of Standards for Statistical Methodologies

The following table provides an account of the major EM&V guidelines that provide explicit guidance on the use of statistical methodologies and reporting of uncertainty. The federal and international documents¹¹⁶ provide general guidelines on the application of techniques without explicit mention of regulatory requirements, and are meant to apply to a wide audience. These documents describe methods for calculating uncertainty, but not explicit requirements for levels of reported uncertainty. Meanwhile, documents from ISO/RTOs administering markets typically include specific confidence and precision requirements that must be achieved.

EESCC Inventory Database Record	Title of Document	Developer/Organization	Topics Covered
SD-32	California Evaluation Framework	California Public Utility Commission	Sample design, combining uncertainty, types of error, regression modeling, survival analysis, power analysis
SD-60 through SD-71	Uniform Methods Protocols	U.S. Department of Energy	Sample design, combining uncertainty, types of error, measure-specific regression modeling

¹¹⁵ California Public Utilities Commission, "2013-2014 Energy Division-Investor Owned Utility Energy Efficiency Evaluation, Measurement and Verification Plan Version 2," August 2013, p. 247, http://www.cpuc.ca.gov/NR/rdonlyres/B6D32B87-249E-44BB-8083-7139EC4D3B3A/0/20132014_EnergyDivisionEMV_Workplan_v2.pdf.

¹¹⁶ This includes the California Evaluation Framework, which has been applied widely outside of California.

EESCC Inventory Database Record	Title of Document	Developer/Organization	Topics Covered
SD-54	IPMVP (Appendix B)	Efficiency Valuation Organization	Types of error, combining uncertainty, general regression analysis
SD-50	M&V Guidelines: Measurement and Verification for Federal Energy Projects	U.S. Department of Energy Federal Energy Management Program (FEMP)	Sample design, combining uncertainty, types of error, regression modeling
SD-53	ASHRAE Guideline 14	ASHRAE	Types of error, sampling (brief), combining uncertainty (brief), modeling and prediction error
SD-568	Energy Efficiency Program Impact Evaluation Guide	State and Local Energy Efficiency Action Network (SEE Action)	Sample design, combining uncertainty, types of error, regression modeling
SD-75	WEQ-021, Measurement and Verification Of Energy Efficiency Programs Model Business Practices	North American Energy Standards Board (NAESB)	Sample design, types of error, meter accuracy requirements, validation editing and estimating (VEE), M&V plan requirements, reporting
SD-76	REQ.19, Model Business Practices for the Measurement and Verification of electrical energy and demand impacts of Energy Efficiency Programs	NAESB	Sample design, allowed savings determination approaches, meter accuracy requirements.
SD-14	ISO-NE Manual	ISO New England	Sample design, types of error, meter accuracy requirements, VEE
SD-46	PJM Manual	PJM	Sample design, types of error, meter accuracy requirements, VEE

Best practices for the use of regression models is covered in most documents, along with techniques for the minimization of bias in the data collection process and approaches to assess sampling, modeling, or other sources of error. Few documents discuss research design (particularly the use of randomized controlled trials, or RCTs) in much detail.

Gap Analysis and Recommendations

The areas where current guidance for statistical calculations and reporting are either inconsistent or absent entirely are:

A. Quantifying uncertainty in regression models for all time periods (e.g., monthly, daily, hourly)

Leveraging the California Evaluation Framework requirements on presenting uncertainty, a voluntary standard should be developed that would apply to regression models.

B. Quantifying uncertainty in energy simulation models, including standard reporting and documentation of parameter assumptions

Guidelines should be developed that would provide model users information on: (1) how well a given model replicates known building energy use; and (2) what the sensitivity of the model outputs to changes in the model inputs is. For example, if hours of occupancy change, what is the energy use change in a fully specified building energy model?

C. General reporting of the identification and quantification of uncertainty beyond sampling error and aggregating all areas of uncertainty in one analysis framework

This could be a voluntary framework. Development could start with the requirements in the California Evaluation Framework.¹¹⁷

Recommended Timeline: These should be addressed in the mid-term: 2-5 years.

4.1.2.3 Whole Building Metered Analysis

Whole building metered data analysis entails the estimation of retrofit savings using data from utility meters or whole building sub-meters. It is most effective when savings are relatively large so as to be discernible from random or unexplained energy variations, typically 10 percent or more of baseline energy use.¹¹⁸ It is important to control for changes that are unrelated to the energy saving retrofit, such as weather and use patterns. This can be done through regression analysis.

Whole building metered data analysis can be performed for single sites or for aggregations of buildings. The latter is typically done for analysis of residential or small commercial and industrial programs. The former is typically done for analysis of commercial and industrial measures, such as:

- HVAC controls in commercial facilities
- Efficient boilers and furnaces at sites without large process gas loads
- Production efficiency (continuous improvement) programs
- Lighting in parking garages or warehouses
- Variable frequency drives (VFDs) on irrigation pumps (dedicated utility meter)

¹¹⁷ TecMarket Works, "The California Evaluation Framework," June 2004, http://www.calmac.org/publications/California_Evaluation_Framework_June_2004.pdf.

¹¹⁸ American Society of Heating, Ventilating, and Air Conditioning Engineers, "ASHRAE Guideline 14, Measuring Energy and Demand Savings," 2002, Atlanta, Georgia.

Guidance on this use of whole building analysis can be found in the IPMVP, ASHRAE Guideline 14, the California Evaluation Framework, the Bonneville Power Administration’s (BPA) *Regression for M&V: Reference Guide*,¹¹⁹ the *Superior Energy Performance Measurement and Verification Protocol*, and the Uniform Methods Project Protocols.¹²⁰ Additional guidance can be found in ASRHAE’s *Performance Measurement Protocols for Commercial Buildings*.¹²¹ Historically, models have been established for statistical fit and validated against datasets of extensive building data. There are many indices of validity, including r-squared, degrees of freedom, t-statistics, and autocorrelation. BPA’s *Reference Guide* provides a good guide to validation.

Standard analyses, using monthly electricity use information augmented by information from on-site surveys, are relatively mature. To ensure reliable analysis using these information sources, the key requirements are based on quality of the data and analytics. Large data set availability gives rise to the opportunity for new analysis techniques to be deployed.

One application that uses large data sets is “inverse” modeling, which acts as predictive models for post-construction operations. Unlike forward models, these simplified models are developed using operational data (often generated from a representative forward model) and can be “trained” to represent building energy use as a function of input variables. Many techniques can be used to develop inverse models.

Recently, utility-sponsored “demonstration” projects by the California Emerging Technologies Program have begun to test several modeling products that use inverse modeling techniques. These projects aim to replicate procedures used in ASHRAE Standard 140, *Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs*. The goal of these demonstration projects is to develop performance criteria (accuracy and reliability), and to produce test protocols for determining efficiency measure effectiveness, while using readily available interval meter data and other key data feeds. This is a new area that raises two questions: *When is one model superior to another? Are there standard forms that produce satisfactory results?*

Gap Analysis and Recommendations

A. Standards for data collection and the appropriate forms of the statistical analyses to be used on these data

For analysis that uses monthly-metered data and survey data about the premises, there is a need to develop standards for data collection and the appropriate forms of the statistical analyses to be used on these data. DOE’s Uniform Methods Project for residential whole buildings may provide a starting point for formal standards development.

Recommended Timeline: This work should be conducted in the mid-term: 2-5 years.

¹¹⁹ Bonneville Power Administration, “Regression for M&V: Reference Guide,” September 2011, http://www.bpa.gov/energy/n/pdf/BPARegression_forMV_ReferenceGuide.pdf.

¹²⁰ Jayaweera, T., Haeri, H., Bruchs, D., Keeling, J., Khawaja, S., Rushton, J., et al. “The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures,” April 2013, National Renewable Energy Laboratory, <http://www.nrel.gov/docs/fy13osti/53827.pdf>.

¹²¹ ASHRAE Journal, vol. 54, no. 7, July 2012.

B. New statistical approaches using high-resolution usage data require additional validation

New statistical approaches using high-resolution usage data require additional validation for more formal acceptance. This activity could be addressed in the near-term through the development of datasets of the high-resolution energy usage of many buildings with known equipment and usage. Although a single model may not be suitable for all applications, a matrix of acceptable models may be developed through a series of generally accepted automated modeling approaches to identify the best fit. Initial proof of concept could be developed using synthetic “data” from building simulation models as a first step to testing with actual building data. Such activities would need research support prior to the development of actual standards.

Recommended Timeline: This should be conducted in the near-term: 0-2 years.

C. Standardization of methods for automated analysis approaches

If suitable data sets and testing procedures can be developed, the standardization of methods for automated analysis approaches that provide performance metrics could be developed.

Recommended Timeline: This should be conducted in the mid-term: 2-5 years.

4.1.2.4 Methodologies Used for Large, Complex Retrofits

Verification of savings for projects involving the installation of multiple efficiency measures at large single or multiple facilities on a campus, for example, is a challenging technical process and may incur large EM&V investment. Some EE programs provide incentives for multiple measures installed at a single site or multiple sites if they are controlled by the same customer. As EE investment goes deeper, multiple EE investments at a single facility are encouraged, as they reduce transaction costs overall. For example, a common, high-impact project might be retrofitting a school under a performance contract or utility program. This type of project may include installation of the following measures for a single site: an energy management system, high-efficiency lighting, variable speed drives, a PC power management system, etc. The interactive effects and unique characteristics of the individual measures, including savings and measure life, make it challenging to assess the near- and long-term impacts.

The number of these types of projects tends to be small relative to the total number of projects implemented by a utility. However, the savings from these projects may be 50 percent or more of the total annual savings achieved by a large utility serving commercial/industrial, residential, and low-income sectors. As discussed in the chapter introduction, there is a benefit to increasing consistency and comparability in the practice of EM&V, especially in large, complex savings opportunities.

Existing technical reference manuals typically do not address methods for evaluating multiple heterogeneous measures having significant interactive effects, though several documents offer guidance on sampling within a project of any size. They typically offer methods for evaluating multiple similar measures, including the installation of lighting or energy efficient motors, but not complex systems. The Federal Energy Management Program's (FEMP) *M&V Guidelines: Measurement and*

*Verification for Federal Energy Projects, Version 3.0*¹²² includes an appendix on sampling. The Uniform Methods Project Metering Protocol includes guidance on sampling within a project that includes multiple measures, as does the BPA's *Sampling for M&V: Reference Guide*.¹²³ Most evaluation guides recommend use of IPMVP for custom projects.

Gap Analysis and Recommendations

A. Guidance on the evaluation of projects that include multiple heterogeneous measures

There is sufficient guidance on sampling within similar sets of measures for a given project, but little guidance exists on how to treat projects that include multiple unique measures.

- Do savings need to be determined for each measure individually? This partly depends on the evaluation framework in place in the jurisdiction. If measure-level savings are required, each measure may need to be evaluated. If only the project-level savings are required, then measures that contribute smaller portions of the savings may not need to be verified.
- If individual measures are to be evaluated, what guidance can be used to select the most representative measures to accurately determine overall project savings? The selection process is complicated by variances in savings magnitude, use conditions, and measurement error.
- What levels of uncertainty are introduced when project-level savings are developed using combinations of deemed savings, partly deemed savings, and directly measured savings?
- How can “value of information” principles be applied?

Recommended Timeline: Guidance should be developed over the long-term (5+ years) on the evaluation of projects that include multiple heterogeneous measures.

B. Guidance on how to present the results of complex site-specific engineering analysis

There is little guidance on how to present the results of complex site-specific engineering analysis (M&V). Verification of such activities is difficult due to the requirement to replicate prior analyses rather than capture and validate results based on common specifications. This adds significant cost to the EM&V process and increases error, as additional analysis of unique, non-standard operations may introduce additional sources of error. While existing EM&V resources generally do not address transparency, the IPMVP, NAESB standards, and ISO/RTO manuals contain requirements for M&V reports that include reporting the raw data and the justification for any corrections made to observed data. This guidance is generally sufficient, but local jurisdictions may wish to formalize requirements for transparency and reporting specifications (see Section 4.2.3, *Reporting*).

Recommended Timeline: This work should be conducted in the long-term: 5+ years.

¹²² U.S. Department of Energy, “M&V Guidelines: Measurement and Verification for Federal Energy Projects, Version 3.0,” April 2008, http://www1.eere.energy.gov/femp/pdfs/mv_guidelines.pdf.

¹²³ Bonneville Power Administration, “Sampling for M&V: Reference Guide,” May 2012, http://www.bpa.gov/Energy/n/pdf/2_BPA_MV_Sampling_Reference_Guide_May2012_FINAL.pdf.

4.1.3 Duration of Savings: Effective Useful Life

The determination of savings over time requires the estimation of how long those savings will last. Historically, this has been termed the analysis of the useful life or effective useful life (EUL) of a measure. The determination of the cost-effectiveness of energy efficiency activities and their use in energy (especially electrical) resource planning relies on the estimated duration of energy efficiency savings. Virtually every existing comprehensive compilation of energy efficiency savings determination methodologies discusses this issue. However, there is a significant lack of consistency and transparency in the development of EULs because similar measures are given different useful lives, often without analysis of why a particular EUL was chosen. This is primarily because a direct determination of EUL would involve the observation of many specific measures in multiple locations over extended periods of time (years and even decades). Such long-term studies are usually impractical and could produce accurate distributions of EULs for measures that were more than likely technologically obsolete. In the absence of such studies, there seem to be three general approaches to estimating EULs because measurement has proven impractical:

1. Use a manufacturer's rated life
2. When there is replacement of a measure prior to its failure, a two-part EUL is used in some venues to reflect different baselines: the period up to the predicted EUL, and the period after (see Section 4.1.1, *Baselines*)
3. For specific issues (e.g., early burn-out of lighting fixtures of lower than average quality), a special study of the problem

Gap Analysis and Recommendations

Overall, the area of EULs has lacked terminology to specify which and why a particular EUL is being used. There is a presumption that EUL can be estimated using survival analysis methods. These methods include non-parametric methods and fit different parametric survival functions to observed data. Survival analysis has already been widely used in EM&V, especially for estimating EULs. However, there are no national standards for which methods are appropriate in different applications, or for how uncertainty about the estimates should be conveyed. This can be especially critical when dealing with data quality issues such as censored data, very small sample sizes, short study timeframes, or extrapolation far beyond the span of the collected data.

A. Straw guidance on the treatment of EULs

In the near term, a group of EM&V practitioners should convene to develop straw guidance on the treatment of EULs, including terminology and reporting or presentation practice. This guidance should be vetted and incorporated into protocols especially for technical reference manuals.

Recommended Timeline: This should be done in the near-term: 0-2 years.

B. Assessing feasibility and usefulness of single national study using survival analysis

In addition, the practitioners should identify several measures, which produce significant portions of the savings in programs nationally, to assess whether a single national study using survival analysis would be feasible or useful given the long lives of many measures and rapid technological change.

Recommended Timeline: This should be done in the near-term: 0-2 years.

C. Studies of EUL

Several studies of EUL should be undertaken to determine if survival studies could add accuracy to the determination of EULs in a manner that could be standardized and lead to protocols on how such studies could be undertaken in the future. As the EUL of a measure depends on the application of that measure, this is particularly complex.

Recommended Timeline: This should be done in the mid-term: 2-5 years.

4.1.4 Technical Reference Manuals (TRMs)

Several states or regions have established processes through which energy efficiency savings for a specific list of measures or activities are established and publically available. The information in the resulting “document” – the technical reference manual (TRM) – is usually used for specific activities in electrical or natural gas industry implementation, public planning, or regulatory processes. TRMs fall under the broad class of M&V supporting documents, and are numerous and widely used, as described below. Further, TRMs as a valid reference tool in conducting M&V is accepted nationally as standard business practice in wholesale and retail electricity markets.¹²⁴

Implementation of M&V practices commonly involves direct measurement of energy use before and after installation of energy efficient devices or practices. This practice of measure- or project-level measurement can be time consuming and expensive for mass-market efficiency programs, such as lighting, motors, and HVAC. As an alternative to direct measurement, using prescriptive or deemed savings estimates can provide accurate quantification of savings, provided the inputs and use of the deemed savings are rigorously applied. Over the past decade, numerous volumes have been developed primarily by regulated electric utilities that catalogue deemed savings in TRMs. These documents are also sometimes called program savings documents (PSDs). As many as twenty-five TRMs have been developed or are in the process of being developed by states, federal agencies, or technical organizations across the United States.

Measure-level information in the TRMs include, but are not limited to: methodologies, calculations for annual and lifetime energy and demand savings, default assumptions not based on site-specific parameters, measure life, baseline criteria, persistence and coincidence factors, gross-to-net calculations, and interactive measure effects. TRMs undergo periodic updates to reflect changes in

¹²⁴ NAESB EE M&V standards were adopted by FERC in February 2013 under order 676-G and are applicable to wholesale electricity markets administered by ISO/RTOs. A similar set of model business practice standards were adopted by NAESB in a final action for Measurement & Verification of Energy Efficiency Programs in October 2012; these are applicable to retail markets and are voluntary. These current set of standards allow for use of TRMs, provided that they are appropriate and current.

engineering analysis or use characteristics such as persistence and coincidence rates. Additionally, TRMs used as part of state-sponsored efficiency programs are subject to regulatory review and approval by state-level utility commissions to ensure third-party independence.

Current State of TRMs

The following summary and analysis draws from a 2011 study looking at the feasibility of national databases for EM&V documents and measure savings.¹²⁵ The table below represents the TRMs or related guides for TRMs identified in the study and elsewhere. There are twenty-one states that maintain TRMs to support their ratepayer-funded efficiency programs, two regional systems, and the EPA ENERGY STAR® Products Guide. The table below illustrates the TRMs captured in the EESCC Inventory Database. A complete list of these TRMs, and website information, is located in Appendix 4A.

EESCC Inventory Database Record	Title of Document	Developer/Organization
SD-227	State of Illinois Energy Efficiency Technical Reference Manual	Illinois Commerce Commission
SD-226	Business Programs: Deemed Savings Manual V1.0	Public Service Commission of Wisconsin
SD-225	Efficiency Vermont Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions	Efficiency Vermont, VT Department of Public Service
SD-224	Deemed Savings, Installation & Efficiency Standards	Public Utilities Commission of Texas
SD-223	Pennsylvania Technical Reference Manual	Pennsylvania Public Utility Commission
SD-222	State of Ohio Energy Efficiency Technical Manual	Public Utilities Commission of Ohio
SD-221	New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs	New York Department of Public Service
SD-220	New Jersey Clean Energy Program Protocols to Measure Resource Savings	New Jersey Board of Public Utilities

¹²⁵ Jayaweera et al., SEE Action, *Scoping Study to Evaluate Feasibility of National Databases for EM&V Documents and Measure Savings*. Cadmus Group: June 2011.

EESCC Inventory Database Record	Title of Document	Developer/Organization
SD-219	Michigan Energy Measures Database	Michigan Public Service Commission
SD-218	Massachusetts Technical Reference Manual for Estimating Savings from Energy Efficiency Measures	Massachusetts Department of Public Utilities, TRM Coordinating Committee, Program Administrators, Department of Energy Resources
SD-217	Efficiency Maine Residential Technical Reference Manual No. 2009-1	Efficiency Maine
SD-216	Efficiency Maine Commercial Technical Reference Manual No. 2006-1	Efficiency Maine
SD-215	Hawaii Energy Efficiency Program TRM	Hawaii Public Utility Commission
SD-214	Connecticut Light and Power and United Illuminating Company Program Savings Documentation	Connecticut Department Public Utility Control
SD-213	Database for Energy Efficient Resources (DEER)	California Energy Commission
SD-212	Arkansas Technical Reference Manual TRM Volume 1/Version 2.0: EM&V Protocols	Arkansas Public Service Commission
SD-211	Mid-Atlantic TRM_V1.2	Northeast Energy Efficiency Partnership - Regional M&V Forum
SD-210	Regional Technical Forum (RTF) Deemed Measures	Northwest Power and Conservation Council - Bonneville Power Administration
SD-209	ENERGY STAR® Products - TRM	U.S. Environmental Protection Agency

The following characteristics are common among all the identified documents:

- TRMs provide either *ex ante* savings values or algorithms
 - For the resources that have *ex ante* savings estimates, a stipulated (deemed) value is given for the savings
 - For the resources primarily composed of algorithms, a formula is given where input parameters are stipulated or determined based on specific conditions (e.g., a lookup table for hours-of-use based on building type)
 - For the resources that include both algorithms and *ex ante* savings values, the primary format for measure savings is algorithms in nearly all cases
- These resources primarily contained energy savings and measure costs
- Few resources included non-energy benefits or market transformation metrics

As can be seen in the table above, TRMs are used to document prescriptive savings from energy efficiency measures, typically for the purpose of compliance with state or federal regulatory requirements. States with regulated energy efficiency programs may elect to develop a set of prescriptive savings calculations for market-based efficiency measures. These are commonly assembled into a TRM. TRMs may also exist for federal facilities or may be utilized for efficiency standards, such as ENERGY STAR®.

Gap Analysis and Recommendations

The current set of TRM documents does not provide a consistent format or treatment of data useful for broader adoption of deemed savings analysis. Regional differences in treatment of non-energy calculations and impact factors add to the difficulty of creating a singular source for deemed savings.

A. Establish a standard format and content guide

In order to promote consistency and wider adoption of TRMs, establish a standard format and content guide. The format could be developed by an independent contractor (national lab, university, industry group) acting under an advisory group of TRM users. Such a guide could come in the form of model business practices, business practice standards, or through other stakeholder-led processes. One area to explore that may create consistency in this area is to define the component factors of the TRMs that may be established as state or federal policy objectives rather than objective engineering analysis. In this manner there would be transparency on the differences between TRMs, rather than the assumption that the fundamental engineering analysis is not applicable across sectors or regions.

Recommended Timeline: This effort is on several stakeholders' work plans, though is yet to be completed. This is an area that is ripe for standardization and considered a near-term priority. This work should be conducted in the near-term: 0-2 years.

4.2 Reporting and Tracking Systems

Energy efficiency projects performed as part of any large-scale program or set of programs have associated data which must be maintained for the purpose of project management and reporting. Generally speaking, each jurisdiction will specify a combination of tools and methods to accomplish its data management and reporting needs. These tools and methods fall broadly into categories like tracking data and reporting data. Supporting tools such as TRMs (see Section 4.1.4, *Technical Reference Manuals*) in managed data systems may also be used to support tracking and reporting needs.

The following sections address the status of industry standardization on these topics. Some of the sections below are informed by recent experience in implementing large EE activities/programs. This experience has revealed that the first step in establishing standard energy efficiency tracking and reporting tools is to consider the general business model under which the programs are deployed to ensure that all participants in a particular activity, (e.g., implementers, analysts, and regulators) share the same underlying principles.

Energy efficiency savings are always defined within a specific business context. In the case of ratepayer-funded Investor Owned Utilities (IOU) programs, the savings may be evaluated in terms of a program's success in influencing the market for a specific technology. In an energy savings performance contract (ESPC), there is usually no consideration for savings attribution. While the energy savings project in both situations may be the same, the types of data tracked and reported depend on the business context.

Understanding the business context is critical to defining the tracking, reporting, and specific technical data needs. Further, these issues can be categorized as those pertaining to the tracking system, data inputs, and reporting.

4.2.1 Tracking Systems

Collecting and reporting energy efficiency technical data is a critical task in every energy efficiency project or program. Increasingly, a wide range of stakeholders, including air resources boards, public utility commissions, financiers, and software/platform providers, are seeking energy efficiency project and program data that can be shared and compared across and between regional and programmatic boundaries. Currently, most regions and projects have adopted naming conventions and taxonomies that apply only to their own programs or jurisdictions. This limits the exchange of data that would allow comparisons and enhance the efficacy of a national marketplace for energy efficiency.

Several states or regions, including California, the Northeast Energy Efficiency Partnership (NEEP), and the Regional Technical Forum (RTF), have established standards for data required to track program effectiveness in utility programs. Additionally, regional entities such as ISO New England and PJM collect standardized data across multiple state and local boundaries as part of administering wholesale markets and system planning studies. Standard Program Tracking (SPT) data typically consists of project- and measure-level data that supports the accounting of program savings, costs, and cost effectiveness. A limited set of data systems collect significantly more detailed information, including billing meter, location, installation, EUL dates, and reference to methodological basis for measured savings, primarily for audit purposes. Such records in a set of SPT data may contain measure data (unit energy savings,

cost), implementation data (building type, building vintage, climate zone), customer, and contractor (address, meter id).

The Building Energy Data Exchange Specification (BEDES)¹²⁶ is just beginning to assemble stakeholders across a wide range of energy data standardization needs. The SEE Action¹²⁷ has begun to work on protocols for sharing program results across regions.

Gaps and Recommendations

Currently, there is no common standard for program tracking data between states or regions. There is no current program addressing the data standards needs on a national level.

A. Set of standard terms and definitions that can be applied nationally

A set of standard terms and definitions for designating and reporting energy efficiency program and project data at all levels (from technologies to projects to programs to portfolios) that can be applied nationally is recommended. This project would leverage the new work being planned under BEDES and coordinate with SEE Action to establish standard reporting requirements for energy efficiency projects and programs.

Recommended Timeline: This should be accomplished in the mid-term: 2-5 years.

4.2.2 Standardized Data Collection

Generally, there is commonality in the kinds of data collected and the format in which it is collected; however, there has not been any examination or standardization to date of the data underlying the calculation of savings. For example, a program to accomplish whole-house retrofits will track the number of homes affected. To calculate savings, additional data is gathered including the number of homes, the number of floors in each home, the square footage, number of occupants, etc. There is no standardization as to whether the square footage is for the total interior space, the portion of the interior that is air conditioned, or whether garages and patios (enclosed or open) are included. Specifications on what these data represent are material to the specific method used to calculate savings, and to the meaning and use of those savings results. This issue points to the lack of common data standards.

In addition, the absence of a standard makes it difficult, if not impossible, to compare or combine data from different sources. For example, two analyses of the savings from residential whole-house retrofits may produce different results. To use the example above, it matters if one study used air-conditioned square footage and the other used total square footage (which might include an attached garage). In order to permit the pooling of data and research that could be built upon larger data sets, a single data taxonomy or specification is essential.

¹²⁶ For additional information on BEDES, visit <http://energy.gov/eere/buildings/building-energy-data-exchange-specification-bedes>.

¹²⁷ Visit <http://www1.eere.energy.gov/seeaction/evaluation.html> for information on the SEE Action Evaluation, Measurement, and Verification Working Group.

There have been efforts to standardize building data. Recently, DOE has begun an effort to establish a data taxonomy and XML specification. This draft Building Energy Data Specification (BEDES) has 200+ data fields.¹²⁸ DOE has begun a process of circulating its specification for review. Another activity in the residential area includes efforts by the Building Performance Institute (BPI), which has worked to standardize data used in residential building descriptions underlying residential energy efficiency and weatherization retrofit work. Their focus is more on the qualifications of personnel and the practice of home energy calculations. The BPI effort covers more topics than described here (e.g., installation and worker qualifications), but overlaps in the data used for home energy audit calculations. Additional discussion on these efforts is included in Chapter Three of this roadmap in Section 3.2.1.2.2, *Energy Simulation for Whole-Building Energy Efficiency Incentives: Residential Buildings*.

Gap Analysis and Recommendations

A single standard taxonomy (and XML specification) does not exist that covers central data needs for calculating savings.

A. Collaborative effort to address central data needs for calculating savings

In the near term, a collaborative effort should be begun to:

1. Examine and consolidate the existing (BPI, BEDES, others) taxonomies of data used in energy efficiency savings calculations
2. Work with stakeholders to refine these definitions to those which are material for different analytic methods
3. Publish a data dictionary and XML specification for use in describing and communicating data
4. Consider “locking down” the agreed-upon data standard through an ANSI-approved standards process under an ANSI-accredited organization
5. Track the development of new EM&V methods to determine whether a new data type is being used that can be included in the data specification, and establish a continuous update process to manage evolving changes

Recommended Timeline: This should be done in the near-term: 0-2 years.

B. Standardizing reporting characteristics of audit and implementation data

An additional gap was identified regarding standardizing reporting characteristics of audit and implementation data which may be routinely communicated to evaluation professionals, including how installation of individual EE measures is tracked. Standardization could improve data quality, EM&V implementation timelines, and reduce cost in the preparation of that data for EM&V purposes. This could be considered as part of future EM&V standardization.

