GOING BEYOND ZERO

A SYSTEMS EFFICIENCY BLUEPRINT FOR BUILDING ENERGY OPTIMIZATION AND RESILIENCE

ALLIANCE TO SAVE ENERGY

Systems Efficiency Initiative

Year 2 Report / May 2017

Acknowledgements

Thank you to all the members of the Systems Efficiency Initiative (SEI) Steering Committee, Technical Committee, and Working Groups who contributed to this Systems Efficiency Blueprint.

SEI Steering Committee Members

Kathryn Clay (Co-Chair), *American Gas Association*
Kelly Speakes-Backman (Co-Chair), *Alliance to Save Energy*
Jen Amann, *American Council for an Energy-Efficient Economy*
Karim Amrane, *Air-Conditioning, Heating, & Refrigeration Institute*
Kateri Callahan, *Alliance to Save Energy*
Rahul Chopra, *Lawrence Berkeley National Laboratory*
Ron Cosby, *Ingersoll Rand/Trane*
Abigail Daken, *U.S. Environmental Protection Agency*
Andrew DeLaski, *Appliance Standards Awareness Project*
Ralph DiNola, *New Buildings Institute*
Richard Dye, *Pacific Gas and Electric Company*
Drake Erbe, *Airxchange*
Mark Frankel, *New Buildings Institute*
Maureen Guttman, *Building Codes Assistance Project*
Jason Hartke, *U.S. Department of Energy*
Robert Horner, *Illuminating Engineering Society*
Peter Horton, *Legrand/Wattstopper*
Katharine Kaplan, *U.S. Environmental Protection Agency*
Paul Karrer, *American Institute of Architects*
Kit Kennedy, *Natural Resources Defense Council*
Chuck Kutscher, *National Renewable Energy Laboratory*
Melissa Lavinson, *Pacific Gas and Electric Company*
Mark Lessans, *Ingersoll Rand*
Richard Lord, *Carrier Corp. / United Technologies Corp.*
Jean Lupinacci, *U.S. Environmental Protection Agency*
Itzhak Maor, *Johnson Controls, Inc.*
John Martin, *International Association of Lighting Designers*
Greg Merritt, *Cree Inc.*
Rich Murphy, *American Gas Association*
Steve Nadel, *American Council for an Energy-Efficient Economy*
Elizabeth Noll, *Natural Resources Defense Council*
Laura Petrillo-Groh, *Air-Conditioning, Heating, & Refrigeration Institute*
Thomas Phoenix, *American Society of Heating, Refrigeration, and Air-Conditioning Engineers*
Kyle Pitsor, *National Electrical Manufacturers Association*
John Pouland, *Philips Lighting*
Susan Rochford, *Legrand*
Kelly Seeger, *Philips Lighting*
Steve Selkowitz, *Lawrence Berkeley National Laboratory*
Bill Sisson, *United Technologies Corporation*
Zolaikha Strong, *Copper Development Association*
David Terry, *National Association of State Energy Officials*
Scott Tew, *Ingersoll Rand*
Matthew Thornblad, *United Technologies Corporation*
Laura Van Wie McGrory, *Alliance to Save Energy*
Craig Walker, *United Technologies Research Center*
Tim Wentz, *American Society of Heating, Refrigeration, and Air-Conditioning Engineers*
John Wilson, *Energy Foundation*

SEI Technical Committee and Working Group Members

Jennifer Amann, *American Council for an Energy-Efficient Economy*
Doug Arduini, *Cisco*
James Baek, *Cisco*
Bruce Beihoff, *Midwest Energy Research Consortium*
Alex Boesenberg, *National Electrical Manufacturers Association*
Joe Borowiec, *New York State Energy Research and Development Authority*
Richard Brown, *Lawrence Berkeley National Laboratory*
Alyssa Bruner, *Alliance to Save Energy*
Anna Chittum, *American Council for an Energy-Efficient Economy*
Ryan Colker, *National Institute of Building Sciences*
Ron Cosby, *Ingersoll Rand/Trane*
Derek Cowburn, *Lumencache Technologies*
Abigail Daken, *U.S. Environmental Protection Agency*
Helen Davis, *Air-Conditioning, Heating, & Refrigeration Institute*

Pierre Delforge, *Natural Resources Defense Council*
Jeff Duncan, *Duncan Government Strategies, LLC*
Paul Ehrlich, *Pacific Northwest National Laboratory*
Drake Erbe, *Airxchange*
Michael Erbesfeld, *National Electrical Manufacturers Association*
Juan Galindo, *Southwire*
David Geary, *DC Fusion*
Joshua Greene, *A.O. Smith Corporation*
Maureen Guttman, *Building Codes Assistance Project*
Pekka Hakkarainen, *Lutron*
Jeffrey Harris, *Consultant*
Jason Hartke, *U.S. Department of Energy*
Tanya Hernandez, *Acuity Lighting*
Terence Hill, *DC-Nexus*
Robert Horner, *Illuminating Engineering Society*
Peter Horton, *Legrand/Wattstopper*
Patrick Hughes, *National Electrical Manufacturers Association*
Dave Hungerford, *California Energy Commission*
Monica Irgens, *Electro Plastics, Inc.*
Karl Johnson, *California Institute for Energy and Environment*
Miha Kavcic, *Danfoss*
Meegan Kelly, *American Council for an Energy-Efficient Economy*
Simon Lee, *California Energy Commission*
Mark Lessans, *Ingersoll Rand*
Richard Lord, *Carrier Corp. / United Technologies Corp.*
Kevin Lucas, *Alliance to Save Energy*
Larry Lutz, *ELTEK*
Itzhak Maor, *Johnson Controls, Inc.*
Brian Marchionini, *National Electrical Manufacturers Association*
John Martin, *International Association of Lighting Designers*
Tim Martinson, *DC Fusion*
Mark Menzer, *Danfoss*
Dave Mercier, *Southwire*
John Montaño, *Bridgers & Paxton Consulting Engineers*
Steve Nadel, *American Council for an Energy-Efficient Economy*
Donald Nicholson, *University of North Carolina at Asheville*
Elizabeth Noll, *Natural Resources Defense Council*
Bruce Nordman, *Lawrence Berkeley National Laboratory*
Tony O'Brien, *Cisco*
Emily O'Connell, *American Gas Association*
Kara O'Connell, *Alliance to Save Energy*
Steve Pantano, *CLASP*
Brian Patterson, *EMerge Alliance*
Laura Petrillo-Groh, *Air-Conditioning, Heating, and Refrigeration Institute*
Michael Poplawski, *Pacific Northwest National Laboratory*
Becky Rainer, *Eaton's Cooper Lighting*
Gerald Robinson, *Lawrence Berkeley National Laboratory*
Helen Sanders, *Technoform*
Paul Savage, *Nextek Power Systems*
Kelly Seeger, *Philips Lighting*
Todd Sims, *National Association of State Energy Officials*
Rodney Sobin, *National Association of State Energy Officials*
Ted Tang, *Cisco*
Scott Thach, *Alliance to Save Energy*
Sandy Vanderstoep, *Alliance for Sustainable Colorado*
Laura Van Wie McGrory, *Alliance to Save Energy*
Vagelis Vossos, *Lawrence Berkeley National Laboratory*
Dave Watson, *Southwire*
John Wilson, *Energy Foundation*
George Zimmerman, *CME Consulting*

CONTENTS

Acronyms and Abbreviations

AC	Alternating Current
AHRI	Air Conditioning, Heating, and Refrigeration Institute
AIA	American Institute of Architects
ASC	Accredited Standards Committee
ASHRAE	American Society of Heating, Refrigeration, and Air Conditioning Engineers
BIPV	Building-Integrated Photovoltaics
BMS	Building Management Systems
BTO	U.S. Department of Energy Building Technologies Office
B2G	Buildings-to-Grid
CEC	California Energy Commission
CEE	Consortium for Energy Efficiency
CEMEP	European Committee of Manufacturers of Electrical Machines and Power Electronics
CERC	China-U.S. Clean Energy Research Center
CHP	Combined Heat and Power
DC	Direct Current
DES	District Energy Systems
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
EPRI	Electric Power Research Institute
FEMP	Federal Energy Management Program
GHG	Greenhouse Gas
GSA	U.S. General Services Administration
HVAC	Heating, Ventilating, and Air Conditioning
ICC	International Code Council
IEC	International Electrotechnical Commission
IECC	International Energy Conservation Code
IEEE	Institute of Electrical and Electronics Engineers
IgCC	International Green Construction Code
IoT	Internet of Things
LBNL	Lawrence Berkeley National Laboratory
LEED	Leadership in Energy and Environmental Design
LVDC	Low Voltage Direct Current
MELs	Miscellaneous Energy Loads
NASEO	National Association of State Energy Officials
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NREL	National Renewable Energy Laboratory
NYSERDA	New York State Energy Research and Development Authority
PEER	Performance Excellence in Electricity Renewal
PoE	Power over Ethernet
PRM	Performance Rating Method
PV	Photovoltaics
R&D	Research and Development
RD&D	Research, Development and Deployment
SEI	Systems Efficiency Initiative
USGBC	U.S. Green Building Council
VA	U.S. Department of Veterans Affairs

Since its launch, SEI has focused on identifying gaps and developing strategies to advance building system efficiency in the market.

INTRODUCTION

Industry experts and efficiency advocates agree that improving the efficiency of building systems is an important strategy for achieving the next level of efficiency in buildings. A systems approach considers the interactions of components within and among various building systems (e.g., heating and cooling systems, lighting systems, miscellaneous electric loads), as well as interactions among multiple buildings, and between the building and the electric grid.

The Systems Efficiency Initiative (SEI) provides a critical forum for understanding the energy savings potential of a systems approach and for developing strategies for moving the market in this direction. Toward this goal, the SEI's Going Beyond Zero: A Systems Efficiency Blueprint for Building Energy Optimization and Resilience offers a broad set of action-oriented recommendations that target specific actors and focus on areas of high potential gains for systems-level energy savings.

Background

The SEI is a multiyear collaboration among more than fifty entities involved in energy use across the entire life cycle of buildings—including manufacturers, designers and builders, electric and natural gas utilities, national and state-level government agencies and efficiency advocates. The Alliance to Save Energy launched the SEI in February 2015 to advance energy efficiency in building systems. SEI participants, along with building energy experts around the world, believe that adopting a systems perspective will become increasingly necessary to achieve meaningful and cost-effective future energy savings within the built environment. Since its launch, SEI has focused on identifying gaps and developing strategies to move the market in this direction.

In May 2016, the SEI published a detailed report, *Greater than the Sum of its Parts: The Case for a Systems Approach to Energy Efficiency* (www.ase.org/sei). The report characterizes the potential benefits of a systems approach, and prioritizes areas for further technical and policy research. **This Going Beyond Zero: A Systems Efficiency Blueprint for Building Energy Optimization and Resilience builds on the findings in that report, and contains recommendations for specific actions to be taken by a range of stakeholders,** including national and state legislators, government agencies, utilities, industry associations, design professionals, the construction industry and building owners themselves.

Building System:
a combination of equipment, operations, controls, accessories, and means of interconnection that use energy to perform a specific function.

The Need for a Systems Approach

Much progress has been made on improving building energy efficiency over the past decades by focusing on the efficiency of individual building components (i.e., appliances and equipment) and the efficiency of the building as a whole. The energy efficiency of building components has improved substantially due to government and industry research and development efforts, minimum efficiency standards, and government, utility and industry programs. Improvements in the energy efficiency and overall performance of buildings also have been driven by policies such as building energy codes and supported by voluntary programs, such as ENERGY STAR Buildings and Leadership in Energy and Environmental Design (LEED), that certify more efficient and sustainable buildings.

Recently, industry experts, manufacturers and efficiency advocates have been looking beyond these measures to consider new energy efficiency opportunities at the building systems level. Compelling reasons to explore and invest in a systems approach to building energy efficiency include:

- ***Some mechanical equipment and other building components are approaching technical and economic limitations*** for achieving further efficiency improvements. As these limits are approached, the costs of marginal efficiency improvements at the component level will rise. A systems approach offers creative avenues to further energy savings.
- ***Highly efficient components do not necessarily result in an efficient building***. There is a need to look at complete systems—including the interactions among components and with the building—to truly optimize building efficiency.
- Emerging opportunities for attaining significant efficiency gains—such as ***through the integration of smart grid connectivity and related control technologies—are optimally applied at the system level.***
- Current metrics and regulations typically address the efficiency of equipment and buildings as designed, but most do not address actual building performance. ***New systems-level metrics, standards and tools could support the improved performance of building systems*** through system design and commissioning, in ways that consider typical building load profiles, operating patterns and regional climate conditions.
- Despite decades of improvement in equipment efficiency, the ***overall energy use of U.S. commercial buildings continues to increase.*** The energy intensity (energy use per floor area) of U.S. commercial buildings is declining but at a decreasing rate, and not fast enough to offset growth in the building stock. Thus, total primary energy use in this sector is projected to grow steadily (Figure 1).

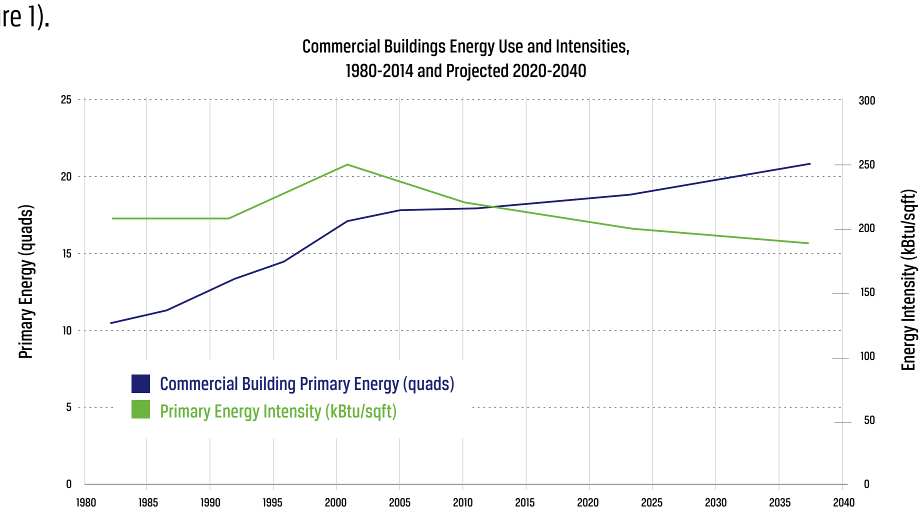

Figure 1—Trends in U.S. Commercial Building Energy Use (per floor area and overall)

Source: U.S. DOE, 2015

One of the key reasons why building energy intensity is not falling more rapidly is the increase in miscellaneous loads from electronics and other electrical equipment in buildings; these not only directly affect the energy use of a building but also create additional cooling loads for mechanical systems. By 2035, miscellaneous end-uses are projected to use as much energy as all other building end-uses combined.[1] The combination of these new loads and growing floor space means that new approaches to efficiency will be needed to stem overall growth in building energy use.

- In addition to reducing energy use, a ***systems approach has the potential to achieve significant non-energy benefits:*** reduced carbon emissions, improved grid reliability, water savings, extended equipment life and increased occupant comfort and productivity. The quantifiable non-energy cost benefits have been estimated to range from 25 to 50 percent of the total benefits of energy efficiency.[2,3]

Systems Efficiency Opportunities

The 2016 SEI report, *Greater than the Sum of its Parts*, outlines system-level opportunities for improving building efficiency, with a focus on heating, ventilating, and air conditioning (HVAC) and lighting systems—which together account for nearly half of total primary energy use in commercial buildings.[4] The report also highlights other areas of opportunity for improving the efficiency of building systems, including miscellaneous electric loads (MELs), direct current (DC) power and buildings-to-grid (B2G) integration.

Integrated communications, controls and smart, "addressable" individual devices are a key enabling technology for all of these systems efficiency measures. However, these addressable devices and expanded communications networks, within and outside the building, in turn call for a higher level of attention to issues of data privacy and cybersecurity.[5]

In addressing these opportunities, the report identifies five strategies for a systems approach to achieve significant energy efficiency savings beyond those available through traditional approaches.

Key Strategies for Improving Building System Efficiency

- ***Breaking down silos.*** A systems-oriented approach will require creativity and a new level of collaboration across a range of stakeholders—including architects, engineers, designers, developers and building operators—as well as between the building industry and policymakers.
- ***Integrating systems.*** Integration both within and among systems operating in a building is vital to maximizing efficiency gains and opportunities.
- ***Optimizing operations through technology.*** Controls and smart technologies are important for improving the efficiency of many types of systems.
- ***Incorporating systems strategies through all phases of the building life cycle.*** Strategies to incorporate a systems approach should be applied during building design and construction, as well as during the operations and maintenance phases.
- ***Thinking outside the building.*** Further opportunities for systems approaches exist beyond a building itself, across multiple buildings, and between a building and the electric grid.

1 U.S. Department of Energy (U.S. DOE) 2015. "Annual Energy Outlook."

2 Livingston, O.V., P.C. Cole, D.B. Elliot, and R. Bartlett. 2014. Building Energy Codes Program: National Benefits Assessment, 1992-2040. Rep. no. PNNL-22610 Rev 1. Prepared for the U.S. Department of Energy. Oak Ridge, TN: Pacific Northwest National Laboratory.

3 Russell, C., B. Baatz, R. Cluett, and J. Amann. 2015. Recognizing the Value of Energy Efficiency's Multiple Benefits. Research Report IE1502. American Council for an Energy-Efficient Economy. aceee.org/research-report/ie1502

4 U.S. DOE 2015. "2015 Commercial Energy End-Use Splits, by Fuel Type." Buildings Energy Data Book: 3.1 Commercial Sector Energy Consumption.

5 Johnson Controls and Booz-Allen-Hamilton. 2017. "Cybersmart Buildings: Securing Your Investments in Connectivity and Automation." February. http://www.johnsoncontrols.com/-/media/jci/be/united-states/specialty-pages/files/be_wp_cybersmartbuildings.pdf

Going Beyond Zero: A Systems Efficiency Blueprint for Building Energy Optimization and Resilience

This Systems Efficiency Blueprint consists of a series of ***Findings and Recommendations*** divided into four sections:

- Key building systems and their interactions
- DC power distribution
- Grid-Edge and District Energy Systems
- Cross-Cutting Strategies

The ***Findings*** summarize key opportunities for systems efficiency that were identified in the 2016 report *Greater than the Sum of its Parts*.

For each finding, the SEI members have developed one or more ***Recommendations*** for specific actions that different types of stakeholders (identified in ***bold and italic*** font) can undertake to promote the adoption of building system efficiency strategies.

The final section of the document consists of a table that ***summarizes all of the recommendations and sorts them according to the targeted actor,*** with hyperlinks to each recommendation in the main body of the Systems Efficiency Blueprint text.

Collaboration and Ongoing Activities

In addition to supporting implementation of the specific recommendations included in this Systems Efficiency Blueprint, efforts of the SEI can be further leveraged by working with other entities engaged in ongoing systems efficiency efforts. In the spirit of a systems approach, the SEI will continue to find ways to collaborate with related efforts such as those listed below.