Recommended Timeline: This should be done in the mid-term: 2-5 years.

¹²⁸ U.S. Department of Energy, “Building Energy Data Exchange Specification,” accessed May 2014, <http://www1.eere.energy.gov/buildings/commercial/bedes.html>.

4.2.3 Reporting

“Reporting” covers the data, process, and formats used to communicate EE EM&V outcomes for use by business, governments, or other stakeholders in EE activity. The issues around useful reporting have been central in a number of forums where EE results are used to assess accomplishment of utility, state or regional energy goals, energy resource planning, and air quality trends.¹²⁹ Many states currently require EE program administrators to report EE savings, expenditures, and other impacts to their state commissions concerned with energy use, federal agencies, and other regional entities.

Reporting requirements are known to vary from state to state. This makes it difficult to compare and/or aggregate state-level data to inform energy and environmental decision-makers concerned with energy markets and policies, or even to understand the success of EE as a policy tool.

The following table lists several significant examples of state, regional, and national reporting standards or practices. These illustrate that the definitions of what is reported – including EE program types, costs, and results (e.g., savings) – differ to various degrees. These reporting practices inform the identification of gaps and opportunities for guidance/standards to support greater consistency in EE reporting.

Title of Reporting Document	Developer/Organization (<i>if active</i>)
NATIONAL REPORTING	
Annual EE Industry Report <ul style="list-style-type: none"> – Annual report of EE impacts at sector level by state for CEE members http://www.cee1.org/annual-industry-reports	Consortium for Energy Efficiency (CEE) <ul style="list-style-type: none"> – Includes aggregate current year budgets and prior year expenditures and savings by program type and customer sector levels – Also includes net-to-gross factors by region
EIA Form 861 Schedule D <ul style="list-style-type: none"> – Basic EE/DSM data reporting required of utilities http://www.eia.gov/survey/form/eia_861/form.pdf	Energy Information Administration (EIA) <ul style="list-style-type: none"> – Includes annual EE program savings at the sector level for energy and demand, as well as cost data by general cost categories
REGIONAL REPORTING	
Regional EE Database (REED) <ul style="list-style-type: none"> – Annual data reported by ten jurisdictions (New England states, NY, MD, DE, DC) – Launched in March 2013 www.neep-reed.org	Northeast Energy Efficiency Partnerships (NEEP), via the Regional EM&V Forum <ul style="list-style-type: none"> – Includes annual and lifetime energy and demand savings and associated expenditures by region, state, sector, and/or program type levels

¹²⁹ While the scope of this section could apply more broadly to all EE reporting, including state efficiency investments in state buildings and municipal/community EE programs, this section focuses on ratepayer-funded EE programs administered by electric and natural gas utilities, and in some cases, designated state EE program administrators.

<p>ISO-New England Electric Utility Program</p> <ul style="list-style-type: none"> – Administrator reporting of EE savings and expenditures – Data collected is published and used by NEEP Regional EE Database (REED) <p>http://www.iso-ne.com/eefwg</p>	<p>ISO New England</p> <ul style="list-style-type: none"> – Collects largely the same data as REED, but with additional detail including measure-level savings data
<p>NW Regional Technical Forum/NWPCC</p> <ul style="list-style-type: none"> – Formerly tracked EE program impacts from across the region, but has not for several years – In process of scoping new reporting system <p>http://rtf.nwcouncil.org</p>	<p>Northwest Power Planning Conservation Council (NWPCC)</p>
STATE REPORTING	
<p>CA Energy Efficiency Groupware Application</p> <ul style="list-style-type: none"> – Utility (IOU) reporting of EE impacts – Currently being re-branded and updated – Data reported by CA IOUs including annual, quarterly, and monthly data at different levels of detail <p>http://eega.cpuc.ca.gov/Savings.aspx</p>	<p>California Public Utilities Commission (CPUC)</p> <ul style="list-style-type: none"> – Monthly data is reported for energy and demand savings, by program category, with information on budget and expenditures (year to date, and since inception) – Also includes benefit/cost ratios by program, savings by end use (measure level), number of program participants, and other details
<p>NY EE Portfolio Standard (EEPS) Scorecard</p> <ul style="list-style-type: none"> – New online database launched fall 2013 – Feeds into REED, and is used by NYISO for system planning <p>http://documents.dps.ny.gov/public/MatterManagement/CaseMaster.aspx?MatterCaseNo=07-M-0548</p>	<p>New York Department of Public Service (NY DPS)</p> <ul style="list-style-type: none"> – Includes data feed to REED and additional information by program type

Gap Analysis and Recommendations

Important differences exist in reporting practices, which make it difficult to compare program impacts:

- **Definitions of Savings and Program Typology:** State, regional, and national reporting entities often use different definitions of savings (i.e., the same term can refer to annual incremental savings, cumulative savings up to the current year, or to the expected future cumulative savings of a program offered in a given year). These entities also use different program type categories. Program typology differs both in the number of program types used and their definitions.

- **Expenditure Categories:** States often utilize different expenditure categories. For example, some states report administration and marketing costs separately, while others combine these costs.
- **Cost of Saved Energy Calculations:** Where this information is reported, definitions often differ across states, in particular, where a levelized value may be used instead of a lifetime value; discount rate assumptions range (utility discount rate vs. other lower long-term discount rate).
- **Net vs. Gross Savings:** States often have different definitions of net savings in terms of free-ridership and spillover (participant and non-participant effects), rebound effect, and/or longer term market effects.

The basis for differences in reporting savings between similar programs may arise from several causes. First, users of energy efficiency results may have different needs. For example, energy use forecasters may need cumulative savings up to the point of forecasting, but separately need predictions of savings going forward based on different scenarios of EE program continuation. State commissions may only care about EE savings accomplished by the programs in a given year, both in that year and over the life of the measures installed in that year, to track progress toward statewide energy goals. Depending on the needs of those participating in the development of a reporting specification, these different needs may cause differences in the reporting specifications that may not be apparent to the user of the reported information.

A. A series of analyses and discussions should be undertaken to:

1. Assess the needs of each of the general types of users of EE reported information, and identify what the parameters are that could be reported that would meet those needs. The analysis could first identify the types of users; for example, program implementers, entities that oversee program implementers, energy system manager and planners, and air quality regulators. It could then identify the information about EE activities most useful to each category of user.
2. Determine, within each category of user, if there was agreement on program type categories, definitions, data, and results to report that would more efficiently meet that user category's needs. The need to more efficiently crosscheck data and to accurately share data across organizations should also be met during this stage. An important question to address is whether data collection can be done in a collaborative manner.
3. Explore issues surrounding transferability of some of the data collection tools/databases in place to support broader coordination across the country. Consideration should also be given throughout for opportunities that take advantage of new technologies for data gathering and sharing.

Recommended Timelines: **Activities 1 and 2** (near-term) should be completed in the next two years through formal, collaborative efforts. Several organizations with wide reach in the programmatic energy efficiency industry are pursuing this issue.¹³⁰

Activity 3 (long-term) should be completed after the first two are complete and within 5 years, also through formal, collaborative efforts.

4.3 Other Evaluation Methodological Approaches

The expansion of energy efficiency as a resource tool in broader policy goals, such as climate change and air emissions, requires that the valuation of EE consider broader-based metrics and determinants. Other approaches to EM&V covered in this chapter expand the lens of measurement to include top-down macro-economic approaches, value risk, and finance considerations. These broader issue areas complement the measure-level approaches and warrant consideration.

Investments in energy efficiency, as managed by utilities and third-party program implementers, often face a variety of additional scrutiny by regulators and a variety of market actors and interveners. Attribution of reduced energy use to the program activities, and not some other influence, is important to the analysis of investments of public funds. In addition, these programs often influence end users and supply chain actors to make additional EE choices beyond those directly incentivized by the programs.

To evaluate attribution and potential market effects, a net-to-gross study is often conducted. While the measured savings for a particular piece of equipment or activity is considered the gross savings, participant and non-participant spillover to other EE purchases and activities are measured via surveys and through the use of supplier data and control groups. Likewise, surveys can help determine what action a particular program participant might have taken in the absence of the program. Several references exist for net-to-gross analysis, including those from SEE Action, and a current effort underway by DOE to develop appropriate net-to-gross protocols within the Uniform Methods Project.

4.3.1 Top-Down and Bottom-Up Methodological Approaches

“Top-down” methods analyze aggregate energy use to assess changes resulting from energy efficiency, typically for a geographic region, entire industry, or economic sector. They often incorporate methods using energy use metrics or energy intensity indicators, along with a structural or economic analysis to isolate drivers of energy use changes at an aggregate level. A common approach is to develop statistical or macro-economic equations to model or predict energy use, including among the energy use determinants, one or more variables that reflect energy efficiency activity. By analyzing energy use at an aggregate level, either for a geographic region, an industry, or customer sector, the overall, combined trends or impacts of policy or a combination of policies can be captured and quantified.

The importance of top-down methods is in their use as overall indicators of progress toward energy use reduction goals at a large scale. Such goals are common at state, regional, or national levels, including

¹³⁰ These organizations are the American Council for an Energy Efficient Economy, the Consortium for Energy Efficiency, Lawrence Berkeley National Laboratory, and the Northeast Energy Efficiency Partnership.

those established for greenhouse gas reductions, climate change, or energy independence. A high-level view of savings reductions allows for the attribution of a combination of multiple (policy) activities without the difficulties of looking at each, and the potential interaction of each (policy) activity with other activities.

“Top-down and bottom-up” methods are those that combine a top-down analysis with a bottom-up analysis, reconciling the differences with the goal of providing a decomposition of the overall changes in energy use into its constituent factors. For example, a top-down and bottom-up analysis of energy use in the state of California might identify the overall change in energy use and decompose it into changes from the specific energy efficiency programs operated by the electric and natural gas utilities (from adding the individual program effects – the “bottom-up” component) and the remaining change assigned to changes in economic activity, population, or demographic changes, and interactions between these factors.

These methods are common in Europe¹³¹ and are under consideration for use by some states (e.g., California¹³²) or organizations. These methods are a direct approach to indicating the overall success of policies designed to impact energy use. Unlike top-down, bottom-up methods focused on a specific policy encounter mounting difficulties in assessing overall impacts. With multiple policies over time, the interactions between individual programs grow and become more complex, especially as these programs are pursued over extended time.

Since each top-down model is usually built to solve a particular problem, there are variations in the approaches. While each application may have been sufficient for solving the problem for which it was designed, this approach poses challenges when the need is to compare policy effects between two different entities (geographic regions, industries, etc.). One example is when the need is to compare the success of one region in reducing energy with that of another region. Another example is when several regions are separately obliged to work toward a common goal. An example in the U.S. might be if the Regional Greenhouse Gas Initiative (RGGI) states¹³³ chose to make overall comparisons of energy efficiency effects.

Gap Analysis and Recommendations

For “top-down” analysis to be used with confidence in the U.S., several gaps need to be overcome. First, there is no systematic, objective method to assess the accuracy of top-down analysis. Second, there is

¹³¹ Typical European summaries are Vreuls, Harry, Wim De Groote, Peter Bach, Richard Schalburg, et al., “Evaluating energy efficiency policy measures & DSM programs - volume I: evaluation guidebook,” October 2005. Accessed 3 November 2013 at <http://www.ieadsm.org/Files/EXCO%20File%20Library/Key%20Publications/Volume1Total.pdf>, or Boonekamp, P.G.M. and S. Thomas, “Evaluation and Monitoring of the EU Directive of Energy End-Use Efficiency and Energy Savings,” WP6.1 Integration of Bottom-Up and top-down methods, ECN, EIE_06_128_EMEEES, 30 April 2009. Accessed 3 November 2013 at http://www.evaluate-energy-savings.eu/emeees/en/publications/reports/EMEEES_WP61_report_090430.pdf.

¹³² A recent summary of work in California is provided by: “Macro Consumption Metrics Pilot Study Technical Memorandum Preliminary Findings,” prepared by Demand Research, LLC, for the California Public Utility Commission, Energy Division. August 21, 2012. Accessed on 3 November, 2013 at <http://www.energydataweb.com/cpucFiles/pdaDocs/866/HOROWITZ-MCM Technical Memo August 21 2012.pdf>.

¹³³ RGGI is a cooperative effort among the states of Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont to cap and reduce CO2 emissions from the power sector. For more information, visit <http://www.rggi.org/>.

insufficient experience with top-down analysis to prescribe for particular use cases a current best practice, or to guide a new implementation of top-down analyses, including:

- Data to gather
- Form (equations) to estimate (the “top-down” model)
- Guidance on how to use the equations to answer questions about energy use
- Guidance on how to assess the usefulness or accuracy of the resulting analysis

A. Build a consistent, logical approach to “top-down” analysis using the expertise of current practitioners, recording current best practice with the following steps:

1. Characterize several important “use cases” for analyzing energy use, including whether the use case is for purely historical analysis or if it also includes use in forecasting. These could be for a single region, a single industry, a comparison of two or more regions, and a comparison of two or more industries.
2. For each use case, the essential explanatory variables need to be described as specifically as possible. Develop standards on how to obtain this data.
3. For each use case, specify preferred functional forms for the equations to estimate. If the use case includes forecasting, include base case development and forecast variable development guidelines relevant to the specific use case.
4. Develop guidance on how to use the estimated top-down model to address particular energy use questions.
5. Develop criteria for assessing the accuracy of the resulting analysis, and guidelines on their presentation.

Recommended Timeline: This is a long-term effort that should be accomplished in 5-7 years.

4.3.2 Use of Evaluation in Financial Risk Analysis

There has been an interest in private finance of energy efficiency activities in recent times. However, to date, private finance has been limited to a few specialized or even publicly supported program activities. The perception in the financial community is that EE provides low and uncertain energy cost reductions. This perception seems to lead potential sources of finance to the conclusion that large-scale lending would have uncertain returns or would carry risk in excess of return, making private finance very difficult. To improve the prospects of private finance, a couple of avenues have been explored that would clarify the riskiness of EE savings (and also energy cost reductions).

Complex energy retrofit projects and energy efficiency portfolios can involve dozens or hundreds of separate input variables (i.e., hours of use, occupant behavior, estimated savings from different measures or programs, etc.). Because many of the input variables are inherently uncertain, estimating the project savings or financial impacts from these complex projects can be difficult and uncertain. The risk associated with different estimates can be quantified using a variety of techniques, including Monte

Carlo sampling and Bayesian methods. Both of these methods use distributions to quantify the uncertainty associated with input variables and provide probability distributions that can be used to compute intervals and descriptive statistics for the quantity of interest. Similar techniques are discussed in the California Evaluation Framework and are being used to plan upcoming evaluations in California. However, the benefits of improved energy efficiency savings estimates remain unquantified. Financiers and parties holding the risk of energy efficiency program performance can help establish this target by providing input on the value of reduced risk/uncertainty.

Monte Carlo methods are but one technique for assessing risk in energy efficiency projects. There are no nationwide standards on how these methods are used to quantify uncertainty and translate that uncertainty into an estimate of financial risk. Furthermore, there are currently no nationwide standards dictating the conditions under which risk or financial gain should be assessed for prospective portfolios or projects. Finally, there is no quantitative guidance on determining the optimum budgeting (as defined by the value of reduced risk to all parties) of evaluation activities for various program/project activities.

Another approach that DOE is attempting to pursue is to develop large-scale databases of actual building characteristics and energy use. This project is called the Building Performance Database.¹³⁴ The variety of buildings can be used to generate distributions of energy use reductions based on the efficiency of equipment in the buildings. These distributions can be translated into energy cost reduction distribution, providing the input for financial risk analysis. If successful in generating distributions of EE's financial benefits, this project may spark further interest in developing these capabilities.

Yet another approach¹³⁵ is the Investor Confidence Project, which seeks to establish rigorous audit, project management, and M&V for particular types of projects. By establishing these rigorous guidelines, potential investors in a given project could be expected to have higher confidence in the resulting savings and be more willing to invest.

Gap Analysis and Recommendations

A. Systematic framework for analyzing the parametric uncertainty of energy efficiency projects and programs

The development of a systematic framework for analyzing the parametric uncertainty of energy efficiency projects and programs is recommended. Use a stakeholder process to establish acceptable tools and methods for calculating and documenting a characterization of program and project savings, particularly uncertainty in underlying parameters. This process would leverage work on Monte Carlo analysis, the Building Performance Database, and the Investor Confidence Project.

Recommended Timeline: This should be accomplished in the mid-term: 2-5 years.

¹³⁴ More information on the Building Performance Database can be found at <http://www1.eere.energy.gov/buildings/commercial/bpd.html>.

¹³⁵ Visit <http://www.eepformance.org> for details.

B. Systematic framework for translating engineering uncertainties into financial instrument ratings

The development of a systematic framework for translating engineering uncertainties into financial instrument ratings is recommended. Use a stakeholder process to establish repeatable, transparent methods for assigning financial risk metrics to specific programs and projects based on reported parametric uncertainties. These metrics should be developed with input from the potential users of the information – the financial community.

Recommended Timeline: This should be accomplished in the mid-term: 2-5 years.

C. Stakeholder process to assess needs

Based on the above two recommendations, a stakeholder process should review the methods used to do EM&V at that time (i.e., in 2 or 3 years) to assess what modifications or additions would be needed to provide the information of use to conduct financial analysis.

Recommended Timeline: This should be accomplished in the mid-term: 2-5 years.

4.4 Emerging Issue Areas

The following section discusses emerging issue areas of note within the field of EM&V.

4.4.1 Role of Conformity Assessment/Accreditation

The successful implementation of EM&V practice requires the use of assessment techniques, software, measurement equipment, and personnel. These elements must conform to minimum requirements for producing accurate measurements for any standard established for EM&V. Accreditation and certification of these elements ensure that entities relying on results from the EM&V practice have actionable assurance that the underlying components utilized in the development of product specifications, engineering practices, and analytical assessments meet minimum criteria for conformance with standard requirements. While conformity assessment practices in general have been established for more than a decade, it is discussed in this section as it is a growing area of interest impacting the EM&V practice.

Gap Analysis and Recommendations

Conformity assessment standards provide a necessary foundation to the base assumption that EM&V practices produce accurate and consistent results.¹³⁶ The use of conformity assessment standards may provide the basis for establishing certificate authorities. While there are products such as metering and measurement devices that have been certified by certification bodies, presently one known certification program for methodological practices or approaches used in the EM&V process is under development by NAESB. In 2014, NAESB completed the first certification specification for compliance with the wholesale energy efficiency M&V standards (WEQ-021).

¹³⁶ The ISO/IEC 17025:2005, *Conformity assessment – General requirements for the competence of testing and calibration laboratories*, supports such accuracy and consistency in results.

Accreditation and its roles in risk and financial management

To create the proper conditions to foster continued investment, countries need to institute comprehensive investment systems supported by a legislative framework that includes a solid system of standards and conformity assessment. Accredited conformity assessment bodies allow consumers, sellers, regulators, and other interested parties to have confidence in the results of conformity assessment, while avoiding the creation of unnecessary barriers to trade. These principles are based on the conformity assessment language in the World Trade Organization (WTO) Agreement on Technical Barriers to Trade (TBT).

Accreditation is an important part of the conformity assessment system, representing a third-party attestation of the management and technical competence of conformity assessment bodies such as laboratories and product certification organizations. Internationally recognized accreditation such as that governed by the International Laboratory Accreditation Cooperation (ILAC) and the International Accreditation Forum (IAF) opens more international market possibilities for those products that receive an accredited test report, inspection, or certification. ILAC/IAF promotes the principle of “test, inspected, or certified once – accepted everywhere,” building market and investment confidence by minimizing barriers to trade.

Accreditation reduces risk for businesses and their customers by assuring them that accredited Conformity Assessment Bodies are competent to carry out the work they undertake within their scope of accreditation. Accreditation body signatories of both the ILAC Mutual Recognition Arrangement and IAF Multilateral Recognition Arrangement undergo regular evaluations to assure the equivalence of their accreditation programs.

A. Establish relationship between conformity assessment standards that impact energy efficiency at a more global level, as well as its impact in risk and financial management

While the conformity assessment standards are equally related to applications in the compliance and enforcement of standards and workforce credentialing, and are covered in Chapters 1 and 5 respectively, it is important to establish the relationship between the different conformity assessment standards that impact EE at a more global level. In addition, it is important to establish the relationship between conformity assessment and its impact in risk and financial management.

Recommended Timeline: This should be done in the near-term: 0-2 years.

4.4.2 Technology-Specific Areas

The topics discussed above are generally of wider scope or applicability to the field of EM&V and the determination of energy efficiency savings for buildings in particular. The sections that follow discuss specific areas in which development is important and highlight where there is a close connection to work covered elsewhere.

4.4.2.1 Behavior-Based Programs

Behavior-based (BB) programs are those programmatic activities that seek to reduce energy use by influencing the behavior of energy users and supply chain actors, as opposed to reducing energy use by providing direct financial incentives for the replacement of equipment.¹³⁷

Behavior-based programs are among the newer EE program concepts to be implemented on a large scale in recent years. The understanding of customer behavior implied by these programs is that even customers attempting to improve their welfare (broadly speaking) often make decisions with an incomplete understanding about energy use, causing them to use more energy than if they had had more complete information. Even customers that understand the decisions needed to use less energy often do not take action due to other priorities, or because of accepted social norms among their social network. The motivating principle of behavior-based programs is that providing customers with targeted information and education can result in reduced energy use. Keeping in mind that customers vary widely in their motivations, baseline behaviors, and ability to capture and understand new information through social networks (e.g., tweets, texts, and emails), there is no “one size fits all” approach for evaluating behavioral programs.

Behavior-based energy efficiency programs may be one of the most challenging types of EE and demand response programs to evaluate:

- Programs sometimes do not have *ex ante* or utility/program administrator-developed savings estimates. In these cases, the evaluator has to develop the first program savings estimates.
- BB programs usually are *not* designed to motivate customers to take one or two predefined actions or to install one or two predefined measures, such as compact fluorescent lights (CFLs). As the programs encourage a variety of energy use behaviors, savings are typically estimated with whole-building energy use data.
- Savings from BB programs may be a small percentage of whole-building energy use and hard to detect statistically in small program populations.
- Because BB programs are typically such a small percentage of whole-building energy use, any bias in the savings estimate can overwhelm the savings itself.
- Persistence or longevity of BB programs’ savings is more uncertain than for traditional rebate programs that promote a small number of well-defined EE measures such as CFLs or T5 lighting systems.
- Estimating net-to-gross ratios for some BB programs can be challenging.
- BB programs may cause customers to participate in other utility energy efficiency programs, creating the potential for double-counting of savings and complicating attribution of savings to

¹³⁷ The SEE Action definition is slightly different, but similar in scope: “Behavior-based energy efficiency programs are those that utilize strategies intended to affect consumer energy use behaviors in order to achieve energy and/or peak demand savings. Programs typically include outreach, education, competition, rewards, benchmarking and/or feedback elements.” For more details, see: <http://emp.lbl.gov/sites/all/files/behavior-based-emv-ppt.pdf>.

different programs. For all BB programs, the double counting of energy savings is a potentially significant issue. The difficulty of addressing this issue ranges from low in the case of an EE program with tracked savings, where the BB programs are determined using a randomized controlled trial (RCT)¹³⁸ design; to extremely high for netting out the savings from an upstream/midstream EE program,¹³⁹ regardless of the program design.¹⁴⁰

Current State of Behavior-Based Programs

BB programs achieve savings by educating customers about the benefits of efficiency and encouraging them to change their energy-use behaviors. Utilities have implemented BB programs in the residential, commercial, and industrial sectors. The total potential for energy savings through behavior change is not well understood empirically, though these programs represent a relatively untapped area for investors in EE resources.

Scope of programs include training efforts (including building operator certification), feedback mechanisms (such as home energy reports and in-home monitors), gamification, community-based social marketing, goal setting programs, mass media efforts, contests, competitions, and continuous energy improvement programs for industry. Programs that are tied to the purchase of specific, pre-defined equipment and rely only on monetary incentives, such as rebate programs, are *outside the scope* of “behavior” programs. While those that motivate people to make purchases of equipment, but do not include financial incentives, are in scope.

The table in Appendix 4B highlights categories of programs that have distinct evaluation approaches. The documented evaluation approaches for each category make it possible to obtain an estimate of savings (*note*: the table uses the phrase “correctly estimating net energy savings” to encompass both low bias and high precision savings estimates). Some approaches will thus include those that have lower confidence and precision in the estimates of savings than others. The programs are categorized by design features, focusing on features with implications for the appropriate evaluation approach. This can help utilities and other stakeholders design programs that increase the likelihood of obtaining reliable (unbiased, high precision) estimates of program savings.¹⁴¹

Gap Analysis and Recommendations

Two gaps in current practices deserve attention now. First, programs are often designed with little consideration for how the program is to be evaluated. Utilities and other program implementers should be strongly encouraged to contract with third-party evaluators to work with implementers in the early

¹³⁸ The RCT for the BB program should identify the savings that occur in the other program’s tracking system.

¹³⁹ Upstream/midstream programs are financial incentives that involve payments to parties that are “up the supply chain” from the individual customer purchase transaction. Upstream incentives reach relatively far up the supply chain, typically to manufacturers; midstream incentives are targeted closer to the customer end of the market, typically to retailers or installation contractors. National Action Plan for Energy Efficiency, “Customer Incentives for Energy Efficiency Through Program Offerings,” last modified February 2010, http://www.epa.gov/cleanenergy/documents/suca/program_incentives.pdf.

¹⁴⁰ For example, the BB program may induce the purchases of efficient light rebated with savings tracked in a separate system. Because such “upstream” programs track only equipment and not the purchaser, the purchaser’s motivations ca not be uncovered and the double counting assessed.

¹⁴¹ A significant focus of ongoing work in BB programs is the SEE Action Workgroup on Customer Information and Behavior. More information can be found at http://www1.eere.energy.gov/seeaction/customer_info.html.

stages of program design. Quite often, minor, low-cost changes in program design generate significant improvements for accurately estimating program effects.

Second, many implementers and even some third-party evaluators do not have sufficient understanding of recent methodological developments in program evaluation. The SEE Action report, *Evaluation, Measurement, and Verification (EM&V) of Residential Behavior-Based Energy Efficiency Programs: Issues and Recommendations*,¹⁴² is an example of attempts to remediate this gap in knowledge, with particular attention on the advantages of randomized control trials. There may be significant benefits from continued efforts to close the gap between the available state-of-the-art methods in impact evaluation and current standard practice.

A. Randomized controlled trials

Randomized controlled trials (RCTs) are the preferred design for behavior-based programs. To the extent that an RCT is not feasible, quasi-experimental designs as outlined in the SEE Action report are the preferred alternative.

Recommended Timeline: This should be done in the near-term: 0-2 years.

B. Impact evaluation approach

The impact evaluation approach should be decided during the initial design of the program. This provides the opportunity for the design to reflect the evaluation approach, and minimizes the likelihood of “conformity bias” (i.e., the tendency for a third-party evaluator to excessively explore various statistical models for the purpose of finding savings agreeable to the client and implementer).

Recommended Timeline: This should be done in the near-term: 0-2 years.

There are several references in the EESCC Inventory Database that provide methodologies for evaluation of feedback programs, specifically those that involve experimental design with large samples of customers and control groups that receive comparative information and billing data are available.

A shortage of EM&V references that analyze the impacts of other types of behavior programs is apparent. While many evaluations of training programs have been completed, a plethora of approaches have been used to determine the impacts and persistence of these efforts. The same is true for mass media campaigns and game-based programs. The table in Appendix 4B indicates program types with limited consensus or available literature on evaluation methods. For example, the benefits of home energy monitors (a technology that provides feedback, but in and of itself does not save energy) and the persistence of savings that may be attributed to their use are not well documented beyond limited pilot programs in some regions.

In the commercial building and industrial facility sectors, there is a growing body of literature on the impacts of continuous energy improvement or strategic energy management programs that do not

¹⁴² State and Local Energy Efficiency Action Network. 2012. *Evaluation, Measurement, and Verification (EM&V) of Residential Behavior-Based Energy Efficiency Programs: Issues and Recommendations*. Prepared by A. Todd, E. Stuart, S. Schiller, and C. Goldman, Lawrence Berkeley National Laboratory. <http://behavioranalytics.lbl.gov>.

involve the installation of new equipment, but rather rely on operational changes at the facility. Methods used in evaluating these programs generally utilize site-specific methods that deploy one or more of the IPMVP protocols described earlier in this chapter.

C. Methods to allow for assessing impacts

Methods are needed that would allow for assessing the impacts of these programs more broadly without the significant expense of extensive site-specific analysis.

Recommended Timeline: This should be done in the near-term: 0-2 years.

4.4.2.2 Evaluating Emerging EE Technologies

There is constant evolution in energy efficiency technology. The process of evaluation and M&V must keep pace with the influx of technology and technology applications. Without reliable and documented savings results, attribution of savings and levels of incentive are difficult to apply. The evaluation of emerging technologies in energy efficiency can be split into three objectives: (1) evaluating actual installations; (2) evaluating “emerging technology” programs; and (3) predicting the contribution of emerging technologies into forecasts or plans for energy efficiency programs.

Several program implementers operate emerging technology programs that attempt to increase the market penetration of promising energy saving technologies. The effectiveness of such programs tends to be evaluated based on the technology’s impact on the market rather than the direct energy savings impacts of the programs. Measure-level savings therefore tend to be unreliable, and the optimization of the M&V process (for example, incorporation in TRMs) is limited.

Some emerging technologies in building energy efficiency include:

- Advanced power strips
- Ductless mini-split AC and heat pumps
- LED/solid state lighting
- Heat pump water heaters
- Home entertainment and other control/automation
- Smart (web-integrated) thermostats for small commercial applications

As explained in the chapter introduction, there is a perceived benefit to increasing consistency and comparability in the practice of EM&V. The IPMVP methods can be applied to all of the technologies listed above to determine savings at the project or measure level. Guidance on how to evaluate emerging technologies programs can be found in the resources in the table below (*note:* this is not intended to be a comprehensive listing). Guidance is also provided through the Federal Energy Management Program (FEMP),¹⁴³ and NEEP’s work on emerging technologies has addressed heat pump water heaters.¹⁴⁴

¹⁴³ FEMP offers information about energy-efficient and renewable energy technologies through the following areas: energy-efficient product procurement, technology deployment, and renewable energy. For more information, visit <http://energy.gov/eere/femp/technologies>.

¹⁴⁴ Visit <https://www.neep.org/efficient-products/emerging-technologies/index> for more information.

EESCC Inventory Database Record	Title of Document	Developer/Organization
SD-563	Establishing Savings Algorithms and Evaluation Procedures for Emerging Technologies and Innovative Program Approaches ¹⁴⁵	American Council for an Energy-Efficient Economy
SD-30	California Energy Efficiency Evaluation Protocols, chapter on “Emerging Technologies Protocol”	California Public Utility Commission
SD-48	Model Impact Evaluation Guide, Appendix C	National Action Plan for Energy Efficiency (NAPEE)
SD-564	Guide for Conducting Energy Efficiency Potential Studies	NAPEE

Issues that have been identified in evaluating such programs include: estimating measure lives, estimating measure persistence, recommending reasonable *ex ante* savings algorithms, small sample sizes where there is a small number of installations, assessing the knowledge created and knowledge disseminated, and estimating adoption rates.

Planning processes that accommodate for forecasted energy efficiency are challenged by capturing the dynamic nature of emerging technology. Estimating the impacts of future programs on energy and demand, as with attribution of delivered EE, must be reliable and robust. This is a challenging process, requiring an assessment of the market place, rates of penetration, and reliability of data. There are existing guidance documents on how to perform potential studies, including one prepared by NAPEE. A few ISO/RTOs forecast EE and incorporate their long range planning studies. They typically use a stakeholder process to inform uncertainty attributes due to changing program makeup and emerging technology.¹⁴⁶

Gap Analysis and Recommendations

Project-level M&V methods to evaluate emerging technologies are adequately addressed by the IPMVP. There is no gap when it comes to evaluating emerging technologies for which incentives are likely to be provided. The current program evaluation guidance on emerging technology programs is adequate.

No gap: At this time, no gaps are seen in evaluating the impacts of installed emerging technologies.

¹⁴⁵ McCowan, Brian et al., “Establishing Savings Algorithms and Evaluation Procedures for Emerging Technologies and Innovative Program Approaches,” Paper presented at the 2012 ACEEE Summer Study on Energy Efficiency in Buildings, Pacific Grove, California, August 12-17, 2012, <http://www.aceee.org/files/proceedings/2012/data/papers/0193-000119.pdf>.

¹⁴⁶ ISO-New England, “Energy-Efficiency Forecast Working Group,” accessed May 2014, <http://www.iso-ne.com/eefwg>.

4.4.2.3 Energy Performance Indicators (EnPIs)

Energy performance indicators (EnPIs) have become key elements of initiatives such as the Superior Energy Performance (SEP) certification program and ISO 50001, the energy management system standard from the International Organization for Standardization (ISO). Central to rigorous energy management has been guidance or specifications on how to calculate the EnPIs used to measure changes in energy performance. The *Superior Energy Performance M&V Protocol for Industry*¹⁴⁷ provides guidance for the SEP; ISO is developing a comparable standard to support ISO 50001. These protocols incorporate many of the elements described above for whole premise statistical analysis, even though they were developed for industrial applications. These include development of a baseline, allowable approaches to compare energy use in two time frames (focused on the issue of baseline), specification of the types of variables to include, and sufficient statistical rigor.

To date, the development of protocols for developing EnPIs has been focused and performed in a manner that generally comports well with typical EM&V practice. However, there are already some notable differences. These differences will become material for organizations that want to practice energy management and participate in state/utility customer-funded energy efficiency programs. The difficulty will be in satisfying multiple measurement requirements raising the cost of energy efficiency and potentially producing conflicting results as to how much energy was saved. For example, the discussion of industrial baselines in Section 4.1.1 indicates that in California and New York there is a specified treatment of baselines when the installed efficiency measure itself raises potential production levels. This treatment may limit or conflict with the guidance that exists in the SEP (draft) protocol.

The specific issue is not insurmountable, but illustrates that the same methods in EM&V support multiple “clients,” each with potentially different needs or objectives to be obtained by having a measurement of energy efficiency savings.

A. Future revisions of protocols (ASHRAE, IPMVP, others) should be coordinated

Future revisions of the SEP M&V protocols, or development of the protocols supporting ISO 50001 can coordinate with a wider circle of EM&V professionals to ensure that the SEP protocols are a subset of current practice, or a superset. In either case, there should be no additional burden on participants of utility programs or in SEP.

Recommended Timeline: This should be done in the near-term: 0-2 years.

¹⁴⁷ The Regents of the University of California, “Superior Energy Performance: Measurement and Verification Protocol for Industry,” November 19, 2012, http://www.superiorenergyperformance.net/pdfs/SEP_MV_Protocol.pdf.

Appendix 4A: Listing of Technical Reference Manuals

Scope of TRM	Resource Name	Web Site	Format	Information Included	Administrator	Update Status (as of October 2013)
National	ENERGY STAR®	http://www.energystar.gov/index.cfm?c=products.pr_find_es_products	Online Calculators	<i>Ex ante</i> savings based on algorithms	Agency	Individual calculators updated periodically
Regional – Northwest	Regional Technical Forum (RTF) Deemed Measures	http://www.nwcouncil.org/energy/rtf/measures/Default.asp	Online Database	<i>Ex ante</i> savings based on algorithms	Advisory Committee	Individual savings estimates updated periodically
Regional – Mid-Atlantic	Mid-Atlantic TRM	http://www.neep.org/Assets/uploads/files/emv/emv-products/TRM_March2013Version.pdf	PDF	Algorithms and <i>ex ante</i> savings	Non-Profit Organization	Updated March 2013; Version 3
Arkansas	Arkansas Deemed Savings Quick Start Programs	http://www.apscservices.info/EEInfo/TRM.pdf	PDF	Algorithms	Public Utility	Updated September 2013; Version 2, Volume 2
California	DEER Database for Energy-Efficient Resources	http://www.deeresources.com/	Software Program	<i>Ex ante</i> savings	State Commission	Updated May 2012. For use in the California IOU 2013-14 Energy Efficiency Planning. Software is downloaded here: \\cadmusgroup.org\Energy\Library\Technical Reference Manual (TRM)\California\DEER READI Database
Colorado	2012/2013 Demand-Side Management Plan	http://www.xcelenergy.com/staticfiles/xcel/Regulatory/2012-2013%20Biennial%20DSM%20Plan.pdf	PDF	Algorithms and <i>ex ante</i> savings	State Commission	Updated August 2013
Connecticut	Connecticut Light & Power and United Illuminating Company Program Savings Documentation	http://www.ctenergyinfo.com/2012%20CT%20Program%20Savings%20Documentation%20FINAL.pdf	PDF	Algorithms and <i>ex ante</i> savings	Public Utility	Updated for 2012 program year
Delaware	Delaware Technical Reference Manual	http://www.dnrec.delaware.gov/energy/information/otherinfo/Documents/EM-and-V-guidance-documents/DELAWARE_TRM_August%202012.pdf	PDF	Algorithms	Agency	Updated April 2012

Scope of TRM	Resource Name	Web Site	Format	Information Included	Administrator	Update Status (as of October 2013)
Hawaii	Hawaii Energy Efficiency Program TRM	http://www.hawaiienergy.com/media/W1siZiIsIjwMTMvMDUvMTcvMTIifNTNfMTZfOTk1X1BZMTFFSGF3YWlpRW5lcmd5VFJNLnBkZiIdXQ/PY11-HawaiiEnergyTRM.pdf?sha=c230e920	PDF	Algorithms and <i>ex ante</i> savings	State Commission	Updated 2011
Illinois	Illinois Statewide TRM for Energy Efficiency	http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Illinois_Statewide_TRM_Version_2.0.pdf	PDF	Algorithms	Advisory Committee	Updated June 2013; Version 2
Indiana	Indiana Technical Resource Manual	\\cadmusgroup.org\Energy\Library\$\Technical Reference Manual (TRM)\Indiana	PDF	Algorithms and <i>ex ante</i> savings	Agency	Updated January 2013; Version 1
Maine	Efficiency Maine TRM – Commercial	http://www.efficiencymaine.com/docs/EMT-Commercial-TRM.pdf	PDF	Algorithms and <i>ex ante</i> savings	Trust	Commercial: Updated August 2013. Version 2014-1.
	Efficiency Maine TRM – Residential	http://www.efficiencymaine.com/docs/EMT-TRM_Residential_v2014-1.pdf				Residential: Updated August 2013. Version 2014-1.
Massachusetts	Massachusetts Statewide TRM for Estimating Savings from Energy Efficiency Measures	http://www.maeac.org/Docs/8.3_TRMs/1MATRM_2013-15%20PLAN_FINAL.pdf	PDF	Algorithms and <i>ex ante</i> savings	Agency	Updated October 2010 for the 2013-2015 program years
Michigan	Michigan Energy Measures Database	http://www.michigan.gov/mpsc/0,1607,7-159-52495_55129---,00.html	Excel Database	<i>Ex ante</i> savings	State Commission	Updated 2014 Excel databases (see dropdown menu at bottom of page)
Minnesota	Minnesota TRM	http://mn.gov/commerce/energy/topics/conservation/Design-Resources/Technical-Reference-Manual%20.jsp	Excel Database	Algorithms and <i>ex ante</i> savings	Agency	Updated 2012
New Jersey	New Jersey Clean Energy Program Protocols to Measure Resource Savings	http://www.njcleanenergy.com/files/file/NJ%20Protocols%20Revisions%208-14-12_Clean%281%29.pdf	PDF	Algorithms and <i>ex ante</i> savings	Agency	Updated August 2012
New York	New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs	http://efile.mpsc.state.mi.us/efile/docs/16671/0026.pdf	PDF	Algorithms and <i>ex ante</i> savings	Agency	Updated October 2010

Scope of TRM	Resource Name	Web Site	Format	Information Included	Administrator	Update Status (as of October 2013)
Ohio	Ohio TRM	http://amppartners.org/pdf/TRM_Appendix_E_2011.pdf	PDF	Algorithms and <i>ex ante</i> savings	State Commission	Updated August 2010
Pennsylvania	Pennsylvania TRM	http://www.puc.pa.gov/filing_resources/issues_laws_regulations/act_129_information/technical_reference_manual.aspx	DOC	Algorithms and <i>ex ante</i> savings	State Commission	Updated for 2013
Rhode Island	Rhode Island TRM for Estimated Savings from Energy Efficiency Measures	http://www.nationalgridus.com/non_html/er/ri/Rhode%20Island%20TRM_PY2013_final.pdf	PDF	Algorithms	State Commission	Updated for 2013 program year
Texas	Deemed Savings, Installation, and Efficiency Standards	http://www.entergy-texas.com/content/Energy_Efficiency/documents/Deemed_Savings_Measures_List.pdf	PDF	Algorithms and <i>ex ante</i> savings	State Commission	Updated January 2013
Vermont	Efficiency Vermont Technical Reference User Manual	http://www.greenmountainpower.com/upload/photos/371TRM_User_Manual_No_2013-82-5-protected.pdf	PDF	Algorithms and <i>ex ante</i> savings	Non-Profit Organization	Updated March 2013; Number 2013-81
Washington	Washington State Energy Code	http://www.energy.wsu.edu/BuildingEfficiency/EnergyCode.aspx#TEXT	PDF	<i>Ex ante</i> savings	Agency	Updated 2012
Wisconsin	Focus on Energy Evaluation Business Programs: Deemed Savings Manual	http://www.focusonenergy.com/sites/default/files/bpdeemedavingsmanuav10_evaluationreport.pdf	PDF	Algorithms and <i>ex ante</i> savings	State Commission	Updated March 2010; Version 1

Appendix 4B: Categories of Behavior-Based Program and Evaluation Concerns

Behavior-Based Program Descriptor	Information Target	Means of recruitment/ exposure	Location of savings	Expected significant cross-customer spill over?	Typical difficulty of correctly estimating net energy savings	Examples of programs
Randomized Controlled Trial (RCT)	End user	RCT design with opt-out or opt-in	End user premises	No	Low, assuming sufficient number of treatment customers, and a very low rate of opt-out	Any program in which treatment results from random assignment from a pool of customers; currently, energy report programs are the common form
Opt-In with Quasi-Experimental Evaluation Method	End user	Opt-in by end user	End user premises	No	Medium-low in best-case scenario in which there are sufficient number of treatment customers and there exists the opportunity to use best available methods for addressing various sources of bias, especially selection bias	Web-based information programs, opt-in home energy display programs; opt-in programs at the organization level when program goal is on-site savings; opt-in programs involving building operator certification/training
Random Encouragement Design (RED)	End user	Opt-in by end user, but with a randomly- selected subset of customers targeted for encouragement	End user premises	No	Low; the design addresses selection bias, though the method requires assumptions that may not be met in some cases, and the method also requires data collection for a relatively large number of customers	Any opt-in program can be designed as an RED program

Behavior-Based Program Descriptor	Information Target	Means of recruitment/ exposure	Location of savings	Expected significant cross-customer spill over?	Typical difficulty of correctly estimating net energy savings	Examples of programs
Organization-Focused, Off-site Savings	Organizations of end users, e.g., employees of a business, children of a classroom or school, members of a religious group	Opt-in at the organization level with contained chained exposure ¹⁴⁸	Organization member premises (homes of employees, homes of schoolchildren, etc.)	No	Medium-low when energy use data of member premises is available (note in particular that selection at the organization level implies a weaker case for selection bias at the member level); high when this data is not available and deemed savings for claimed behaviors is necessary	Programs at businesses or schools that organize "teams" (e.g., by business department, by classroom) that compete with one another to save energy at the residences of team members
Emerging Program Strategies/Designs¹⁴⁹ <ul style="list-style-type: none"> – Uncontained Social Networking – Community-based Social Marketing – Gamification 	Social network, online community	Typically opt-in	Premises of social network members	Yes	High, due to difficulty of tracking networks and getting data to evaluate	A few programs are being operated by utilities in various states

¹⁴⁸ **Chained exposure** refers to a design feature in which some customers receive information from a primary source and are explicitly tasked with passing it on to other customers; **contained chained exposure** is chained exposure that stays within a population known to the analyst (e.g., within employees of a business).

¹⁴⁹ These are provided to acknowledge the fast-moving evolution of behavior-based programs. Some emerging program strategies are mentioned, as they might become a bigger part of the behavioral program mix in the future (though the difficulty of estimating savings from them, and getting the necessary data to do so may keep them from becoming an important part of the behavioral program mix).

CHAPTER FIVE: WORKFORCE CREDENTIALING


5.0 Introduction

Verifiable and standards-based workforce credentials serve as an anchor for growing energy efficiency industries. A strong and competent workforce – one that is agile enough to meet changing market demands – provides the underpinning for growth and consumer acceptance, resulting in reduced energy use and the creation of market-valued jobs. However, unsubstantiated claims of competency and inconsistent assessment practices have given rise to a confusing and rather chaotic assortment of workforce credentials. The good news is that a core of quality standards and credentialing schemes are in place and provide a strong launching pad from which to build a competent workforce. The challenge is sorting through the various credentials offered, finding the credential that meets the needs of employers and consumers, and making sure that both consumers and workers select industry-developed and recognized standards. This chapter is intended to guide stakeholders in understanding, identifying, and selecting quality credentials.

At the heart of the issue is understanding credentialing in the first place. In reviewing standards and conformity assessment schemes to identify those appropriate to workforce credentialing in energy efficiency, the EESCC workforce credentialing working group requested and received almost 90 submittals from 28 organizations. Not all of the entries met the definition of energy efficiency credentials; others did not provide enough information to support their energy efficiency content. But for those that did, members of the committee looked for evidence that the credentials were industry-aligned, developed according to best practices, current, and relevant for today's workforce. During its review, the working group reached a number of conclusions.

Currently, there is confusion in the marketplace about the various types of credentialing programs offered – including certificate, training, and certification – and what these credentials are intended to achieve for the worker. Often, terminology is used incorrectly. For example, some “certificate” programs describe their scope as “certification.”

While seemingly a minor inaccuracy, credentials can carry varying degrees of rigor; some demonstrate learning outcomes, while others assess occupational competencies. There is also a lack of understanding




In workforce credentialing, **standards** and **conformity assessment** are the two guiding elements in selecting credentials.

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Voluntary consensus standards establish valid requirements that assure appropriate stakeholder involvement.

Conformity assessment schemes assure compliance with the standards.



of the components that describe quality credentialing programs, and measures to differentiate “market-valued” credentials from those that are not. The end result is confusion among various industry stakeholders, including the worker seeking a credential, and end users such as employers and regulators who rely on the credential as a means of qualifying the workforce. This chapter is intended to address these issues in an effort to guide stakeholders in the selection of quality credentials.

What stands behind a credential – how it is developed and maintained – is as important as the end product itself. Rigor and adherence to best credentialing practices lay a solid foundation for well-developed credentialing programs. Ongoing maintenance and review are also critical components of well-designed and managed credentialing programs. These elements help to ensure the integrity of a program, and in turn, the value of the credential. Not only should the public, government officials, utility companies, employers, and other consumers support credentialed workers and services, they should expect and ask for evidence that the credentials are meaningful and follow accepted measures of conformance to industry-driven standards. Credentials play a pivotal role in assuring safety and in preparing a workforce. When developed correctly, credentials bring value to *all* stakeholders, whether they are directly using services of credentialed individuals, or indirectly benefiting from higher industry standards that focus on quality and safe practices.

While not all standards and credentials are alike in terms of quality and industry relevance, this chapter should enable stakeholders to better understand the type of credential most suitable for their purposes. Several references are provided in the chapter appendix to guide stakeholders in the selection of credentials that qualify a workforce. Stakeholders are encouraged to review the references in their entirety, and to compare standards and conformity assessment programs.

5.1 Terminology: Defining Workforce Credentialing

As noted above, much confusion surrounding workforce credentialing stems from the incorrect use of terminology. The select definitions that follow are intended to guide stakeholders in understanding key terms, and to establish consistency in and correct usage of these terms. In selecting the definitions for this section, several sources were referenced and are noted in Appendix 5A; users of this roadmap are encouraged to refer to those documents in their entirety.

- **Accreditation**—third-party attestation related to a conformity assessment body conveying formal demonstration of its competence to carry out specific conformity assessment tasks (Reference ISO/IEC 17000, *Conformity assessment—Vocabulary and general principles*).
- **Programmatic Accreditation**—third-party conformity assessment of an academic program’s conformance with standards specifically developed in an area of study (as defined by the EESCC workforce credentialing working group).
- **Certificate**—document issued by a certification body under the provisions of the international standard, ISO/IEC 17024:2012, *Conformity assessment—General requirements of bodies operating certification of persons*, indicating that the named person has fulfilled the certification requirements; document (letter, card, or other medium) awarded to the certificate holders that

designates the successful completion of a certificate program's requisites (Reference ASTM E2659-09, *Standard Practice for Certificate Programs*).

- **Certification**—third-party attestation related to products, processes, systems, or persons (Reference ISO/IEC 17000, *Conformity assessment—Vocabulary and general principles*).
- **Personnel Certification**—a process of verifying that an individual meets the competency requirements of an established standard to perform in a job or occupation. Personnel certifications include an assessment and maintenance requirements (as defined by the EESCC workforce credentialing working group).
- **Educational/Training Certificate Program**—non-degree-granting education or training program consisting of (1) a learning event or series of events designated to educate or train individuals to achieve specified learning outcomes within a defined scope; and (2) a system designed to ensure individuals receive a certificate only after verification of successful completion of all program requisites, including but not limited to, an evaluation of learner attainment of intended learning outcomes (Reference ASTM E2659-09, *Standard Practice for Certificate Programs*).
- **Credentialing**—the process by which a body or organization recognizes or records the recognition status of persons that meet predetermined criteria (Reference ISO/IEC TS 17027, *Conformity assessment—Vocabulary related to competence of persons used for certification of persons*).
- **License, Licensure**—the recognition of competence to practice a given occupation or profession conveyed to a person or entity by a regulatory body; approval process, carried out by an authorized body granting permission to a person or organization to engage in a given occupation after verifying that he/she/they have met predetermined requirements. This is usually demonstrated by a document or card (a license). (Reference ISO/IEC TS 17027, *Conformity assessment—Vocabulary related to competence of persons used for certification of persons*).

While not considered workforce credentialing terminology, the following are used in this roadmap and considered important to quality workforce credentials:

- **Industry Recognized**—acceptance of the credential by industry as a valid job, skill set, or knowledge area (as defined by the EESCC workforce credentialing working group).
- **Market-Valued Certificate**—certificate issued has value in the market by teaching skills that are in demand by employers, and/or by achieving recognition by industry, government, and/or the public that training outcomes result in marketable and job-related skills (Reference IREC Standard 14732:2013, *General Requirements for Renewable Energy & Energy Efficiency Certificate Programs*).

- **Registered Apprenticeship Program**—government (state or federal) approved program of learn-and-earn training programs in a particular trade or occupation. Required features include approval by the government accrediting agency of minimum training standards; a standardized curriculum approved by industry partners in labor and management; fair and impartial selection processes; and work site supervision by journey-level workers of the same trade. Includes increases in pay as skills are acquired, and upon graduation, award of journey-level status by certifying government agency (as defined by the EESCC workforce credentialing working group).
- **Stakeholder**—any materially affected or interested party (as defined by the EESCC workforce credentialing working group).

Recommendation

Standard and industry-accepted credentialing and workforce terminology should be used to avoid confusion and promote understanding for stakeholders searching for and utilizing conformity assessment programs.

5.2 Indicators of Quality Credentialing Programs

In addition to understanding the correct use of terminology in selecting standards and conformity assessment schemes for workforce credentials, knowing the indicators of quality credentialing programs will assist stakeholders in differentiating programs of integrity from those of lesser quality.

One of the first indicators of quality to look for is accreditation. Accreditation is typically a voluntary process, although it can be mandated by industry and/or professions associated with workforce credentialing or by federal or state government. There are numerous organizations that administer accreditation programs for personnel certification and certificate programs that take the guesswork out of finding quality credentialing programs, including but not limited to the American National Standards Institute (ANSI), the International Accreditation Service (IAS), and the Institute for Credentialing Excellence (ICE).¹⁵⁰ Accreditation is most applicable to personnel certification, certificate programs, and programmatic accreditation, which applies to programs in institutions of higher education and/or vocational and technical training institutes. Programmatic accreditation is discussed in Section 5.6.

¹⁵⁰ For **personnel certification**, ANSI and IAS administer ISO/IEC 17024:2012, *Conformity assessment—General requirements for bodies operating certification of persons*; the National Commission for Certifying Agencies (NCCA), a branch of ICE, administers *Standards for the Accreditation of Certification Programs*, 2004; IREC administers IREC Standard 01024:2013, *General Requirements for the Certification of Clean Energy Technology Instructors and Master Trainers*. For **certificate programs**, ANSI and IAS administer ASTM E 2659-09, *Standard Practice for Certificate Programs*; ANSI/IREC administers Standard 14732:2013, *General Requirements for Renewable Energy & Energy Efficiency Certificate Programs*; and IREC administers IREC Standard 01023:2013, *General Requirements for the Accreditation of Clean Energy Technology Training*.

While accreditation is a highly valued indicator of quality credentialing programs, few credentialing programs seek accreditation; and yet, these programs can be of high quality. This section details indicators of quality credentialing programs to help guide stakeholders in selecting standards and conformity assessment schemes.¹⁵¹

INDICATORS OF QUALITY PERSONNEL CERTIFICATION PROGRAMS:

- Third-party, independent governing body that demonstrates impartiality
- Scope of certification available to the public without request
- Current job task analysis
- Process for examination development, maintenance, and administration (psychometric review)
- Eligibility requirements (prerequisites)
- Recertification requirements
- Code of ethics
- Disciplinary procedures
- Certificate awarded includes expiration date
- Publication of certified individuals (website, directory)
- Policies that guide all certification decisions, including due process
- Protection of intellectual property, including examination, logos, marks, and certificates
- Balanced stakeholders that provide ongoing systematic input
- Separation of training from testing
- Complaints and appeals process
- Ongoing professional development/recertification

INDICATORS OF QUALITY CERTIFICATE PROGRAMS:

- Balanced stakeholders that provide ongoing systematic input
- Job task analysis or other content standard on which the program is based
- Validation study
- Published scope of certificate
- Program prerequisites
- Alignment of learning objectives with assessments
- Certificate and training is industry recognized
- Criterion-referenced assessments of the learner
- Qualified faculty
- Environments conducive to learning
- Available resources to support learning
- Program evaluation (summative and formative)
- Policies that guide program decisions, including due process

INDICATORS OF QUALITY ACCREDITATION PROGRAMS:

- Third-party independent governing board

¹⁵¹ For the purposes of this roadmap, indicators are limited to personnel certification, certificate programs, and accreditation.

- Scope of accreditation available to the public without request
- Balanced stakeholder input on accreditation requirements representing the market served
- Policies that guide the accreditation programs
- Due process
- Publication of accreditation requirements
- Desk review and site visit
- Separation of assessors from an accreditation body that make the accreditation decision
- Qualified and trained assessors
- Continual training of assessors to facilitate consistent decisions
- Inter-rater reliability studies for assessors
- Appeals and complaints process

Stakeholders selecting workforce credentials may encounter several credentials for the same job or skill set. In credentialing, competition exists. Assessing available credentials for the same skills will invariably lead to comparisons and judgment based on a variety of criteria, so differentiating between credentials may require careful review of standards to identify indicators of quality.

Recommendations

Indicators of quality credentialing programs should be drawn on to guide stakeholders in selecting standards and conformity assessment schemes.

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Both certifications and certificates for personnel should include assessment of attainment of competencies and skills.

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State and federal agencies should recognize accredited credentialing programs.