Lighting Systems

- ***ANSI C137 Lighting Systems Standards***—The ANSI Accredited Standards Committee (ASC) C137 Lighting Systems Committee is developing lighting systems standards to help promote industry and market acceptance of a systems approach to lighting. Representatives of the SEI participate in the ANSI C137 group, and can make the case for potential adoption at the federal, state, or municipal level.
- ***California Title 24***—The SEI will explore opportunities to support ongoing discussions in California regarding the potential incorporation of a systems approach in California Energy Commission (CEC) lighting regulations, Title 24 and its adjunct appliance regulation, Title 20. This would entail adoption of an overall energy consumption metric in place of the current emphasis on connected load (power) and could provide opportunity for replication in other jurisdictions.

Mechanical Systems

- ***Air Conditioning, Heating, and Refrigeration Institute (AHRI)***—Through the coordination of AHRI Steering Committee members participating in SEI, the SEI will continue to explore opportunities to support AHRI initiatives aimed at developing new subsystem and system guidelines and metrics for mechanical systems. Collaboration may include engagement with the U.S. Department of Energy (DOE); drafting of proposed legislation; and exploring potential for adding systems-focused elements to standards such as American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) 90.1 (*Energy Standard* *for Buildings Except Low-Rise Residential Buildings*), ASHRAE 189.1 (the "green building standard"), and ASHRAE 90.4 (the "data center standard"), as well as to ENERGY STAR and Consortium for Energy Efficiency (CEE) programs. Other areas for collaboration may include benchmarking of building systems and additional research on the benefits of a systems approach.

- ***ASHRAE 205***—To facilitate standardization of modeling techniques used in the U.S. and internationally, and thereby to ensure consistency of building blocks for systems modeling, the SEI can work with industry groups to support the development of new models through ASHRAE Standard 205 (*Standard Representation of Performance Simulation Data for HVAC&R and Other Facility Equipment*).

Cross-Cutting Coordination

- ***ANSI/ASHRAE/IES Standard 90.1 and ANSI/ASHRAE/USGBC/IES Standard 189.1***—The SEI will continue to engage with standards groups to explore options for systems-focused compliance paths for meeting standards requirements (e.g., providing system- and subsystem efficiency targets against a fixed baseline model), and for promoting the adoption of such alternative compliance paths in building codes and programs at the state level.
- ***International Code Council (ICC)***—The International Code Council, which produces the International Energy Conservation Code (IECC) and International Green Construction Code (IgCC), is in the process of incorporating Standard 189.1 into the IgCC. Therefore, any SEI efforts related to Standard 189.1 will be included in the integrated IgCC.
- ***States and Municipalities***—The National Association of State Energy Officials (NASEO) has recognized the growing interest of its members in building systems efficiency and buildings-to-grid integration. Other potential partners include state energy centers (e.g., Wisconsin and Iowa) and municipalities (e.g., New York City, Austin, Seattle) that are on the leading edge of implementing energy efficiency programs.
- ***New York State Energy Research and Development Authority (NYSERDA)***—NYSERDA's Commercial Implementation Assistance Program[6] already recognizes the value of a system approach, offering "financial support to implement advanced, system-based energy efficiency, or deep energy-savings projects at commercial and institutional facilities." The SEI will work with NYSERDA to consider additional opportunities for incorporating a systems approach in their program portfolio.
- ***Electric and Gas Utilities***—SEI members are in discussion with utilities about a potential collaboration to design incentive programs for system efficiency upgrades to help reduce the need for additional utility system capacity.

6 https://www.nyserda.ny.gov/All-Programs/Programs/Commercial-Implementation-Assistance-Program

Systems Efficiency Blueprint recommendations provide specific actions diverse stakeholders can take to drive a systems approach.

FINDINGS AND RECOMMENDATIONS

1.Key Building Systems and their Interactions

Lighting and Daylighting

Finding 1-1: A systems approach to lighting efficiency should be integrated into energy codes/standards, either as a separate standard or as an alternate compliance path. Lighting systems are increasingly sophisticated and complex, including more sensors and controls. In addition, there are multiple protocols, many of them manufacturer-specific, for communication among these devices. Owners and architects would be more inclined to require systems with improved energy efficiency and performance if a lighting system standard were in place to ensure that equipment followed a common set of protocols, including standards for interoperability and interchangeability.

Current energy codes and standards typically have two paths to compliance: a prescriptive path that designates the minimum efficiency or efficacy of equipment to be installed, and a performance path based on the energy consumption of the entire building. The performance path does not allow higher energy consumption than if the designer had followed the prescriptive path. The performance option requires addressing not just lighting but all systems in the building, and may not be worth the extra cost and effort, particularly for smaller buildings, even though a more efficient and comfortable building may result. To provide some flexibility in lighting design, most codes do allow trade-offs in lighting power density (W/ft^2) among spaces in the building, to achieve an overall building average. However, these lighting trade-offs do not provide the same credit for lighting controls, thus limiting the options for achieving overall lighting system performance. An optional system *performance* path for lighting would give the designer maximum flexibility to perform trade-offs among the various spaces in a building without the restrictions imposed by the prescriptive approach, or the necessity of preparing a whole-building performance analysis for all energy use covered by the codes.

Furthermore, building energy codes are generally developed in silos: Because prescriptive lighting requirements are developed independently from envelope requirements, potential synergies to provide enhanced energy performance cannot easily be captured. And finally, current energy codes do not cover interior design, which can have a significant impact on daylight performance in a building.

- **Recommendation 1-1.1:** ***National Electrical Manufacturers Association (NEMA) should*** drive completion of work on the new standards under development by the ANSI ASC C137 Lighting Systems. This Standards Committee should continue to develop standards that define the electrical and physical parameters of high performance lighting systems, and encourage the industry to develop and accept standards that allow reliable interconnectivity, interoperability and networking. This would remove many of the barriers created by proprietary hardware/software and promote widespread adoption of high performance lighting systems.

- **Recommendation 1-1.2:** ***Code and standards bodies (ICC, ASHRAE), and states that develop their own codes*** (e.g., CA, OR, WA) should explore options for:
  - Inclusion of a lighting systems approach (e.g., optimization of individual systems and the interactions of lighting with other building systems) as an alternate compliance path.
  - Increased focus on design for good daylighting (including integration of lighting, envelope and interior design).
- **Recommendation 1-1.3:** ***States and local governments*** should include as part of their code compliance activities training and tools to support the energy-efficient design, installation, commissioning and post-occupancy measurement of building lighting systems.

Finding 1-2: Daylighting Systems can contribute to overall building system efficiency and occupant satisfaction. The efficiency/efficacy of electric lighting systems has been steadily improving due to the industry's application of solid-state technology. It is now possible to properly light a typical commercial office space using as little as 0.6 watt/ft^2, depending on the characteristics of the space and its occupants. To further reduce energy consumption by a significant amount, it will be necessary to augment high-efficiency electric lighting with daylighting systems, as well as controls that balance these light sources to maintain occupant comfort and provide adequate, glare-free lighting. While the energy savings from daylighting will decline as the efficacy of solid-state lighting continues to improve, daylighting of occupied spaces can also contribute to improved occupant comfort, increased alertness and higher overall occupant satisfaction.

- **Recommendation 1-2.1:** ***DOE***[7] should work with lighting design professionals to develop and disseminate resources on daylighting best practices—by building type and occupancy—to ensure proper lighting system performance, reliability and occupant acceptance.
- **Recommendation 1-2.2:** ***Congress*** should explore legislative opportunities (e.g., tax incentives or mandatory reporting of building energy usage) that encourage integration of daylighting with electric lighting systems to improve overall lighting system efficiency.
- **Recommendation 1-2.3:** ***Professional lighting and interior design associations*** should ensure that daylighting and other efficient lighting system design strategies are integrated into building design guidelines, and should provide guidance to the ICC and ASHRAE on integrating these strategies into building codes.

Hot Water

Finding 1-3: The efficiency of hot water systems has increased markedly in recent years with the introduction of heat pump water heaters. As a result, other system factors (including the design and location of the hot water distribution system) account for an increasing share of the total energy used by the hot water system.

- **Recommendation 1-3.1:** ***Building designers*** should prioritize the design of hot water distribution systems (e.g., pipe layout and the location of the heating system relative to points of use) to minimize the total heat lost while serving the load.

7 Throughout this report, references to actions by DOE may include, as appropriate, the DOE National Laboratories.

Motor Systems

Finding 1-4: Motor systems (including stand-alone motors, pumps and vertical transport) are responsible for a significant portion of the energy used in buildings, but the individual motor is only one component responsible for energy losses. Shifting to a systems approach that considers additional factors such as drivetrains, inverters and electronic drive controls—as well as the design of the motor-driven system (e.g., for pumps and air-handlers)—has the potential to substantially increase the efficiency of the total motor system.

NEMA and the European Committee of Manufacturers of Electrical Machines and Power Electronics (CEMEP) developed a white paper[8] that discusses a new approach to motors and motor-driven systems. The joint working group of these two associations is analyzing a new approach aimed at minimizing total energy losses rather than just improving component efficiency. This type of approach can help set new test procedures and standards for measuring multi-component motor systems.

- **Recommendation 1-4.1:** Based on the new findings, ***NEMA*** should provide recommendations to DOE on alternative approaches for developing test procedures and setting standards for multi-component motor systems.

Waste Heat Recovery

Finding 1-5: Many potential sources of low-level heat, such as heat rejected from HVAC or refrigeration systems or from telecom and server rooms, could be captured for beneficial use in pre-heating hot water systems or to condition outside ventilation air. This "free" heat can substantially increase the overall efficiency and cost effectiveness of heating and hot water systems.

- **Recommendation 1-5.1:** ***Building designers*** should locate heating systems or energy recovery systems to capture rejected and/or waste heat from any viable heat source in the building.
- **Recommendation 1-5.2:** ***DOE*** should work with manufacturers on out-of-the-box solutions that make it easier to capture and recover waste heat.

Miscellaneous Electric Loads

Finding 1-6: A recent estimate by DOE finds that miscellaneous electric loads (MELs) in the aggregate currently account for 30 percent of primary energy in all residential buildings and 36 percent in all commercial buildings.[9] In a high-efficiency building, MELs can account for over 50 percent of the electric load.[10] There are several strategies to reduce MELs, which can be implemented independently or simultaneously: (1) energy reduction at the device level by improving device efficiency, (2) enhanced control of an individual device to reduce standby power, and (3) integration of MEL device controls with system-level sensors and controls and with other building systems to optimize building operation.

8 NEMA and CEMEP. 2016. "New Systems Approach to Motor Efficiency Standards Promises Electrical Energy Savings in Practical Applications," presented at Motor Summit, Zurich, Switzerland, 11-12 October 2016.

9 Phelan, P. 2016. "Building Technologies Office: R&D Opportunities to Reduce Energy Consumption in Miscellaneous Electric Loads (MELs). Workshop briefing. June.

10 Kwatra, S., J. Amann, and H. Sachs. 2013. "Miscellaneous Energy Loads in Buildings." ACEEE Rep. no. A133. 27 June 2013. http://aceee.org/research-report/a133
Lobato, C., S. Pless, M. Sheppy, and P. Torcellini. 2011 (b). "Reducing Plug and Process Loads for a Large Scale, Low Energy Office Building: NREL's Research Support Facility." NREL/CP-5500-49002. Oak Ridge, TN. February. http://www.nrel.gov/docs/fy11osti/49002.pdf
McKenney, K., M. Guernsey, R. Ponoum, and J. Rosenfield. 2010. "Commercial Miscellaneous Electric Loads: Energy Consumption Characterization and Savings Potential in 2008 by Building Type." Lexington, MA: TIAX LLC. May. http://zeroenergycbc.org/pdf/2010-05-26%20TIAX%20CMELs%20Final%20Report.pdf

DOE, in a 2016 research and development (R&D) solicitation, identified the need for systems-level solutions to maximize savings from MELs:

> ...the amount of energy savings from replacing an individual device often does not justify the replacement cost. As a result, there is a need for developing overarching technological solutions that can achieve crosscutting reductions in energy consumption at minimum cost. Instead of targeting individual MELs, R&D advancements require going up one level (to systems of MELs) or down one level (to common MELs components).[11]

DOE's proposed research on MELs targets DC power distribution, component-level solutions, non-intrusive monitoring and identification of MELs and fully automated controls—particularly "...applications for developing control systems that can reduce consumption from a variety of different MELs and dynamically adjust control rules to incorporate the preferences of building occupants, so that energy consumption is minimized without negatively impacting the occupants."

- **Recommendation 1-6.1:** ***DOE*** should continue to develop and update minimum efficiency requirements for new and existing MEL devices.
- **Recommendation 1-6.2:** ***State standard-setting bodies*** should add minimum efficiency requirements for new and existing MEL devices to state standards, such as California Title 20[12] or standards proposed through the Multi-State Appliance Standards Collaborative.[13]
- **Recommendation 1-6.3:** ***DOE*** should analyze the economic feasibility of expanding to other states California's code requirement that 50 percent of all electric receptacles (i.e., electrical fittings connected to a power source and equipped to receive an insert) have automated controls.[14] Based on the results, consider recommending model code modifications, including provisions for system-level, integrated controls.
- **Recommendation 1-6.4:** ***ASHRAE*** should add minimum requirements in building energy codes for control, monitoring and tracking of local MEL equipment, such as local automatic receptacle control and internet-enabled electrical outlets and switches (i.e., smart wi-fi outlets and plugs).
- **Recommendation 1-6.5:** ***Manufacturers and manufacturer associations*** should work to enhance open-system protocols to facilitate the integration of MEL local controls with Building Management Systems (BMS) to optimize total building operation (e.g., using shared occupancy sensors to turn off or put in "sleep" mode computers, printers, lighting and/or zoned HVAC). Several manufacturers currently offer these capabilities.
- **Recommendation 1-6.6:** ***DOE and ASHRAE*** should develop improved end-use data and energy models to more reliably predict system-level energy savings potential from MELs. As a first step, DOE and its national laboratories should undertake case studies to compare savings and cost-effectiveness of MEL control methods for different categories of MELs[15] and at different

11 U.S. DOE. 2016. "Buildings Energy Efficiency Frontiers & Innovation Technologies (BENEFIT)—2017 Funding Opportunity Announcement (FOA) Number: DE-FOA-0001632." https://eere-exchange.energy.gov/Default.aspx?Search=1383&SearchType=#FoaId8e546c7c-c277-4c71-aae3-f62e15a95aef

12 http://www.energy.ca.gov/appliances/

13 https://www.appliancestandards.org/

14 ASHRAE Standard 90.1 has a similar requirement for receptacles in offices and computer classrooms.

15 For example, some miscellaneous devices require constant power, others have one or more reduced levels of "standby" power, and still others can be placed in an "off" mode when not in actual use, to be awakened either manually or by a wired or wireless signal or timing circuit.

levels of aggregation (i.e., single device, multiple MEL devices and MEL controls integrated with other building system controls).

Finding 1-7: Several studies suggest that occupant education and engagement are critical to reducing the energy use of MELs. For instance, one study of occupants' use of advanced power strips (which shut off supply power to devices not in use) showed reductions of 27-69 percent in printer energy use and reductions of 51-81 percent for miscellaneous equipment, depending on the type of control used.[16]

- **Recommendation 1-7.1:** ***DOE and ASHRAE*** should model and develop case studies related to occupant engagement in MEL control/reduction measures. Types of occupant engagement to investigate include: (1) implementing systems for enhanced MEL control, and (2) motivating responsible manual control by users in cases where automatic or advanced MEL control is not practical.

Dynamic and Passive Integrated Facades

Finding 1.8: DOE-funded R&D has demonstrated that it is feasible to create a "net-zero energy façade"[17] in virtually all climates and has estimated that these solutions—including highly insulated windows and dynamic solar control, integrated with continuously dimmable lighting controls[18]—could save up to 2.6 quads of energy per year if fully deployed.[19] However, achieving this aggressive goal will require a coordinated effort across the full spectrum of research, development, demonstration and deployment, involving coordinated public and private investment on the part of the building industry, government and utilities. Rapid deployment of scalable solutions will require:

1. Development of cost-effective component and subsystems technologies such as highly insulating and "smart" (switchable) glazing systems, and building-integrated photovoltaics (BIPV);

2. Industry agreement on interoperable sensor and control protocols and networks;

3. Optimization studies to define specific solution sets by building type and climate;

4. Demonstration projects to validate and verify the performance capabilities of integrated systems;

5. Refinement and widespread use of an integrated design process, in which architects work alongside lighting/daylighting designers, engineers and building operators from the inception of the project;

6. Better modeling tools to simulate the performance of integrated façade systems, including their interaction with lighting and HVAC systems, and grid impacts of BIPV in the façade;

16 Metzger, I., et al. 2012. "Plug-Load Control and Behavioral Change Research in GSA Office Buildings." NREL Report to U.S. General Services Administration." June. https://www.gsa.gov/graphics/pbs/GSA-GPG-PlugLoadsReport-FINAL.pdf

17 A net-zero energy façade system can produce as much useful solar heat gain and daylighting energy as it loses (on an annual basis) from thermal transfer during heating plus cooling seasons. Adding building-integrated solar PV to wall or glass surfaces may further improve the energy balance, perhaps creating a "net-positive" façade.

18 Lee, E.S., et al. 2015. "Integrated Control of Dynamic Facades and Distributed Energy Resources for Energy Cost Minimization in Commercial Buildings." November. Lawrence Berkeley National Laboratory Report LBNL-1003927. https://eetd.lbl.gov/publications/integrated-control-of-dynamic-facades

19 Arasteh, D., et al. 2006. "Zero Energy Windows." Proceedings, ACEEE Summer Study on Energy Efficiency in Buildings. August. (LBNL-60049).

7. Research that defines and quantifies critical market drivers such as thermal and visual comfort and health impacts of integrated facades; and

8. Trained facility managers to ensure that savings are captured and maintained over time.

- **Recommendation 1-8.1:** ***DOE*** should work with federal and state agencies as well as commercial building owners, utilities and the commercial supply chain to develop market-ready integrated façade systems, to demonstrate their technical and commercial viability via building-scale projects, and then to promote widespread adoption of net-zero energy façades through an integrated design, build and operate process. Since similar efforts are underway in Europe and Asia, and because the design profession and supply chains are often global, DOE's efforts can be accelerated by collaborating with partners around the world.[20]

2.DC Power Distribution

Direct current (DC) microgrid distribution systems, along with DC-driven building equipment, have significant untapped potential to improve the efficiency of building systems, including by improving the utilization of solar photovoltaics (PV) and other on-site power in combination with on-site battery storage.[21] In commercial buildings, some of the largest efficiency gains from DC distribution and end-use applications include motors, LED lighting, office equipment, refrigeration, data centers and fast-charging of electric and hybrid-electric vehicles.[22] Many of these same DC devices, along with numerous "DC-internal" appliances, are also found in multi-family and single-family homes.

While there are challenges to the large-scale introduction of direct current (DC) systems, DC power distribution at the building or microgrid scale can offer significant benefits in terms of energy efficiency (reduced AC/DC conversion and wiring losses); potential for improved power quality, safety and reliability; a means to effectively integrate on-site renewable generation with energy storage; and an important strategy for U.S. industry to remain internationally competitive in building products, equipment and services.

The Department of Energy has identified DC-driven HVAC systems as an R&D priority, but has not yet allocated resources to address this opportunity. A 2014 Navigant report to DOE on emerging energy-efficient HVAC technologies[23] recommended as the first item under "Priority Direct-Impact HVAC R&D Initiatives" that DOE "Develop a DC-powered HVAC system to utilize DC power from a solar PV system without inverter losses and facilitate microgrid integration." An air conditioner that is powered directly with DC is an attractive idea for three reasons: 1) the coincidence of peak cooling loads with peak output from a solar PV system; 2) the potential to use DC motors for the compressor and fans and thus avoid DC-to-AC inverter losses; and 3) the ability to

20 International Energy Agency (IEA). 2013a. "Energy in Buildings and Communities Programme—Strategic Plan, 2014-2019." October, page 13. http://www.iea-ebc.org/fileadmin/user_upload/images/Pictures/EBC_Strategic_Plan_2014_19.pdf
IEA. 2013b. "Technology Roadmap: Energy Efficient Building Envelopes." https://www.iea.org/publications/freepublications/publication/TechnologyRoadmapEnergyEfficientBuildingEnvelopes.pdf

21 For example, the Department of Defense (DoD) is demonstrating the value of a DC microgrid with solar PV and on-site battery storage, at Ft. Bragg, NC, as an efficiency and energy security resource. https://www.serdp-estcp.org/Program-Areas/Energy-and-Water/Energy/Microgrids-and-Storage/EW-201352

22 Ton, M., W. Tschudi, and B. Fortenbery. 2008. "DC Power for Improved Data Center Efficiency." Lawrence Berkeley National Lab (LBNL). March. http://energy.lbl.gov/ea/mills/HT/documents/data_centers/DCDemoFinalReport.pdf

23 Goetzler, W. et al. 2014. "Research & Development Roadmap for Emerging HVAC Technologies." Navigant report to DOE/BTO. http://energy.gov/sites/prod/files/2014/12/f19/Research%20and%20Development%20Roadmap%20for%20Emerging%20HVAC%20Technologies.pdf

provide DC wiring to a single, major load rather than wiring the entire building. Using DOE's buildings R&D prioritization model (P-Tool), the report identifies a technical potential for DC powered HVAC to save 1.9 Q by 2030 in the residential sector alone—more than any of the other HVAC technology initiatives evaluated.

Estimates of energy savings from DC distribution vary. In one case, researchers concluded that medium voltage (380 Volts) DC is 7-8 percent more efficient than AC power.[24] A recent review of the literature on DC-distribution projects concluded that model-estimated energy savings range between 2 and 14 percent, while measured results show savings from 2 to 8 percent.[25] The variation in savings is due to several factors: the building types and end uses served by DC distribution, presence of battery storage and on-site PV power, the number and efficiencies of power conversion components (DC/AC, AC/DC, DC/DC), DC voltage levels and their associated line losses and the overall power system configuration.

DC power distribution and DC end-use applications also can deliver significant energy savings in residential buildings. A Lawrence Berkeley National Laboratory (LBNL) study estimated potential savings of 33 percent by replacing typical residential end-uses with the most efficient DC-internal technologies available in the market, including solid-state lighting and DC-driven heat pumps for resistance, space and water heating.[26] The study found that combining DC distribution with PV and efficient DC-internal appliances can lead to 5 percent electricity savings for houses without battery storage, and 14 percent for houses with storage. These savings are separate from the 33 percent appliance efficiency savings for switching from typical AC to efficient DC-internal appliances.

A growing number of end-use appliances and equipment in both commercial buildings and homes are either "native-DC-powered" (LED and fluorescent lighting, computers and office equipment, consumer electronics, security systems) or use DC power for internal components such as sensors, controls and variable speed motors. Many more devices could be reconfigured to directly use distributed DC power; according to one estimate almost 70 percent of residential electric load either requires DC power today or could be easily converted to operate on DC power. [27]

Despite the growing prevalence of DC (or DC-capable) devices, the majority of DOE's appliance energy test methods either are explicitly limited to mains-voltage AC power input, or are ambiguous about whether DC input is allowed. In the case of refrigerators and freezers, for example, statutory language limits the DOE "covered products" to AC models only.[28] On the other hand, the current test methods for ENERGY STAR computer displays and imaging equipment (e.g., printers, copiers) explicitly provide for both AC and direct DC input power.[29]

Finding 2-1: The potential for DC power distribution opportunities to improve building system efficiency have not yet been widely incorporated into national energy policy, programs and construction practices in the U.S. This offers an important opportunity for

24 Hardcastle, Jessica Lyons. 2013. "DC Distribution Market to Hit $24.1B by 2025," 18 June 2013. Energy Manager Today. http://www.energymanagertoday.com/dc-distribution-market-to-hit-24-1b-by-2025-092835/

25 Vossos, V. et al. 2017 (DRAFT). "DC and AC-DC Hybrid Systems: Summary Report. Lawrence Berkeley National Laboratory report EPC-14-015 Task 2 Summary Report. January.

26 Vossos, V., K. Garbesi and H. Shen. 2014. "Energy Savings from Direct-DC in U.S. Residential Buildings." Energy and Buildings 68, Part A (January): 223–31.

27 Pantano, S. et al. 2016. "Demand DC: Accelerating the Introduction of DC Power in the Home." Prepared by Xergy Consulting for CLASP. pp 8-9. http://clasp.ngo/~/media/Files/DemandDC/CLASP%20DemandDC%20White%20Paper%20-%20May%202016.pdf

28 See 42 USC 6292 (https://www.gpo.gov/fdsys/pkg/USCODE-2010-title42/pdf/USCODE-2010-title42-chap77-subchapIII-partA-sec6291.pdf, page 5806).

29 https://www.energystar.gov/products/office_equipment/imaging_equipment/partners

research, development and deployment (RD&D) collaboration among government, the research community and the private sector, as its efficiency impact can cut across multiple systems within a building. Notably, a recent DOE funding solicitation identified DC-powered distribution as a specific area of interest and noted the "need for rigorous evaluations to provide standard, well-defined system boundaries and systematic, impartial comparison to effectively design DC distribution for a variety of scenarios and building types with the best pathway to energy savings."[30]

In addition, the growing number of PV installations at federal facilities can create significant opportunities for on-site DC distribution to enhance the efficiency and value of on-site power generation, especially when combined with battery storage. The DOE Federal Energy Management Program (FEMP) has identified 58 federal sites with PV systems (alone or in combination with other on-site renewables), totaling over 325 MW of on-site power. In June 2016, the White House announced several new federal initiatives and ongoing private sector activities to promote the development of distributed renewable energy and electricity storage systems, to be integrated with the electricity grid based on market transactions and automated controls.

- **Recommendation 2-1.1:** ***DOE's Building Technologies Office (BTO)*** should:
  - Report on ongoing assessments of the potential energy savings, reliability and resilience advantages and other benefits and costs of DC-powered appliances and equipment when combined with DC power distribution at the building (or community microgrid) scale;
  - Report on ongoing demonstrations of DC-based distribution and end-use equipment in a range of buildings;
  - Work with industry and consumers to build on these assessments and demonstrations to identify the technical, institutional and market barriers to the wider use of DC-powered appliances, equipment and systems; and
  - Develop strategies to address these barriers, consistent with DOE's other energy efficiency and renewable energy goals.
- **Recommendation 2-1.2:** ***DOE/BTO in partnership with other federal, state and utility programs*** should undertake activities to speed the commercial development and market acceptance of DC-powered (or hybrid) appliances, building equipment and systems. Examples could include:
  - Sponsoring DC System "challenge" or "X-prize" initiatives;
  - Encouraging field demonstrations in federal and other facilities, especially in cases where DC driven equipment can directly use DC power from on-site solar PV panels, either directly or in combination with on-site battery storage;
  - Working with voluntary energy rating and recognition programs such as ENERGY STAR, 80-Plus[31] and LEED as well as utility incentive programs to incorporate DC-powered devices and systems;
  - Engaging industry, the design and engineering community, building owners and other stakeholders to strengthen market awareness and acceptance of DC power technologies, broaden voluntary industry alliances and expand the technical dialogue on DC products and systems across the multiple supply chains serving the buildings sector; and
  - Identifying and working to eliminate any building code or appliance standard barriers to market adoption of DC equipment and systems. This includes updating federal test methods to accommodate DC and hybrid HVAC&R

30 USDOE. 2016. Op. cit.

31 80-Plus is a voluntary certification for energy-efficient power supplies (https://www.plugloadsolutions.com/80PlusPowerSupplies.aspx).

equipment (see Finding 2-4).

- **Recommendation 2-1.3:** Based on positive findings from demonstrations in federal and other public or private facilities, ***Congress or the Administration*** should direct federal agencies to consider use of DC power distribution at the building or microgrid scale, for all existing or proposed projects involving on-site solar photovoltaics, especially where PV is combined with on-site battery storage to support grid reliability and operational resilience. ***State governments and municipalities*** should adopt similar policies, especially in those jurisdictions seeking to improve infrastructure resiliency.
- **Recommendation 2-1.4:** ***DOE*** should convene an inter-program/interagency working group to address DC barriers and opportunities, and invite participation by industry, state government and utility stakeholders. At the federal level, this group could include DOE's building technologies programs as well as representation from the DOE Solar program, the DOE Office of Electricity Delivery and Energy Reliability, DOE's Grid Modernization Laboratory Consortium and the ENERGY STAR program, among others. For example, the Federal Emergency Management Agency and Department of Defense (DoD) have opportunities for DC distribution for mobile installations (e.g., temporary housing, field hospitals and kitchens),[32] and the U.S. Agency for International Development could encourage DC applications for remote power in rural and other underserved areas in developing countries.

Finding 2-2: New models for DC power distribution can create new opportunities for system integration and control. DC power distribution has been successful to date primarily where the power is digitally managed, as with USB and Ethernet. Future systems might build on this, incorporating DC capabilities that are not possible with AC, or where DC is less costly. Examples include plug-and-play installation of local generation and storage, microgrids and improvements in local reliability, safety and fine-grained system management when power supply is constrained.[33] Combining power and communications over structured wiring allows the power distribution network to also serve as a secure communications and control network. New technologies could enable power networks inside a building that include electricity storage and can be connected to end-use devices, local generation, vehicles and the existing AC wiring and utility grid. Field demonstrations of DC-powered buildings, such as the Sustainable Colorado office building,[34] can show how a systems approach to intelligent buildings allows the merging of power, data and control into a single unified platform.

- **Recommendation 2-2.1:** ***DOE*** should collaborate with industry and standard-setting bodies to create a roadmap of the RD&D needed to fully exploit the potential for DC power distribution and control to improve building system efficiency. Issues to consider include:
  - Development of a standardized mechanism to add digital power management to 380V DC (e.g., using conventional Ethernet or the new 2-wire version of Ethernet);
  - Working with the Institute of Electrical and Electronics Engineers (IEEE) and others to develop a standard architecture

32 An early DoD project developed a microgrid approach for field deployment using combinations of solar PV, wind, fuel cells, and battery storage—but not including DC distribution (https://www.serdp-estcp.org/Program-Areas/Energy-and-Water/Energy/Microgrids-and-Storage/EW-1650). DoD demonstrated a transportable microgrid system but evidently not including DC distribution (https://www.serdp-estcp.org/Program-Areas/Energy-and-Water/Energy/Microgrids-and-Storage/EW-201605). Another DoD demonstration explored thermo-electric generation from waste heat in field-deployed generators but again without considering DC distribution to improve system efficiencies (https://www.serdp-estcp.org/Program-Areas/Energy-and-Water/Energy/Conservation-and-Efficiency/EW-1651).

33 Nordman, B, and K. Christensen. 2015. "The Need for Communications to Enable DC Power to be Successful," First International Conference on DC Microgrids. Atlanta, GA. June.

34 http://www.sustainablecolorado.org/what-we-do/building-innovation/dc-project/

for networked DC power distribution; and

- Working with IEEE and others to integrate the architecture into each physical layer of technology, existing and new, that includes digitally managed power distribution.

Finding 2-3: There are multiple barriers to realizing the full potential of DC power distribution to improve system efficiency in new and existing buildings. These include limited commercial availability of DC-only or hybrid AC/DC products, including metering, safety and distribution control devices; a lack of supplier, installer and consumer awareness about the benefits and availability of DC power distribution; insufficient workforce training on DC system installation and code requirements; absence of industry consensus on a limited number of DC voltage levels; and the need to update technical standards and electrical code provisions for both hard-wired and plug-in DC end-use devices and distribution system components.

- **Recommendation 2-3.1:** ***Manufacturers*** should develop products and systems that: (a) offer a better performance/cost ratio for standardized DC solutions across multiple building applications; (b) are cost-effective from an overall system perspective; and (c) provide at least the same capabilities (e.g., efficiency, control, longevity) as equivalent AC solutions. Note that relevant voluntary standards are being developed through collaborations such as the EMerge Alliance.[35] A transitional step might involve the development of hybrid AC/DC devices, i.e., products marketed with an on-board AC/DC power supply that can be bypassed when DC distributed power is available (e.g., from on-site PV or battery storage), thus avoiding the added losses of converting DC power to AC at line voltages and then back to DC. Today, some high-efficiency DC power supplies for servers in data centers are currently configured to run on either AC or DC input.[36]
- **Recommendation 2-3.2:** ***DOE*** should engage its Better Buildings partners and other industry stakeholders, as well as state initiatives such as California's "Existing Buildings Energy Efficient Action Plan,"[37] to help develop and test innovative ways to reduce the complexity of introducing DC distribution in existing commercial buildings. For example, a staged process of introducing DC distribution could be tied to building renovations, tenant improvements, relighting or major equipment replacement. In addition, electrical service wiring and sub-panels could be designed to enable easy and safe future conversion to DC circuits.
- **Recommendation 2-3.3:** ***IEEE*** should work with other standards and certification organizations and with industry groups (e.g., Ethernet Alliance, USB Implementers Forum) to develop and disseminate training materials that help designers, installers and facility operators understand the proper, safe and energy-efficient application of DC power to power distribution and end-use applications.

35 The EMerge Alliance -- an industry group with broad participation from manufacturers, building designers and owners, researchers and other stakeholders -- sets voluntary standards for DC products and systems and created a working group to develop specifications for a DC smart meter (https://www.metering.com/news/smart-meter-standards-emerge-alliance/ and http://www.prweb.com/releases/2016/09/prweb13659398.htm).

36 See for example https://www.hpe.com/h20195/v2/GetDocument.aspx?docname=c04111541&doctype=quickspecs&doclang=EN_US&searchquery=&cc=us&lc=en

37 See the 2016 plan update at http://docketpublic.energy.ca.gov/PublicDocuments/16-EBP-01/TN214801_20161214T155117_Existing_Building_Energy_Efficency_Plan_Update_Deceber_2016_Thi.pdf

- **Recommendation 2-3.4:** DOE should provide guidance in coordinating workforce training efforts on code issues involving DC distribution, along with states and code organizations such as the ICC and ASHRAE.[38]

Finding 2-4: To encourage innovation and avoid creating a market barrier to emerging DC powered (or AC/DC hybrid) products, many DOE test procedures used for energy efficiency standards, labeling and utility incentive programs will need to accommodate DC-powered as well as conventional AC-powered devices. DOE's energy test procedures are used not only for mandatory minimum efficiency standards but also for Federal Trade Commission EnergyGuide labels, ENERGY STAR recognition labeling utility rebate programs, building energy code compliance and above-code programs such as, ENERGY STAR Homes and LEED building ratings—all of which should be open to efficient DC-powered as well as AC-powered devices.

- **Recommendation 2-4.1:** ***DOE*** should pro-actively review its energy test methods and update these as appropriate to allow DC input power. DOE also should recommend to Congress a technical change to the existing statutory language that restricts the definition of a "covered product" to lines-voltage AC input only. This change will enable manufacturers to develop and introduce DC-powered appliances, building equipment and lighting that can be appropriately tested and compared with their conventional AC (mains-powered) counterparts. Absent prompt Congressional action, DOE should exercise its statutory authority to define certain DC-powered products as additional "covered products" if the Department determines that these products meet the statutory requirements for inclusion.

In updating its energy test methods, DOE should ensure that efficiency requirements remain comparable for AC or DC powered appliances, taking into account the energy losses from distributed (device-level) AC/DC power and voltage conversions vs building-level DC power distribution (which in turn may come from various combinations of centralized mains-AC-to-DC conversion, DC power provided directly from an on-site source such as a PV array or fuel cell, or DC power from on-site battery storage). As an alternative to modifying test methods individually for each covered product, DOE might consider adopting a "horizontal" standard that allows any existing AC test method to also apply to DC input—similar to the cross-cutting approach in IEC Standard 62301 for measuring standby power across a wide range of devices.[39]

- **Recommendation 2-4.2:** ***Industry stakeholders and efficiency advocates*** should submit comments to DOE in rulemakings on individual test procedures, as applicable, urging that the test method be revised to allow DC input power in addition to AC input power. ***States*** that separately regulate certain energy-using appliances not covered by DOE[40] should update their test methods to allow for DC-powered products. ***Other voluntary energy rating program leaders,*** such as Ecos Consulting and the Electric Power Research Institute (EPRI), which developed the 80-Plus label for power supplies,[41] should also update these programs to include DC-input or hybrid AC/DC products. On an international level, there should be advocacy to include DC-compatible test methods for appliance labeling and standards in individual countries and with international testing and standards bodies.

38 For example, DOE could include this topic in its online codes training (https://www.energycodes.gov/training) or/and add it as a priority for competitive "innovation grants" to states (http://energy.gov/eere/wipo/state-energy-program-competitive-award-selections-2012-2016). Both California and New York have funded energy efficiency training and curriculum development at community colleges (http://www.energy.ca.gov/drive/funding/workforce_training.html, https://www.nyserda.ny.gov/All-Programs/Programs/Clean-Energy-Workforce-Development/Energy-Efficiency-Training, and http://www.cunybpl.org/training/); multi-state collaboration on code training curricula could be encouraged by DOE and the National Association of State Energy Offices (NASEO).

39 https://webstore.iec.ch/publication/6789

40 For a list of state-adopted standards see http://www.appliance-standards.org/states#states-table

41 80 PLUS is a voluntary certification program designed to promote efficient energy use in computer power supply units (PSUs). Launched in 2004 by Ecos Consulting, it certifies products that have more than 80% energy efficiency at 20%, 50% and 100% of rated load, and a power factor of 0.9 or greater at 100% load.

Finding 2-5: There is a need for a systematic review and updating of building electrical codes and technical standards to ensure their applicability to DC power distribution. It will be difficult for DC power distribution to enter the market without changes in today's AC-oriented National Electrical Code (NEC), due to ambiguity in how to apply the code to different DC "use cases." Stakeholders have identified at least 14 articles in the current 2017 NEC that are directly relevant to DC power distribution, and some recent additions to the code appear to have introduced new problems. For example, where managed DC power distribution has been used effectively in Power over Ethernet (PoE) systems, the NEC recently adopted new restrictions treating these low-power systems the same as line-voltage AC systems, without any demonstrated problem or need. These changes have added new inspection requirements into the previously user-managed PoE installation process, and already are resulting in feedback from code instructors that the new provisions are contradictory and confusing. Without appropriate code language—communicated in training for installers and code officials—DC distribution is likely to increase wiring and other construction costs rather than fulfilling its potential to reduce costs in homes and commercial buildings.