5.3 Role of Registered Apprenticeships in Workforce Credentialing

Registered apprenticeship programs play a role in training and qualifying a skilled energy efficiency workforce and should be considered part of the workforce credentialing framework. The U.S. Department of Labor (DOL) and/or state labor agencies provide registration¹⁵² of apprenticeship training programs, and graduates of federal- or state-approved programs receive a federal- or state-issued,

¹⁵² According to DOL, registered apprenticeship combines on-the-job training with theoretical and practical classroom instruction to prepare workers for American industry. The process of apprenticeship program registration with federal and state government agencies is standards-based, and is designed to ensure that working apprentices, program sponsors, and the general public can gain a clear understanding of the training content and the measures that are in place to ensure ongoing quality. Additional information on registered apprenticeship is available on DOL's website: <http://www.doleta.gov/OA/apprenticeship.cfm>.

nationally-recognized credential. This credential indicates occupational proficiency and is portable, conveying significant value in the market. Apprenticeship is an “earn-while-you-learn” model that provides employment with on-the-job training and technical classroom instruction provided by an apprenticeship training center, technical school, community college, or other educational partner. Programs are funded through employer and employee contributions, and employers sit on curricula committees and thus ensure training is directly linked to industry needs.

Apprenticeship programs may offer energy efficiency-specific training and credentials embedded in broader occupational training programs. These credentials are embedded in apprenticeship training as one component of the broad and comprehensive foundational training learned over the three to five years of an apprenticeship for each particular occupation. The market value of apprentice programs is linked to the availability of the apprenticeship based on the demand for jobs, which avoids training workers for non-existent jobs. Additional details on the role of apprenticeship in workforce credentialing are provided in Appendix 5D.



Recommendations

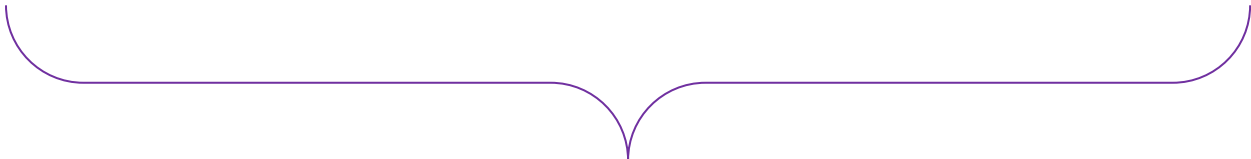
Energy efficiency skills and knowledge should be incorporated into training and credentialing programs for traditional craft occupations and other relevant professions, such as engineering and architecture. In instances in which this approach is not feasible, training may focus on a specific skill area.

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A clear, formal process beginning with a job task analysis should be used to delineate the knowledge, skills, and abilities (KSAs) required for major occupations related to energy efficiency.

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Technical specifications for installation, maintenance, and operations of energy efficiency equipment and systems should be formalized and then mapped to occupations, job task analyses, KSAs, training programs, and certifications.



5.4 Determining Market Value of Workforce Credentialing Programs

Credentials play a key role in identifying a qualified workforce. Frequently, credentials are used as a means of selecting workers for jobs and in enabling workers to demonstrate the currency and job-relatedness of their skills, advance in their field, and increase their compensation. For both employers and workers, credentials can have a high market value. The more employers and workers demand a credential, the greater its market value can become, and the wider its value can reach to the organization that administers it, the industry that supports it, and the consumer who relies on it. The market value of a credential can be assessed by one or several of these variables, and at any given time one indicator of market value may trump others.

There is broad recognition of workforce credentials in the field of energy efficiency, from government agencies, trade associations, and standards developing organizations to educational institutions, manufacturers, distributors, utilities, and the consumer. Each has a stake in the efficient use of energy and the workforce that installs, services, and maintains the systems using the energy. The support of a workforce credential by any of these sectors can also define the market value of a credential.

Stakeholders can define the market value of the credential by considering the following factors relative to industry and/or its workforce:

- *What would happen if the credential did not exist—would errors and accidents occur?*
- *Is the credential linked to industry, and is it job- and/or skills-related?*
- *Are the skills and knowledge current and relevant, and can the student begin working immediately without further training?*
- *How does the credential qualify a workforce?*
- *Who are the end users of the credential—workers, employers, consumers?*
- *Will there be an ongoing need for the credential?*

Recommendations

Credentials should hold demonstrated market value for workers, employers, and consumers.

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The energy efficiency industry and credentialing bodies should jointly market the quality assurances built into credentialing the workforce.

5.5 The Role of Conformity Assessment in Building Confidence in Credentialing Programs

The practices and procedures involved in the daily operation and maintenance of buildings have significant impact on energy performance. Credibility and confidence in the professionals charged with safeguarding the value of building stock, complying with evolving energy codes, and carrying out mission-critical directives to drive down energy use and costs are essential.

A building-trades professional who holds a credential is said to possess distinct qualifications. Personnel certification confirms the competence of individuals to perform specified services or duties. A personnel certification program develops criteria against which an individual needs to demonstrate competencies, and ensures these criteria are held by applicants before certifying them. Just as credential holders are held to standards with regard to skills and ethics, credentialing bodies are held to standards of practice. By placing confidence in the standards and practices of a third-party accredited personnel certification body, stakeholders can save the cost of independently assessing the qualifications of a candidate or the time-intensive work of comparing those qualifications to others. For example, ANSI's and IAS's accreditation programs for personnel certification bodies are based on the international standard ANSI/ISO/IEC 17024: 2012, *Conformity assessment—General requirements for bodies operating certification of persons*. An impartial assessor evaluates the certification process, determining if the examination is evaluating the identified competencies and enhancing consumer and public confidence in a certification program and the person who holds the certification.

The accreditation process is designed to provide assurance that accredited personnel certifiers are accurately assessing the knowledge and skills possessed by professionals, bolstering the mobility of these professionals and industry confidence in the legitimacy and accuracy of these certifications. Third-party accreditation is valuable to consumers, employers, governments, and the industry because it ensures the certification program and its credential have been vetted to meet all established benchmarks for operating a competent and impartial certification program.

Recommendation

Third-party accreditation of energy efficiency credentialing programs by an independent party should be encouraged to ensure that the program has met established benchmarks for operating a competent and impartial credentialing program.

5.6 Programmatic Accreditation for Training

While the accreditation of institutions of higher education and vocational/technical programs is an accepted and critical indicator of quality education in the United States, institutional accreditation does not provide an indicator of the quality of energy efficiency programs. To assure that the technical content delivered meets industry standards, and that the program prepares energy efficiency workers to perform discrete jobs safely and effectively, the next step in credentialing is programmatic accreditation.

A key component of programmatic accreditation is the development of the accreditation standards, including the curricular content, by industry stakeholders. The involvement of industry stakeholders – educators, manufacturers, distributors, contractors, and technicians – results in an industry-supported program and curriculum that covers the knowledge, skills, abilities, attitudes, and tasks each accredited program must deliver, thereby assuring greater consistency in the performance of the graduate and future worker. Additionally, industry sets criteria for the equipment, educators, and program funding needed to support the workforce.

One industry accreditation may not fit all workforce career programs in a given discipline. Therefore, industry partners, even in small groups, may develop more than one accreditation program with the intent of raising the educational bar. Criteria for recognizing any accrediting body shall include evidence that the accrediting body follows an open, transparent, and inclusive process for awarding accreditation.

Recommendations

Energy efficiency training programs should be accredited to technical and programmatic content to assure workers perform jobs safely and effectively. In some cases, the most appropriate accreditation body may exist outside of the current scope of higher education accreditation.

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Energy efficiency training should result in an industry-supported program and curriculum that covers the knowledge, skills, abilities, attitudes, and tasks each accredited program must deliver, thereby assuring greater consistency in the performance of the graduate and future worker.

5.7 Defining the Energy Efficiency Content of Occupations

Energy efficiency is frequently an *aspect* of a job or trade, but not necessarily an occupation in and of itself. Therefore, stakeholders seeking workforce credentials in energy efficiency may not find credentials exclusive to energy efficiency. Stakeholders reviewing workforce credentials for individuals qualified in energy efficiency should review the job task analysis (JTA) upon which certification and certificate programs are based in order to determine if competencies and skills include energy efficiency.

Appendix 5E contains a methodology to assist stakeholders in calculating the energy efficiency content of a credential. The goal of the methodology is to encourage inclusion of relevant energy efficiency content in occupational training or testing, and also to allow students or candidates and their sponsors a way to evaluate energy efficiency content in courses or tests. Furthermore, the methodology should allow clients of courses or tests to evaluate the extent to which appropriate energy efficiency content is included, and how much a career could impact the efficiency of a given building type.

As shown in Appendix 5E, job task analyses from two programs (facility manager and energy/sustainability manager) were analyzed to determine the percentage of the JTA that is energy-related, and how much they could impact the efficiency of a building. The energy/sustainability manager has both greater energy content and greater potential to impact the efficiency of a commercial building than the facility manager. The methodology can be used to rank occupations by both energy content of the JTA and also the potential energy impact the career can have on the energy efficiency of the building types the occupation serves. This information can be used by various stakeholders to determine which careers to focus on when trying to improve the energy efficiency of an organization.

Recommendations

Stakeholders reviewing workforce credentials should review the job task analysis on which the certification or certificate program is based in order to determine if energy efficiency competencies and skills are included.

To better quantify an occupation's actual impact on energy efficiency, a two-step methodology is recommended. Occupations should first be measured and ranked on how much of the job task analysis is related to energy using a comprehensive review of the existing job task analysis. A second measure is an estimation of how much an occupation can impact the overall energy efficiency of the building types the occupation serves. Combined, these two metrics give good indication if an occupation can impact the energy marketplace

5.8 Measuring Outcomes on the Performance of the Credentialed Workforce

The assurance that an individual has the needed competencies is a key goal of credentialing, and the attainment of credentials enables workers to demonstrate their skill set, knowledge, and/or competencies. While this demonstration of competence adds value to the worker, employer, consumer, and benefits industry, the measure of outcomes of credentialing in terms of job-performance and actual energy savings is not always available or calculated. Validation and impact studies with a well-developed methodology, sampling plan, data collection tools, and protocols could help to resolve these issues.

In determining variables of market value, validation and impact studies that calculate energy savings gained by a credentialed workforce performing a job correctly would strengthen the relationship between credentialing and a qualified, effective workforce. There are two key areas of interest for performance outcomes: **validation of the credential** and **energy savings impact** of credential holders.

From a practical standpoint, it is worthwhile to note that these studies are research-intensive and could be costly. Organizations committed to this level of rigor should be prepared to devote the necessary resources to produce meaningful results for assessment of the credential program. Methodologies for conducting an impact study and a credential validation study are provided in Appendix 5F.

1. Credential Validation Study

A validation can help to address the measure of actual performance of an exam.

2. Impact Study

Impact studies aim to quantify the energy and demand impacts attributed to credentialing. Existing methodologies include credential holder surveys and site visits to determine energy impacts through engineering analysis. An evaluation can provide annual energy and demand savings per participant, per square foot, per site address (and/or company), and other aggregate levels.

Recommendations

Outcomes on credentialing should be tied to job performance. Validation studies with a well-developed methodology, sampling plan, data collection tools, and protocols should show the link between the credentialed individual and job performance.

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Validation and impact studies are needed to promote models for credentialing organizations to implement in order to consistently gather and interpret data regarding the effectiveness of the credentialing programs in reducing energy use.

5.9 Summary of Recommendations to Advance Credentialing for the Energy Efficiency Workforce

A qualified workforce has a significant impact on energy performance. Credibility and confidence in the workers charged with safeguarding the value of building stock, complying with evolving energy codes, and carrying out mission-critical directives to drive down energy use and costs is critical. Standards and conformity assessment programs can guide stakeholders in determining energy efficiency practices and the requirements of the workforce to implement them. It is hoped that the issues discussed in this chapter will provide stakeholders with the necessary tools to increase energy performance in their jobs, businesses, and daily lives.

In an effort to advance and improve credentialing for the energy efficiency workforce, the EESCC working group on workforce credentialing puts forth the following overarching recommendations:

Recommendation: Standard and industry-accepted credentialing and workforce terminology should be used to avoid confusion and promote understanding for stakeholders searching for and utilizing conformity assessment programs. *(Section 5.1)*

Recommendation: Indicators of quality credentialing programs should be drawn on to guide stakeholders in selecting standards and conformity assessment schemes. *(Section 5.2)*

Recommendation: Both certifications and certificates for personnel should include assessment of attainment of competencies and skills. *(Section 5.2)*

Recommendation: State and federal agencies should recognize accredited credentialing programs. *(Section 5.2)*

Recommendation: Energy efficiency skills and knowledge should be incorporated into training and credentialing programs for traditional craft occupations and other relevant professions, such as engineering and architecture. In instances in which this approach is not feasible, training may focus on a specific skill area. *(Section 5.3)*

Recommendation: A clear, formal process beginning with a job task analysis should be used to delineate the knowledge, skills, and abilities (KSAs) required for major occupations related to energy efficiency. *(Section 5.3)*

Recommendation: Technical specifications for installation, maintenance, and operations of energy efficiency equipment and systems should be formalized and then mapped to occupations, job task analyses, KSAs, training programs, and certifications. *(Section 5.3)*

Recommendation: Credentials should hold demonstrated market value for workers, employers, and consumers. *(Section 5.4)*

Recommendation: The energy efficiency industry and credentialing bodies should jointly market the quality assurances built into credentialing the workforce. *(Section 5.4)*

Recommendation: Third-party accreditation of energy efficiency credentialing programs by an independent party should be encouraged to ensure that the program has met established benchmarks for operating a competent and impartial credentialing program. *(Section 5.5)*

Recommendation: Energy efficiency training programs should be accredited to technical and programmatic content to assure workers perform jobs safely and effectively. In some cases, the most appropriate accreditation body may exist outside of the current scope of higher education accreditation. *(Section 5.6)*

Recommendation: Energy efficiency training should result in an industry-supported program and curriculum that covers the knowledge, skills, abilities, attitudes, and tasks each accredited program must deliver, thereby assuring greater consistency in the performance of the graduate and future worker. *(Section 5.6)*

Recommendation: Stakeholders reviewing workforce credentials should review the job task analysis on which the certification or certificate program is based in order to determine if energy efficiency competencies and skills are included. *(Section 5.7)*

Recommendation: To better quantify an occupation's actual impact on energy efficiency, a two-step methodology is recommended. Occupations should first be measured and ranked on how much of the job task analysis is related to energy using a comprehensive review of the existing job task analysis. A second measure is an estimation of how much an occupation can impact the overall energy efficiency of the building types the occupation serves. Combined, these two metrics give good indication if an occupation can impact the energy marketplace. *(Section 5.7)*

Recommendation: Outcomes on credentialing should be tied to job performance. Validation studies with a well-developed methodology, sampling plan, data collection tools, and protocols should show the link between the credentialed individual and job performance. *(Section 5.8)*

Recommendation: Validation and impact studies are needed to promote models for credentialing organizations to implement in order to consistently gather and interpret data regarding the effectiveness of the credentialing programs in reducing energy use. *(Section 5.8)*

Appendix 5A: Reference Documents for Terminology¹⁵³

Reference Document	Scope/Description
<p>ASTM E2708-10, <i>Standard Terminology for Personnel Credentialing</i></p>	<p>This terminology defines terms related to the credentialing of persons. These terms are offered to enable the development of future ASTM documents relating to personnel certificate and certification programs. The source document for each definition is cited when an appropriate document is available. Many definitions are the product of the committee that compiled this terminology, and as such, are the result of the collected knowledge and experience of the committee members. Since credentialing of persons is being carried out by many different bodies in many career fields, usage of descriptive terms can vary. There is no attempt to include all credentialing terms in this terminology. Rather, this terminology contains those terms most commonly encountered in the credentialing process.</p>
<p>ASTM E2659-09, <i>Standard Practice for Certificate Programs</i></p>	<p>ASTM E2659-09 specifies general terms and definitions relating to the accreditation of certificate issuers to develop and administer quality certificate programs and to stakeholders for determining the quality of certificate programs. The standard includes the requirements for both the entity issuing the certificate and requirements for the specific certificate programs for which it issues certificates, and provides the foundation for the recognition or accreditation or both of a specific entity to issue a specific certificate or certificates to individuals after successful completion of a certificate program.</p>
<p>ASTM E2849-13, <i>Standard Practice for Professional Certification Performance Testing</i></p>	<p>This practice for performance testing provides guidance to performance test sponsors, developers, and delivery providers for the planning, design, development, administration, and reporting of high-quality performance tests. This practice assists stakeholders from both the user and consumer communities in determining the quality of performance tests. This practice includes requirements, processes, and intended outcomes for the entities that are issuing the performance test, developing, delivering, and evaluating the test, users and test takers interpreting the test, and the specific quality characteristics of performance tests. This practice provides the foundation for both the recognition and accreditation of a specific entity to issue and use effectively a quality performance test. Accreditation agencies are presently evaluating performance tests with criteria that were developed primarily or exclusively for multiple-choice examinations. The criteria by which performance tests shall be evaluated and accredited are ones appropriate to performance testing. As accreditation becomes more critical for acceptance by federal and state governments, insurance companies, and international trade, it becomes more critical that appropriate standards of quality and application be developed for performance testing. This practice covers both the professional certification performance test itself and specific aspects of the process that</p>

¹⁵³ Unless noted with an asterisk, * information on these documents is also available in the EESCC Inventory Database: <http://toolswiki.ansi.org/tiki-index.php?page=EESCCTabs>.

	<p>produced it. This practice does not include management systems. In this practice, the test itself and its administration, psychometric properties, and scoring are addressed. This practice primarily addresses individual professional performance certification examinations, although it may be used to evaluate exams used in training, educational, and aptitude contexts. This practice is not intended to address on-site evaluation of workers by supervisors for competence to perform tasks.</p>
<p>ISO/IEC 17000:2004, <i>Conformity assessment—Vocabulary and general principles</i></p>	<p>ISO/IEC 17000:2004 specifies general terms and definitions relating to conformity assessment, including the accreditation of conformity assessment bodies, and to the use of conformity assessment to facilitate trade. A description of the functional approach to conformity assessment is included as a further aid to understanding among users of conformity assessment, conformity assessment bodies, and their accreditation bodies, in both voluntary and regulatory environments. ISO/IEC 17000:2004 does not set out to provide a vocabulary for all of the concepts that may need to be used in describing particular conformity assessment activities. Terms and definitions are given only where the concept defined would not be understandable from the general language use of the term or where an existing standard definition is not applicable.</p>
<p>ISO/IEC TS 17027:2014, <i>Conformity assessment—Vocabulary related to competence of persons used for certification of persons*</i></p>	<p>ISO/IEC TS 17027:2014 specifies terms and definitions related to the competence of persons used in the field of certification of persons, in order to establish a common vocabulary. These terms and definitions can also be used as applicable in other documents specifying competence of persons, such as regulations, standards, certification schemes, research, training, licensing and registration.</p>
<p>ISO/IEC 17024:2012, <i>Conformity Assessment—General requirements for bodies operating certification of persons</i></p>	<p>ISO/IEC 17024:2012 specifies general terms and definitions relating to certification of persons, as well as the requirements for a body certifying persons against specific requirements, and includes the development and maintenance requirements of the certification scheme for persons. Terminology includes certification process, certification scheme, certification requirements, and certificate.</p>

Appendix 5B: Reference Documents for Guidance on Credentialing Programs¹⁵⁴

Document	Scope/Description
ISO/IEC 17024: 2012 , <i>Conformity assessment—General requirements for bodies operating certification of persons</i>	ISO/IEC 17024:2012 contains principles and requirements for a body certifying persons against specific requirements, and includes the development and maintenance of a certification scheme for persons.
ST10 ICE 1100 2010 (E) , <i>Standard for Assessment-Based Certificate Program</i>	The standard specifies essential requirements for certificate programs and provides guidance to program providers, consumers, and others on what defines a high-quality program.
ASTM E2833 , <i>Standard Practice for Certification Bodies that Certify Personnel Engaged in Inspection and Testing of Construction Activities and Materials Used in Construction, Including Special Inspection</i>	This practice provides supplemental requirements to those of ANSI/ISO/IEC 17024 for bodies that certify personnel engaged in inspection and testing of construction activities and materials used in construction, including special inspection. ANSI/ISO/IEC 17024 provides generic requirements that can be adapted to any discipline where assurance that certified individual meets the requirements of the certification scheme. Therefore, certification bodies certifying personnel engaged in inspection and testing of construction activities and materials used in construction, including special inspection, must meet the requirements of this practice and ANSI/ISO/IEC 17024.
ASTM E2659-09 , <i>Standard Practice for Certificate Programs</i>	This practice provides guidance to certificate issuers for developing and administering quality certificate programs and to stakeholders for determining the quality of certificate programs. This practice includes requirements for both the entity issuing the certificate and requirements for the specific certificate programs for which it issues certificates. This practice provides the foundation for the recognition or accreditation or both of a specific entity to issue a specific certificate or certificates to individuals after successful completion of a certificate program. This practice does not address guidance pertaining to certification of individuals nor does it address guidance pertaining to education or training programs in general, including those that issue certificates of participation or certificates of attendance.
IAS - International Accreditation Service, Inc. AC371 , <i>Accreditation Criteria for Training Agencies for Work Force Qualification Programs</i>	These criteria set forth requirements for obtaining and maintaining International Accreditation Service, Inc. (IAS) accreditation for non-degree-granting training agencies for adult education for work force qualification programs, and to certificates which may be issued by these agencies to successful participants.
IAS - International Accreditation Service, Inc. AC372 , <i>Accreditation Criteria for Curriculum Development for Work Force Qualification Programs</i>	These criteria set forth requirements for obtaining and maintaining International Accreditation Service, Inc. (IAS) accreditation for curriculum development for work force qualification programs. The scope of these criteria does not extend to users of approved curricula (training schools).

¹⁵⁴ Unless noted with an asterisk*, information on these documents is also available in the EESCC Inventory Database: <http://toolswiki.ansi.org/tiki-index.php?page=EESCCTabs>.

<p>IAS – International Accreditation Service, Inc., AC476, Accreditation Criteria for Organizations Providing Training and/or Certification of Commissioning Personnel</p>	<p>The purpose of the criteria is to develop an accreditation protocol for organizations providing training and/or certification of commissioning personnel. Personnel involved in commissioning may include commissioning providers or commissioning specialists. Accreditation to these criteria will assist the authority having jurisdiction (AHJ) in ensuring competency of commissioning providers.</p>
<p>IREC (Interstate Renewable Energy Council, Inc.) Standard 01023:2013, General Requirements for the Accreditation of Clean Energy Technology Training</p>	<p>This standard identifies requirements for the quality systems, resources, personnel, and curriculum by which job-related training in clean energy technologies and practices may be accredited. For the purposes of this standard, clean energy technologies and practices include renewable energy, energy efficiency, distributed renewable energy generation, and other sustainability practices.</p>
<p>IREC Standard 01024:2013, General Requirements for the Certification of Clean Energy Technology Instructors and Master Trainers</p>	<p>This standard establishes requirements for the instructional and professional field experience, subject-matter expertise, and instructional quality by which instructors and master trainers in clean energy technologies and practices may become certified. For the purposes of this standard, clean energy technologies and practices include renewable energy, energy efficiency, distributed renewable energy generation, and other sustainability practices.</p>
<p>IREC Standard 14732:2013, General Requirements for Renewable Energy & Energy Efficiency Certificate Programs</p>	<p>This standard forms the foundation for the accreditation of certificate-awarding entities that develop and administer credit or non-credit energy efficiency and renewable energy-related programs offered in formal educational institutions and other legal entities. For the purposes of this standard, energy efficiency is defined as the result of efforts to reduce the amount of energy consumed in producing a service, product, or condition. Renewable energy constitutes wind, solar, geothermal, bioenergy, hydrogen, non-conventional hydro, and renewable fuels. This standard provides the accreditation requirements that energy efficiency and renewable energy programs must meet and document to earn and maintain accreditation. The purpose of accreditation is to determine whether the program meets the requirements for issuing a market-valued certificate. This standard does not address requirements for the certification of individual practitioners, educators, or trainers in energy efficiency and renewable energy programs. Organizations shall abide by local, state, and federal regulatory requirements. This standard is not intended to supersede any codes, requirements, or regulation.</p>
<p>ANSI/IACET Standard for Continuing Education and Training</p>	<p>The ANSI/IACET Standard for Continuing Education and Training defines a proven model for developing effective and valuable continuing education and training (CE/T) programs. Because the Standard focuses on <i>how</i> learning programs are developed, not <i>what</i> they cover, it provides a framework of best practices that can be applied across disciplines and industries.</p>
<p>Distance Education and Training Council - DETC Publications*</p>	<p>The Distance Education and Training Council offers a number of publications on its website. (http://www.detc.org/publications/index.html)</p>

<p>Registered Apprenticeships Requirements*</p>	<p>The Registered Apprenticeship system provides an opportunity for workers seeking high-skilled, high-paying jobs and for employers seeking to build a qualified workforce. The U.S. Department of Labor regulates apprenticeship programs at the national level according to federal regulations that set standards for establishing and registering apprenticeship programs.¹⁵⁵ State laws also regulate apprenticeship and these standards are fairly similar among states with such laws. In California, for example, the Division of Apprenticeship Standards (DAS) administers California apprenticeship law and enforces apprenticeship standards for wages, hours, working conditions, and specific skills required for state certification as a journey person in an occupation that has apprenticeships.¹⁵⁶ (http://www.doleta.gov/oa/)</p>
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¹⁵⁵ Federal Register, Vol. 73, No. 210, “29 CFR Part 29 Apprenticeship Programs, Labor Standards for Registration, Amendment of Regulations; Final Rule” October 29, 2008, <http://www.doleta.gov/OA/pdf/FinalRule29CFRPart29.pdf>, and U.S. Department of Labor, Employment and Training Administration, “Labor Standards for the Registration of Apprenticeship Programs (Title 29, CFR Part 29),” October 29, 2008, <http://www.doleta.gov/OA/regulations.cfm>.

¹⁵⁶ State of California Department of Industrial Relations, “Overview of DAS,” accessed May 2014, http://www.dir.ca.gov/das/DAS_overview.html.

Appendix 5C: Additional Reference Documents and Initiatives¹⁵⁷

Document	Scope/Description
<p>IREC Job Task Analysis Guidance Document</p> <p>For use with IREC Standard 14732:2013 and IREC Standard 01023:2013</p>	<p>This document is intended to provide guidance for conformity with IREC Standard 14732:2013, <i>General Requirements for Renewable Energy & Energy Efficiency Certificate Programs</i>, and IREC Standard 01023:2013, <i>General Requirements for the Accreditation of Clean Energy Technology</i>, in particular, to assist training organizations in developing and/or selecting a job task analysis (JTA) from which to form the basis of their curriculum or syllabus. This guidance document does not prescribe specific methodologies for conducting job task analysis studies. Rather, it provides guidance on key elements applicant organizations should consider, whether they use an existing JTA, or elements of an existing JTA upon which to base their education/training curricula, or choose to develop a JTA themselves. Therefore, an overview of key elements considered “acceptable” JTA practices have been outlined below to help applicant organizations determine if the JTA being utilized or developed as the foundation for their curricula in clean energy technology meets the requirements of the applicable standard.</p>
<p>Public Guidance PCAC-GI-502, Guidance on Psychometric Requirements for ANSI Accreditation</p>	<p>This document has been developed to provide guidance about compliance with psychometric requirements of ANSI/ISO/IEC 17024, <i>Conformity Assessment—General Requirements for Bodies Operating Certification of Persons</i>, to certification bodies interested in ANSI accreditation. It does not prescribe specific statistics that should be computed and displayed or specific procedures/methods to be used. Rather, it emphasizes classes of methods and procedures, types of analyses, and how they are applied, as a basis for the accreditation standards in ANSI/ISO/IEC 17024 (Section 4.3.6).</p>
<p>U.S. Department of Labor, Credential Resource Guide, December 2010*</p>	<p>The purpose of this Credential Resource Guide is to provide information on the types of credentials available to workforce program participants and explain how they can acquire and leverage these credentials to build lasting careers. (http://wdr.doleta.gov/directives/attach/TEGL15-10a2.pdf)</p>
<p>Better Buildings Workforce Guidelines Project</p>	<p>Under the Better Buildings Workforce Guidelines project, the U.S. Department of Energy and the National Institute of Building Sciences (NIBS) have convened industry stakeholders to develop voluntary national guidelines to improve the quality and consistency for commercial building workforce credentials for five key energy efficiency jobs:</p> <ul style="list-style-type: none"> • Building Energy Auditor • Building Commissioning Professional • Energy Manager • Building Operations Professional • Facility Manager (Focus on Federal Buildings Personnel Training Act) <p>A committee of subject matter experts will produce an industry-validated job task analysis (JTA), outlining key duties, tasks, knowledge, skills, and abilities. Based on the JTA, each committee will develop guidelines.</p>

¹⁵⁷ Unless noted with an asterisk, * information on the documents listed here can also be found in the EESCC Inventory Database: <http://toolswiki.ansi.org/tiki-index.php?page=EESCCTabs>.

	<p>For competency-based professional certifications, the guidelines will consist of validated JTAs along with certification schemes identifying eligibility criteria and prerequisites, exam structures, recertification requirements, and other elements for qualified industry certification bodies to use to develop performance-based assessments, write test questions, screen candidates, administer examinations, and confer certification.</p> <p>For assessment-based certificate programs, the guidelines will include content outlines and learning objectives derived from the validated JTAs. Certificate program providers can use these guidelines to inform curriculum development and approaches to instructional delivery, and to measure whether learning objectives are being met. Third-party accreditation for certification and certificate programs is an intrinsic component of the project and will be a requirement under certain federal programs. When complete, the guidelines will be available for adoption by certification and certificate program providers, enabling them to develop new or revised high quality, industry-endorsed, and nationally-recognized credentials.</p>
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Appendix 5D: Apprenticeships

The most common type of apprenticeship program is the Joint Apprenticeship Committee (JAC) or Joint Apprenticeship and Training Committee (JATC), sponsored by a collaborative arrangement between an employer association (or single large employer) and a labor union. The Plant Standard or Unilateral Apprenticeship Committee (UAC), sponsored by a single employer or trade association, is a less common type of program; unilateral programs generally graduate fewer apprentices.

Federal and state standards help to ensure the quality and consistency of apprenticeship programs, which can vary widely without regulation. The U.S. Department of Labor (DOL) regulates apprenticeship programs at the national level according to federal regulations that set standards for establishing and registering apprenticeship programs.¹⁵⁸ DOL or a State Apprenticeship Agency provides assistance identifying training needs, developing apprenticeship standards, and developing apprentice recordkeeping systems, among other services. State laws also regulate apprenticeship, and these standards are fairly similar among states with such laws. In California, for example, the Division of Apprenticeship Standards (DAS) administers California apprenticeship law and enforces apprenticeship standards for wages, hours, working conditions, and the specific skills required for state certification as a journeyman in an occupation that has apprenticeships.¹⁵⁹

There are roughly 9,000 DOL Registered Apprenticeship programs training and credentialing workers across the U.S. for the occupations most closely related to energy efficiency in major building systems including electrical, mechanical, and building envelope systems. This estimate is derived by analyzing DOL Registered Apprenticeships¹⁶⁰ (as of the end of FY 2012) that correspond to selected occupations for the energy efficiency and green construction sectors, as listed in the O-NET online database.¹⁶¹ This is a rough estimate intended to provide a snapshot of the national landscape for apprenticeship, and does not include or compare apprenticeship programs approved at the state-level, where applicable.¹⁶² Apprenticeship programs provide solid outcomes and returns on investment for both employers and workers. From workers' perspective, indicators of quality apprenticeship programs include high graduation/completion rates, high job placement rates, and career pathway development (such as wage progressions and credentials). It is more difficult to measure the productivity gains or market advantage that employers receive from investments in training, but some indicators include lower turnover, market recognition of worker credentials, employers' willingness to continue to invest in training, and quality work that delivers the full potential of energy efficiency savings.

¹⁵⁸ Federal Register, Vol. 73, No. 210, "29 CFR Part 29 Apprenticeship Programs, Labor Standards for Registration, Amendment of Regulations; Final Rule," (October 29, 2008): <http://www.doleta.gov/OA/pdf/FinalRule29CFRPart29.pdf> and U.S. Department of Labor, Employment and Training Administration, "Labor Standards for the Registration of Apprenticeship Programs (Title 29, CFR Part 29)," (October 29, 2008): <http://www.doleta.gov/OA/regulations.cfm>.

¹⁵⁹ State of California Department of Industrial Relations, "Overview of DAS," accessed May 2014, http://www.dir.ca.gov/das/DAS_overview.html.

¹⁶⁰ U.S. Department of Labor, Employment and Training Administration, "Available Occupations," accessed May 2014, <http://www.doleta.gov/OA/occupations.cfm>.

¹⁶¹ O-NET Online is available at <http://www.onetonline.org/find/green>.

¹⁶² U.S. Department of Labor, Employment and Training Administration, "State Apprenticeship Information" accessed May 2014, <http://www.doleta.gov/oa/sainformation.cfm>.

Appendix 5E: Defining the Occupation of Energy Efficiency

The goal of the methodology described in this appendix is to develop metrics to determine the impact of an occupation on the building efficiency marketplace, as well as to:

- Encourage inclusion of appropriate energy efficiency content in occupational training or testing
- Allow students or candidates and their sponsors to evaluate energy efficiency content in courses or tests
- Allow clients of courses or tests to evaluate the extent to which appropriate energy efficiency content is included
- Gauge the impact of a profession on how much it could impact the energy efficiency of a given type of building

PROPOSED METHODOLOGY

To better quantify an occupation's actual impact on energy efficiency, a two-step methodology is recommended. First, occupations should be measured and ranked by the energy content (EC) of the job task analysis (JTA). Second, occupations should be measured by how much an occupation can impact the overall energy efficiency of the building types the occupation serves, or its potential energy impact (PEI). Combined, these two metrics give good indication if an occupation can impact the energy marketplace.

Note: PEI may be different for residential/commercial/industrial/public buildings.

- **Methodology:**
 - i. Rate (qualitatively) how much a given domain in JTA is related to energy efficiency (percent wise), then multiply this by the already established weighting percent of that domain. Add these numbers to determine how much the JTA is energy-related (EC from 0-100 percent).

Note: This may have to be done separately for different building sector types, depending on the occupation (residential/commercial/industrial/public buildings).

- ii. Rate (quantitatively) how much this career could impact the building types the occupation serves (PEI with scale of 1-10). This rating would depend on how much the occupation can affect the energy efficiency of a given building type. As an example, a janitor would have less impact than an energy manager on the efficiency of a commercial office building. Again, different ratings might apply to different building types.
- iii. Report a dual score of: (1) how much the career is energy-related; and (2) how much the career can impact the efficiency of buildings.

REVIEWS OF TWO ENERGY EFFICIENCY ROLES

Following are reviews of two roles in the commercial building sector: facility manager and energy/sustainability manager. A comprehensive JTA was developed for each by DOE. These evaluations

were done solely to demonstrate the feasibility of this methodology; they are not to be considered authoritative.

Example 1, Facility Manager

A facility manager is a building maintenance specialist and property administrator who conducts building operations and maintenance activities, coordinates facility programs and projects, and supervises building personnel by inspecting the facility, analyzing building data, forecasting future needs, solving problems, and communicating with others. A facility manager ensures the efficient and sustainable operations of the facility and the satisfaction of the facility occupants. Energy efficiency/management skills/topics are a somewhat important part of a facility manager’s career, but represent a somewhat small fraction of the overall skills/topics needed (estimated at 15-25 percent). This person is responsible for managing the facility as a whole, and is responsible for a diverse range of responsibilities, from safety to janitorial/grounds maintenance to developing budgets:

- Managing facility operations and maintenance (O&M) programs
- Managing people/personnel
- Managing other internal/external facility programs
- Managing facility projects
- Managing facility finances
- Conducting strategic planning activities
- Managing facility assets
- Managing facility resources

Parts of each of these topics relate to energy efficiency/management, but it is not a major focus of any of them. Nevertheless, this career does have a fairly large potential to impact the energy efficiency of a commercial office building (PEI is estimated 5 on a scale of 1-10, especially if the organization does not have a regional/corporate energy/sustainability manager). A certification program could be developed just for the energy efficiency/management skills/topics for a facility manager. It would be much smaller in scope compared to a full program for a facilities manager. In the table below, En % is the percentage of the task that is estimated to be energy related. The energy content (EC) is the task weighting multiplied by the En %.

FACILITY MANAGER EXAMPLE

Duties and Tasks	Weighting	En %	EC
A Managing Facility O&M Programs	32%	25%	8%
B Managing People/Personnel	15%	5%	1%
C Managing Other Internal/External Facility Programs	15%	20%	3%
D Managing Facility Projects	10%	25%	3%
E Managing Facility Finances	11%	20%	2%
F Conducting Strategic Planning Activities	5%	20%	1%
G Managing Facility Assets	7%	20%	1%
H Managing Facility Resources	5%	15%	1%
	100%	Total	20%

Example 2, Energy/Sustainability Manager

An energy/sustainability manager monitors energy and material usage in facilities by performing site audits and conducting energy and sustainability analyses to identify opportunities to increase building efficiencies, promote renewable resources, and minimize the social, environmental, and financial impacts of an organization's operation. For an energy/sustainability manager, almost every skill/topic associated with the career relates to energy efficiency/management (estimated at 90 percent). The following are the major domains:

- Developing strategic plans (related to energy efficiency/management)
- Performing site audits (related to energy efficiency/management)
- Performing energy and sustainability accounting and analysis
- Improving energy efficiency and sustainability
- Communicating with others (about energy efficiency/management)

Each of these focuses almost exclusively on energy efficiency/management. This career has a large potential to impact the energy efficiency of a commercial building (PEI is estimated 8 on a scale of 1-10). In the table below, En % is the percentage of the task that is estimated to be energy related. The energy content (EC) is the task weighting multiplied by the En %.

ENERGY MANAGER EXAMPLE

Duties and Tasks		Weighting	En %	EC
A	Developing Strategic Plans	26%	85%	22%
B	Performing Site Audits	18%	90%	16%
C	Performing Energy and Sustainability Accounting and Analysis	22%	95%	21%
D	Improving Energy Efficiency and Sustainability	22%	95%	21%
E	Communicating with Others	12%	80%	10%
		100%	Total	90%

Appendix 5F: Measuring Outcomes on the Performance of the Credentialed Workforce

METHODOLOGY FOR CREDENTIAL VALIDATION STUDY

A methodology for conducting a credential validation study is provided below:

1. Create two versions of energy efficiency credentials for jobs with high PEI (potential energy impact). Some jobs, like building architect, purchasing agent, or energy architect, have a high impact on the energy efficiency of the building they are constructing (= high PEI). Other credentialed workers, like roofers, window installers, and cement layers, have less direct impact on the building energy efficiency, even though what they do actually impacts the building tremendously.
2. Create criterion measures of the energy measures these credentials impact.
3. Evaluate 200 people employed with this credential.
4. Select the 100 with the highest contrast between their performance and written test scores.
5. Evaluate the 100 selected in terms of their energy performance on the job.
6. See which test (written or performance) better predicts energy efficiency on the job.
7. Use the results of several of these studies to predict energy performance resulting from the two test types.
8. Create incentives to use the most effective test type.

METHODOLOGY FOR IMPACT STUDY

Annual gross energy and demand impacts may be estimated through the following data type collection efforts and appropriate engineering analysis. These details provide a simplified view of the main activities and should not be considered all inclusive of the activities conducted in an impact evaluation.

1. **Participant Survey via Internet:** Field an internet survey to a census of credential holder population. The survey will gather data to identify and collect detailed inputs needed for engineering analysis.
2. **Secondary Data Review:** To support the engineering analysis, draw upon data collected in the internet survey.
3. **Site Visits:** To enhance the rigor of estimates and reduce respondent burden, conduct site visits on the population of survey respondents to verify actions taken and collect additional data required for selected measures.

NEXT STEPS FOR THE EESCC ROADMAP

Energy efficiency is a complex, cross-cutting issue that impacts all industry sectors, government policy, and consumers alike. While this roadmap represents a specific snapshot in time, it is envisioned as an ongoing effort that will evolve in tandem with market and standardization needs. The aim is to help guide, coordinate, and enhance the standardization landscape to support energy efficiency in the United States.

This roadmap will be widely promoted, and its recommendations are expected to see broad adoption and implementation. Looking forward, the EESCC will monitor implementation of the roadmap's recommendations, follow updates on work to close identified gaps, and create a mechanism by which this information can be broadly shared. It is envisioned that a future report will highlight progress to close gaps and provide an update on new developments and updates. The EESCC will work with relevant groups, as appropriate, to ensure gaps are addressed, and facilitate coordination and collaboration among domestic, regional, and international standardization activities.

Closing Standardization Gaps: A Call for Action

Organizations intending to carry out standardization work to close a gap identified in this roadmap are asked to **notify the EESCC**¹⁶³ so that the collaborative can monitor the roadmap's implementation and assist with coordination of standardization activities, as appropriate.

¹⁶³ Complete the online **EESCC Standardization Action Form** at www.ansi.org/eesc.



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ROADMAP APPENDIX A: SUMMARY OF GAPS/RECOMMENDATIONS

RECOMMENDED TIMELINES: NEAR-TERM (0-2 YEARS); MID-TERM (2-5 YEARS); LONG-TERM (5+ YEARS).

Chapter	Issue Area	Section	Gap/Recommendation	Recommended Timeline
Chapter One: Building Energy and Water Assessment and Performance Standards	Water-Energy Nexus	1.1	<p>A. Standards that address supply chain- and product- embedded water–energy evaluations</p> <p>There is a need for standards that address supply chain- and product-embedded water–energy evaluations that can inform consumers of the energy and water intensity of the building systems, products, or services they buy. There is currently no recognized consistent methodology for the way building systems, products, and services are evaluated for their overall water and energy footprint. Architects, engineers, consumers, and companies wishing to proactively reduce their water and energy intensity often receive mixed messages as a result.</p> <p>Developing uniform standards that address the water and energy embedded in a system’s or product’s supply chain would: (1) provide a needed consistent method that would allow proper cross-comparison of options for products and services; (2) smooth out the duplicative and competing footprint methodologies, some of which unfairly favor certain companies, processes, or products, and most of which do not correctly count both water and energy interactions back through the supply chain; and (3) allow a deeper focus on systems, products, and services in the commercial and industrial sectors where the combined water and energy savings potential is very high.</p>	While work should begin as soon as possible, this is a complex issue and is therefore a long-term effort: 5+ years.
Chapter One: Building Energy and Water Assessment and Performance Standards	Water-Energy Nexus	1.1	<p>B. Water and energy industry-accepted EM&V protocols</p> <p>There is a need for water and energy industry-accepted evaluation, measurement, and verification (EM&V) protocols that can be utilized by standards developers to help make determinations on provisions where water and energy tradeoffs exist. Detailed EM&V protocols already exist for analyzing energy efficiency performance, but these protocols need to be revised to properly address the embedded energy savings emanating from water conservation and management programs. To date, only savings from hot water conservation programs have been included in these evaluation protocols. Interactive water and energy savings need to be properly documented where they occur, and greenhouse gas emission reduction calculation methodologies need to be revised to correctly recognize the contributions coming from the saved embedded energy in water supply, treatment, pumping, and consumer end use consumption.</p>	While work should begin as soon as possible, this is a complex issue and is therefore a long-term effort: 5+ years.
Chapter One: Building Energy and Water Assessment and Performance Standards	Building Envelope	1.2	<p>A. Window installation guidance for effective energy, air, and moisture management</p> <p>Within the building envelope, windows are often the most common source of heat loss, heat gain, and air leakage – often due to deficits in detailing and installation. Proper window installation is necessary to manage the heat transfer, air leakage, and water management in the building envelope. While activities are currently underway at ASTM and elsewhere, significant effort is needed to develop and deliver meaningful window installation guidance that could be adopted into voluntary programs as well as incorporated into building codes. In the field, training is needed with a specific focus on replacement window installation to deliver effective energy, air, and moisture management.</p>	These activities should be conducted in the near-term: 0-2 years.

Chapter	Issue Area	Section	Gap/Recommendation	Recommended Timeline
Chapter One: Building Energy and Water Assessment and Performance Standards	Building Envelope	1.2	<p>B. Lifecycle valuation of envelope improvements</p> <p>All energy efficiency options must be considered when evaluating portfolios of materials, technologies, and methods in construction. There is currently a deficit in service life considerations as applied to total energy efficiency, particularly with regard to the long-term durability and performance of the building envelope. The building envelope is often undervalued because its permanence in the structure is not reflected in immediate resource savings. As codes and standards evolve, a life cycle assessment (LCA) methodology for valuing options should be given further consideration and should be included, where possible.</p>	These activities should be conducted in the mid-term: 2-5 years.
Chapter One: Building Energy and Water Assessment and Performance Standards	Building Envelope	1.2	<p>C. Standards that evaluate insulation materials performance in reducing heat flow under dynamic conditions</p> <p>The current industry accepted standard, ASTM C-518, is a static test (steady-state) at one temperature that does not represent actual in-field conditions and material performance. A dynamic test standard is needed that accounts for a material's resistance to heat transfer and a material's heat capacity at a range of temperatures, relative humidity (%RH), and air flow infiltration rates through a material.</p>	This work should be conducted in the near-term: 0-2 years.
Chapter One: Building Energy and Water Assessment and Performance Standards	Building Envelope	1.3	No gap	N/A
Chapter One: Building Energy and Water Assessment and Performance Standards	Cooling Systems	1.4	<p>A. Standards for energy performance</p> <p>The codes and standards related to the energy performance of individual air-conditioning and cooling systems are well defined. Establishing independently developed performance metrics that specify the cost and efficiency benefits of the overall performance of integrated air-conditioning and cooling systems would enhance the basis in which architects, designers, engineers, and builders incorporate these systems in residential, commercial, and industrial applications. ASHRAE is looking at this issue for potential inclusion in Standard 90.1-2016 for commercial and multi-family residential buildings over three stories.</p>	This work should be conducted in the mid-term: 2-5 years.
Chapter One: Building Energy and Water Assessment and Performance Standards	Cooling Systems	1.4	<p>B. Standards for integrated control</p> <p>Control standards for integrated air-conditioning and cooling systems are needed so that the performance and use of the systems can be optimally controlled. ASHRAE is looking at this issue for potential inclusion in Standard 90.1-2016 for commercial and multi-family residential buildings over three stories.</p>	This work should be conducted in the mid-term: 2-5 years.

Chapter	Issue Area	Section	Gap/Recommendation	Recommended Timeline
Chapter One: Building Energy and Water Assessment and Performance Standards	Cooling Systems	1.4	<p>C. Standards for building air leakage testing (unique for various building types)</p> <p>Test methods for measuring the air leakage rates of a building envelope have been established for many years. In recent history, the level of interest associated with this area of building construction (e.g., green program requirements, commissioning requirements) has sizably grown due to the establishment and refinement of green, sustainable, and high performance energy codes and standards. The current methods only apply a single standard to all building categories and thus, do not address the complexities and difficulties that are present within the array of structure types. In order to recognize each structure’s applicable limitations, it is recommended that unique standards be developed for the various building construction types.</p>	This work should be conducted in the mid-term: 2-5 years.
Chapter One: Building Energy and Water Assessment and Performance Standards	Cooling Systems	1.4	<p>D. Partial load efficiencies for variable speed equipment</p> <p>Air conditioning and cooling systems are sized to meet design conditions that occur at their rated, peak efficiencies (i.e., full load or capacity); however, in most instances, these systems only operate at partial load or capacity. For equipment that is able to vary its output capacity, efficiencies are needed that specify the systems’ optimal conditions at partial load.</p>	This work should be conducted in the near-term: 0-2 years.
Chapter One: Building Energy and Water Assessment and Performance Standards	Heating Systems	1.5	<p>A. Standards for energy performance</p> <p>The codes and standards related to the energy performance of individual heating systems are well defined. Establishing independently developed performance metrics that specify the cost and efficiency benefits of the overall performance of integrated heating systems would enhance the basis in which architects, designers, engineers, and builders incorporate these systems in residential, commercial, and industrial applications. ASHRAE is looking at this issue for potential inclusion in Standard 90.1-2016 for commercial and multi-family residential buildings over three stories.</p>	This work should be conducted in the mid-term: 2- 5 years.
Chapter One: Building Energy and Water Assessment and Performance Standards	Heating Systems	1.5	<p>B. Standards for integrated control</p> <p>Control standards for integrated heating systems are needed so that the performance and use of the systems can be optimally controlled. ASHRAE is looking at this issue for potential inclusion in Standard 90.1-2016 for commercial and multi-family residential buildings over three stories.</p>	This work should be conducted in the mid-term: 2- 5 years.
Chapter One: Building Energy and Water Assessment and Performance Standards	Heating Systems	1.5	<p>C. Rating system for radiant windows</p> <p>Radiant windows are increasingly being used for various heating applications in buildings. In addition to interior space heating applications, radiant windows are also being used to control the build-up of ice and snow on high-rise buildings. A standards development activity is needed to develop a consensus based rating system for radiant windows that will allow specifiers to compare the energy efficiency levels of various models.</p>	This activity should be conducted in the near-term: 0- 2 years.

Chapter	Issue Area	Section	Gap/Recommendation	Recommended Timeline
Chapter One: Building Energy and Water Assessment and Performance Standards	Heating Systems	1.5	<p>D. Standards for building air leakage testing (unique for various building types)</p> <p>Test methods for measuring the air leakage rates of a building envelope have been established for many years. In recent history, the level of interest associated with this area of building construction (e.g., green program requirements, commissioning requirements) has sizably grown due to the establishment and refinement of green, sustainable, and high performance energy codes and standards. The current methods only apply a single standard to all building categories and thus, do not address the complexities and difficulties that are present within the array of structure types. In order to recognize each structure’s applicable limitations, it is recommended that unique standards be developed for the various building construction types.</p>	This activity should be conducted in the mid-term: 2-5 years.
Chapter One: Building Energy and Water Assessment and Performance Standards	Heating Systems	1.5	<p>E. Partial load efficiencies for variable speed equipment</p> <p>Heating systems are sized to meet design conditions that occur at their rated, peak efficiencies (i.e., full load or capacity); however, in most instances, these systems only operate at partial load or capacity. For equipment that is able to vary its output speed, efficiencies are needed that specify the systems’ optimal conditions at partial load.</p>	This work should be conducted in the near-term: 0-2 years.
Chapter One: Building Energy and Water Assessment and Performance Standards	Mechanical Systems	1.6	<p>A. Heat energy as an underutilized resource</p> <p>Thermal energy is a grossly underutilized resource in the United States relative to other developed countries. The development of an American National Standard for heat metering, led by ASTM International with cooperation from the International Association of Plumbing and Mechanical Officials (IAPMO), is currently underway and will address a major gap in standardization that will allow for thermal technologies to be more easily utilized in residential and commercial buildings. Geothermal and hydronic cooling and heating systems can provide significantly increased levels of efficiencies in both residential and commercial applications. Standards are required to help designers, engineers, and home builders better understand the long-term benefits of employing these technologies in buildings. CSA Group began the process of developing an ANSI/Standards Council of Canada bi-national standard, C448 Design and Installation of Earth Energy Systems, for the design and installation of geothermal ground heat pumps in response to needs that U.S. stakeholders identified for a bi-national design / installation standard.</p>	This work should be conducted in the mid-term: 2-5 years.
Chapter One: Building Energy and Water Assessment and Performance Standards	Mechanical Systems	1.6	<p>B. Duct leakage testing</p> <p>i. Independently developed data pertaining to the practical levels of duct leakage testing</p> <p>Forced-air heating and cooling systems utilize ducts to distribute conditioned air throughout the building. According to the EPA, about 20 percent of the air that moves through the duct system is lost due to leaks, holes, and poorly connected ducts in homes. Currently, there is considerable debate at codes and standards meetings in the industry regarding the minimum level of duct leakage testing that is required to improve efficiencies. Independently developed data pertaining to the practical levels of duct leakage testing is needed.</p>	This work should be conducted in the mid-term: 2-5 years.

Chapter	Issue Area	Section	Gap/Recommendation	Recommended Timeline
Chapter One: Building Energy and Water Assessment and Performance Standards	Mechanical Systems	1.6	<p>B. Duct leakage testing</p> <p>ii. Testing protocols for whole HVAC duct system components</p> <p>To improve energy efficiency, there is a need to develop testing protocols for whole HVAC duct system components. There is a high need for this as codes move toward requiring system testing prior to certificate of occupancy. There is also a need to standardize various techniques for measuring leakage in non-residential and multi-family air distribution and exhaust systems. Several standards developers are starting development on this topic, including ASHRAE, which is looking at this issue for potential inclusion in Standard 90.1-2016. Existing standards such as ASTM E1554/E1554M are being reviewed to improve understanding of precision and bias to aid in their use as code compliance tools.</p>	This work should be conducted in the mid-term: 2-5 years.
Chapter One: Building Energy and Water Assessment and Performance Standards	Mechanical Systems	1.6	<p>C. Employing nontraditional and emerging technologies</p> <p>The potential to use nontraditional and emerging technologies for improving efficiencies in mechanical systems should be addressed by standards developers. Solar air conditioning, which can utilize several processes to cool buildings (e.g., open desiccant cooling, passive solar, photovoltaic solar cooling, and solar closed loop absorption systems); transcritical CO₂ systems, where improvements to system components may yield new efficiencies; and heat from energy-generating microturbines are technologies where standardization activities can help determine the potential for improved levels of efficiency.</p>	This work should be conducted in the long-term: 5+ years.
Chapter One: Building Energy and Water Assessment and Performance Standards	Mechanical Systems	1.6	<p>D. Fault detection in HVAC systems</p> <p>Research has shown that component faults in HVAC systems that significantly diminish efficiencies are common and go mostly undetected. Standards are needed to quantify the benefits of installing fault detection technologies on mechanical systems that can alert building and home owners to malfunctioning components.</p>	This work should be conducted in the mid-term: 2-5 years.
Chapter One: Building Energy and Water Assessment and Performance Standards	Energy Storage	1.7	<p>A. Standards for system safety issues for energy storage systems</p> <p>Safety is a crucial element for the success of energy storage systems. Issues including ratings, markings, personnel barriers/setbacks, system access (e.g., entry and exit points), physical abuse, and temperature ratings come immediately to mind. These may be addressed by SDOs like UL, IEC, and others. The standards should make use of previously identified standards in SAE and UL for battery components, should the system use batteries as the storage medium.</p>	This should be conducted in the near-term: 0-2 years.

Chapter	Issue Area	Section	Gap/Recommendation	Recommended Timeline
Chapter One: Building Energy and Water Assessment and Performance Standards	Energy Storage	1.7	<p>B. Standards for availability, reliability, and maintenance</p> <p>Energy storage systems are envisioned to be controlled autonomously by a central energy management systems or a building energy management system with little human interference on a regular basis. In order to make sure the energy storage systems are functioning as specified, standards need to be developed to determine:</p> <ul style="list-style-type: none"> ▪ Availability – optimal times and levels of charge and discharge for the energy storage system based on physical location, historical patterns, and other relevant factors ▪ Reliability – determining the mean uptime and mean time to failure; the mean lifetime and cycle life of the energy storage system; and/or storage medium component associated with the system ▪ Maintenance – determining what maintenance routines should be performed on the energy storage system and when 	This should be conducted in the mid-term: 2-5 years.
Chapter One: Building Energy and Water Assessment and Performance Standards	Energy Storage	1.7	<p>C. Standards for electromagnetic compatibility (EMC)</p> <p>As information technology becomes layered over electrical components, it is essential that each smart grid component, including energy storage systems, is interoperable and that each component is appropriately shielded, insulated, or otherwise designed to reduce or prevent electromagnetic interference. Note that there are currently significant barriers to testing electromagnetic compatibility in many instances.</p>	This work is a long-term effort: 5+ years.
Chapter One: Building Energy and Water Assessment and Performance Standards	Energy Storage	1.7	<p>D. Standards for load flow, protection coordination, automatic gain control</p> <p>The need exists to limit or prevent electrical damage to the energy storage system through the development of standards for load flow, protection coordination, and automatic gain control.</p>	This should be conducted in the mid-term: 2-5 years.
Chapter One: Building Energy and Water Assessment and Performance Standards	Energy Storage	1.7	<p>E. (Partial Gap) Standards to identify representative duty cycles and performance metrics for each application and/or use case</p> <p>Until recently there was no methodology for comparing the performance attributes of energy storage systems. The DOE/PNNL <i>Protocol for Uniformly Measuring and Expressing the Performance of Energy Storage Systems</i> can provide a basis for addressing this issue. It can be applied across systems that employ different types of storage mediums because it establishes a representative duty cycle for each possible energy storage system application. A starting point for developing such a list of applications and/or use cases is the California Public Utility Commission (CPUC) <i>Energy Storage Staff Proposal</i>. A series or family of standards specifying representative duty cycles and performance metrics applicable by representative duty cycle should be written that would foster the uniform and comparable measurement and expression of energy storage system performance. This series of standards would allow a customer or other end user to evaluate which product is best for their use, and to establish universal testing and reporting criteria.</p>	This should be conducted in the near-term: 0-2 years.