- **Recommendation 2-5.1:** ***DOE should work with code-setting bodies and industry stakeholders*** to review existing codes and standards related to DC power—including electrical codes, building energy codes and product safety standards—to assess whether they are "DC-compatible." Problem areas should be identified and suggested revisions submitted to the cognizant standards bodies. For example, standards for residential DC should enable the use of low-voltage DC (e.g., via Bluetooth, Zwave, ZigBee) for control of appliances, light bulbs, HVAC dampers and windows with automated shades or switchable glass. Changes in codes and standards to accommodate DC power distribution must also maintain safety and reliability, based on DC-appropriate standards from organizations such as the Underwriters Laboratories.

  Practical, cost-reducing changes also should be considered for the current NEC for residential wiring, for example:

  - To ensure that DC wiring is safe for non-electricians to install or modify, DC panel boxes or combined AC/DC panel boxes should have external, low power DC terminals (24VDC-4A) protected by breakers.
  - As a cost-saving measure, code requirements for placement of 120V AC receptacles should be changed to allow greater separation of 120V receptacles provided there are additional DC receptacles.
  - Where residential appliances currently require dedicated 120V or 240V AC lines, for safety the code should require a hard-wired DC connection if conventional appliances (e.g., refrigerators, microwaves, dishwashers, washers/dryers, ovens, heat pumps) are replaced with DC appliances.
  - Where homes have a significant number of DC devices the code should allow downsizing of AC panel box amps, street junction boxes and subdivision transformers.

- **Recommendation 2-5.2:** ***ASHRAE*** should consider creating a committee to identify changes needed in Standard 90.1 and other standards, as well as guidelines and training materials to support DC power distribution in new and existing commercial buildings.

Finding 2-6: Rapidly growing interest in DC building systems outside the U.S. suggests that U.S. policymakers and other stakeholders need to act promptly to ensure that domestic manufacturers and consumers stay at the forefront of technical innovation in DC building system applications. The global market for DC power in commercial buildings is projected to grow from

$609 million in 2013 to $9.7 billion in 2020.[42] Grid-connected commercial buildings are one of four vertical markets leading much of this growth for DC power; the other three are data centers, telecommunications and military bases—all energy intense vertical markets.[43] A parallel (and partly overlapping) market is emerging in the residential sector for DC distribution systems to connect on-site power and storage with DC or hybrid AC/DC appliances, lighting and electronics.

In Europe, the ENIAC Joint Undertaking, a public-private partnership between the EU and the electronics industry, has sponsored a project on DC Components and Grid.[44] The project supports DC microgrid demonstrations in retail premises to advance the use of renewables in net-zero energy buildings. In addition, Germany published a standardization roadmap for low-voltage DC microgrids that discusses technical, market, and regulatory issues; advantages of localized DC distribution; standards-related developments; and the status of DC technology.[45]

As an activity of the China-U.S. Clean Energy Research Center (CERC), the Chinese Ministry of Housing and Urban Development is working with DOE and LBNL on a bilateral project that includes DC distribution in buildings.[46] The objective is to document the benefits of DC distribution for both power and communications. Year 1 of this five-year project is focused on modeling to estimate energy savings, reliability and other benefits of DC power.

In other rapidly developing Asian markets, a number of manufacturers already supply small DC-powered air conditioners designed to be connected directly to PV panels.[47] This technology is attracting interest in other warm-climate regions,[48] and these products are starting to appear in the U.S. market. [49]

Finally, in 2015 the International Electrotechnical Commission (IEC) created a Systems Evaluation Group on "Low Voltage Direct Current Applications, Distribution and Safety for use in Developed and Developing Economies" (SEG 4). The IEC/SEG 4 is conducting studies related to low voltage direct current (LVDC) standards and applications to develop recommendations for technical standards, including safety and promising DC applications at the building and microgrid scale.[50]

- **Recommendation 2-6.1:** ***DOE*** should collaborate with ***other federal agencies*** and with interested ***U.S. industry stakeholders*** to monitor developments outside the U.S. regarding DC power for HVAC and other building applications.

42 Navigant Research. 2013a. "DC Power for Commercial Buildings." Navigant Research. Report: 4Q. Web. http://www.navigantresearch.com/research/dc-power-for-commercial-buildings

43 Navigant Research. 2013b. "Direct Current Distribution Networks." http://www.navigantresearch.com/research/direct-current-distribution-networks

44 ENIAC Joint Undertaking. 2011. "DCC+G: DC Components and Grid." Project Profile. Call 2011-1. http://www.eniac.eu/web/downloads/projectprofiles/pp_call4_dccg.pdf

45 DKE German Commission for Electrical, Electronic & Information Technologies. 2016. "German Standardization Roadmap—Low Voltage DC, Version 1." Published in association with VDE Association for Electrical, Electronic & Information Technologies. https://www.dke.de/de/std/documents/rm_gleichstrom_v1_en.pdf

46 http://www.us-china-cerc.org/pdfs/CERC-BEE-2-0-JWP_English.pdf

47 https://www.alibaba.com/trade/search?fsb=y&IndexArea=product_en&CatId=&SearchText=solar+photovoltaic+air+conditioner

48 For international examples of "solar AC" see http://www.greenworldinvestor.com/2011/07/06/solar-air-conditioner-in-india-typeshybrid-sun-powered-direct-current-acscost-and-manufacturers-onyx/, https://www.alibaba.com/showroom/dc-air-conditioner.html, and http://www.bharatsolarenergy.com/1077-solar-powered-air-conditioners-ac-india-/details.html

49 http://www.hotspotenergy.com/solar-air-conditioner/; http://www.securusair.com/; and https://www.practicalpreppers.com/online-shop/air-conditioning/ac-dc-air-conditioner-hybrid

50 A SEG 4 overview is at http://www.iec.ch/dyn/www/f?p=103:186:0::::FSP_ORG_ID,FSP_LANG_ID:11901,25 with reports posted at http://www.iec.ch/dyn/www/f?p=103:194:0::::FSP_ORG_ID,FSP_LANG_ID:11901,25

3.Grid-Edge and District Energy Systems

This section includes findings and recommendations related to *three distributed-energy resources* that have potential to improve the overall energy performance of a building and its surrounding infrastructure: combined heat and power (CHP); district energy systems (DES, also referred to as district heating and cooling); and buildings-to-grid integration (B2G) including micro-grids. While these three systems share some "beyond-the-building" characteristics, and can be complementary when implemented together,[51] they also have distinct opportunities and constraints that merit separate treatment. The SEI provides recommendations for promotion of these resources in the context of improving the overall efficiency of building systems.

Conceptually, the common ground among CHP, DES and B2G (or microgrids) involves the spatial re-distribution of thermal and electric energy resources. In conventional electricity systems generation is centralized and the end-use applications are dispersed, in buildings or other facilities. CHP decentralizes the electrical and thermal generation function, while District Energy centralizes the production and distribution of thermal energy from individual building boilers or heat pumps to district energy loops. These spatial shifts (1) allow CHP systems to make local use of the heat from power generation that would otherwise be wasted, and (2) allow DES systems to take advantage of thermal load diversity, especially in mixed-use developments—and in some cases to diversify the mix of energy sources.[52]

Community-scale energy planning is starting to incorporate CHP as the common element linking buildings, microgrids and district energy thermal systems. For example, Duke Energy is planning to build and operate a microgrid-ready CHP plant on the Duke University campus. And the three respective industry organizations—the International District Energy Association, Combined Heat and Power Association, and Microgrid Resources Coalition—are forming new alliances to encourage integrated decision-making and project development.[53] Finally, the US Green Building Council and Green Building Certification, Inc. are working to refine ways to credit LEED-certified buildings for incorporating CHP systems[54] and to expand the new Performance Excellence in Electricity Renewal (PEER)[55] sustainability rating for energy utilities to also include district energy systems.

For all three of these distributed, multi-building energy systems, the policy drivers include energy efficiency and the associated energy cost savings, as well as improved energy reliability, building and infrastructure operating resiliency and environmental benefits: cleaner air and water, and reduced greenhouse gas (GHG) emissions.

Building and infrastructure resilience continues to be a primary focus for states and communities, especially in those areas that experienced storm damage and sustained grid outages from Hurricane Sandy. New Jersey, for example, has allocated $200M

51 For example, it is common to find CHP used as the heat source for a campus DES system with an associated campus microgrid. Similarly, there is growing interest in DC or hybrid AC/DC microgrids at the community scale or for individual buildings (sometimes referred to as a "nanogrid").

52 Most new DES systems in the U.S. use natural gas, although there are also opportunities to use industrial waste heat and interest in some communities, especially in Canada, in DES boilers that burn wood chips or methane recovered from landfills or wastewater treatment plants. Some communities are also considering shared geothermal wells for DES systems.

53 See for example http://www.districtenergy.org/blog/2016/06/29/is-this-the-%E2%80%98non-weird%E2%80%99-future-of-microgrids/, http://www.districtenergy.org/president-s-message-3rd-quarter-7/ and https://www.iea.org/chp/

54 From EPA Combined Heat and Power Partnership. 2016. "Treatment of District Energy CHP Outputs in LEED® for Building Design and Construction: New Construction and Major Renovations." September 1. https://www.epa.gov/sites/production/files/2016-09/documents/chp-treatment-distinct-energy-leeds.pdf
Also see EPA Combined Heat and Power Partnership. 2015. "Treatment of CHP in LEED® for Building Design and Construction: New Construction and Major Renovations." May 15. https://www.epa.gov/sites/production/files/2015-07/documents/treatment_of_chp_in_leedr_for_building_design_and_construction_new_construction_and_major_renovations.pdf

55 http://www.usgbc.org/articles/what-peer

for a "Resilience Bank" for microgrids and distributed generation projects,[56] with similar programs in nearby New York and Connecticut. Resilience strategies include CHP and DES, as well as other forms of distributed energy (especially locally-sited solar PV and wind generation), distributed storage and microgrids.[57]

Combined Heat and Power (CHP)

CHP systems traditionally have been associated with large industrial plants with relatively constant and well-matched baseload needs for both heat and electricity. However, a recent DOE study[58] found that there is even more untapped potential for CHP in certain commercial and multifamily buildings with significant thermal loads (a total of 75,900 MW) than in industry (65,400 MW).[59]

Whereas industrial CHP installations range upwards of 20 MW, opportunities for commercial building CHP systems are concentrated in the under-500 kW range. Smaller CHP systems for commercial buildings are well suited to the "packaged system" approach pioneered by the NYSERDA and now being adopted by DOE for dissemination nationwide.[60] According to NYSERDA, this packaged CHP approach has reduced both project costs and timetables by 25-30 percent, compared with conventional, custom-designed systems. In many cases, packaged CHP systems can cost-effectively meet the building's thermal and electrical loads while providing net reductions in energy use and emissions of criteria air pollutants and GHGs.

States and local jurisdictions have very significant roles in either encouraging or discouraging CHP projects. Depending on the state, regulatory provisions for grid interconnection, feed-in tariffs, air pollutant sources, GHG cap-and-trade and utility resource portfolio standards may need to be revised to fully reflect the value of CHP to the entire energy system.[61] Utility regulations can encourage innovative ownership and financing models, including utility (or joint public/private) ownership of CHP. A major aspect of CHP and district energy deployment missing from most state-level energy planning is utility-owned infrastructure. Most CHP forecasts assume that the systems will be owned by individual facilities. However, owners of these facilities cannot fully monetize many of the benefits of CHP, and thus often do not invest in the systems even if they are cost-effective.

Recent work on the role of CHP systems in enhancing building operational resilience and grid reliability points to additional benefits of these systems, beyond their potential to save energy and reduce building operating costs.[62] In addition to the potential direct energy savings from CHP, analysts have identified three categories of CHP "resilience value": (1) continued operation during major (low-probability/high-consequence) events; (2) power reliability under routine conditions; and (3) improved power quality.[63] This value applies not only to critical public facilities such as hospitals, wastewater treatment plants,

56 https://www.greentechmedia.com/articles/read/New-Jersey-Launches-200M-Energy-Resilience-Bank-For-Microgrids-and-Distrib (July 2014).

57 "Resiliency through Energy Efficiency: Disaster Mitigation and Residential Rebuilding Strategies for and by State Energy Offices." April 2015. http://www.naseo.org/data/sites/1/documents/publications/NASEO-Disaster_Mitigation_and_Rebuilding_Report1.pdf

58 U.S. DOE, 2016. "Combined Heat and Power (CHP): Technical Potential in the United States." Report DOE/EE-1328. March. http://www.energy.gov/sites/prod/files/2016/04/f30/CHP%20Technical%20Potential%20Study%203-31-2016%20Final.pdf

59 These figures are for on-site use of heat and power only, excluding "bottoming cycle" (i.e., waste-heat-to-power) systems, power generated for off-site use or district-energy CHP, which together account for another 99,300 MW of CHP potential.

60 See http://betterbuildingssolutioncenter.energy.gov/sites/default/files/Packaged_CHP_Off_the_Shelf_Solutions-High%20Impact%20Technologies-WED.pdf

61 See, for example, Neff 2012, op. cit., Chapter 6 for a list of policy and regulatory recommendations in California.

62 Chittum, A. 2016. "Valuing Resiliency: How Should We Measure Risk Reduction?" Proceedings of the 2016 ACEEE Summer Study on Energy Efficiency in Buildings. August. Asilomar, CA.

63 Chittum, 2016. Op. cit.

and schools or community centers that double as emergency shelters, but also to high-rise multifamily and commercial buildings where CHP systems help these buildings remain habitable during extended grid outages.[64] Because CHP units are operated and maintained regularly, and tend to be fueled by natural gas (or with dual-fuel capability), they are more likely than conventional back-up generators to operate reliably during an emergency and more likely able to be permitted for extended use.[65] Recognition of this added resilience value of CHP has led DOE recently to announce a "CHP resiliency accelerator" in partnership with states, communities, utilities and facility owners.[66]

In New York State, NYSERDA recently added an important element to its statewide CHP program: encouraging some new CHP installations to build in excess generating capacity, beyond that required to meet the building's baseload thermal needs. This may take the form of an added CHP module that can be operated in rotation with the baseload unit, thus extending the service life of both CHP modules and providing an added level of redundancy to assure reliable power and heat during a grid outage. Moreover, the added CHP capacity can be brought on line at times of utility peak demand, feeding excess power back to the utility grid to help maintain grid reliability while providing an added source of revenue to the building owner. While the use of this supplemental CHP capacity during an emergency will increase the building's on-site emissions, and may produce more heat than the building can use, these disadvantages should be weighed against the avoided emissions and waste heat from the alternative of the utility firing up a conventional "peaker" powerplant.[67]

Finding 3-1: While most CHP development to date has focused on large industrial plants, there is a major untapped opportunity—especially for packaged CHP systems—in both commercial and multi-family buildings. As with District Energy Systems (see below) the barriers here are mainly financial, legal/institutional and regulatory rather than technical.

- **Recommendation 3-1.1:** ***DOE*** should continue to support the application of CHP systems by: (1) encouraging the use of high-efficiency packaged CHP systems for commercial and multifamily buildings through provision of a national e-catalog of qualified systems, software to guide investment decisions and system sizing and information on innovative financing and leasing strategies; and (2) Supporting the CHP Technical Assistance Partnerships[68] at a level that enables the program to raise awareness of CHP opportunities and pro-actively encourage new CHP installations, in addition to responding to requests for technical assistance from facility owners, CHP developers, utilities and local or state agencies. The added DOE funding could be used in part to develop and make available case studies of utility ownership structures for CHP, and to develop suggested standardized/simplified permitting forms.

64 Chittum, A. 2012. "How CHP Stepped Up When the Power Went Out During Hurricane Sandy." http://aceee.org/blog/2012/12/how-chp-stepped-when-power-went-out-d

65 U.S. Environmental Protection Agency Combined Heat and Power Partnership (EPA/CHPP). 2007." Valuing the Reliability of Combined Heat and Power." https://www.epa.gov/sites/production/files/2015-07/documents/valuing_the_reliability_of_combined_heat_and_power.pdf

Also see ICF International. 2013a. "Combined Heat and Power: Enabling Resilient Energy Infrastructure for Critical Facilities." March. Prepared for Oak Ridge National Laboratory. https://www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/chp_critical_facilities.pdf

And ICF International. 2013b. "Guide to Using Combined Heat and Power for Enhancing Reliability and Resiliency in Buildings." September. Report to HUD, DOE, and EPA. http://portal.hud.gov/hudportal/documents/huddoc?id=CHPSept2013.pdf

66 U.S. DOE. 2016. "Better Buildings Fact Sheet: Combined Heat and Power for Resiliency Accelerator." http://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/Better%20Buildings%20Combined%20Heat%20and%20Power%20for%20Resiliency%20Accelerator%20Factsheet.pdf

Also see https://betterbuildingssolutioncenter.energy.gov/sites/default/files/Combined_Heat_and_Power_for_Resiliency_Organizational_Strategies_WED.pdf#

67 Neff, B. 2012. "A New Generation of Combined Heat and Power: Policy Planning for 2030." California Energy Commission Staff Paper CEC-200-2012-005. September. http://www.energy.ca.gov/2012publications/CEC-200-2012-005/CEC-200-2012-005.pdf (p. 49).

68 Formerly called Clean Energy Application Centers. http://energy.gov/eere/amo/chp-technical-assistance-partnerships-chp-taps

- **Recommendation 3-1.2:** ***DOE's Office of Energy Policy and Systems Analysis*** should take the lead in coordinating the efforts of DOE's offices and programs to expand and reorganize the current CHP program activities. In addition, to take full advantage of CHP opportunities in large buildings, campuses and non-industrial infrastructure facilities (such as landfills and wastewater treatment plants), DOE should organize a cross-cutting federal initiative within the framework of the Partnership for Energy Sector Climate Resilience[69] to engage other federal agencies, the DOE national laboratories, states and municipalities, utilities and industry stakeholders, perhaps modeled along the lines of DOE's Water/Energy Nexus.[70]

- **Recommendation 3-1.3:** To support early adopters of packaged CHP systems in buildings, ***Congress and state governments*** should authorize tax incentives (e.g., business tax credits, accelerated depreciation, tax-free bonding authority) as well as matching grants and other conservation financing mechanisms to assist non-profit and local government sponsors.[71] These incentives can be gradually phased out once customer awareness and demand—along with a reliable, competitive supply chain—show evidence of a self-sustaining market.[72] Financial assistance should be structured to provide support for early-stage feasibility studies.[73]

- **Recommendation 3-1.4:** ***State utility regulators*** should develop utility resource-portfolio strategies that include consideration of CHP as a planned resource, and that explore the possible use of regulatory incentives and retail rates to encourage utilities and their customers to consider cost-effective CHP systems in new commercial and multi-family buildings with significant thermal loads, and as part of refurbishment of existing buildings. State utility planning frameworks should encourage consideration of the locational value of certain distributed resources, as well as the extent to which these resources might improve the reliability of the electric grid.