Chapter	Issue Area	Section	Gap/Recommendation	Recommended Timeline
Chapter One: Building Energy and Water Assessment and Performance Standards	Water Heating	1.8	A. Standards for heat metering and solar thermal systems Consensus standards for heat metering and hot water solar thermal systems need to be completed to advance the use of thermal technologies for water heating applications. This represents a significant and very achievable advancement in energy efficiency.	This work should be conducted in the mid-term: 2-5 years.
Chapter One: Building Energy and Water Assessment and Performance Standards	Water Heating	1.8	B. Design standards for plumbing systems Design standards for architects and home builders are needed to illustrate how efficient building and home design can provide for greater efficiencies in water heating applications.	This work should be conducted in the mid-term: 2-5 years.
Chapter One: Building Energy and Water Assessment and Performance Standards	Water Heating	1.8	C. Standards that address the location of the heating source and end-use point Standards are needed for water heating and delivery systems to address the location of the heating source and the end-of-use point to ensure that the most efficient system is installed while meeting consumers' hot water use expectations. Activity is currently under way within several codes and standards development venues, including the IgCC and IAPMO's Green Plumbing and Mechanical Code committees, to address the use of recirculation systems and length of pipe requirements, and to provide guidance on how to design the most efficient systems.	This work should be conducted in the near-term: 0-2 years.
Chapter One: Building Energy and Water Assessment and Performance Standards	Indoor Plumbing	1.9	A. Research evaluating the impact of efficient plumbing component design on the plumbing system's overall performance Current codes and standards continue to provide significant improvements in water and energy efficiency requirements for plumbing components used in plumbing systems. However, there is considerable pressure to further increase the water savings by requiring decreased flows and flush volumes. It has been shown that further reduction in water usage can be achieved through more efficient plumbing component design. However, there is little research available today that evaluating the impact of those designs on the plumbing system's overall performance due to reduced flows in the system, particularly the drainage system. There are research projects underway in the U.S., notably the Plumbing Efficiency Research Coalition, that will help to determine "how low we can go" without negatively impacting public health and safety.	While some research will be conducted in the short term: 0-2 years, achieving optimum efficiency levels in plumbing systems through standardization efforts that consider the entire plumbing system will be an ongoing, long-term project: 5+ years.
Chapter One: Building Energy and Water Assessment and Performance Standards	Indoor Plumbing	1.9	B. Revised pipe sizing calculation methods that take modern lower flow rates and lower waste discharges into account along with use patterns associated with building types Another question currently being addressed through research is the ability to design plumbing systems using smaller diameter piping due to the decreased water demand and decreased volumes needed to supply residential buildings. While it is anticipated that this research will be completed within the next 1-2 years for residential applications, similar research efforts that study water use patterns associated with increasingly complex commercial buildings needs to be conducted so that pipe size reductions that deliver energy and water efficiencies throughout the life of the building at lower construction costs can be realized.	This work constitutes a long-term project: 5+ years.

Chapter	Issue Area	Section	Gap/Recommendation	Recommended Timeline
Chapter One: Building Energy and Water Assessment and Performance Standards	Indoor Plumbing	1.9	<p>C. The combined energy and water savings associated with the use of thermal insulation on hot water pipes</p> <p>Hot water delivery systems routinely use thermal insulation (pipe insulation) to maintain the temperature of the water as it travels from the source (the water heater) to the destination (the faucet at the sink). All current energy codes and standards require some degree of thermal insulation on potable hot water piping. However, the requirements between codes vary, and most requirements are normally considered minimum levels. Existing research has not considered the value of water when making the business case for putting additional pipe insulation on hot water piping, increasing the thickness of insulation or identifying a scope of work for insulation installation. While studies have looked at energy efficiency, they have not addressed the short-term economics, which depend on frequency, duration, and pattern of usage, and remain the overriding consideration for most building owners.</p>	This work should be conducted in the near-term: 0-2 years.
Chapter One: Building Energy and Water Assessment and Performance Standards	Indoor Plumbing	1.9	<p>D. Reducing the potential for Legionellosis and other pathogenic outbreaks</p> <p>Reducing hot water temperatures in plumbing systems has been proven to both reduce scalding incidences and to save energy. However, hot water temperature reductions also provide a perfect environment for opportunistic pathogens to grow in hot water pipes. ASHRAE is currently in the process of completing BSR/ASHRAE Standard 188P, <i>Prevention of Legionellosis Associated with Building Water Systems</i>, and the accompanying Guideline 12. When published, these guidance documents will provide facility managers with techniques that can be employed to mitigate Legionellosis outbreaks, as well as a set of best practices for when outbreaks occur.</p>	This work should be conducted in the near-term: 0-2 years.
Chapter One: Building Energy and Water Assessment and Performance Standards	Alternate Water Sources	1.10	<p>A. “Fit for use” standards that provide appropriate treatment requirements for the intended use of the water</p> <p>The biggest challenge facing the expanded use of water from alternate water sources is the need for agreed-upon “fit for use” standards that provide appropriate treatment and water quality requirements for the intended use of the water regardless of the source, and that ensure health and safety. Several codes and standards organizations have made excellent progress toward creating classifications of alternate water sources and corresponding applications, as well as treatment strategies. However, a one-size-fits-all approach to design and treatment may be unachievable. For example, rainwater in one area of the country may have higher heavy metals contamination than rainwater in other areas, therefore requiring different treatment measures. Standards developers need to continue to expand their knowledge base and consider provisions that will foster increased use of alternate water sources.</p>	Improvements to alternate water use standards should be an ongoing process with advancements made by consensus, and achieved in the short-, mid-, and long- term.

Chapter	Issue Area	Section	Gap/Recommendation	Recommended Timeline
Chapter One: Building Energy and Water Assessment and Performance Standards	Alternate Water Sources	1.10	<p>B. Comprehensive stormwater standard</p> <p>There is a need to develop a comprehensive stormwater standard. There is great potential for stormwater to be better utilized as an important alternative water source. Current stormwater infrastructure serves only to carry stormwater away from developed areas as quickly as possible. However, stormwater is a valuable resource that, when utilized properly, can buffer runoff and combined sewer overflows and replenish the aquifers through irrigation, soak-away pits, rain gardens, and other designed stormwater features. ASPE, ARCSA, and ICC are currently developing a stormwater harvesting design standard which may address this gap. A national standard for green infrastructure/low impact design has been provided for federal facilities by implementation of EISA Section 438.</p>	Development of these standards will necessitate collaboration between water use experts, civil engineers, and other stakeholders. This is a long-term effort: 5+ years.
Chapter One: Building Energy and Water Assessment and Performance Standards	Landscape Irrigation	1.11	<p>A. Standards for design practices and validating product performance</p> <p>Additional standards for landscape irrigation systems would be useful in establishing minimum safety requirements and validating performance claims of products. Standards facilitate the comparison of different products to aid the consumer in making a selection for a particular application. PINS have been filed with ANSI for controllers and rain sensors, but no committees have been formed to develop the standards. ICC is currently developing an irrigation emission device standard, which may address this gap.</p> <p>The following gaps are becoming apparent as competing green codes are being developed with regard to landscape irrigation. Because landscape irrigation is the assembly of various components to create a system, the system needs to be designed, installed, and maintained properly. While there are documents that have been created by industry to identify best practices for each of these areas, the potential exists to create standards out of the identified best practices that could be referenced in the codes. Such standards could eliminate conflicting or differing provisions, and thus minimize confusion in the marketplace. This would allow the green codes to be less prescriptive in nature and move more toward performance-based outcomes in managing resources. Some prescriptive irrigation provisions within the green codes conflict with implementing best practices that should be used to address the unique challenges of individual landscapes. Standards should enhance the development of a quality irrigation system that would be based on well-developed best practices for:</p> <ul style="list-style-type: none"> ▪ Designing an irrigation system ▪ Installing/commissioning an irrigation system ▪ Long-term maintenance of an irrigation system for optimal performance <p>One challenge of developing standards about design, installation, and maintenance is the perceived notion that by following a standard, an untrained person can achieve the desired results, the same as a qualified professional. The reality is that each landscape project is unique and the professional applies standards to achieve the desired outcome. Care should be taken so that standards do not become training manuals for design, installation, or maintenance.</p>	This work should be conducted in the mid-term: 2-5 years

Chapter	Issue Area	Section	Gap/Recommendation	Recommended Timeline
Chapter One: Building Energy and Water Assessment and Performance Standards	Landscape Irrigation	1.11	<p>B. Standards for landscape sustainability and ecosystem services Gaps in standards for landscape irrigation are interrelated, but currently not enough information or research has been done to provide guidance for standards development.</p> <ol style="list-style-type: none"> 1. A standard is needed for evaluating all water sources so that the most sustainable water source(s) would be used for irrigation. This standard would address the water-energy nexus, and would be useful in evaluating the embedded energy in all potential irrigation water sources. 2. A standard is needed that would address the benefits derived from an irrigated landscape compared to the resources used to maximize the ecosystem services from the managed urban landscape. 	If standards are developed, they should address the process to follow in making the evaluation. This work constitutes a long-term effort: 5+years.
Chapter One: Building Energy and Water Assessment and Performance Standards	Swimming Pools, Hot Tubs, Spas, Aquatic Features	1.12	<p>A. Standards for filters and filter media testing that address water efficiency Standards are needed to evaluate the water consumption of a pool and spa filtration system. The efficiency of a filter's backwash ability is critical to its water consumption. The industry often uses the backwash to help eliminate contaminants in the pool. The backwash water is sent to waste and new water – "make up water" – is added to dilute contaminants. This industry best practice will need to be addressed, but the need for backwash efficiency still exists.</p>	This should be done in the near-term: 0-2 years.
Chapter One: Building Energy and Water Assessment and Performance Standards	Swimming Pools, Hot Tubs, Spas, Aquatic Features	1.12	<p>B. Standards for UV systems that address energy efficiency Currently there are no existing standards to cover the energy efficiency for UV light generators. Standards are needed to evaluate the energy efficiency through analysis of the power delivery level and flow rates.</p>	This should be done in the near-term: 0-2 years.
Chapter One: Building Energy and Water Assessment and Performance Standards	Swimming Pools, Hot Tubs, Spas, Aquatic Features	1.12	<p>C. Standards for testing the energy efficiency of disinfection systems (ozone generators, electrolytic chlorinators, and copper and silver ionizers) Standards are needed to test the energy efficiency of disinfection systems (ozone generators, electrolytic chlorinators, and copper and silver ionizers) to determine the energy use at integral power levels of chemical output.</p>	This should be done in the near-term: 0-2 years.
Chapter One: Building Energy and Water Assessment and Performance Standards	Swimming Pools, Hot Tubs, Spas, Aquatic Features	1.12	<p>D. Standards for testing the efficiency of pool covers and liquid barriers Pool covers and liquid barriers represent a significant opportunity to minimize pool energy use by reducing heat loss and evaporation. However, they cannot provide efficiencies if they are not utilized. Research is needed to investigate the behavioral aspects of pool cover use by homeowners, and facility managers and to determine realistic potential for efficiency gains. Where research shows that efficiency gains can be reasonably expected from the use of pool covers or liquid barriers, regional construction codes and best practice maintenance guidelines should be developed that require their use.</p>	This should be done in the mid-term: 2-5 years.

Chapter	Issue Area	Section	Gap/Recommendation	Recommended Timeline
Chapter One: Building Energy and Water Assessment and Performance Standards	Commissioning	1.13	<p>A. Commissioning practices</p> <p>Currently, there appears to be much confusion on what constitutes quality commissioning practices, how it can be incorporated into codes and other standards, and the identification of quality commissioning providers. Many of these questions have been addressed by commissioning industry organizations, but not in an organized fashion. Addressing these issues in the short-term will be essential to the widespread and productive use of commissioning and the achievement of the anticipated levels of building system and utility cost performance. Many of the organizations identified above have agreed to work collectively to address these issues. ICC is currently developing a standard to address these issues as they relate to the International Codes, which may address this gap. Additionally, ASTM and the National Institute of Building Sciences (NIBS) have begun the process of developing a set of standards and guidelines that may help to address this concern through a process referred to as building enclosure commissioning (BECx).</p>	These activities should be conducted in the near-term: 0-2 years.
Chapter One: Building Energy and Water Assessment and Performance Standards	Commissioning	1.13	<p>B. Education and training on commissioning process</p> <p>There is a lack of understanding of the commissioning process among many commissioning users, such as building owners, facility managers, and personnel. There needs to be education, documentation, and training developed for commissioning users on the commissioning process, deliverables and expected results. Having educated consumers is equally important to a quality process and providers. ASTM and NIBS have begun development of a Building Enclosure Certification and Training Program, which may help to address this need. The program will be developed in accordance with ISO 17024, <i>Conformity assessment – General requirements for bodies operating certification of persons</i>, which will be a requirement of the new ICC 1000, Standard for Commissioning, and the Better Buildings Workforce Guidelines project, an initiative led by NIBS and the U.S. Department of Energy.</p>	These activities should be conducted in the near-term: 0-2 years.
Chapter One: Building Energy and Water Assessment and Performance Standards	Commissioning	1.13	<p>C. Methods for third-party provider conformity assessment and accreditation</p> <p>Research, guidance and common agreement are needed regarding the methods for third-party provider conformity assessment and accreditation. Additionally, data is needed on commissioning results and how the practices can enhance building performance and safety.</p>	This work should be conducted in the mid-term: 2-5 years.

Chapter	Issue Area	Section	Gap/Recommendation	Recommended Timeline
Chapter One: Building Energy and Water Assessment and Performance Standards	Commissioning	1.13	<p>D. Commissioning standards and guidelines for building systems</p> <p>While standards and guidelines now exist for the commissioning process and many building systems have been included as identified above, several additional building systems can and should be commissioned. Standards and guidelines will need to be developed or adapted in these areas, including irrigation and decorative water systems; on-site renewable energy systems; integrated energy systems; indoor environmental quality systems; building enclosures; fire alarm, security systems and IT systems; vertical conveyance (elevators); and integrated building automation/energy management systems.</p> <p>The gap that currently exists with regard to building enclosure commissioning includes the development of a consensus guide for the implementation of the building enclosure commissioning process, which differs slightly from ASHRAE Guideline 0 and ASHRAE Standard 202, in that it speaks specifically to commissioning of the materials, components, systems and assemblies that comprise the exterior enclosure of a building or structure. ASTM, in cooperation with NIBS, will address this gap in the Spring/Summer of 2014 with the publication of a new ASTM Standard Guide for Building Enclosure Commissioning, which will replace NIBS Guideline 3, Building Enclosure Commissioning Process BECx.</p>	These activities should be conducted in the mid-term: 2-5 years.
Chapter One: Building Energy and Water Assessment and Performance Standards	Commissioning	1.13	<p>E. Communications from and to building equipment, sensors, and security protocols</p> <p>Ongoing commissioning will depend on monitoring of all building systems in order to assure that the systems are operating in a manner consistent with the owner's current facility performance requirements. This will require the standardization of communications from and to building equipment and sensors and security protocols to allow any alteration of building systems electronically. Commissioning practices that ensure proper communication with energy providers and energy efficient operation in a smart grid environment will need to be developed. Increased understanding of the linkages between building systems and their contributions to total building performance will be necessary. This includes the development of metrics and methods to support such whole building assessments and existing building commissioning process.</p>	These activities should be completed in the long-term: 5+ years.
Chapter One: Building Energy and Water Assessment and Performance Standards	Conformity Assessment in Building Energy and Water Assessment and Performance Standards	1.14	<p>A. Gaps in the actual accreditation standards</p> <p>There are various standards such as the ISO/IEC 17000 series that are designed to work together with technical standards in the energy efficiency field. The 17000 standards have systematic reviews that take place five years after publication. If they are reaffirmed, the standards are reviewed five years later unless a new work item proposal (NWIP) is proposed earlier by a CASCO member and approved by CASCO for a compelling need. The gaps from this perspective are addressed through the systematic reviews.</p>	This depends on ISO's systematic review process; however, some of these standards such as ISO/IEC 17011 and ISO/IEC 17000 are in need of update as soon as possible. This should be conducted in the near-term: 0-2 years.

Chapter	Issue Area	Section	Gap/Recommendation	Recommended Timeline
Chapter One: Building Energy and Water Assessment and Performance Standards	Conformity Assessment in Building Energy and Water Assessment and Performance Standards	1.14	<p>B. Gaps in the implementation of accreditation</p> <p>Accreditation is a tool for decision makers/regulators to assist in risk reduction. Some product characteristics are vital for safe and effective performance; however, many of these characteristics cannot be reasonably evaluated simply by observation or examining the product in the marketplace. Such characteristics need to be determined and assessed, and assurance needs to be provided to the buyer (or other interested party) that the product conforms to requirements and that conformance is consistent from product to product. The following are specific areas to be addressed:</p> <ul style="list-style-type: none"> • Need of consensus standards in the different areas of energy efficiency: this is being addressed in this roadmap by identifying areas where standardization is needed to advance energy efficiency. • Research on applications and emerging technologies related to inspection, testing, and monitoring of energy efficiency devices and equipment. • Research on traceability measurement for energy efficiency. Traceable measurements must have both the correct equipment and be used in the correct ways in a valid method. Questions that should be considered include: <i>Are the current testing methods appropriate to the test, and are the compliance specifications appropriate for the current technologies and market needs?</i> • Research on the application of calibration of energy efficiency equipment. • Documentation of accreditation best practices to demonstrate to regulators and other stakeholders the increase to the bottom-line. • Documentation of how accreditation increases market value and confidence, and how governments can be involved and use accreditation to increase their confidence. • Documentation of how accreditation increases market value in international trade. • Reinforcement of the body of knowledge related to the implementation of accreditation standards such as laboratory accreditation (17025), product certification (17065), and inspection bodies (17020). <p>Refer to roadmap section for full gap analysis/recommendation.</p>	This should be conducted in the mid-term: 2-5 years.
Chapter Two: System Integration and Systems Communications	System Integration and Systems Communications	2.3	<p>A. Common information models and taxonomies</p> <p>Standards are needed around common information models and taxonomies using common protocols to transmit data between the building and the smart grid, so that smart grid service providers can utilize data in a consistent way.</p>	This work should be conducted in the near-term: 0-2 years.

Chapter	Issue Area	Section	Gap/Recommendation	Recommended Timeline
Chapter Two: System Integration and Systems Communications	System Integration and Systems Communications	2.3	B. Communication between building energy management systems and the grid As standards are implemented to support communication between building energy management systems and the grid, there will be an ongoing need for standards to support communication.	This work should be conducted in the mid-term: 2-5 years, with ongoing attention to evolving needs.
Chapter Two: System Integration and Systems Communications	System Integration and Systems Communications	2.3	C. Consistent data communication Standards are needed to support more consistent data communication back to the utility or service provider.	This work should be conducted in the near-term: 0-2 years.
Chapter Two: System Integration and Systems Communications	System Integration and Systems Communications	2.3	D. Methodology and identification of energy data formats and attributes There is a need for standards to provide for the development of the methodology and identification of the commonly exchanged device, asset, process, and system integration parameters and specifications (data formats and attributes) related to significant energy uses or objectives of an energy management system.	This work should be conducted in the near-term: 0-2 years.
Chapter Two: System Integration and Systems Communications	System Integration and Systems Communications	2.3	E. Measurement and monitoring protocols for energy data There is a need for standards to establish measurement and monitoring protocols to support energy data.	This work should be conducted in the near-term: 0-2 years.
Chapter Two: System Integration and Systems Communications	System Integration and Systems Communications	2.3	F. Methodology for energy information sharing There is a need for standards that provide a methodology for energy information sharing within a building, facility, or group of facilities, as well as with the grid.	This work should be conducted in the mid-term: 2-5 years.
Chapter Two: System Integration and Systems Communications	System Integration and Systems Communications	2.3	G. Methodology of integrating the building sub-systems into an energy system There is a need for a technical guide to provide for the development of the methodology of integrating the building sub-systems into an energy system serving the mutual interests of each sub-system's to perform and the overall building energy efficiency.	This should be conducted in the near-term: 0-2 years.
Chapter Two: System Integration and Systems Communications	System Integration and Systems Communications	2.3	H. Standards to provide for a building energy information model There is a need for standards to provide for a building energy information model, consisting of a series of use cases, to shape future standards related to building energy performance and management, and to test that the content of the standard provides for all of the information needed to optimize the energy performances of the building.	This should be conducted in the near-term: 0-2 years.
Chapter Two: System Integration and Systems Communications	System Integration and Systems Communications	2.3	I. Workforce training and certification programs A better integration of automation and controls into the skills standards underlying workforce training and certification programs is needed.	This should be conducted in the mid-term: 2-5 years

Chapter	Issue Area	Section	Gap/Recommendation	Recommended Timeline
Chapter Three: Building Energy Rating, Labeling, and Simulation	Rating and Labeling Programs	3.1.5	<p>A. Data availability</p> <p>Operational ratings and labeling programs rely on data that is representative of the existing building and industrial plant stock. As noted earlier, data sources such as the Residential Energy Consumption Survey (RECS), Commercial Building Energy Consumption Survey (CBECS), Manufacturing Energy Consumption Survey (MECS), and the Census of Manufacturing are commonly used for operational rating development. However, these data sets are frequently limited in the number and types of buildings included in the surveys, the granularity of building characteristics, robustness of the sample, and timeliness of the data.</p> <p>There are many issues due to limited data sets. One critical issue is that limitations in the amount and quality of data in the CBECS and RECS studies can impact the consistency within a rating system. CBECS results for specific building types can vary significantly from survey to survey. This creates changes in the rating scores for buildings with no action taken by the owner. A high scoring building may become a low scoring building. Investment in additional data collection will reduce this noise and increase trust in the ratings.</p> <p>In addition, many building types have insufficient data on which to base a rating program. This is most evident in the commercial building arena, but also affects mixed use and multi-family building types. An expansion in the types of buildings included in the consumption surveys listed above would help to remedy this situation. Additional data sets could also benefit asset ratings by providing more robust information on which to base standard occupancy assumptions.</p> <p>In recent years, funding for building energy surveys has been questioned, and in some cases, reduced. If further development or refinement of existing operational ratings is to take place, additional steps should be taken to expand or establish new data sets that can be used to create operational ratings. Additionally, steps could be taken to establish criteria or standards for guiding data collection by organizations seeking to collect building performance data for operational rating development.</p>	<p>Existing efforts underway need to be accelerated in the near-term: 0-2 years. However, this is an ongoing need that is going to exist in the long-term.</p> <p>Those organizations in charge of collecting data (U.S. Energy Information Administration, Census) should continue to solicit feedback from stakeholders with each iteration of their surveys in order to improve the data collected and the collection process.</p>
Chapter Three: Building Energy Rating, Labeling, and Simulation	Rating and Labeling Programs	3.1.5	<p>B. Taxonomy and terminology</p> <p>Currently, different systems use different definitions for common terms such as baseline, benchmark, label, reference, etc. As a result, it can be difficult to compare or quickly understand the structure and design of various rating systems. Further dialogue (and consensus where possible) is needed to clarify terminology used in this field. There is at least one standard under development that might be able to address this.¹⁶⁴</p>	This should be conducted in the near-term: 0-2 years.
Chapter Three: Building Energy Rating, Labeling, and Simulation	Rating and Labeling Programs	3.1.5	<p>C. Rating and labeling directory</p> <p>Through the process of inventorying operational rating and labeling systems, it became clear that there is no central resource or catalogue that outlines existing programs and their focus. There is an opportunity for the establishment of a consistently updated “rating and labeling directory” that catalogues different programs and discusses each program’s design and focus in a systematic format.</p>	This should be conducted in the near-term: 0-2 years; however, it will require update over time.

¹⁶⁴ ASHRAE 214P, *Standard for Measuring and Expressing Building Energy Performance in a Rating Program*.

Chapter	Issue Area	Section	Gap/Recommendation	Recommended Timeline
Chapter Three: Building Energy Rating, Labeling, and Simulation	Energy Simulation for Code Compliance and Asset Rating: Commercial Buildings	3.2.1.1.1	A. Single rule set All codes and beyond-code programs should use a single rule set for performance-path modeling.	This process should be initiated in the near-term: 0-2 years, but may not be fully implemented for 2-5 years.
Chapter Three: Building Energy Rating, Labeling, and Simulation	Energy Simulation for Code Compliance and Asset Rating: Commercial Buildings	3.2.1.1.1	B. Prescriptive baselines The prescriptive baseline should not change with improvements to codes and standards. Rather than ratcheting up prescriptive baselines, standards should advance by ratcheting up performance increases over a fixed prescriptive baseline. In this setup, different standards could continue to set and advance performance increments independently and even set minimum prescriptive responses independently.	This should be conducted in the near-term: 0-2 years
Chapter Three: Building Energy Rating, Labeling, and Simulation	Energy Simulation for Code Compliance and Asset Rating: Commercial Buildings	3.2.1.1.1	C. Comprehensive, robust rule sets Rule sets need to be better defined, more comprehensive, and more robust.	This should be conducted in the near-term: 0-2 years
Chapter Three: Building Energy Rating, Labeling, and Simulation	Energy Simulation for Code Compliance and Asset Rating: Residential Buildings	3.2.1.1.2	A. Standards for different rating purposes Recognizing that increased cost effectiveness of rating delivery can be improved by data and process integration, it is recommended that standards be identified and developed that consider different rating purposes (e.g., real estate transaction, posting on multiple listing service (MLS) or commercial listing service, energy audit, new home, financial incentive applications).	This should be conducted in the near-term: 0-2 years. Identification could be completed within 1 year and standards could be developed within 2 years.
Chapter Three: Building Energy Rating, Labeling, and Simulation	Energy Simulation for Code Compliance and Asset Rating: Data Centers	3.2.1.1.4	A. Standard for data centers If possible, ASHRAE should seek to publish the first version of the 90.4 standard by the next update cycle in 2016. This first version should, to the extent possible, align with the protocols and methodologies of the 90.1 standard.	This should be conducted in the mid-term: 2-5 years.

Chapter	Issue Area	Section	Gap/Recommendation	Recommended Timeline
Chapter Three: Building Energy Rating, Labeling, and Simulation	Energy Simulation for Whole-Building Energy Efficiency Incentives: Commercial Buildings	3.2.1.2.1	<p>A. Simulation methodologies and protocols</p> <p>Energy design assistance program implementation details vary, but most programs confront the same standards gaps. Specifically, simulation methodologies and protocols need to be included in published standards so that they can be referenced in contracts for design work. ASHRAE has proposed a standard on simulation-driven design assistance, but publication of that standard is several years away. While there are a number of sophisticated simulation tools on the market, it is less clear which tools are appropriate for use with different design elements, especially HVAC system types. The current ASHRAE Standard 140 is not sufficiently comprehensive for this purpose at this time.</p> <p>The proposed standard, ASHRAE Standard 209P, is designed to fill the modeling protocol gap described above. A reasonable goal is for a first version of the standard to be published along with the next update to Standard 90.1 in 2016. ASHRAE Standard 140 will eventually address the simulation tool suitability gap, but the effort to bring the standard to the necessary level will be highly data-driven, and therefore may evolve slowly. Accelerating the development of the standard – specifically on the data gathering and model reconciliation activities that underlie the standard – will require substantial resources.</p>	This should be conducted in the mid-term: 2-5 years.
Chapter Three: Building Energy Rating, Labeling, and Simulation	Energy Simulation for Whole-Building Energy Efficiency Incentives: Residential Buildings	3.2.1.2.2	<p>A. Develop standardized definitions for energy conservation measures, standard protocols for simulation, and standard implementations of those protocols</p> <p>The recommendation is to cascade the BEDES, BPI 2100/2200, measure cutsheet, NREMDB, and BCL projects, potentially using ASHRAE Standard 209P as a standards vehicle for the simulation protocols. HERS BESTEST, BPI 2400, and the RESNET extensions to HERS BESTEST for heating plant, distribution system, DHW (domestic hot water), and improvement measure interaction need to be expanded, especially in the HVAC space, to support this effort. This is a cascading, multi-step effort that could take 5-10 years to complete.</p>	This is a long-term priority and should be completed in 5+years.
Chapter Three: Building Energy Rating, Labeling, and Simulation	Energy Simulation for Whole-Building Energy Efficiency Incentives: Residential Buildings	3.2.1.2.2	<p>B. Develop a standardized procedure for simulation model review</p> <p>Model review, including benchmarking, can be built into the modeling but the entire review and acceptance framework needs to be agreed upon. An initial framework can likely be put together in about 2 years.</p>	This is a near-term priority and should be conducted in 0-2 years.
Chapter Three: Building Energy Rating, Labeling, and Simulation	Energy Simulation for Whole-Building Energy Efficiency Incentives: Residential Buildings	3.2.1.2.2	<p>C. Develop standard methods for estimating uncertainty in energy-savings calculations as well as acceptability ranges for uncertainty</p> <p>Ad hoc tools for uncertainty analysis are very close and should help. However, there is some research to be done before a sound, useful, comprehensive framework is put in place 3-5 years from now.</p>	This is an urgent priority; however, it will not likely be fully resolved in the near-term. Conversations should begin immediately, and work should be completed in the mid-term: 2-5 years.

Chapter	Issue Area	Section	Gap/Recommendation	Recommended Timeline
Chapter Three: Building Energy Rating, Labeling, and Simulation	Energy Simulation for Whole-Building Energy Efficiency Incentives: Multi-family Buildings	3.2.1.2.3	A. Standardized modeling requirements for multi-family buildings New work on multi-family modeling should be done to develop standardized modeling requirements.	Work to address this should gap begin immediately and should be completed in the mid-term: 2-5 years
Chapter Three: Building Energy Rating, Labeling, and Simulation	Building Energy Simulation for Use in Evaluation, Measurement, and Verification: Commercial Buildings	3.2.1.3.1	A. Explicit linkages for standards specifying building simulation Standards specifying building simulation software should provide explicit linkages to other standards providing specifics related to calibration, training, and certification of software, including ASHRAE Guideline 14 (calibration), ASHRAE Standard 140 (software certification), BPI 2400-S-2011 (calibration), and the California Evaluation Framework and Protocols (training). Software certification is discussed in Section 3.2.2, <i>Energy Simulation Software Capabilities and Accuracy</i> .	This should be conducted in the near-term: 0-2 years.
Chapter Three: Building Energy Rating, Labeling, and Simulation	Building Energy Simulation for Use in Evaluation, Measurement, and Verification: Residential Buildings	3.2.1.3.2	A. Explicit linkages for standards specifying building simulation Standards specifying building simulation software should provide explicit linkages to other standards providing specifics related to calibration, training, and certification of software, including ASHRAE Guideline 14 (calibration), ASHRAE Standard 140 (software certification), BPI 2400-S-2011 (calibration), and the California Evaluation Framework and Protocols (training).	This should be addressed in the near-term: 0-2 years.
Chapter Three: Building Energy Rating, Labeling, and Simulation	Building Energy Simulation for Use in Evaluation, Measurement, and Verification: Residential Buildings	3.2.1.3.2	B. EM&V simulation standards are needed for multi-family buildings BPI 2400 applies to 1-4 unit residential buildings, but no standards currently exist for larger multi-family buildings.	Work to address this gap should be conducted in the near-term: 0-2 years.
Chapter Three: Building Energy Rating, Labeling, and Simulation	Energy Simulation Software Capabilities and Accuracy: Commercial and Residential Buildings	3.2.2.1	A. Roadmap for improving the coverage and physical fidelity of energy simulation engine tests The recommendation is to develop a roadmap for improving the coverage and physical fidelity of energy simulation engine tests, including expanding the range of tests for existing buildings and potentially including reference results from empirical measurements. This activity would use the growing collection of test facility data to characterize and benchmark the simulated accuracy of major building-physics phenomena and common HVAC system types, and create a prioritized list of missing or lagging simulation capabilities combined with measurement experiments needed to resolve or upgrade them.	This should be completed in the mid-term: 2-5 years.

Chapter	Issue Area	Section	Gap/Recommendation	Recommended Timeline
Chapter Three: Building Energy Rating, Labeling, and Simulation	Energy Simulation Software Capabilities and Accuracy: Commercial and Residential Buildings	3.2.2.1	<p>B. Tests for energy simulation software and supporting software</p> <p>There is a need to develop and reference suites of tests for energy simulation software and supporting software – potentially with accuracy guidelines – that are appropriate for specific use cases. Each suite should be designed to: (1) be applicable to market uses and/or connected to standard program types such as residential, commercial, new, existing, whole building, retro-commissioning, code compliance, ratings, incentives; and (2) where appropriate, explicitly test before- and after-simulation of efficiency measures associated with these use cases.</p> <p>Such test suites should be designed to: (a) assess accuracy and coverage of software capabilities; (b) standardize the level of effort required by software vendors to test software; and (c) foster development and implementation of third-party validation methods/systems.</p> <p>In regulated contexts, credentials for the accuracy of savings calculations are extremely valuable. Utility programs rely on state-level technical reference manuals to approve calculation methodologies. The manuals, which often include references to standards as opposed to specific tools, could cite these standard suites of tests along with acceptability/accuracy criteria that meet the programs’ needs. This would parallel the simulation accuracy benchmarking activity described above. It could be led by a standards organization whose published scope covers this type of activity.</p>	This should be completed in the mid-term: 2-5 years.
Chapter Three: Building Energy Rating, Labeling, and Simulation	Energy Simulation Software Capabilities and Accuracy: Commercial and Residential Buildings	3.2.2.1	<p>C. Develop a robust and low-cost testing procedure for model-input calibration</p> <p>This is a 1-2 year activity already undertaken by RESNET, which has formed a working group to generalize and codify the BESTEST-EX methodology for calibrating energy model inputs using measured data, e.g., utility bill data.</p>	This should be completed in the near-term: 0-2 years.
Chapter Three: Building Energy Rating, Labeling, and Simulation	Energy Simulation Professionals: Commercial Buildings	3.2.3.1	<p>A. Harmonize – or at least differentiate – the BESA™ and BEMP certificates</p> <p>The relationship between the BEMP and BESA™ certificates is not clear, although the BESA™ certificate requires less experience for qualification.</p>	Differentiation is a near-term goal: 0-2 years. Harmonization is a long-term goal: 5+ years
Chapter Three: Building Energy Rating, Labeling, and Simulation	Energy Simulation Professionals: Commercial Buildings	3.2.3.1	<p>B. Any simulation used for code compliance or asset rating should be overseen by a credentialed simulation professional</p> <p>Beginners should not be responsible for simulations that explicitly support regulatory or financial transactions. However, they do have to learn somewhere, and furthermore, to learn by doing. The apprenticeship and responsibility structure should track that which is used in other engineering fields. An engineer in training may do the work, but a credentialed engineer, e.g., a PE, reviews it, stamps it, and is ultimately responsible for it. A time frame for enforcing this requirement generally should be at least five years because the number of credentialed simulation professionals is currently small.</p>	This is a long-term priority and should be completed in 5+years.
Chapter Three: Building Energy Rating, Labeling, and Simulation	Energy Simulation Professionals: Residential Buildings	3.2.3.2	<p>A. Standardized methods for credentialing</p> <p>A standardized process for credentialing qualified users of residential energy simulation software currently does not exist. Standardized methods of credentialing qualified users of residential energy simulation software should be created to address this gap.</p>	This should be conducted in the near-term: 0-2 years.

Chapter	Issue Area	Section	Gap/Recommendation	Recommended Timeline
<p>Chapter Four: Evaluation, Measurement, and Verification (EM&V)</p>	<p>Measurement and Verification Methodological Approaches: Baselines</p>	<p>4.1.1</p>	<p>A. Selecting between existing conditions baselines and common practice baselines</p> <p>While the documents listed in this discussion indicate “best practice” in determining a baseline, one area that could use further clarification is when there are two possible approaches to determining the baseline. This occurs when a code or legal standard (e.g., for new construction) or industry common practice could be used to determine a baseline, or a baseline could be determined using the specific circumstances at the retrofit site (existing conditions baseline).</p> <p>Determining if a project or measure triggers a Code/ISP baseline or an existing conditions baseline is often determined through governing rules, as in the NAESB standards and ISO markets, or may require a degree of evaluator judgment. Except in the case when there are governing rules (e.g., the NAESB case), existing literature provides little guidance in these areas.</p> <p>These considerations necessarily require a degree of evaluator judgment and do not lend themselves to a fully prescriptive approach. The best option may be to address these types of occurrences through nonbinding guidance documents rather than formal standards in unregulated environments.</p>	<p>This is a long-term priority: 5+ years.</p>
<p>Chapter Four: Evaluation, Measurement, and Verification (EM&V)</p>	<p>Measurement and Verification Methodological Approaches: Baselines</p>	<p>4.1.1</p>	<p>B. Treatment of dual baselines</p> <p>When an EE program induces the replacement of equipment before it would otherwise have been replaced; an issue arises as to whether the applicable baseline should be based on the efficiency of the replaced equipment, or an applicable standard or industry best practice at the time of replacement. According to the Pennsylvania TRM, “Retrofit measures have a dual baseline: for the estimated remaining useful life of the existing equipment the baseline is the existing equipment; afterwards the baseline is the applicable code, standard, and standard practice expected to be in place at the time the unit would have been naturally replaced.”</p> <p>While this theoretical construct has always been well understood, it has been common practice in impact evaluation to determine the first year energy savings from energy efficiency measures and, then to multiply this savings by the effective useful life of the measure to obtain lifetime savings. If the existing equipment would have failed in five years, a more reasonable estimate of the lifetime impact of the measure is obtained by using an existing conditions baseline for the remaining years of useful life, and then using a code or industry common practice baseline for the remainder of the measure life. This approach is not required by most jurisdictions outside of California, though there is some indication that other jurisdictions are beginning to adopt it. Finally, the use of dual baselines only applies to measures with early replacement.</p> <p>The gap is that there are no unequivocal methods for determining how long the functioning equipment would have operated. Inconsistent application of this approach hinders comparability of savings across jurisdictions. However, as the treatment of baselines are often embedded in jurisdiction-specific protocols, such as state TRMs and state evaluation frameworks, treating the issue in a national or international standard is recommended.</p>	<p>This should be conducted in the mid-term: 2-5 years.</p>

Chapter	Issue Area	Section	Gap/Recommendation	Recommended Timeline
<p>Chapter Four: Evaluation, Measurement, and Verification (EM&V)</p>	<p>Measurement and Verification Methodological Approaches: Baselines</p>	<p>4.1.1</p>	<p>C. Industrial baselines In industrial retrofits, when production levels change, there has been inconsistent guidance on establishing a baseline. In California and New York, the baseline accounts for production increases differently if the measure allowed production to increase versus if the production increase occurred due to market forces only. If market forces drove the increase, the lifetime impacts are based on post-installation production levels. If the measure allowed production to increase, pre-installation levels are the basis of the savings. Other jurisdictions are largely silent on baseline estimation given externalities that impact savings. Given the standard evaluation practice of establishing energy savings based on post-intervention operating conditions, most jurisdictions may not be consistent with California and New York in the treatment of projects that allow for production increases. Inconsistent definitions for baseline production levels hinder comparability of savings across jurisdictions. However, as the treatments of baselines are often embedded in jurisdiction-specific protocols, it is recommended that the issue be treated in a national or international standard.</p>	<p>This should be conducted in the mid-term: 2-5 years.</p>
<p>Chapter Four: Evaluation, Measurement, and Verification (EM&V)</p>	<p>Measurement and Verification Methodological Approaches: Baselines</p>	<p>4.1.1</p>	<p>D. Non-direct dependence on production levels Baselines are sometimes defined in terms of a metric that is a form of energy use per unit of production. This energy use index is then applied to the post-installation production levels, or to a typical production level, in order to obtain an estimate of the baseline energy use. The implicit assumption is that the energy use is linearly related to production, and that the energy use tends toward “0” when production is “0.” This assumption is almost never explicitly stated, and the assumption may be incorrect. A relationship between energy input and production output can typically be determined, but it is rarely of a form that is both linear and is zero with no production. Practice in this area should be examined, and to the extent possible, standardized. If that proves infeasible, standards should be developed to describe the method or procedure used so that there is transparency.</p>	<p>This should be conducted in the mid-term: 2-5 years.</p>

Chapter	Issue Area	Section	Gap/Recommendation	Recommended Timeline
<p>Chapter Four: Evaluation, Measurement, and Verification (EM&V)</p>	<p>Measurement and Verification Methodological Approaches: Baselines</p>	<p>4.1.1</p>	<p>E. Automatic benchmarking of commercial and residential buildings</p> <p>The advent of higher resolution data and more complete data sets describing buildings has opened the possibility of building energy management systems (EMSs) themselves “automatically” benchmarking a building by recording energy use and being programmed to estimate equations describing building energy use. The advantages are that the EMS would have a basis for diagnosing building performance. For EM&V, a “baseline” of pre-upgrade performance would automatically be available. If many buildings in a given program had this capability, EM&V approaches could be modified to use larger samples (of self-benchmarking buildings), but at potentially different accuracy at each individual building. While this is an interesting possibility for developing faster, less costly EM&V, it relies on the quality of the benchmark the building’s EMSs are creating.</p> <p>The gap is that metrics or testing procedures to assess the accuracy of these self-created benchmarks do not exist. Some initial work in this regard has been done, but more must be done for self-benchmarking buildings to provide a reliable basis for EM&V. Organizations with access to high-resolution building energy usage should research automatic benchmarking approaches to determine suitable metrics for the accuracy of self-benchmarking algorithms. This should be done with industry input regarding the purpose and use of the self-benchmarking capability.</p>	<p>This should be conducted in the mid-term: 2-5 years.</p>

Chapter	Issue Area	Section	Gap/Recommendation	Recommended Timeline
Chapter Four: Evaluation, Measurement, and Verification (EM&V)	Methods for Determining Annual Savings	4.1.2	<p>A. Potentially inconsistent savings estimates</p> <p>1. The issue of consistency requires that the data and a description of the methodology be available to replicate the savings calculation. As a first step, the information required for replication of the energy savings result should routinely be available. This has the advantage of allowing annual savings calculations to be auditable.</p> <p>2. Another important step would be to analyze and provide guidance on how a comparison of two annual savings results could be done, provided that all the information needed to replicate each is available. For example, starting with UMP use cases, a study could be conducted to consider whether it is possible to develop a transparent, standard approach to comparing the savings estimates in different locations. This could be a step-wise change of one location’s data and measurement approach to the other, with each step following a logical progression, and the change in the annual savings figure provided and compared to previous and subsequent values. The analysis could also indicate when a logical, transparent comparison was not feasible. After the UMP use cases were explored, other annual savings calculation approaches could be examined. The objective would be to define a comparison methodology that is as broad as possible. The result would be that when a comparison is undertaken, the method employed by the comparison would not be a source of difference between the two compared results.</p> <p>3. A final step would be to consider the development of standardized testing procedures for energy savings determination methodologies. The California Emerging Technologies Coordinating Council (ETCC) details initial work in this direction, in which standard datasets are used to compare different energy savings approaches. This approach or another could be examined, including the development of criteria for assessing savings approaches, model or sample test procedures, etc. The goal would be to understand from an objective, quantifiable perspective the qualities of a given method. This could be first undertaken with the more simple annual savings calculation methodologies, and could take advantage of the increasing availability of larger datasets and computing power.</p>	This should be conducted in the near-term: 0-2 years.
Chapter Four: Evaluation, Measurement, and Verification (EM&V)	Methods for Determining Annual Savings: Site-Specific Verification, IPMVP Option A, B, C, and D	4.1.2.1	<p>A. Explore and refine the calibration requirements of Option D</p> <p>Exploring additional standardization of calibration requirements used in Option D could increase understanding of the usefulness of EM&V results obtained with this method. Areas to be explored could include a description of how and why the simulation model was modified to achieve calibration, as well as graphical or other approaches to comparing the calculated energy use values and the actual energy use values. The goal is for users of the method to fully understand the accuracy and applicability of the calibrated model. Standardized documentation of the calibration process and data should include sufficient information so that a qualified third party could verify the results.</p>	This should be conducted in the near-term: 0-2 years.
Chapter Four: Evaluation, Measurement, and Verification (EM&V)	Methods for Determining Annual Savings: Statistical Methodologies	4.1.2.2	<p>A. Quantifying uncertainty in regression models for all time periods (e.g., monthly, daily, hourly)</p> <p>Leveraging the California Evaluation Framework requirements on presenting uncertainty, a voluntary standard should be developed that would apply to regression models.</p>	This should be addressed in the mid-term: 2-5 years.

Chapter	Issue Area	Section	Gap/Recommendation	Recommended Timeline
Chapter Four: Evaluation, Measurement, and Verification (EM&V)	Methods for Determining Annual Savings: Statistical Methodologies	4.1.2.2	B. Quantifying uncertainty in energy simulation models, including standard reporting and documentation of parameter assumptions Guidelines should be developed that would provide model users information on: (1) how well a given model replicates known building energy use; and (2) what the sensitivity of the model outputs to changes in the model inputs is. For example, if hours of occupancy change, what is the energy use change in a fully specified building energy model?	This should be addressed in the mid-term: 2-5 years.
Chapter Four: Evaluation, Measurement, and Verification (EM&V)	Methods for Determining Annual Savings: Statistical Methodologies	4.1.2.2	C. General reporting of the identification and quantification of uncertainty beyond sampling error and aggregating all areas of uncertainty in one analysis framework This could be a voluntary framework. Development could start with the requirements in the California Evaluation Framework.	This should be addressed in the mid-term: 2-5 years.
Chapter Four: Evaluation, Measurement, and Verification (EM&V)	Methods for Determining Annual Savings: Whole Building Metered Analysis	4.1.2.3	A. Standards for data collection and the appropriate forms of the statistical analyses to be used on these data For analysis that uses monthly-metered data and survey data about the premises, there is a need to develop standards for data collection and the appropriate forms of the statistical analyses to be used on these data. DOE's Uniform Methods Project for residential whole buildings may provide a starting point for formal standards development.	This work should be conducted in the mid-term: 2-5 years.
Chapter Four: Evaluation, Measurement, and Verification (EM&V)	Methods for Determining Annual Savings: Whole Building Metered Analysis	4.1.2.3	B. New statistical approaches using high-resolution usage data require additional validation New statistical approaches using high-resolution usage data require additional validation for more formal acceptance. This activity could be addressed in the near-term through the development of datasets of the high-resolution energy usage of many buildings with known equipment and usage. Although a single model may not be suitable for all applications, a matrix of acceptable models may be developed through a series of generally accepted automated modeling approaches to identify best fit. Initial proof of concept could be developed using synthetic "data" from building simulation models as a first step to testing with actual building data. Such activities would need research support prior to the development of actual standards.	This should be conducted in the near-term: 0-2 years.
Chapter Four: Evaluation, Measurement, and Verification (EM&V)	Methods for Determining Annual Savings: Whole Building Metered Analysis	4.1.2.3	C. Standardization of methods for automated analysis approaches If suitable data sets and testing procedures can be developed, the standardization of methods for automated analysis approaches that provide performance metrics could be developed.	This should be conducted in the mid-term: 2-5 years.

Chapter	Issue Area	Section	Gap/Recommendation	Recommended Timeline
Chapter Four: Evaluation, Measurement, and Verification (EM&V)	Methods for Determining Annual Savings: Methodologies Used for Large, Complex Retrofits	4.1.2.4	<p>A. Guidance on the evaluation of projects that include multiple heterogeneous measures</p> <p>There is sufficient guidance on sampling within similar sets of measures for a given project, but little guidance exists on how to treat projects that include multiple unique measures.</p> <ul style="list-style-type: none"> Do savings need to be determined for each measure individually? This partly depends on the evaluation framework in place in the jurisdiction. If measure-level savings are required, each measure may need to be evaluated. If only the project-level savings are required, then measures that contribute smaller portions of the savings may not need to be verified. If individual measures are to be evaluated, what guidance can be used to select the most representative measures to accurately determine overall project savings? The selection process is complicated by variances in savings magnitude, use conditions, and measurement error. What levels of uncertainty are introduced when project -level savings are developed using combinations of deemed savings, partly deemed savings, and directly measured savings? How can “value of information” principles be applied? <p>Guidance should be developed over the long-term on the evaluation of projects that include multiple heterogeneous measures.</p>	Guidance should be developed over the long-term (5+ years) on the evaluation of projects that include multiple heterogeneous measures.
Chapter Four: Evaluation, Measurement, and Verification (EM&V)	Methods for Determining Annual Savings: Methodologies Used for Large, Complex Retrofits	4.1.2.4	<p>B. Guidance on how to present the results of complex site-specific engineering analysis</p> <p>There is little guidance on how to present the results of complex site-specific engineering analysis (M&V). Verification of such activities is difficult, due to the requirement to replicate prior analyses rather than capture and validate results based on common specifications. This adds significant cost to the EM&V process and increases error, as additional analysis of unique, non-standard operations may introduce additional sources of error. While existing EM&V resources generally do not address transparency, the IPMVP, NAESB standards, and ISO/RTO manuals contain requirements for M&V reports that include reporting the raw data and the justification for any corrections made to observed data. This guidance is generally sufficient, but local jurisdictions may wish to formalize requirements for transparency and reporting specifications (see Section 4.2.3, <i>Reporting</i>).</p>	This work should be conducted in the long-term: 5+ years.
Chapter Four: Evaluation, Measurement, and Verification (EM&V)	Duration of Savings: Effective Useful Life	4.1.3	<p>A. Straw guidance on the treatment of EULs</p> <p>In the near term, a group of EM&V practitioners should convene to develop straw guidance on the treatment of EULs, including terminology and reporting or presentation practice. This guidance should be vetted and incorporated into protocols especially for technical reference manuals.</p>	This should be done in the near-term: 0-2 years.
Chapter Four: Evaluation, Measurement, and Verification (EM&V)	Duration of Savings: Effective Useful Life	4.1.3	<p>B. Assessing feasibility and usefulness of single national study using survival analysis</p> <p>Practitioners should identify several measures, which produce significant portions of the savings in programs nationally, to assess whether a single national study using survival analysis would be feasible or useful given the long lives of many measures and rapid technological change.</p>	This should be done in the near-term: 0-2 years.

Chapter	Issue Area	Section	Gap/Recommendation	Recommended Timeline
Chapter Four: Evaluation, Measurement, and Verification (EM&V)	Duration of Savings: Effective Useful Life	4.1.3	C. Studies of EUL Several studies of EUL should be undertaken to determine if survival studies could add accuracy to the determination of EULs in a manner that could be standardized and lead to protocols on how such studies could be undertaken in the future. As the EUL of a measure depends on the application of that measure, this is particularly complex.	This should be done in the mid-term: 2-5 years.
Chapter Four: Evaluation, Measurement, and Verification (EM&V)	Technical Reference Manuals (TRMs)	4.1.4	A. Establish a standard format and content guide In order to promote consistency and wider adoption of TRMs, establish a standard format and content guide. The format could be developed by an independent contractor (National Lab, University, Industry Group) acting under an Advisory Group of TRM Users. Such a guide could come in the form of model business practices, business practice standards, or through other stakeholder-led processes. One area to explore that may create consistency in this area is to define the component factors of the TRMs that may be established as state or federal policy objectives rather than objective engineering analysis. In this manner there would be transparency on the differences between TRMs rather than the assumption that the fundamental engineering analysis is not applicable across sectors or regions.	This effort is on several stakeholders' work plans, though is yet to be completed. This is an area that is ripe for standardization and considered a near-term priority. This work should be conducted in the near-term: 0-2 years.
Chapter Four: Evaluation, Measurement, and Verification (EM&V)	Reporting and Tracking Systems: Tracking Systems	4.2.1	A. Set of standard terms and definitions that can be applied nationally A set of standard terms and definitions for designating and reporting energy efficiency program and project data at all levels (from technologies to projects to programs to portfolios) that can be applied nationally is recommended. This project would leverage the new work being planned under BEDES and coordinate with SEE Action to establish standard reporting requirements for energy efficiency projects and programs.	This should be accomplished in the mid-term: 2-5 years.
Chapter Four: Evaluation, Measurement, and Verification (EM&V)	Reporting and Tracking Systems: Standardized Data Collection	4.2.2	A. Collaborative effort to address central data needs for calculating savings A single standard taxonomy (and XML specification) does not exist that covers central data needs for calculating savings. In the near term, a collaborative effort should be begun to: <ol style="list-style-type: none">1. Examine and consolidate the existing (BPI, BEDES, others) taxonomies of data used in energy efficiency savings calculations2. Work with stakeholders to refine these definitions to those which are material for different analytic methods3. Publish a data dictionary and XML specification for use in describing and communicating data4. Consider "locking down" the agreed-upon data standard through an ANSI-approved standards process under an ANSI-accredited organization5. Track the development of new EM&V methods to determine whether a new data type is being used that can be included in the data specification and establish a continuous update process to manage evolving changes	This should be done in the near-term: 0-2 years.

Chapter	Issue Area	Section	Gap/Recommendation	Recommended Timeline
Chapter Four: Evaluation, Measurement, and Verification (EM&V)	Reporting and Tracking Systems: Standardized Data Collection	4.2.2	<p>B. Standardizing reporting characteristics of audit and implementation data</p> <p>An additional gap was identified regarding standardizing reporting characteristics of audit and implementation data which may be routinely communicated to evaluation professionals, including how installation of individual EE measures is tracked. Standardization could improve data quality, EM&V implementation timelines, and reduce cost in the preparation of that data for EM&V purposes. This could be considered as part of future EM&V standardization.</p>	This should be done in the mid-term: 2-5 years.
Chapter Four: Evaluation, Measurement, and Verification (EM&V)	Reporting and Tracking Systems: Reporting	4.2.3	<p>A. A series of analyses and discussions should be undertaken to:</p> <ol style="list-style-type: none"> 1. Assess the needs of each of the general types of users of EE reported information, and identify what the parameters are that could be reported that would meet those needs. The analysis could first identify the types of users, for example, program implementers, entities that oversee program implementers, energy system manager and planners, and air quality regulators. It could then identify the information about EE activities most useful to each category of user. 2. Determine, within each category of user, if there was agreement on program type categories, definitions, data and results to report that would more efficiently meet that user category's needs. The need to more efficiently crosscheck data and to accurately share data across organizations should also be met during this stage. An important question to address is whether data collection can be done in a collaborative manner. 3. Explore issues surrounding transferability of the some of the data collection tools/databases in place to support broader coordination across the country. Consideration should be also given throughout to opportunities to take advantage of new technologies for data gathering and sharing. 	<p>Activities 1 and 2 (near-term) should be completed in the next two years through formal, collaborative efforts. Note several organizations with wide reach in the programmatic energy efficiency industry are pursuing this issue.¹⁶⁵</p> <p>Activity 3 (long-term) should be completed after the first two are complete, and within 5 years, also through formal, collaborative efforts.</p>

¹⁶⁵ These organizations are the American Council for an Energy Efficient Economy, the Consortium for Energy Efficiency, Lawrence Berkeley National Laboratory, and the Northeast Energy Efficiency Partnership.