Utility regulators also should consider policies to encourage utility-owned, supply-side CHP resources, in cases where these resources are more cost-effective than traditional generation.[74] For example, the California Public Utilities Commission approved a special tariff allowing Southern California Gas Company to build, own and operate CHP facilities on its customers' premises; this approach may be especially relevant for smaller CHP installations (under 20 MW) in commercial and multifamily buildings and campus facilities.[75] Also, the Minnesota "Final Combined Heat and Power Action Plan" discusses a range of CHP financing options, including utility financing and ownership.[76]

- **Recommendation 3-1.5:** ***State and Municipal governments*** should offer technical assistance and other tangible incentives for developers to consider CHP at an early stage of project planning. Developer incentives might include accelerated permit

69 http://energy.gov/epsa/partnership-energy-sector-climate-resilience

70 See http://www.energy.gov/under-secretary-science-and-energy/water-energy-tech-team and http://www.energy.gov/sites/prod/files/2014/06/f16/Water%20Energy%20Nexus%20Report%20June%202014.pdf

71 While the federal business energy investment tax credit (26 USC § 48) includes a 10% tax credit for CHP, this incentive has been extended by Congress year-by-year only (and currently ends in December 2016) which does not encourage long-term investment planning (http://energy.gov/savings/business-energy-investment-tax-credit-itc). Nor is there a federal funding source for early-stage CHP feasibility studies. Detailed information on state financing mechanisms for energy efficiency investments is at http://www.naseo.org/state-energy-financing-programs

72 NYSERDA offers CHP project matching grants, beginning with early-stage feasibility studies aimed at attracting private investors by reducing their perceived risk. Funding of early-stage feasibility studies has also proven useful to advance CHP projects in the UK. NYSERDA plans to phase out these incentives as the state's CHP market matures.

73 In California, the Self-Generation Incentive Program (SGIP) provides grants at $0.50/watt for smaller CHP projects up to 3 MW but does not provide funding for early-stage analysis.

74 Chittum, A. 2013. "How Electric Utilities Can Find Value in CHP." ACEEE White Paper. http://aceee.org/files/pdf/white-paper/chp-and-electric-utilities.pdf

75 California Energy Commission. 2015. "Integrated Energy Policy Report—2015." http://www.energy.ca.gov/2015_energypolicy/index.html (pp 152-153).

76 http://mn.gov/commerce-stat/pdfs/CHP%20pdfs/final-unabridged-chp-action-plan-2015.pdf

review or density bonuses for mixed-use developments that incorporate CHP.

- **Recommendation 3-1.6:** ***State governments*** should consider adopting the CHP protocol under development by DOE and National Renewable Energy Laboratory (NREL) as part of the Uniform Methods Project, to help mainstream standard methodologies for evaluating, measuring and verifying savings from CHP.[77]

Finding 3-2: CHP installations can enhance both building resilience and grid reliability, especially where the CHP system's capacity exceeds what is needed to meet the building's baseload heat requirements. However, at present these potential resilience and reliability benefits are poorly quantified and documented; there is a need for broader and more consistent data collection.

- **Recommendation 3-2.1:** ***Government at all levels, including energy offices and emergency preparedness agencies,*** should work with the CHP industry, utility organizations and facility owners and operators to collect and analyze data on the resilience benefits of CHP. In addition to supporting decisions by project developers and lenders, these data may be useful to the insurance industry in adjusting property and liability premiums for the resilience value of CHP, which may exceed that of conventional back-up generators.[78]
- **Recommendation 3-2.2:** ***DOE*** should assist utilities, state regulators, building owners and third-party developers in establishing CHP sizing guidelines to help determine when supplemental CHP capacity should be installed and operated in rotation with baseload CHP capacity, as well as available for demand-response during peak demand periods or grid outages.
- **Recommendation 3-2.3:** ***State legislators and local officials*** should encourage public facilities, such as hospitals and civic centers, along with critical infrastructure, such as water and wastewater treatment systems, to consider efficiency gains and resiliency benefits in the decision to invest in CHP systems as part of new construction or major renovation. States also should encourage large public and private institutions to account explicitly for the added value of CHP resilience and reliability in their strategic planning and cost-effectiveness calculations.[79]
- **Recommendation 3-2.4:** ***State regulators and utilities***—in planning for new generating, transmission and distribution capacity—should use metrics for CHP that account not only for improved system efficiency but also for advantages in resilience, reliability, demand-response potential and power quality when compared with conventional utility-side generation.[80] The DOE/NREL Uniform Methods Project protocol on CHP can be helpful here.[81]

Finding 3-3: Installing CHP in federal facilities can play an important market leadership role, but federal CHP projects face significant constraints. The federal sector, representing more than 350,000 buildings, 3 billion ft^2, and over 360 TBtu of annual energy use,[82] can contribute significantly to growing the CHP market for individual buildings and for incorporating CHP into

77 http://www.nrel.gov/extranet/ump/pdfs/ump-chp-steering-committee.pdf

78 Chittum, 2016. Op. cit.

79 New or renovated public facilities in TX, LA, and WA are currently required to consider CHP. (Chittum, 2016. op. cit., and NASEO, "Combined Heat and Power: A Resource Guide for State Energy Officials." February 2013. http://www.naseo.org/data/sites/1/documents/publications/CHP-for-State-Energy-Officials.pdf

80 New York State's "NY PRIZE" program is already moving in this direction; other states may also be doing so. (Chittum, 2016. Op. cit.).

81 Simons, G. and S. Barsun. 2016. "The Uniform Methods Project: Methods for Determining Energy-Efficiency Savings for Specific Measures—Chapter 23: Combined Heat and Power." National Renewable Energy Laboratory report NREL/ SR-7A40-67307. November. http://www.nrel.gov/docs/fy17osti/67307.pdf

82 http://energy.gov/eere/femp/federal-facility-annual-energy-reports-and-performance

district energy systems serving military bases, health care centers, national laboratories and other research campuses.[83] Recognizing the importance of CHP for larger federal facilities, beginning in 2014 DOE's FEMP included CHP as one of its priority areas for technical assistance and capital grants to other federal agencies.[84] However, both new natural-gas fired CHP systems and refurbishment of existing systems are hampered by a federal law that limits their useful life, by requiring a phase-out of all fossil fuel generated energy use in new and renovated federal buildings by 2030.[85]

- **Recommendation 3-3.1:** ***Congress*** should amend current law to reduce the barrier to CHP installations created by the fossil fuel phaseout in federal facilities with significant thermal and electrical loads. This can be done either by replacing the fossil-fuel phaseout with more stringent long-term federal energy efficiency goals for all types of energy, or by providing an exception for natural-gas-fired CHP systems that meet specified requirements and will result in a net reduction in energy use and GHG emissions.

District Energy Systems (DES)

District energy systems in appropriate circumstances can significantly improve energy productivity and energy diversity while reducing GHG emissions. According to the UN Environment Programme, DES can reduce heating and cooling energy in urban buildings by as much as 30–50 percent.[86] While DES systems currently provide heating and cooling to several hundred multi-building campus facilities and urban communities in the U.S.,[87] this represents a far lower market penetration than in Europe and other countries.[88]

In general, DES systems offer enormous potential for energy diversity. District energy is intrinsically open to diverse fuel sources on the thermal side; when combined with CHP it can diversify the source of both electricity and heat. In addition to CHP boilers or turbines, waste heat streams from industry, supermarket or industrial refrigeration and data centers[89] have all been used as DES heat sources. Geothermal and solar thermal systems have been used as renewable heat sources for district heat loops, along with wood chips as a boiler fuel and landfill methane to fire boilers or turbines. For campus-type facilities with simultaneous heating and cooling needs, the load diversity among buildings may provide a "free" resource when the

83 For an example of a "bottoming cycle" CHP retrofit to use boiler waste heat at a military base, see https://www.serdp-estcp.org/Program-Areas/Energy-and-Water/Energy/Conservation-and-Efficiency/EW-201250

84 http://energy.gov/eere/femp/assisting-federal-facilities-energy-conservation-technologies-affect-funding-opportunity and http://www.2016energyexchange.com/wp-content/tracks/track13/T13S6_Boomsma.pdf

85 Energy Independence and Security Act of 2007, Section 433; codified in 42 U.S.C. 6834(a)(3)(D)(i), see https://www.law.cornell.edu/uscode/text/42/6834

86 UN Environment Program (UNEP). N.D. "District Energy in Cities—Unlocking the Potential of Energy Efficiency and Renewable Energy." http://www.unep.org/energy/portals/50177/DES_District_Energy_Report_full_02_d.pdf

87 It is difficult to find a complete, up to date inventory of DES installations, although the International District Energy Association publishes an interactive map at http://www.districtenergy.org/map-of-district-energy-in-north-america/
A 2002 report identified 176 systems in U.S. universities and airports alone (http://www.districtenergy.org/ornl-doe-survey-data), while earlier surveys found roughly 1200 installations nationwide (http://www.districtenergy.org/assets/pdfs/ORNL-DOE_2002_data/IDEACHPCampusCensusReport11.21.02.pdf). The International District Energy Association (IDEA) has identified 837 existing DES systems in the U.S., including campus facilities such as universities, health care, and military—see http://www.districtenergy.org/u-s-district-energy-systems-map/. And a paper presented at the 2012 ACEEE Summer Study on Energy Efficient Buildings cites 5,800 DES systems in the U.S.; see L. Cooper and N. Rajkovich, "An Evaluation of District Energy Systems in North America: Lessons Learned from Four Heating Dominated Cities in the U.S. and Canada" at http://aceee.org/files/proceedings/2012/data/papers/0193-000354.pdf. These discrepancies may be due to very different definitions of DES.

88 For an international perspective, see UNEP, op. cit.

89 For an example of data centers as a waste heat source for DES see this 2013 Energy Manager Today report at https://www.energymanagertoday.com/seattle-looks-to-data-centers-as-a-heat-source-096358/

circulating loop is combined with building-level heat pumps and in some cases supplemented by seasonal thermal storage using "shared" geothermal wells or nearby bodies of water. Finally, DES systems can readily incorporate ice storage tanks to offset peak demands or to make better use of surplus generation from intermittent wind and solar resources. DES systems in British Columbia and Ontario use community-scale energy planning to take advantage of these diverse resources.

New research focusing on low-temperature district heating, with reduced distribution losses, has prompted a move to "fourth generation" district heating in parts of Europe.[90] However, buildings must be designed to take advantage of this low-grade heat to adequately meet space heating demands, based on measures such as improved thermal envelopes, expanded radiant-heat surfaces and heat pumps. This could be an appropriate topic for DOE Building Technologies RD&D on next-generation HVAC systems and whole-building integration.

Among the cities in the U.S. and Canada that are installing new DES facilities or upgrading older systems are West Union, Iowa;[91] Arlington County, VA; Burlington, VT; Guelph, ONT; Pittsburgh, PA; Portland, OR; St. Paul, MN; Seattle, WA; and Vancouver, BC.[92] Many cities with existing DES systems are converting old steam loops to more efficient hot-water loops. For the estimated 290 district energy systems in the U.S. that do not currently use CHP, conversion to CHP represents a tremendous opportunity for efficiency improvement and an increased revenue stream.[93] Other communities see installation of a new DES system—typically in areas slated for renewal or newly open for development—as an opportunity to make effective use of a renewable resource and reduce net GHG emissions.[94]

Finding 3-4: While some U.S. states and communities have shown interest in modernizing, expanding, or creating new district energy systems, this technology has yet to achieve national recognition and support at the levels needed to overcome the obstacles—which are more legal and institutional than technical.

Since the responsibility for promoting DES is not clearly defined within DOE's program and office structure, promoting DES on a national scale will require effective collaboration across several DOE offices and programs. Responsibility for technical assistance on district energy is nominally assigned to the DOE-funded Regional CHP Partnerships (formerly Clean Energy Application Centers), and several of these Partnerships have sections on their websites devoted to district energy applications of CHP.[95] However, the Centers have limited resources to provide DES technical assistance to communities that request it—let alone

90 A. della Rossa et al. 2014. "Toward 4th Generation District Heating: Experience and Potential of Low-Temperature District Heating." IEA CHP/DHC Annexe X Final Report. http://orbit.dtu.dk/files/105525998/IEA_Annex_X_Toward_4th_Generation_District_Heating_Final_Report.pdf

H. Lund et al. 2014. "4th Generation District Heating (4GDH): Integrating Smart Thermal Grids into Future Sustainable Energy Systems." Energy 68 (2014) 1-11. http://studylib.net/doc/18551789/4th-generation-district-heating--4gdh-

91 http://www.westunion.com/uploads/PDF_File_17418597.pdf

92 See http://www.districtenergy.org/blog/2014/10/10/vancouver-heating-the-city-one-neighborhood-at-a-time/; https://www.energymanagertoday.com/canadian-town-builds-district-energy-network-098696/ and http://guelph.ca/wp-content/uploads/011514_DistrictEnergyStrategicPlan_web.pdf; http://web.mit.edu/colab/gedi/pdf/Financing%20District%20Energy/MIT_CoLab_GEDI_Financing%20District%20Energy.pdf; http://powersource.post-gazette.com/powersource/consumers-powersource/2016/05/04/DOE-researchers-see-Pittsburgh-s-progress-on-district-energy/stories/201605040028; http://www.districtenergy.org/blog/2016/09/29/waste-heat-recovery-district-heating-proposal-revived-for-burlington-vt/; http://www.districtenergy.com/

93 International District Energy Association (IDEA). N.D. "Smart Tools in a 111d Toolbox: Combined Heat and Power and District Energy." http://www.districtenergy.org/assets/pdfs/111d/111d-Toolbox-v10.pdf

94 For a primer on the role of DES in green renovation of existing neighborhoods see http://www.preservationnation.org/information-center/sustainable-communities/green-lab/additional-resources/District-Energy-Long-Paper.pdf

95 See for example http://www.midwestchptap.org/cleanenergy/district/ and http://www.midatlanticchptap.org/cleanenergy_district.html

to aggressively pursue new opportunities.

- **Recommendation 3-4.1:** ***DOE*** in cooperation with ***other federal agencies*** and interested ***states*** [96] should provide increased technical assistance to communities and campus-based institutions looking to create or expand DES systems. DOE should expand the mission and resources of its regional CHP Centers to explicitly include DES, not only when combined with CHP, but also when combined with other environmentally friendly heat sources such as biomass, geothermal and solar thermal and industrial recovered heat.[97]

- **Recommendation 3-4.2:** ***DOE*** should extend its EnergyPlus and OpenStudio energy modeling tools with DES modeling capabilities to enable evaluation of DES in building design and retrofit projects, to support DES operation and to calculate and report metrics for DES performance assessment.[98]

- **Recommendation 3-4.3:** ***DOE's Regional Centers*** should work with the DES industry, states, and major cities to: (1) create and maintain an inventory of existing DES installations; (2) survey prospective opportunities for new or expanded DES systems; and (3) assist local communities with early-stage DES feasibility studies. Both Canada and the UK provide funding for DES feasibility studies (also called "heat mapping").[99] Such feasibility studies can be key to attracting both public and private capital, by reducing the perceived risk of a DES project.

  DOE also should partner with industry to develop a publicly available decision tool to help community leaders and developers assess whether new developments or redevelopments are potentially well-suited to district energy. Such a tool should be designed for use by municipal agency staff with little or no DES technical knowledge.

- **Recommendation 3-4.4:** ***Congress and state governments*** should authorize tax incentives (including business tax credits, accelerated depreciation and tax-free bonding authority) for district energy, as well as matching grants to support non-profit and local government sponsors.[100] This suggestion parallels Recommendation 3-1.3 (CHP), however the 10 percent federal business energy investment tax credit for CHP (which expired in December 2016) did not extend to DES systems without CHP, or to the non-CHP components of a district energy system (distribution loops, pumps, building-level heat exchangers and heat pumps). In addition to renewing the CHP tax credit, a multi-year DES credit should be put in place to ease investor uncertainty and should be broadened to include privately owned (building and central-system) DES system components. Moreover, the federal incentive should be complemented with funding support to local jurisdictions or private developers for early-stage DES feasibility studies.

Finding 3-5: Federal, state, and municipal governments all have significant opportunities for market leadership in developing new or expanded DES systems for campus-scale public facilities such as colleges and universities, health care, and military bases.

96 DES installations could support the missions of these other federal agencies since DES is often well suited to hospital/health care and university campuses, airports, and urban redevelopment areas, among others.

97 New York State, for example, is looking at ways to increase the use of biomass for DES and other purposes in upstate areas without natural gas service.

98 For more on these DOE-sponsored tools see the discussion of metrics and modeling in Section 4.

99 UN Environment Program (UNEP). 2016. "C40 Cities Good Practice Guide: District Energy." http://c40-production-images.s3.amazonaws.com/good_practice_briefings/images/1_C40_GPG_DE.original.pdf?1456788189
Also see UNEP (N.D.), op. cit.

100 A variety of state financing mechanisms for energy efficiency are described at http://www.naseo.org/state-energy-financing-programs. For examples of financial incentives used for DES in other countries, see UNEP (N.D.), op. cit., Section 2.3.1.

Federal agencies also can assure local municipalities that existing or new federal buildings will step forward to serve as "anchor customers" for proposed new DES installations.

- **Recommendation 3-5.1:** ***Congress or the Administration*** should direct all federal agencies to consider opportunities for new or expanded DES systems in campus facilities, and to ensure that new or renovated federal facilities in urban areas with existing or planned DES systems are designed to be "DES-ready" (i.e., with hydronic distribution and provisions for connecting to district heating or cooling[101] loops).
- **Recommendation 3-5.2:** ***Congress*** should direct DOE, the General Services Administration (GSA), DoD, Department of Veterans Affairs (VA), and other relevant agencies to establish a collaborative interagency process to advance DES within the federal sector and to provide information and technical assistance to states and communities. This could be modeled on provisions in the 2007 Energy Independence and Security Act that define a coordinated, interagency federal structure and responsibilities for high-performance, net-zero energy federal and commercial buildings.[102]
- **Recommendation 3-5.3:** ***State and municipal governments*** should adopt policies committing major public facilities to help "anchor" new or expanded DES systems.

Finding 3-6: State and local policies have an important role to play in the future of district energy, since DES opportunities often depend on local circumstances, planning processes, and development controls. Municipal governments, and to some extent states, can have a significant influence on DES implementation through their planning and regulatory roles, and in some cases as direct participants or partners in project development, financing, ownership and operation.[103]

For example, in Vancouver BC, local policies require some buildings to connect to the DES system as a condition of development permitting if they are located in designated "Development Planning Areas."[104] These are either existing neighborhoods served by older steam DES systems that may be converted to a more efficient boiler or CHP system fired by wood chips, or new close-in urban development areas with planned density sufficient to justify district energy. In the former, buildings subject to renovation or replacement may be required to be connected to the DES loop; in newly developing areas all new construction may be required to connect to DES as a condition of the building permit.

As with CHP systems, local governments can offer accelerated permitting, density bonuses, or other regulatory incentives to

101 Note that hydronic cooling may be difficult in warm, humid climates, although in Singapore and Dubai Some new buildings do use hydronic (radiant) cooling with separate dehumidification, and some new buildings in the Middle East use district energy loops as a heat source for absorption cooling systems (Personal communication—Miha Kavcic, Danfoss No. America).

102 See 42 USC 17081 and 42 USC 17092.

103 For examples of ways that local and state government can support DES, along with case studies, see:
a) UNEP C40. "District Energy Good Practice Guide." http://c40-production-images.s3.amazonaws.com/good_practice_briefings/images/1_C40_GPG_DE.original.pdf?1456788189. Section 3.6 addresses local policies and case studies
b) International District Energy Association. "IDEA Planning Guide for Community Energy." www.districtenergy.org/community-energy-planning-development-and-delivery
c) Pacific Institute. 2012. "The Regulation of District Energy Systems," which includes examples from BC communities. http://www.toolkit.bc.ca/Resource/Regulation-District-Energy-Systems

104 Detailed information on Vancouver BC policies and experience with DES are at http://vancouver.ca/green-vancouver/neighbourhood-energy-strategy.aspx;
(briefing); http://vancouver.ca/files/cov/neighbourhood-energy-design-guidelines.pdf (neighborhood energy connectivity guidelines); http://vancouver.ca/files/cov/neighbourhood-energy-map-of-priority-zones.pdf (map). The basis for these policies was a 2010 report at http://www.districtenergy.org/assets/CDEA/Industry-Information/CDEA-Elenchus-Report-DE-Opportunities-Final.pdf
General guidance on Development Planning Areas (DPAs) for energy/water/GHG, and Canadian case studies, is found in the "BC Climate Action Toolkit." http://www.toolkit.bc.ca/dpa

encourage buildings to connect to a district energy system. Where a developer is required to provide open space for recreation or ground-water recharge, the local jurisdiction could allow that open space to be leased to a DES developer for distribution lines, geothermal wells, or pumping stations and thus provide the developer a source of additional revenue. Other instruments available to the municipality include tying in DES rights-of-way or pre-installing underground piping as part of other infrastructure projects such as sewers, storm drains, or undergrounding of gas and electric lines. Finally, prior to completion of a new district energy loop, the city or DES developer might arrange for a building owner to lease a packaged boiler until the new DES system is ready for connections.

- **Recommendation 3-6.1:** ***Communities*** should establish non-financial incentives for new and renovated buildings to be "DES-ready" and to join a DES system when it becomes available.
- **Recommendation 3-6.2:** ***DOE and state governments***, in cooperation with the DES industry and federally funded regional partnerships, should establish or strengthen peer-to-peer networks among cities with operating experience and those with prospective interest in DES systems.[105] This can include identifying "sister cities" in Europe, Asia and other regions where district energy is widespread.[106]

Buildings-to-Grid (B2G) Integration

The evolution of a fully integrated, transaction-based B2G ecosystem will create new opportunities for optimizing system efficiencies, reliability and cost-effectiveness at both the building and grid scale, while paving the way for more effective integration of renewable resources and electric vehicles. In the past, the relationship between buildings and the electricity grid was a one-way flow of power from the grid to the final point of use in a building or home. The growth in distributed generation (e.g., natural gas or diesel back-up generators, CHP, wind or solar PV), along with demand response[107] and developments in battery storage, are all transforming this simple paradigm into a more complex, multi-directional flow of power and information between a utility and its customers. Further, the convergence of "smart" sensing, metering and control technologies with remote, wireless connectivity and "big data" analytics is making it even easier for building systems to act as distributed energy assets for the utility grid.

The future vision of a fully-integrated B2G network represents a significant departure from past practice in managing demand to address utility grid conditions. Until now, B2G interactions mostly have been limited to a small number of large building owners or operators responding to a utility request to address a specific generation or distribution system need. The customer's demand-response decisions are thus reactive rather than pro-active, and actions are most often manual rather than automated.[108]

105 Many states, along with federal agencies such as DOE and EPA, already provide technical assistance, financial resources, and networking support to local government energy efficiency programs—see for example http://aceee.org/white-paper/state-enabling-local-ee, https://www.illinois.gov/dceo/AboutDCEO/ReportsRequiredByStatute/Energy%20Conservation%20Act%202014.pdf, http://www.energy.ca.gov/localgovernment/, https://www.epa.gov/sites/production/files/2015-08/documents/ee_municipal_operations.pdf, and https://www.energy.gov/eere/slsc/state-and-local-solution-center

106 The C40 Cities Network on District Energy has a website with case studies and other materials at http://www.c40.org/networks/district-energy, and a "District Energy Good Practice Guide" (2016) which also includes case studies, at http://c40-production-images.s3.amazonaws.com/good_practice_briefings/images/1_C40_GPG_DE.original.pdf?1456788189

107 Demand response refers to the ability of customers to exercise automatic or manual control over the magnitude and timing of electrical loads in response to grid conditions or pricing.

108 An important exception is the growing body of work on "automated demand-response"; see the publications of the Demand Response Research Center (DRRC) at Lawrence Berkeley National Laboratory (http://drrc.lbl.gov/publications), and the industry sponsored Open ADR Alliance (http://www.openadr.org/). Also, note that utilities do have a long history of direct control ("cycling") of customer-side air conditioners and electric water heaters during peak demand periods. These voluntary controls, however, are typically invoked only for a limited number of times each year, are predicted hours or days in advance, last for a limited period, and offer customers the ability to opt out of any single event. They are also strictly on/off controls, rather than modulating the output of the end-use device.

The B2G relationship is evolving toward a "transactive energy ecosystem," offering consumers the ability to buy and sell energy and related services in a dynamic and interactive manner.[109] This evolution also enables the integration and scaling-up of renewable generation and energy storage, and enhances the value of electric vehicles by adjusting recharge timing and feeding power back from vehicle batteries to the electric grid when needed. In summary, enabling more rapid, automated and mutually beneficial B2G interactions can broaden the opportunities for building energy management and controls, improve utilization of distributed generation and of intermittent renewable wind and solar power, accelerate the introduction of energy storage and improve the overall system efficiency of electricity and natural gas delivery.

There are a large number of B2G related activities underway by federal agencies, utilities and state regulators, standard-setting bodies, researchers and various industry sectors in their role as both suppliers and customers. These efforts aim at better understanding and guiding the future of B2G, the emerging picture of device connectivity (the "Internet of Things" or IoT) and the physical, legal and market structures that will link utility and customer sides of the meter.[110]

In response to the growing interest in these issues at the state level, NASEO adopted a Board resolution to encourage states to address a range of B2G and other building systems issues, including utility regulatory incentives and rate design, infrastructure resilience, building codes, public sector leadership and demonstrations in public buildings.[111] In states where the governor and State Energy Office work together closely in formulating state energy plans and policies, this policy role can provide important guidance to the utility commissioners on ways to advance B2G as well as other efficient building energy systems.

Finding 3-7: Establishing a truly interactive B2G "meta-system" is a chicken-and-egg problem. On the one hand, building owners are unlikely to invest in grid-connected and grid-responsive systems unless there is a clear economic benefit based on clear price signals or incentives from the utility or grid operator. On the other hand, utilities and grid operators may see little value in

109 Gridwise. 2015. "The Future of the Grid: Evolving to Meet America's Energy Needs, Final Report." Gridwise Architecture Council. October. http://www.gridwiseac.org/about/transactive_energy.aspx

110 Following is a very selective sample of recent publications.

Gridwise Architecture Council. 2015. "Valuation of Transactive Energy Systems: Technical Meeting Proceedings." July 7-8. http://www.gridwiseac.org/pdfs/tes/pnnl_sa_112507_july_2015_valuation_tes_proceedings.pdf

Hagerman, J. 2014. "Buildings to Grid Technical Opportunities: Introduction and Vision." DOE Building Technologies Office Report DOE/EE-1051. March. http://energy.gov/sites/prod/files/2014/03/f14/B2G_Tech_Opps--Intro_and_Vision.pdf

Hammerstrom, D.J. et al. 2015. "Valuation of Transactive Systems: Final Report." Pacific Northwest National Laboratory Report PNNL-25323. May. http://bgintegration.pnnl.gov/pdf/ValuationTransactiveFinalReportPNNL25323.pdf

Hardin, D.B. et al. "Buildings Interoperability Landscape." Pacific Northwest National Laboratory Report PNNL-25124. December. http://energy.gov/eere/buildings/downloads/buildings-interoperability-landscape

Heffner, G., et al. 2007. "Loads Providing Ancillary Services: Review of International Experience." LBNL Report 62701. May. http://emp.lbl.gov/publications/loads-providing-ancillary-services-review-international-experience

Kiliccote, S. and M.A. Piette. 2014. "Buildings to Grid Technical Opportunities: From the Buildings Perspective." DOE Building Technologies Office Report DOE/EE-1052. March. http://energy.gov/eere/buildings/downloads/buildings-grid-technical-opportunities-buildings-perspective

Kirby, B. 2006. "Demand Response for Power System Reliability: FAQ." ORNL/TM-2006-565. http://www.consultkirby.com/files/TM_2006_565_Demand_Response_For_Power_System_Reliability_FAQ.pdf

Satchwell, A. and R. Hledik. 2013. "Analytical Frameworks to Incorporate Demand Response in Long-Term Resource Planning." LBNL Report 6546e. September. http://emp.lbl.gov/sites/all/files/lbnl-6546e.pdf

Somasundaram, S. et al. 2014. "Transaction-Based Building Controls Framework, Volume 1: Reference Guide." PNNL-23302. Richland, WA: Pacific Northwest National Laboratory. December. http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-23302.pdf

US Department of Energy (US DOE). 2016. "The National Opportunity for Interoperability and its Benefits for a Reliable, Robust, and Future Grid Realized Through Buildings." February. http://energy.gov/eere/buildings/downloads/national-opportunity-interoperability-and-its-benefits-reliable-robust-and

US DOE, Office of Building Technologies. 2014. "A Framework for Characterizing Connected Equipment." August. https://www.gpo.gov/fdsys/pkg/FR-2014-08-14/pdf/2014-19297.pdf

111 "National Association of State Energy Officials Board of Directors Resolution Supporting Buildings-to-Grid Integration and Improved Systems Efficiency." 12/14/2016.

creating the infrastructure to send these signals and incentives to customers until they are convinced of the availability, size and reliability of demand-side resources "behind the meter."

Some experts suggest that creating transactive markets that include both utility and customer sides of the meter will eventually solve this quandary. However, exploratory efforts to date suggest that integrated markets are very challenging to create and operate, and limited in their ability to attract widespread participation by smaller buildings and small loads—which individually may appear to offer little dollar value from grid-responsive control but collectively may represent a very sizable demand-response resource. Thus, we offer the following recommendations to complement the market-development initiatives by some state regulators and grid operators, as well as DOE's efforts to help advance a framework for B2G market transactions:

- **Recommendation 3-7.1:** ***State utility regulators*** should continue to authorize or direct utilities to undertake experiments on demand-response and demand-side participation in markets for energy, capacity and so-called "ancillary services" to support grid reliability.[112] In addition to demonstrating the practical operation of B2G connections, an objective of these pilot projects should be to better quantify the energy and non-energy benefits of device/building/grid connectivity (which can vary by location and timing), as well as the value of B2G contributions to grid reliability and building or infrastructure resilience. The results of these field experiments need to be shared among states and utilities, working through organizations such as the National Association of Regulatory Utility Commissioners and EPRI.
- **Recommendation 3-7.2:** ***DOE, in cooperation with states, utilities and industry,*** should undertake RD&D on ways to ensure that smaller commercial and multi-family buildings, as well as smaller individual loads (which are significant in the aggregate) can participate fully in B2G transactions. There is already some research literature on ways to qualify small loads for demand-response,[113] and the CEC has initiated projects on this topic.[114]
- **Recommendation 3-7.3:** ***DOE, in cooperation with states, utilities and industry***, should undertake RD&D on the best ways to reduce building load given a percent reduction request from the utilities. Research also should incorporate the impact on occupants if some building energy equipment is shut down or reduced in speed in response to a load reduction request from the utility.
- **Recommendation 3-7.4:** ***Manufacturers, energy services companies and building owners*** should look for opportunities to build up B2G capabilities incrementally and in combination with IoT systems designed around the non-energy benefits of connected devices. For example, building-level energy management and control systems should be developed with an eye to future B2G upgrades, including standardized, open-system protocols for data exchange and sufficiently short time intervals for monitoring and control. Device connectivity outside the building—for eventual use in B2G functionality—might initially be cost-justified on the basis of one or more non-energy IoT applications. Examples include security and fire safety, home

112 Ancillary services could include demand-side load management on both short and longer time-scales to offer cold and spinning reserve, voltage support, and frequency support. See US Department of Energy, Office of Electricity Distribution and Energy Reliability (DOE/OE). 2011. "Load Participation in Ancillary Services," DOE/OE Workshop Report. December. http://www1.eere.energy.gov/analysis/pdfs/load_participation_in_ancillary_services_workshop_report.pdf. Also see workshop presentations at http://www1.eere.energy.gov/analysis/load_participation_workshop.html

113 Kiliccote, S. et al. 2014. "Fast DR: Controlling Small Loads over the Internet." Proceedings of the ACEEE Summer 2014 Study on Energy Efficient Buildings. http://aceee.org/files/proceedings/2014/data/papers/11-183.pdf. Also Lanzisera, S. et al. 2015. "Field Testing of Telemetry for Demand Response Control of Small Loads." Lawrence Berkeley National Laboratory Report LBNL-1004415. https://drrc.lbl.gov/publications/field-testing-telemetry-demand. And California Public Utilities Commission. N.D. "California Demand Response: A Vision for the Future." CPUC Staff Draft Report. http://www.caiso.com/1fe3/1fe3ebb5d860.pdf

114 See http://www.energy.ca.gov/contracts/epic.html#GFO-15-311

automation, diagnostics for pre-failure maintenance and repair, corporate supervision, inventory control and real-time retail shopping diagnostics.[115]

- **Recommendation 3-7.5:** ***DOE*** should collaborate with states and utilities to develop a "B2G data repository" to share data and models that reflect: (a) the technical potential to reduce (or increase) individual building electrical loads for various periods of time with different amounts of advance notice; and (b) the demonstrated willingness of building owners and occupants to accept changes in service which may accompany load variations of different frequencies, intensity and duration. This data repository, which could be an extension of DOE's existing Building Performance Database,[116] should be built with attention to standardized data categories and definitions, as well as an analytical framework that moves beyond occasional, planned peak load reductions to include continual, fine-tuning adjustments between building operations and grid conditions.

  At present, the load management literature reflects consumer experience with relatively "lumpy" (and rarely used) on/off control of a few larger end-use devices (air conditioners and ventilation fans, water heaters, sometimes office lighting). What is needed is a detailed map of potentially controllable loads by building type, representing a wider range of control scenarios ranging from very short-term "trimming" to longer interruptions—varying by time of day, season and frequency of occurrence. This technical potential for fine-grained load control could then be tested against actual consumer response. A better understanding of the implications for occupant comfort and convenience of these and other load control strategies should also take into account the available incentive structure (financial or other) and how the load adjustments are communicated to building occupants.

- **Recommendation 3-7.6:** ***DOE*** should coordinate with the ENERGY STAR program, ASHRAE, ICC and other organizations responsible for model energy codes, test methods, building energy rating, equipment labeling and appliance standards to consider ways to better reflect the value of connectivity and load controllability as added features of buildings, equipment and systems—complementing energy efficiency metrics such as annual energy use or steady-state efficiency.

At present, national energy efficiency standards and model energy building codes—as well as advanced codes, design guides, and voluntary efficiency programs—consider only annual energy consumption or steady-state efficiency as measures of energy performance. The emerging B2G and IoT opportunities raise the question of whether connectivity and inherent load controllability (including dimmable lighting and multi-stage compressors, fans, pumps) also should be valued, encouraged, and perhaps ultimately required for new products and buildings. In some cases, there may be a significant trade-off between annual energy use efficiency and connectivity/controllability, due to the added energy use for communications and control circuitry. Weighing this trade-off will require better quantification of the private and societal value of connecting and controlling our devices and systems.

4.Cross-Cutting Strategies

Optimizing system efficiency in new and existing buildings will require addressing building system performance and multi-system interactions throughout the design, project delivery and building occupancy and operation stages. Changes in tax policy and DOE programs, as well as actions by state and local governments, manufacturers and standards setting organizations can accelerate

115 The linkage between B2G and a broader set of IoT applications is recognized by many in the field—see for example DOE's Interoperability Vision website for workshop presentations from April 2014 and March 2015 at: http://energy.gov/eere/buildings/downloads/technical-meeting-buildings-interoperability-vision.

116 http://energy.gov/eere/buildings/building-performance-database

adoption of a systems efficiency approach by affecting a range of actors across all phases in the building life cycle. The findings and recommendations in this section apply to many or all of the systems and technologies discussed in the previous sections.

Modeling and Metrics for Building System Energy Performance

As the complexity and interconnectedness of building technology increases through the inclusion of sensors, controls and daylighting, building and system designers need tools that allow them to make informed choices among the many available options for improving building energy performance. To satisfy overall design requirements, modeling tools are needed that can accurately simulate the interaction of various system combinations, and can incorporate weather data, occupant requirements and other variables that affect efficiency, performance, occupant comfort and cost. In addition, metrics are needed that can account for system-level efficiency improvements.

Finding 4-1: Whole-building energy modeling that can identify and quantify systems efficiency opportunities is becoming more common in larger buildings, yet the vast majority of the building stock is composed of small buildings for which detailed modeling is often impractical. About half of all commercial buildings (representing 10 percent of commercial energy use) are smaller than 5,000 ft^2, and 88 percent (representing almost one-third of energy use) are smaller than 25,000 ft^2.[117]

- **Recommendation 4-1.1:** ***Utilities and state utility regulators*** should allow alternatives to full-building modeling when designing energy efficiency programs and when evaluating the energy savings of installed system-level measures. For example, utilities currently offer customer rebates based on ex ante, "deemed" (i.e., pre-calculated) savings for individual and often weather-independent energy conservation measures. Utilities could expand these programs to cover weather-dependent measures as well as common packages of energy conservation measures for lighting systems or HVAC systems in smaller buildings, such as offices, retail spaces, or restaurants (under 25,000 ft^2).[118]
- **Recommendation 4-1.2:** ***DOE*** should continue to develop measurement-based methods for evaluating energy-saving measures in small buildings. One example is an analytic approach (currently available from several vendors) that looks at whole-building interval meter data to disaggregate electricity consumption by end-use based on the time of use and short-term changes in power levels. These same methods can potentially improve the estimates of savings from efficiency measures in HVAC, lighting, or other systems. These statistical methods can be further improved by submetering that isolates specific end-uses or major equipment—a design strategy that should be applied wherever possible in new construction and major renovations or additions.
- **Recommendation 4-1.3:** ***DOE*** should initiate cooperation among research labs, manufacturers and the design community to develop tools that have the capability to model stochastic-based occupant behavior/movement (for large commercial buildings) and occupancy sensor controlled applications (e.g., lighting, HVAC equipment).
- **Recommendation 4-1.4:** ***Utilities*** should verify and approve measurement-based methods to compare actual, ex post energy savings with the initial ex ante savings estimates and then refine the estimation methods as needed.