Chapter	Issue Area	Section	Gap/Recommendation	Recommended Timeline
Chapter Four: Evaluation, Measurement, and Verification (EM&V)	Other Evaluation Methodological Approaches: Top-Down and Bottom-Up Methodological Approaches	4.3.1	<p>A. Build a consistent, logical approach to “top-down” analysis using the expertise of current practitioners, recording current best practice with the following steps:</p> <ol style="list-style-type: none"> 1. Characterize several important “use cases” for analyzing energy use, including whether the use case is for purely historical analysis or if it also includes use in forecasting. These could be for a single region, a single industry, a comparison of two or more regions, and a comparison of two or more industries. 2. For each use case the essential explanatory variables need to be described as specifically as possible. Develop standards on how to obtain this data. 3. For each use case, specify preferred functional forms for the equations to estimate. If the use case includes forecasting, include base case development and forecast variable development guidelines relevant to the specific use case. 4. Develop guidance on how to use the estimated top-down model to address particular energy use questions. 5. Develop criteria for assessing the accuracy of the resulting analysis, and guidelines on their presentation. 	This is a long-term effort and should be accomplished in 5-7 years.
Chapter Four: Evaluation, Measurement, and Verification (EM&V)	Other Evaluation Methodological Approaches: Use of Evaluation in Financial Risk Analysis	4.3.2	<p>A. Systematic framework for analyzing the parametric uncertainty of energy efficiency projects and programs</p> <p>The development of a systematic framework for analyzing the parametric uncertainty of energy efficiency projects and programs is recommended. Use a stakeholder process to establish acceptable tools and methods for calculating and documenting a characterization of program and project savings, particularly uncertainty in underlying parameters. This process would leverage work on Monte Carlo analysis, the Building Performance Database, and the Investor Confidence Project.</p>	This should be accomplished in the mid-term: 2-5 years.
Chapter Four: Evaluation, Measurement, and Verification (EM&V)	Other Evaluation Methodological Approaches: Use of Evaluation in Financial Risk Analysis	4.3.2	<p>B. Systematic framework for translating engineering uncertainties into financial instrument ratings</p> <p>The development of a systematic framework for translating engineering uncertainties into financial instrument ratings is recommended. Use a stakeholder process to establish repeatable, transparent methods for assigning financial risk metrics to specific programs and projects, based on reported parametric uncertainties. These metrics should be developed in with input from the potential users of the information – the financial community.</p>	This should be accomplished in the mid-term: 2-5 years.
Chapter Four: Evaluation, Measurement, and Verification (EM&V)	Other Evaluation Methodological Approaches: Use of Evaluation in Financial Risk Analysis	4.3.2	<p>C. Stakeholder process to assess needs</p> <p>Based on the above two recommendations, a stakeholder process should review the methods used to do EM&V at that time (i.e., in 2 or 3 years) to assess what modifications or additions would be needed to provide the information of use to conduct financial analysis.</p>	This should be accomplished in the mid-term: 2-5 years.

Chapter	Issue Area	Section	Gap/Recommendation	Recommended Timeline
Chapter Four: Evaluation, Measurement, and Verification (EM&V)	Emerging Issue Areas: Role of Conformity Assessment/Accreditation	4.4.1	A. Establish relationship between conformity assessment standards that impact energy efficiency at a more global level, as well as its impact in risk and financial management While the conformity assessment standards are equally related to applications in the compliance and enforcement of standards and workforce credentialing, and are covered in Chapters 1 and 5 respectively, it is important to establish the relationship between the different conformity assessment standards that impact EE at a more global level. In addition, it is important to establish the relationship between conformity assessment and its impact in risk and financial management.	This should be done in the near-term: 0-2 years.
Chapter Four: Evaluation, Measurement, and Verification (EM&V)	Technology-Specific Areas: Behavior-Based (BB) Programs	4.4.2.1	A. Randomized controlled trials Randomized controlled trials (RCTs) are the preferred design for behavior-based programs. To the extent that an RCT is not feasible, quasi-experimental designs as outlined in the SEE Action report are the preferred alternative.	This should be done in the near-term: 0-2 years.
Chapter Four: Evaluation, Measurement, and Verification (EM&V)	Technology-Specific Areas: Behavior-Based (BB) Programs	4.4.2.1	B. Impact evaluation approach The impact evaluation approach should be decided during the initial design of the program. This provides the opportunity for the design to reflect the evaluation approach, and minimizes the likelihood of “conformity bias” (i.e., the tendency for a third-party evaluator to excessively explore various statistical models for the purpose of finding savings agreeable to the client and implementer).	This should be done in the near-term: 0-2 years.
Chapter Four: Evaluation, Measurement, and Verification (EM&V)	Technology-Specific Areas: Behavior-Based (BB) Programs	4.4.2.1	C. Methods to allow for assessing impacts Methods are needed that would allow for assessing the impacts of these programs more broadly without the significant expense of extensive site-specific analysis.	This should be done in the near-term: 0-2 years.
Chapter Four: Evaluation, Measurement, and Verification (EM&V)	Evaluating Emerging EE Technologies	4.4.2.2	No gap	N/A
Chapter Four: Evaluation, Measurement, and Verification (EM&V)	Technology-Specific Areas: Energy Performance Indicators (EnPIs)	4.4.2.3	A. Future revisions of protocols (ASHRAE, IPMVP, others) should be coordinated Future revisions of the SEP M&V protocols, or development of the protocols supporting ISO 50001 can coordinate with a wider circle of EM&V professionals to ensure that the SEP protocols are a subset of current practice, or a superset. In either case, there should be no additional burden on participants of utility programs or in SEP.	This should be done in the near-term: 0-2 years.
Chapter Five: Workforce Credentialing	Terminology	5.1	Standard and industry-accepted credentialing and workforce terminology should be used to avoid confusion and promote understanding for stakeholders searching for and utilizing conformity assessment programs.	Overarching recommendation
Chapter Five: Workforce Credentialing	Indicators of Quality Credentialing Programs	5.2	Indicators of quality credentialing programs should be drawn on to guide stakeholders in selecting standards and conformity assessment schemes.	Overarching recommendation

Chapter	Issue Area	Section	Gap/Recommendation	Recommended Timeline
Chapter Five: Workforce Credentialing	Indicators of Quality Credentialing Programs	5.2	Both certifications and certificates for personnel should include assessment of attainment of competencies and skills.	Overarching recommendation
Chapter Five: Workforce Credentialing	Indicators of Quality Credentialing Programs	5.2	State and federal agencies should recognize accredited credentialing programs.	Overarching recommendation
Chapter Five: Workforce Credentialing	Role of Registered Apprenticeships in Workforce Credentialing	5.3	Energy efficiency skills and knowledge should be incorporated into training and credentialing programs for traditional craft occupations and other relevant professions, such as engineering and architecture. In instances in which this approach is not feasible, training may focus on a specific skill area.	Overarching recommendation
Chapter Five: Workforce Credentialing	Role of Registered Apprenticeships in Workforce Credentialing	5.3	A clear, formal process beginning with a job task analysis should be used to delineate the knowledge, skills, and abilities (KSAs) required for major occupations related to energy efficiency.	Overarching recommendation
Chapter Five: Workforce Credentialing	Role of Registered Apprenticeships in Workforce Credentialing	5.3	Technical specifications for installation, maintenance and operations of energy efficiency equipment and systems should be formalized and then mapped to occupations, job task analyses, KSAs, training programs, and certifications.	Overarching recommendation
Chapter Five: Workforce Credentialing	Determining Market Value of Workforce Credentialing Programs	5.4	Credentials should hold demonstrated market value for workers, employers, and consumers.	Overarching recommendation
Chapter Five: Workforce Credentialing	Determining Market Value of Workforce Credentialing Programs	5.4	The energy efficiency industry and credentialing bodies should jointly market the quality assurances built into credentialing the workforce.	Overarching recommendation
Chapter Five: Workforce Credentialing	The Role of Conformity Assessment in Building Confidence in Credentialing Programs	5.5	Third-party accreditation of energy efficiency credentialing programs by an independent party should be encouraged to ensure that the program has met established benchmarks for operating a competent and impartial credentialing program.	Overarching recommendation
Chapter Five: Workforce Credentialing	Programmatic Accreditation for Training	5.6	Energy efficiency training programs should be accredited to technical and programmatic content to assure workers perform jobs safely and effectively. In some cases, the most appropriate accreditation body may exist outside of the current scope of higher education accreditation.	Overarching recommendation
Chapter Five: Workforce Credentialing	Programmatic Accreditation for Training	5.6	Energy efficiency training should result in an industry-supported program and curriculum that covers the knowledge, skills, abilities, attitudes, and tasks each accredited program must deliver, thereby assuring greater consistency in the performance of the graduate and future worker.	Overarching recommendation
Chapter Five: Workforce Credentialing	Defining the Energy Efficiency Content of Occupations	5.7	Stakeholders reviewing workforce credentials should review the job task analysis on which the certification or certificate program is based in order to determine if energy efficiency competencies and skills are included.	Overarching recommendation

Chapter	Issue Area	Section	Gap/Recommendation	Recommended Timeline
Chapter Five: Workforce Credentialing	Defining the Energy Efficiency Content of Occupations	5.7	To better quantify an occupation's actual impact on energy efficiency, a two-step methodology is recommended. Occupations should first be measured and ranked on how much of the job task analysis is related to energy using a comprehensive review of the existing job task analysis. A second measure is an estimation of how much an occupation can impact the overall energy efficiency of the building types the occupation serves. Combined, these two metrics give good indication if an occupation can impact the energy marketplace.	Overarching recommendation
Chapter Five: Workforce Credentialing	Measuring Outcomes on the Performance of the Credentialed Workforce	5.8	Outcomes on credentialing should be tied to job performance. Validation studies with a well-developed methodology, sampling plan, data collection tools, and protocols should show the link between the credentialed individual and job performance.	Overarching recommendation
Chapter Five: Workforce Credentialing	Measuring Outcomes on the Performance of the Credentialed Workforce	5.8	Validation and impact studies are needed to promote models for credentialing organizations to implement in order to consistently gather and interpret data regarding the effectiveness of the credentialing programs in reducing energy use.	Overarching recommendation



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ROADMAP APPENDIX B: ADDITIONAL RELATED ACTIVITIES OF INTEREST

As this roadmap makes clear, energy efficiency in the United States is being shaped by the standards activities of a number of SDOs – both U.S.-based and non-U.S.-based. The U.S. standards system acknowledges that there are multiple paths to achieving globally relevant standards. What matters is that the standards are developed according to the principles of the World Trade Organization's Technical Barriers to Trade Agreement, which are also consistent with ANSI's *Essential Requirements: Due process requirements for American National Standards*. The process must be consensus-based, open, with balanced participation – and include all the other elements that are the hallmarks of the U.S. standards system. For a comprehensive listing of standardization activities developed by U.S.-based and non-U.S.-based organizations, the reader is directed to the EESCC Inventory Database.¹⁶⁶

Listed in this appendix are some of the international and regional (multi-national) standardization activities, U.S. federal agency programs, and standards-related cross-sector initiatives that are influencing energy efficiency in the United States. The following is meant to be broadly representative and is not necessarily exhaustive.

INTERNATIONAL (ISO, IEC) AND REGIONAL STANDARDIZATION ACTIVITIES

International Electrotechnical Commission (IEC)

Within the IEC, a number of technical committees (TC) are actively engaged in energy efficiency-related standardization, including IEC TC 13, *Electrical energy measurement and control*; IEC TC 57, *Power systems management and associated information exchange*; IEC TC 65, *Industrial-process measurement, control and automation*; and IEC TC 85, *Measuring equipment for electrical and electromagnetic quantities*.

The recently formed **IEC Advisory Committee on Energy Efficiency (ACEE)** deals with energy efficiency matters that are not specific to one single IEC technical committee, and is responsible for the assignment of horizontal energy efficiency requirements. The **U.S. Coordinating Committee on Energy Efficiency (USCCEE) Virtual Technical Advisory Group (V-TAG)** to the IEC coordinates U.S. positions in the various IEC technical committees, subcommittees, and working groups dealing with energy efficiency, and reviews positions taken by the ACEE.

On the conformity assessment front, the **IEC Working Group 12 Conformity Assessment Board** was formed to identify all sectors of electrotechnology where current and future energy efficiency developments may give rise to a market need for conformity assessment, and to develop a roadmap to guide IEC's response to these needs.

International Organization for Standardization (ISO)

The **ISO Strategic Advisory Group on Energy Efficiency and Renewable Resources (SAG E)** is engaged in a roadmapping initiative to identify short-, medium-, and long-term requirements for energy efficiency and renewable energy, with the goal of publishing the roadmap in September 2014. The **ANSI V-TAG** to

¹⁶⁶ The EESCC Inventory Database is available at <http://www.ansi.org/eesc>.

ISO SAG E provides an opportunity for U.S. stakeholders to be involved in this process, and is responsible for bringing U.S. positions forward.

Among the ISO TCs working on energy efficiency-related standardization are: ISO TC 205, *Building environment design*; ISO TC 163, *Thermal performance and energy use in the built environment*; ISO TC 257, *General technical rules for determination of energy savings in renovation projects; industrial enterprises and regions*; and ISO TC 242, *Energy Management*. With the chairmanship held by the United States, TC 242 developed ISO 50001, which specifies requirements for establishing, implementing, maintaining, and improving an energy management system.

A joint effort of the ISO and IEC, **ISO/IEC Joint Project Committee (JPC) 2, Energy Terminology**, is currently working on a standard, ISO/IEC 13273, which will specify terms and definitions used in the field of energy efficiency and renewable energy sources.

CEN CENELEC

The European Standards Organizations (ESOs), **CEN** – the European Committee for Standardization and **CENELEC** – the European Committee for Electrotechnical Standardization, formed the **Sector Forum Energy Management (SFEM)**¹⁶⁷ in 2006 to define and monitor the European standardization strategy on energy management, energy efficiency, renewable, and alternative energy sources.

European directives covering energy efficiency include Directive 2012/27/EU, which establishes a framework of measures to achieve the European Union’s 20 percent target on energy efficiency by 2020, and Directive 2010/31/EU, which promotes the energy performance of buildings and building units. In 2010, the **Directorate-General for Energy of the European Commission**¹⁶⁸ issued a mandate to CEN, CENELEC, and the European Telecommunications Standards Institute (ETSI) to develop standards to promote the energy efficiency of buildings, including a methodology for calculating the energy performance of buildings, in line with Directive 2010/31/EU.

U.S. FEDERAL GOVERNMENT AGENCY PROGRAMS

U.S. Department of Energy (DOE)

DOE supports the development of this roadmap and the growth of the energy efficiency market on a number of fronts. The long-term goal of DOE’s Building Technologies Office is to reduce energy use by 50 percent as compared to a 2010 baseline. DOE’s **Better Buildings Initiative** is a broad, multi-strategy initiative to make commercial and industrial buildings 20 percent more energy efficient over the next ten years and to accelerate private sector investment in energy efficiency. In September 2013, DOE launched the **Better Buildings Workforce Guidelines Project**¹⁶⁹ in partnership with the National Institute of Building Sciences (NIBS) to develop voluntary national guidelines to improve the quality and consistency of commercial building workforce credentials for five key energy-related jobs.

¹⁶⁷ Information on the SFEM is available at <http://www.cen.eu/cen/Sectors/Sectors/UtilitiesAndEnergy/Energy/Forum/Pages/default.aspx>.

¹⁶⁸ The Directorate-General for Energy of the European Commission is responsible for developing and implementing European energy policy. Visit http://ec.europa.eu/dgs/energy/index_en.htm for more information.

¹⁶⁹ Details are available at <https://www4.eere.energy.gov/workforce/projects/workforceguidelines>.

DOE also sponsors **Superior Energy Performance™ (SEP)**,¹⁷⁰ a voluntary certification that industrial facilities earn by demonstrating continual improvement in energy efficiency. SEP builds on the ISO 50001 framework for an energy management system and provides targets for improvements in energy performance. SEP was developed with DOE support and technical input and testing from the U.S. Council for Energy-Efficient Manufacturing (U.S. CEEM). The program is accredited by ANSI and the ANSI-American Society of Quality (ANSI-ASQ) National Accreditation Board (ANAB). Information on DOE's many energy efficiency-related programs is available at <http://energy.gov/eere>.

U.S. Environmental Protection Agency (EPA)

Among the EPA initiatives that support U.S. energy efficiency is **ENERGY STAR®** – a voluntary program that promotes energy efficiency in consumer products, homes, commercial buildings, and industrial sectors. Since the program began in 1992, ENERGY STAR® has helped Americans save nearly \$230 billion on utility bills and prevented more than 1.7 billion metric tons of greenhouse gas emissions.

U.S. Department of Commerce (DOC)

In support of U.S. renewable energy and energy efficiency manufacturers and services providers, DOC established the **Renewable Energy and Energy Efficiency Advisory Committee (RE&EEAC)**. The RE&EEAC provides input on trade issues that will support the international competitiveness of U.S. companies in this expanding sector.

National Institute of Standards and Technology (NIST)

NIST's **Net-Zero Energy, High-Performance Buildings Program** develops and deploys advances in measurement science to move the nation toward net-zero energy, high-performance buildings while maintaining a healthy indoor environment. Under this program, NIST convened stakeholders to develop the 2010 report, *Measurement Science Roadmap for Net-Zero Energy Buildings*,¹⁷¹ which outlines goals for achieving improvements in building performance and sustainability through measurement science. Currently, researchers at NIST's Engineering Laboratory are testing various high-efficiency and alternative energy systems, materials, and designs at the **Net-Zero Energy Residential Test Facility (NZERTF)** with the goal of demonstrating that a net-zero energy house – one that produces as much energy as it consumes over the course of a year – can become a reality in any neighborhood.

U.S. Department of Housing and Urban Development (HUD)

HUD leads several energy initiatives that promote energy efficiency in HUD Homes. The Partnership for Advancing Technology in Housing (PATH) aims to accelerate the creation and widespread use of advanced technologies in order to improve the affordability, quality, durability, and energy efficiency of homes. PATH's TOOLBASE provides a housing industry resource for technical information on building products, materials, new technologies, business management, and housing systems.

¹⁷⁰ For more information on SEP, visit <http://superiorenergyperformance.energy.gov/>.

¹⁷¹ National Institute of Standards and Technology, "Measurement Science Roadmap for Net-Zero Energy Buildings," 2010: <http://www.energetics.com/news/Documents/NetZeroEnergyBuildings.pdf>.

OTHER STANDARDS-RELATED CROSS-SECTOR INITIATIVES

National Energy Efficiency Technology Roadmap Portfolio

The *National Energy Efficiency Technology Roadmap Portfolio*¹⁷² exists to define and refine a technology research agenda for the medium and long-term (five to twenty years) to guide institutional and regional investment strategies. It does so by identifying the landscape of energy efficiency R&D programs linked directly to desired technology characteristics and by tracking research needs that are already being addressed. Coordinated by the **Bonneville Power Administration (BPA)**, the *Roadmap Portfolio* identifies and prioritizes R&D gaps to allow for a more rational allocation of limited funding and resources by organizations such as the BPA, national labs, research universities, private businesses, and venture capitalists.

The *National Energy Efficiency Technology Roadmap Portfolio* does not explicitly cover standards, but rather, is focused on technology R&D programs. Given the important link between standards and technology, the *Roadmap Portfolio* and *EESCC Standardization Roadmap* are seen as complementary initiatives. The EESCC roadmap references relevant sections of the *National Energy Efficiency Technology Roadmap Portfolio* where alignment between the two roadmaps has been noted.

High-Performance Building Council (HPBC)

Under a directive of the *Energy Policy Act of 2005*, the National Institute of Building Sciences (NIBS) established the HPBC to assess the existence of guidance and technology for achieving high performance, identify research needs, and make recommendations to accelerate development of high-performance building processes. In 2008, the Council released its report, *Assessment to the U.S. Congress and U.S. Department of Energy on High Performance Buildings*.¹⁷³ The Council is presently in the process of identifying high-performance building attributes, high-performance goals, primary indicators, performance metrics, high-performance benchmarks, standards, and guidelines for establishing, verifying, or validating these benchmarks.

Smart Grid Interoperability Panel (SGIP)

The SGIP was established to support NIST in its fulfillment of its responsibilities pursuant to the *Energy Independence and Security Act of 2007* (EISA). SGIP's mission is to provide a framework for coordinating all Smart Grid stakeholders in an effort to accelerate standards harmonization and advance the interoperability of Smart Grid devices and systems. SGIP fulfills this mission by facilitating standards development for Smart Grid interoperability; identifying necessary testing and certification requirements; overseeing the performance of these activities; and conducting outreach to establish global interoperability alignment.

¹⁷² The *National Energy Efficiency Technology Roadmap Portfolio* is available at http://www.bpa.gov/energy/n/emerging_technology/pdf/EE_Tech_RM_Portfolio.pdf.

¹⁷³ National Institute of Building Sciences, *Assessment to the U.S. Congress and U.S. Department of Energy on High Performance Buildings*, 2008: http://c.ymcdn.com/sites/www.nibs.org/resource/resmgr/HPBC/NIBS_HighPerformanceBuilding.pdf.

Clean Energy Ministerial (CEM)

The Clean Energy Ministerial is a high-level, global forum to promote policies and programs that advance clean energy technology, to share lessons learned and best practices, and to encourage the transition to a global clean energy economy. Initiatives are based on areas of common interest among participating governments and other stakeholders. The U.S. serves as a lead on several CEM projects, including the **Global Superior Energy Performance Partnership (GSEP)**¹⁷⁴ to accelerate energy efficiency improvements throughout industrial facilities and large buildings. The purpose of this initiative is to significantly cut global energy use by encouraging industrial facilities and commercial buildings to pursue continuous improvements in energy efficiency, and by promoting public-private partnerships for cooperation on specific technologies or in individual energy-intensive sectors. GSEP is also a task group under the **International Partnership for Energy Efficiency Cooperation (IPEEC)**,¹⁷⁵ an international forum that provides global leadership on energy efficiency by identifying and facilitating government implementation of policies and programs that yield high energy-efficiency gains.

¹⁷⁴ For details, visit http://www.cleanenergyministerial.org/our_work/buildings_and_industry/index.html.

¹⁷⁵ Visit <http://www.ipeec.org/> for further information.



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ROADMAP APPENDIX C: INDEX OF ACRONYMS AND ABBREVIATIONS

A

A2LA – American Association for Laboratory Accreditation

ACCA – Air Conditioning Contractors of America

ACM – Alternative Calculation Method

AEA – American Evaluation Association

AEO – Annual Energy Outlook

AFD – Automated Fault Diagnostics

AHRI – Air-Conditioning, Heating, and Refrigeration Institute

AI – Analog Inputs

ANSI – American National Standards Institute

AO – Analog Output

APIs – Application Programming Interfaces

ARCSA – American Rainwater Catchment Systems Association

ASABE – American Society of Agricultural and Biological Engineers

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

ASME – American Society of Mechanical Engineering

ASPE – American Society of Plumbing Engineers

ASTM – ASTM International

ATIS – Alliance for Telecommunications Industry Solutions

AWS – American Welding Society

B

BAR – Building Asset Rating

BAS – Building Automation System

BB – Behavior-Based

BCL – Building Component Library

BCxA – Building Commissioning Association

BECx – Building Enclosure Commissioning

BEDES – Building Energy Data Exchange Specification

BEI – Business Enterprise Integration

BEMP – Building Energy Modeling Professional

bEQ – Building Energy Quotient

BESA™ – Building Energy Simulation Analyst

BESTEST – Building Energy Simulation Test

BI – Binary Inputs

BO – Binary Outputs

Btu – British Thermal Unit

C

CARB – California Air Resources Board

CBECs – Commercial Building Energy Consumption Survey

CEC – California Energy Commission

CEE – Consortium for Energy Efficiency

CEI – Continuous Energy Improvement

CEM – Clean Energy Ministerial

CFL – Compact Fluorescent Lighting

CIEB – Continual Improvement of Existing Buildings

CPUC – California Public Utility Commission

D

DAS – Division of Apprenticeship Standards

DER – Distributed Energy Resource

DEER – Database for Energy Efficient Resources

DHW – Domestic Hot Water

DLC – Direct Load Control

DOE – U.S. Department of Energy

DOL – U.S. Department of Labor

E

ECB – Energy Cost Budget

EC – Energy Content

ECMs – Energy Conservation Measures

EDA – Energy Design Assistance

EE – Energy Efficiency

EEGA – Energy Efficiency Groupware Application

EEPS – Energy Efficiency Portfolio Standard

EIA – U.S. Energy Information Administration

EISA – Energy Independence and Security Act of 2007

EMC – Electromagnetic Compatibility

EM&V – Evaluation, Measurement, and Verification

EnMS – Energy Management System

EPA – U.S. Environmental Protection Agency

EPIs – Energy Performance Indicators

ESCOs – Energy Consumers and Energy Services Companies

ESI – Energy Services Interface

ETCC – Emerging Technologies Coordinating Council

EUI – Energy Use Intensity

EUL – Effective Useful Life

EVO – Efficiency Valuation Organization

F

FEM – Federal Energy Management

FEMP – Federal Energy Management Program

FSGIM – Facility Smart Grid Information Model

G

GBI – Green Building Initiative

GBCI – Green Building Certification Institute

H

HERS – Home Energy Rating System

HPwES – Home Performance with ENERGY STAR®

HVAC – Heating, Ventilation, and Air Conditioning

HUD – U.S. Department of Housing and Urban Development

I

IA – Irrigation Association

IAF – International Accreditation Forum

IAPMO – International Association of Plumbing and Mechanical Officials

IAS – International Accreditation Service

ICC – International Code Council

ICE – Institute for Credentialing Excellence

IEC – International Electrotechnical Commission

IECC – International Energy Conservation Code

IES – Illuminating Engineering Society

IgCC – International Green Construction Code

ILAC – International Laboratory Accreditation Cooperation

IMC – International Mechanical Code

IOU – Investor Owned Utilities

IPMVP – International Performance Measurement and Verification Protocol

IREC – Interstate Renewable Energy Council

IRS – Internal Revenue Service

ISO – International Organization for Standardization

ISO/CASCO – ISO Committee on Conformity Assessment

ISOs – Independent System Operators

ISP – Industry Standard Practice

J

JAC – Joint Apprenticeship Committee

JATC – Joint Apprenticeship and Training Committee

JTAs – Job Task Analyses

K

KSAs – Knowledge, Skills, and Abilities

L

LADWP – Los Angeles Department of Water and Power

LBNL – Lawrence Berkeley National Laboratory

LEDs – Light Emitting Diodes

LEED – Leadership in Energy and Environmental Design

M

M&V – Measurement and Verification

MECS – Manufacturing Energy Consumption Survey

MGP – Modeling Guidelines and Procedures

MPP – Multifamily Performance Program

N

NAESB – North American Energy Standards Board

NAICS – North American Industry Classification System

NAPEE – National Action Plan for Energy Efficiency

NEC[®] – National Electric Code[®]

NECA – National Electrical Contractors Association

NEEC – Northwest Energy Efficiency Council

NEEP – Northeast Energy Efficiency Partnerships

NFPA – National Fire Protection Association

NIBS – National Institute of Building Sciences

NIST – National Institute of Standards and Technology

NREL – National Renewable Energy Laboratory

NREMDB – National Residential Efficiency Measures Database

NVLAP – National Voluntary Laboratory Accreditation Program

NWPCC – Northwest Power Planning Conservation Council

NYSDERDA – New York State Energy Research and Development Authority

P

PEI – Potential Energy Impact

PNNL – Pacific Northwest National Laboratory

PRM – Performance Rating Method

PSDs – Program Savings Documents

PUE – Power Use Efficiency

Q

QA – Quality Assurance

R

RCTs – Randomized Controlled Trials

RECS – Residential Energy Consumption Survey

RED – Random Encouragement Design

REED – Regional EE Database

RESNET – Residential Energy Services Network

RTF – Regional Technical Forum

S

SCTE – Society of Cable Telecommunications Engineers

SDOs – Standards Developing Organizations

SEE Action – State and Local Energy Efficiency Action Network

SEP – Superior Energy Performance

SGIP – Smart Grid Interoperability Panel

SMACNA – Sheet Metal and Air Conditioning Contractors' National Association

SPC – Standard Project Committee

SPT – Standard Program Tracking

STEP – Sustainable Technology Environment Program

T

TBT – Technical Barriers to Trade

TDH – Total Dynamic Head

TIA – Telecommunications Industry Association

TRM – Technical Reference Manual

U

UAC – Unilateral Apprenticeship Committee

UMC – Uniform Mechanical Code

UMP – Uniform Methods Project

UPC – Uniform Plumbing Code

USCAP – United States Conformity Assessment Principles

USSS – United States Standards Strategy

V

VEE – Validation Editing and Estimating

VFD – Variable Frequency Drive

W

WBDG – Whole Building Design Guide

WTO – World Trade Organization



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