117 U.S. Department of Energy, Energy Information Administration (DOE/EIA). "2012 COMMERCIAL BUILDINGS ENERGY CONSUMPTION SURVEY (CBECS)." https://www.eia.gov/consumption/commercial/data/2012/

118 Lawrence Berkeley National Laboratory's "Beyond Widgets" project is currently developing and validating such packages of measures. https://cbs.lbl.gov/beyond-widgets-for-utilities

Finding 4-2: Most energy modeling is carried out after the building design is complete to document predicted performance for code compliance purposes, green building ratings and utility incentives. However, energy modeling is also critical during the early design stage of a building, when designers, architects and engineers have the ability to optimize the building's parameters for efficiency. To facilitate this type of modeling, tools are needed that enable fast, parametric analysis of different building characteristics. Several such tools exist: DOE's OpenStudio enables users to design "what-if" scenarios and quickly make changes to test building response, and Autodesk (a commercially available architectural, engineering and construction software) has incorporated DOE's EnergyPlus modeling software to enable annual energy simulations. In addition, the US Green Building Council has encouraged designers who are attempting LEED[119] certification to use "Shoebox Energy Modeling," i.e., quick, early simulations focused on fundamental design decisions that can significantly affect whole-building energy performance.[120]

- **Recommendation 4-2.1:** ***DOE*** should continue to refine OpenStudio and to develop OpenStudio Measures (model transformation scripts) that support parametric analysis. DOE should continue to encourage third-party application developers to build on top of OpenStudio so that parametric analysis becomes a mainstream tool for building designers, especially during early-stage design. Specifically, DOE should encourage third-party development of OpenStudio based "shoebox" modeling tools.
- **Recommendation 4-2.2:** ***Building designers, architects and engineers*** should incorporate additional modeling at the outset of the design phase where feasible, specifically testing different building parameters to determine where additional savings might be realized.

Finding 4-3: Implementing a systems approach will require the development and use of metrics that can account for system-level efficiency improvements. For mechanical systems, for example, system metrics designed around an annualized efficiency target would enable the development of creative solutions—including those involving sophisticated controls—that are not recognized by current industry metrics. New part-load and annualized metrics, combined with the use of "smart" technologies and capabilities at a system level, could offer opportunities for energy savings past the point at which individual components meet technical limitations.

- **Recommendation 4-3.1:** ***DOE, Appliance Manufacturers and Standards Setting Organizations*** should develop metrics that capture building system and subsystem performance and support systems approaches to energy efficiency, particularly for:
    - Mechanical systems (continuing the ongoing efforts by ASHRAE, AHRI and NEMA), including metrics for air-cooled chillers, cooling towers, water heaters and water pumps.
    - Lighting systems, including annualized and peak metrics, controls, daylighting and renewable energy.
    - Envelope systems, including combined ratings and metrics for the opaque envelope, windows and other glazed areas and infiltration leakage.
    - Plug and miscellaneous load systems, including controls, heat recovery and renewable energy and storage.
    - Building energy management and grid-connected building systems, including metrics that account for peak electric and fossil fuel loads, energy storage, energy recovery, diagnostics and dashboards.

119 LEED: the "Leadership in Energy and Environmental Design" voluntary rating system for buildings, sponsored by the U.S. Green Building Council (http://www.usgbc.org/leed).

120 http://www.usgbc.org/education/sessions/energy-models-how-do-you-know-if-your-results-are-reasonable-10188639

As accepted metrics emerge, DOE should calculate and report them through its modeling tools, and encourage third-party tool developers to do the same.

Links to other recommendations addressing modeling and metrics:

- 1-6.6: ***DOE*** should develop improved end-use data and energy models to more reliably predict system-level energy savings potential from MELs (with ASHRAE).
- 1-7.1: ***DOE*** should carry out modeling and develop case studies related to occupant engagement in MEL control/reduction measures (with ASHRAE).
- 3-2.4: In planning for new capacity, ***state utility regulators*** should use metrics for CHP that account for improved system efficiency as well as for resilience, reliability, demand-response potential and power quality.
- 3-4.2: ***DOE*** should extend its EnergyPlus and OpenStudio energy modeling tools with DES modeling capabilities to enable evaluation of DES in building design and retrofit projects, to support DES operation and to calculate and report metrics for DES performance assessment.
- 3-7.5: ***DOE*** should collaborate with states and utilities to develop a "B2G data repository" to share data and models that reflect technical potential to reduce (or increase) building electrical loads and the willingness of building owners and occupants to accept changes in service of different frequencies, intensity and duration.

Integrated Project Delivery

One of the principal barriers to energy efficiency in the building design and construction market is fragmentation in the project procurement system. The traditional "design-bid-build" project delivery mechanism intentionally separates the design and construction functions, which fails to capture the potential performance benefits and life-cycle cost reductions that can be realized by collaboration between the design and construction teams.

One solution is the "Integrated project delivery" or "integrated procurement" model.[121] Beginning at the earliest stages of design and continuing through project "hand-over" to a client, this model integrates all of the people involved as a team, working under a single contract. This approach facilitates optimized design and construction by providing numerous opportunities for collaboration, and can include the engagement of operations personnel. Several new practices are emerging within the industry, such as pre-installation testing and commissioning, which enable building professionals to determine how various systems and devices actually will perform in relation to one another throughout the life of a building.

Finding 4-4: Widespread adoption of an integrated project delivery model by the building design and construction industry would allow greater opportunity for building systems efficiency improvements. [122] Pilot projects on integrated procurement, led by the GSA, have demonstrated that this alternative procurement model can result in significant energy savings. In these pilots, involving renovations to existing federal buildings, one building achieved a 50 percent reduction in energy usage and a 60 percent reduction in water usage; another achieved energy performance 30 percent better than the ASHRAE 90.1 (2007)

121 For more information see http://info.aia.org/siteobjects/files/ipd_guide_2007.pdf

122 AIA. 2007. "Integrated Project Delivery: A Guide." https://info.aia.org/SiteObjects/files/IPD_Guide_2007.pdf. The LEED building rating system currently provides a credit for projects that use an Integrative Design Process (http://www.usgbc.org/credits/new-construction-core-and-shell-schools-new-construction-retail-new-construction-healthca-21?view=guide).

standard; and a third achieved an 84 percent reduction in energy use intensity compared to other buildings of its type.[123] Using a similar collaborative process, GSA also has undertaken pilot projects of "deep energy retrofits" (i.e., a whole-building analysis and construction process that uses integrative design to achieve much larger energy cost savings than conventional energy retrofits); eight such projects achieved an average 58 percent reduction in energy use.[124]

The results of these pilot projects indicate that the accelerated use of integrated project delivery could result in widespread energy savings for major renovations or deep energy retrofits of existing buildings. Leadership is needed by federal and state governments to demonstrate these types of results and to require or incentivize integrated project delivery for both renovations and new construction of public buildings. In addition, actions by Congress, utilities and design professionals can help promote the wider use of the integrated project delivery model.

- **Recommendation 4-4.1:** ***Federal and state government agencies*** should promote integrated project delivery for new construction, and for renovation and "deep energy retrofit" projects in existing government buildings. Specifically:
  - ***Federal and state government agencies*** should set a goal for use of integrated design and delivery for all new construction and renovation projects over $1 million.
  - ***GSA*** should implement a pilot program for wider utilization of Public-Private Partnership/Design-Build-Operate-Maintain contracting.[125] It would be useful to extend the integrated procurement model to new construction pilots to demonstrate the efficacy of this model in maximizing building systems efficiencies in new buildings.
  - ***DOE*** should assist state and local governments in modifying their building procurement policies and programs to incorporate integrated project delivery.
  - Where ***state architects*** provide design assistance to local governments and school districts, they should encourage the use of integrated design and delivery.
- **Recommendation 4-4.2:** ***Congress*** should support and expand GSA pilot programs on integrated procurement and deep retrofits to ensure that public building construction and renovations incorporate building system efficiency.
- **Recommendation 4-4.3:** ***Utilities*** should promote integrated project design and delivery through design-assistance and rebate programs. Although it may be difficult for some single-fuel utilities to promote truly integrated design across both gas and electricity end-use systems, one successful approach has been the statewide "Savings by Design" program in California.[126] Co-sponsored by the state's larger electric, gas and combined-fuel utilities, Savings by Design emphasizes integrated, systems-oriented design through design rebates and technical assistance, starting at the early stages of a project; the same approach could be effective for combined electric/gas utilities in other states. Alternatively, utility regulators could direct both gas and electric utilities to collaborate in funding a joint, statewide program.

123 See https://www.gsa.gov/portal/category/101378 and "Integration at Its Finest: Success in High-Performance Building Design and Project Delivery in the Federal Sector," April 14, 2015, Renée Cheng, AIA, Professor, School of Architecture, University of Minnesota
Sponsored by Office of Federal High-Performance Green Buildings, U.S. General Services Administration, at https://www.gsa.gov/portal/mediaId/118514/fileName/Interactive_PDF_2015-11-02.action

124 See "Deep Energy Retrofits Using Energy Savings Performance Contracts: Success Stories (https://www.gsa.gov/portal/getMediaData?mediaId=243379).

125 Contracting methods such as design-build-operate-maintain (DBOM) place increased focus on incorporating operations and performance into a project contract.

126 http://www.savingsbydesign.com/

- **Recommendation 4-4.4:** ***Architects and other design professionals*** should move toward widespread adoption of an integrated procurement model that allows greater opportunity for building systems efficiency improvements.
    - Education and professional training programs for architects and other design professionals should include instruction regarding efficient building system modeling and design.
    - Architects and other building design professionals should fully exploit the existing "energy budget" performance approach or the new performance rating method (PRM) under ASHRAE Standard 90.1 (Appendix G) to pursue innovative system-efficient approaches.

Benchmarking and Disclosure

Energy benchmarking is an important process to monitor energy use and understand overall building performance. Many building owners and facility managers benchmark their facilities as a best practice for their own management purposes. The ENERGY STAR Portfolio Manager software tool is commonly used for voluntary benchmarking and often is the reporting mechanism used for mandatory benchmarking and disclosure programs. The ENERGY STAR 1–100 score used in Portfolio Manager for certain building types provides owners of multi-building portfolios the ability to compare the performance of their own buildings with that of similar buildings nationwide. Owners use Portfolio Manager and the ENERGY STAR scores to track progress in energy management and prioritize investments in energy saving improvements.

In general, energy benchmarking is conducted at the whole-building level. Whole building benchmarking, by nature, assesses the overall energy performance of buildings by capturing the overall efficiency from the building equipment and systems, building controls, maintenance and occupant behavior to provide a general assessment of how the building performs. To the extent practical, sub-metering and benchmarking at the systems level would be extremely valuable to measure and compare the efficiencies of various building systems, and to help owners pinpoint the areas in need of improvement.

Finding 4-5: There is an important role for government agencies at all levels and for utilities to promote building energy benchmarking and disclosure at the whole building and, eventually, the building system level. A number of communities have adopted either voluntary or mandatory benchmarking programs, some of which require that buildings be benchmarked and energy performance disclosed on an annual basis. These benchmarking and disclosure ordinances typically require that recent building performance information be made available to potential buyers or tenants of a building. In some jurisdictions, such as New York City, such information also must be made available to the general public, either through reporting the data on the internet or by posting the data at the building site. Other jurisdictions, such as the city of Seattle, require that such information be submitted to the city as a basis for evaluating the performance of the building stock as a whole.

- **Recommendation 4-5.1:** ***States and municipalities*** should encourage or require commercial building owners to benchmark and disclose the energy performance of their buildings; and should adopt sub-metering requirements into building codes to support future systems level benchmarking.
- **Recommendation 4-5.2:** ***Public agencies*** at all levels of government should lead the way by voluntarily benchmarking and publicly disclosing their buildings' ongoing energy performance.
- **Recommendation 4-5.3:** ***Utilities*** should support benchmarking programs by partnering with their customers to make it easier to access and interpret metered data.

- **Recommendation 4-5.4:** To enable and support benchmarking at the systems level as well as at the whole-building level, ***standards-setting bodies*** should create test procedures and simulation programs relevant to various building systems, validated with field measurements, so that building designers and owners can perform "apples to apples" comparisons.

Workforce Development

A significant barrier to systems efficiency improvements is the lack of a trained workforce with specific skills in designing, building, assessing, operating and enforcing building system efficiency. For example, proper installation of integrated systems and controls depends on the capabilities of engineers and contractors, which are highly variable. In addition, because more than 80 percent of the current code enforcement workforce in the U.S. is expected to retire within the next 15 years,[127] there is an urgent need to increase the pipeline of new professionals entering this workforce.

Finding 4-6: A number of available workforce training resources that on systems efficiency,[128] but expanded and improved tools, resources and workforce training in these areas are needed to ensure better contractor performance and commissioning as well as to increase the pipeline of skilled professionals.

- **Recommendation 4-6.1:** *Manufacturers* should provide designers and installers with guidance and training on the role of their components within the building system and the ideal configuration to optimize system efficiency.
- **Recommendation 4-6.2:** *DOE* should expand its Better Buildings Workforce Guidelines to include systems-level training and knowledge.
- **Recommendation 4-6.3:** *Building owners and managers' associations* should educate members on the role of both start-up and ongoing commissioning in advancing building performance and achievement of project goals; participate in long-term pilot programs; and support education and training of the building operations workforce, particularly at a systems level, to support achievement of design intent. Programs recognized by the DOE Better Buildings Workforce Guidelines may be a starting point.
- **Recommendation 4-6.4:** *American Institute of Architects (AIA)/architects and other design professionals* should supplement existing training resources on integrated project delivery,[129] building energy modeling, and public-private partnerships to include guidance on goal setting and utilization of systems-based approaches to achieve project goals. The materials should include information on continuing education opportunities.

127 International Code Council (ICC). 2014. "The Future of Code Officials: Results and Recommendations from a Demographic Survey," National Institute of Building Sciences. Web. http://c.ymcdn.com/sites/www.nibs.org/resource/resmgr/ncgbcs/future-of-code-officials.pdf?hhSearchTerms=%22code+and+enforcement%22

128 Available workforce training resources include:
DOE/NIBS "Better Buildings Workforce Guidelines" (https://c.ymcdn.com/sites/www.nibs.org/resource/resmgr/CWCC/BBWG_Fact_Sheet.pdf)
"BEST" (Building Efficiency for a Sustainable Tomorrow) Center at Laney College, Oakland CA, with affiliated 2 and 4-year colleges and industry partners in over 30 states (http://www.bestctr.org/)
Association of Energy Engineers (http://www.aeecenter.org/)
Utility-sponsored Center for Energy Workforce Development (www.cewd.org) and state/regional consortia involving 35 states
Numerous training programs on energy efficiency topics at the local (community college) state, and regional levels (e.g., see https://energy.gov/eere/education/federal-energy-and-manufacturing-workforce-training-programs).

129 AIA. 2007. "Integrated Project Delivery: A Guide." https://info.aia.org/SiteObjects/files/IPD_Guide_2007.pdf

Links to other recommendations addressing workforce development and training:

- 1-1.3: ***State and municipal governments*** should include as part of code compliance activities training and tools to support EE design, installation, commissioning and post-occupancy measurement of building lighting systems.
- 2-3.3: ***IEEE*** should work with other organizations and industry groups to develop and disseminate training materials on the proper, safe and efficient application of DC power.
- 2-3.4: ***DOE*** should coordinate workforce training efforts on code issues involving DC distribution, for states and code organization.
- 2-5.2: ***ASHRAE*** should create a committee to identify changes needed in Standard 90.1 and other standards, as well as guidelines and training materials, to support DC power in new and existing commercial buildings.
- 4-4.4: ***Architects and other design professionals*** should move toward widespread adoption of an integrated procurement model through inclusion of this model in training programs, and utilizing performance rating methods for code compliance.

Building Energy Codes

Many aspects of the design and construction of commercial buildings in the U.S. are governed by energy codes and standards that set minimum requirements for new and renovated buildings. These codes are often based on national model codes and standards developed by two non-governmental standards-setting organizations, ASHRAE and the ICC. Building codes (which cover a range of structural, mechanical, electrical and health and safety topics in addition to energy) then are adopted—sometimes with changes—by the state or local authority having jurisdiction. The model codes and standards are created and updated every three years through a stakeholder process, although some also are updated under a "continuous maintenance" process, through which modifications can be made between the dates of formal publication of a new standard. The relevant model codes for energy are the ICC's International Energy Conservation Code for both residential and commercial buildings, and ASHRAE Standard 90.1 for commercial buildings.

Finding 4-7: Building energy codes offer an important opportunity to promote a systems approach, since requirements can be included in the code to govern the efficiency of building systems—not just components. Some building code requirements already take advantage of system efficiencies. For example, HVAC fans above a certain size (i.e., 5.0 horsepower) are required to be installed with some form of speed control to increase energy savings during part-load operation. With respect to lighting, certain fixtures are required to be connected to occupancy sensors, and some areas are required to use daylight dimming controls. Combined with maximum lighting power density requirements, these lighting control requirements improve the efficiency of lighting systems.

Ideally, the code development process will shift from prescriptive requirements that inform performance requirements to one in which building system performance is the starting point and prescriptive options are developed based on measurable performance criteria.[130] This approach may reduce the complexity of a systems approach and would be especially useful for smaller buildings, for which detailed systems analyses often are not cost-effective.

130 Conover, D., M. Rosenberg, M. Halverson, Z. Taylor, and E. Makela. 2013. "Alternative Formats to Achieve More Efficient Energy Codes for Commercial Buildings." ASHRAE Transactions 119 (1).

- **Recommendation 4-7.1:** ***DOE*** should continue its support for building energy code development and implementation, and should focus specifically on opportunities for systems energy efficiency to be included in the model codes.
- **Recommendation 4-7.2:** ***DOE*** should work with ASHRAE and with state and local code setting and enforcement officials to promote use of the new performance rating method available under the ASHRAE Standard 90.1 Appendix G alternative compliance pathway and other building codes, to encourage systems-efficient building design and construction.
- **Recommendation 4-7.3:** ***State and local governments***, with technical support from DOE and involvement of code experts and stakeholders, should develop mechanisms for third-party certification of systems energy performance to support code compliance.
- **Recommendation 4-7.4:** In future code development, ***ASHRAE and the IECC*** should explore coverage of additional building loads (such as plug loads), enhancing sub-metering requirements and use of performance criteria for systems and whole-building energy use (modeled or actual).

Links to other recommendations addressing building energy codes:

- 1-1.2: ***State standard-setting bodies*** should explore options for inclusion of a systems approach as an official alternate compliance path; and increase focus on design for good daylighting.
- 1-2.3: ***Professional Lighting and Interior Design Associations*** should integrate efficient lighting system design strategies into building design guidelines, and provide codes guidance to ICC and ASHRAE.
- 1-6.4: ***ASHRAE*** should add minimum requirements in building energy codes for control, monitoring and tracking of local MEL equipment.
- 2-5.1: ***Codes and standards bodies*** should work with DOE and industry stakeholders to review existing codes and standards to assess whether they are "DC-compatible."
- 3-7.6: ***DOE*** should coordinate with ENERGY STAR program, ASHRAE, ICC and others responsible for codes, standards and rating systems to consider ways to reflect the value of connectivity and load controllability as added features of buildings, equipment and systems.
- 4-5.1: ***State and municipal governments*** should encourage or require commercial building owners to benchmark and disclose building energy performance; and adopt sub-metering requirements in building codes to support systems-level benchmarking.

Public Sector Leadership and Incentives

Numerous policies and programs implemented at the federal, state and local levels affect the design, construction and operation of buildings. For example, energy performance targets for public buildings set at the federal or state level can provide leadership in the industry and drive capacity within the private sector.[131] NASEO has created a state "Lead by Example Network" involving 30

131 Among the many examples of federal leadership by example on energy efficiency, see Executive Order 13693 (2015) at: https://www.fedcenter.gov/programs/eo13693
State examples are documented in U.S. EPA. 2009. "Clean Energy Lead by Example Guide: Strategies, Resources, and Action Steps for State Programs." https://www.epa.gov/sites/production/files/2015-08/documents/state_lead_by_example_guide_full_report.pdf

states.[132] This network, along with other federal/state/industry partnerships such as the Better Buildings network[133] can provide a forum for sharing results and perhaps coordinating demonstration projects on a range of systems-efficiency measures.

In addition, tax and other incentives provide opportunities for incorporating a systems approach into tools, guidance and mandates that affect building efficiency. One key example pertains to treatment in the federal tax code of depreciation periods for equipment. For federal tax purposes, equipment that is attached to a building is depreciated over the life of a building (now set at 39 years), even though much of this equipment has a much shorter service life. When equipment fails before it is fully depreciated, an incentive exists to repair rather than replace it, instead of having to write off the undepreciated value, even though the original equipment may be less efficient. Incentives for replacing equipment more quickly would enable buildings to reap the benefits of the many types of equipment that have achieved significant efficiency improvements over the past several decades.

Finding 4-8: Policies and programs applied to public buildings at the federal, state and local levels offer opportunities for providing leadership by example, and a basis for incorporating a systems approach into tools, guidance, incentives and mandates that also affect non-governmental building efficiency.

- **Recommendation 4-8.1:** ***Congress*** should maintain or strengthen energy efficiency performance targets for existing and new federal buildings to provide leadership by example, as well as to reduce ongoing operation and maintenance costs. This should accompany action to amend current law to reduce the barrier to CHP installations created by the fossil fuel phase-out in federal facilities with significant thermal and electrical loads–e.g., by allowing a limited exception for deployment of CHP as a significant energy saver (see Recommendation 3-3.1).
- **Recommendation 4-8.2:** ***Congress*** should enact legislation that would reduce the depreciable life of building energy equipment to reflect these products' typical useful life span and provide an incentive to upgrade efficiency when equipment is replaced. Specifically, such legislation should reduce the depreciation period to 12-15 years, with a shorter depreciation period allowed for equipment and systems that exceed the federal minimum efficiency standards or, where there are industry-accepted performance metrics but no federal standards for equipment and systems in the top quartile of rated performance.
- **Recommendation 4-8.3:** ***Local zoning authorities*** should consider use of accelerated permit review, density bonuses, or other zoning variances to incentivize developers to use system approaches that achieve efficiencies that go beyond those mandated under existing state and local building codes.[134]
- **Recommendation 4-8.4:** ***Utilities*** should develop incentive programs, including long-term pilot projects that support system-efficient buildings and help demonstrate to building owners and developers the savings resulting from such an approach.
    - As a first step, the ***CEE*** should develop a systems approach for utility rebate programs and demonstrate it through a pilot program with one or more of its member utilities. Results of the pilot program should be made publicly available to all interested parties.

132 https://www.naseo.org/news-article?NewsID=1040

133 http://energy.gov/eere/better-buildings

134 For example, Arlington Co., VA allows density bonuses for commercial development that achieves certification under the LEED green building rating program and also meets additional energy efficiency requirements—see http://www.usgbc.org/articles/how-arlington-county-incentivizing-leed. For other examples of local governments using their development permit process to encourage energy-efficient and green construction see: Institute for Local Government. 2009. "Green Building—Ten Case Stories." http://www.ca-ilg.org/sites/main/files/file-attachments/resources__green_building_case_stories_all_in_one_4.pdf

- Following completion of the pilot, ***CEE and the utility industry*** should consider initiating or expanding inclusion of systems efficient buildings in utility rebate programs.

Links to other recommendations addressing government leadership and incentives:

- 1-2.2: ***Congress*** should explore legislative opportunities that encourage integration of daylighting with electric lighting systems to improve overall lighting system efficiency.
- 2-1.2: ***DOE/BTO*** should partner with other federal, state and utility programs to speed commercial development and market acceptance of DC-powered (or hybrid) appliances, building equipment and systems.
- 3-1.3: ***State and municipal governments*** should authorize tax incentives, matching grants and other financing mechanisms to support early adopters of packaged CHP systems in buildings.
- 3-1.5: ***State and municipal governments*** should offer technical assistance and other incentives for developers to consider CHP at an early stage of project planning.
- 3-4.4: ***State governments*** should authorize tax incentives for DES as well as matching grants to support non-profit and local government sponsors.
- 3-5.1: ***Congress*** should direct all federal agencies to consider opportunities for new or expanded DES systems in campus facilities, and to ensure that new or renovated federal facilities in urban areas with DES systems are "DES-ready."
- 3-5.2: ***Congress*** should direct DOE, GSA, DoD, VA and other agencies to establish a collaborative interagency process to advance DES in the federal sector and to provide assistance and information to states and communities.
- 3-5.3: ***State and municipal governments*** should adopt policies committing major public facilities to help "anchor" new or expanded DES systems.
- 3-6.1: ***Communities*** should establish non-financial incentives for new and renovated buildings to be "DES-ready" and to join a DES system when it becomes available.
- 4-4.1: ***DOE*** should assist state and local governments in modifying their building procurement policies and programs to incorporate integrated project delivery.
- 4-4.2: ***Congress*** should support and expand GSA pilot programs on integrated procurement and deep retrofits to ensure that public building construction and renovations incorporate building system efficiency.
- 4-5.2: ***Federal agencies*** should lead the way by voluntarily benchmarking and publicly disclosing government buildings' energy performance.

Recommendation Summaries by Target Audience

Recommendation Summary	Rec. #
U.S. Congress	
Explore legislative opportunities that encourage integration of daylighting with electric lighting systems to improve overall lighting system efficiency.	1-2.2
Direct federal agencies to consider use of DC power distribution at the building or microgrid scale, for all existing or proposed projects involving on-site solar photovoltaics.	2-1.3
Authorize tax incentives, matching grants and other financing mechanisms to support early adopters of packaged CHP systems in buildings.	3-1.3
Amend current law to reduce the barrier to CHP installations created by the fossil-fuel phaseout in federal facilities with significant thermal and electrical loads.	3-3.1
Authorize tax incentives for DES as well as matching grants to support non-profit and local government sponsors.	3-4.4
Direct all federal agencies to consider opportunities for new or expanded DES systems in campus facilities, and to ensure that new or renovated federal facilities in urban areas with DES systems are "DES-ready."	3-5.1
Direct DOE, GSA, DoD, VA and other agencies to establish a collaborative interagency process to advance DES in the federal sector and to provide assistance and information to states and communities.	3-5.2
Support and expand GSA pilot programs on integrated procurement and deep retrofits to ensure that public building construction and renovations incorporate building system efficiency.	4-4.2
Maintain or strengthen energy efficiency performance targets for existing and new federal buildings to provide leadership by example and reduce costs.	4-8.1
Enact legislation to reduce the depreciable life of building energy equipment and provide an incentive to upgrade equipment efficiency.	4-8.2

Recommendation Summary	Rec. #
U.S. Administration	
Direct federal agencies to consider use of DC power distribution at the building or microgrid scale, for all existing or proposed projects involving on-site solar photovoltaics.	2-1.3
Direct all federal agencies to consider opportunities for new or expanded DES systems in campus facilities, and to ensure that new or renovated federal facilities in urban areas with DES systems are "DES-ready."	3-5.1
U.S. Department of Energy (including DOE National Laboratories)	
Work with lighting design professionals to develop and disseminate resources on daylighting best practices.	1-2.1
Work with manufacturers on out-of-the-box solutions to capture and recover waste heat.	1-5.2
Continue to develop minimum efficiency requirements for new and existing MEL devices.	1-6.1
Analyze the economic feasibility of expanding California's code requirement for MELs to other states and/or the model code.	1-6.3
Develop improved end-use data and energy models to more reliably predict system-level energy savings potential from MELs (with ASHRAE).	1-6.6
Carry out modeling and develop case studies related to occupant engagement in MEL control/reduction measures (with ASHRAE).	1-7.1
Work with federal and state agencies, commercial building owners and utilities to develop, demonstrate and promote market-ready integrated façade systems.	1-8.1
Engage state and industry partners to convene an inter-program/interagency working group to address DC barriers and opportunities.	2-1.4
Collaborate with industry and standard-setting bodies to create a roadmap of the RD&D that would be needed to fully exploit the potential for DC power distribution and control at the building scale.	2-2.1

Recommendation Summary	Rec. #
Engage Better Buildings partners, other industry stakeholders and state initiatives to develop and test innovative ways of introducing DC distribution in commercial buildings.	2-3.2
Coordinate workforce training efforts on code issues involving DC distribution, for states and code organizations.	2-3.4
Review and update energy test methods to allow DC input power; recommend that Congress revise statutory language that restricts "covered products" to lines-voltage AC input only; and if necessary exercise statutory authority to define certain DC-powered products as "covered products."	2-4.1
Work with code-setting bodies and industry stakeholders to review existing codes and standards to assess whether they are "DC-compatible."	2-5.1
Collaborate with other federal agencies and with U.S. industry stakeholders to monitor developments outside the U.S. regarding DC power for HVAC and other building applications.	2-6.1
Support application of packaged CHP systems for commercial and multifamily buildings and support CHP Technical Assistance Partnerships.	3-1.1
Assist utilities, state regulators, building owners and developers in establishing CHP sizing guidelines to help determine when supplemental CHP capacity should be installed and operated.	3-2.2
In cooperation with other federal agencies and states, provide increased technical assistance to communities and campus-based institutions to create or expand(DES); regional CHP centers should explicitly include DES when combined with CHP.	3-4.1
Extend its EnergyPlus and OpenStudio energy modeling tools with DES modeling capabilities to enable evaluation of DES in building design and retrofit projects, to support DES operation and to calculate and report metrics for DES performance assessment.	3-4.2
Provide funding for early-stage district energy feasibility studies and partner with industry to develop a publicly available decision tool to help community leaders and developers assess whether new developments are well-suited to district energy.	3-4.3

Recommendation Summary	Rec. #
In cooperation with the DES industry and regional partnerships, establish or strengthen peer-to-peer networks among cities with operating and prospective DES systems.	3-6.2
In cooperation with states, utilities and industry, undertake RD&D on ways smaller commercial and multi-family buildings can participate fully in B2G transactions.	3-7.2
In cooperation with states, utilities and industry, should undertake RD&D on ways to reduce building load given a percent reduction request from the utilities.	3-7.3
Collaborate with states and utilities to develop a "B2G data repository" to share data and models that reflect technical potential to reduce (or increase) building electrical loads and the willingness of building owners and occupants to accept changes in service of different frequencies, intensity and duration.	3-7.5
Coordinate with the ENERGY STAR program, ASHRAE, ICC and others responsible for codes, standards and rating systems to consider ways to reflect the value of connectivity and load controllability as added features of buildings, equipment and systems.	3-7.6
Continue the development or validation of simplified tools for building designers and utilities to evaluate energy-saving approaches in small buildings.	4-1.2
Initiate cooperation among research labs, manufacturers and the design community to develop tools that can model stochastic-based occupant behavior/movement for large commercial buildings and occupancy sensor controlled applications.	4-1.3
Continue to refine OpenStudio and its applications, and encourage cooperation among research labs, software developers and the design community to improve the treatment of systems in building energy models for early-stage design analysis.	4-2.1
Develop metrics to measure the performance of various building systems and subsystems, and to support systems approaches to reducing building energy consumption.	4-3.1
Assist state and local governments in modifying their building procurement policies and programs to incorporate integrated project delivery.	4-4.1

Recommendation Summary	Rec. #
Expand Better Buildings Workforce Guidelines to include systems-level training and knowledge.	4-6.2
Continue support for building energy code development and implementation, and focus on opportunities to include systems energy efficiency.	4-7.1
Work with ASHRAE and with state and local code setting and enforcement officials to promote use of new performance rating methods available under the ASHRAE Standard 90.1 Appendix G alternative compliance pathway and other building codes.	4-7.2
BTO: Assess benefits of DC-powered equipment; demonstrate DC-based distribution and end-use equipment; and identify barriers to their wider use.	2-1.1
BTO: Partner with other federal, state and utility programs to speed commercial development and market acceptance of DC-powered (or hybrid) appliances, building equipment and systems.	2-1.2
Office of Energy Policy and Systems Analysis: Coordinate across DOE offices and programs, other federal agencies, states, communities and the private sector to reorganize and expand CHP program activities.	3-1.2
Regional Centers: Work with the DES industry, states and major cities to create an inventory of existing DES installations; survey opportunities for new or expanded DES systems; and assist local communities with early-stage DES feasibility studies.	3-4.3
Federal Agencies	
Collaborate with U.S. industry stakeholders to monitor developments outside the U.S. regarding DC power for HVAC and other building applications.	2-6.1
Work with the CHP industry, utility organizations and facility owners and operators to collect and analyze data on the resilience benefits of CHP.	3-2.1
In cooperation with DOE and interested states, provide increased technical assistance to communities and campus-based institutions to create or expand DES.	3-4.1

Recommendation Summary	Rec. #
Promote integrated project delivery for new construction, and for renovation and "deep energy retrofit" projects in existing government buildings. Specifically, set a goal for use of integrated design and delivery for all new construction and renovation projects over $1 million.	4-4.1
Lead the way by voluntarily benchmarking and publicly disclosing government buildings' energy performance.	4-5.2
GSA: Implement a pilot program for wider utilization of Public-Private Partnership/Design-Build-Operate-Maintain contracting.	4-4.1
State and Municipal Governments	
Include as part of code compliance activities training and tools to support EE design, installation, commissioning and post-occupancy measurement of building lighting systems.	1-1.3
Direct agencies to consider use of DC power distribution at the building or microgrid scale, for all projects involving on-site solar photovoltaics (especially in jurisdictions seeking to improve resiliency).	2-1.3
Authorize tax incentives, matching grants and other financing mechanisms to support early adopters of packaged CHP systems in buildings.	3-1.3
Offer technical assistance and other incentives for developers to consider CHP at an early stage of project planning.	3-1.5
Consider adopting the DOE/NREL CHP protocol (Uniform Methods Project) for evaluating, measuring and verifying savings from CHP.	3-1.6
Work with the CHP industry, utility organizations and facility owners and operators to collect and analyze data on the resilience benefits of CHP.	3-2.1
Encourage major public facilities to invest in CHP systems as part of new construction or major renovation; encourage large public and private institutions to account explicitly for the added value of CHP resilience and reliability in strategic planning.	3-2.3
Adopt policies committing major public facilities to help "anchor" new or expanded DES systems.	3-5.3

Recommendation Summary	Rec. #
Encourage or require commercial building owners to benchmark and disclose building energy performance; and adopt sub-metering requirements in building codes to support systems-level benchmarking.	4-5.1
Lead the way by voluntarily benchmarking and publicly disclosing government buildings' energy performance.	4-5.2
With technical support from DOE and involvement of code experts and stakeholders, develop mechanisms for third-party certification of systems energy performance to support code compliance.	4-7.3
State governments: Authorize tax incentives for DES as well as matching grants to support non-profit and local government sponsors.	3-4.4
State governments: In cooperation with the DES industry and regional partnerships, establish or strengthen peer-to-peer networks among cities with operating and prospective DES systems.	3-6.2
State governments: In cooperation with DOE, utilities and industry, undertake RD&D on ways smaller commercial and multi-family buildings can participate fully in B2G transactions.	3-7.2
State governments: In cooperation with DOE, utilities and industry, undertake RD&D on ways to reduce building load given a percent reduction request from the utilities.	3-7.3
State governments: Promote integrated project delivery for new construction, and for renovation and "deep energy retrofit" projects in existing government buildings. Specifically, set a goal for use of integrated design and delivery for all new construction and renovation projects over $1 million.	4-4.1
State standard-setting bodies: Explore options for inclusion of a systems approach as an official alternate compliance path; and increase focus on design for good daylighting.	1-1.2
State standard-setting bodies: Add minimum efficiency requirements for MEL devices to state standards.	1-6.2
States standard-setting bodies: Update test methods to allow for DC-powered products.	2-4.2
State architects: Encourage the use of integrated design and delivery when providing design assistance to local governments and school districts.	4-4.1

Recommendation Summary	Rec. #
Communities: Establish non-financial incentives for new and renovated buildings to be "DES-ready" and to join a DES system when it becomes available.	3-6.1
Local zoning authorities: Consider use of accelerated permit review, density bonuses, or other zoning variances to incentivize developers to use system approaches.	4-8.3
State Utility Regulators	
Develop utility resource-portfolio strategies that include consideration of CHP as a planned resource, and that explore the possible use of regulatory incentives and retail rates to encourage consideration of cost-effective CHP systems; and consider policies to encourage utility-owned supply-side CHP resources.	3.1-4
In planning for new capacity, use metrics for CHP that account for improved system efficiency as well as for resilience, reliability, demand-response potential and power quality.	3-2.4
Authorize or direct utilities to undertake experiments on demand-response and demand-side participation in markets for energy, capacity and "ancillary services" to support grid reliability. Share the results of these field experiments with states and utilities.	3-7.1
Allow alternatives to full-building modeling when designing energy efficiency programs and when evaluating the energy savings of installed system-level measures.	4-1.1
Utilities	
In planning for new capacity, use metrics for CHP that account for improved system efficiency as well as for resilience, reliability, demand-response potential and power quality.	3-2.4
In cooperation with DOE, states and industry, undertake RD&D on ways smaller commercial and multi-family buildings can participate fully in B2G transactions.	3-7.2
In cooperation with DOE, states and industry, undertake RD&D on ways to reduce building load given a percent reduction request from the utilities.	3-7.3

Recommendation Summary	Rec. #
Allow alternatives to full-building modeling when designing energy efficiency programs and when evaluating the energy reductions of installed system-level measures.	4-1.1
Verify and approve simplified tools and methods to validate actual building system energy performance compared with initial savings estimates.	4-1.4
Promote integrated project design and delivery through design-assistance and rebate programs.	4-4.3
Support benchmarking programs by partnering with customers to make it easier to access and interpret metered data.	4-5.3
CEE and utilities: Develop systems-efficiency incentive (e.g., rebate) pilot projects and programs.	4-8.4
Building Professionals	
Building Designers: Prioritize the design of hot water distribution systems to minimize total heat lost.	1-3.1
Building Designers: Locate heating systems or energy recovery systems to capture rejected and/or waste heat from viable heating sources in the building.	1-5.1
Professional Lighting and Interior Design Associations: Integrate efficient lighting system design strategies into building design guidelines, and provide codes guidance to ICC and ASHRAE.	1-2.3
Building Designers, Architects and Engineers: Incorporate additional modeling of different building parameters at the start of the design phase to determine where additional savings might be realized.	4-2.2
Architects and other Design Professionals: Move toward widespread adoption of an integrated procurement model through inclusion of this model in training programs, and utilizing performance rating methods for code compliance.	4-4.4
AIA/Architects and other Design Professionals: Supplement resources on integrated project delivery, building energy modeling and public-private partnerships to include guidance on goal setting and use of systems approaches to achieve project goals.	4-6.4

Recommendation Summary	Rec. #
Codes and Standards Bodies	
Explore options for inclusion of a systems approach as an official alternate compliance path; and increase focus on design for good daylighting.	1-1.2
Update test methods to allow for DC-powered products.	2-4.2
Work with DOE and industry stakeholders to review existing codes and standards to assess whether they are "DC-compatible."	2-5.1
Develop metrics to measure the performance of various building systems and subsystems, and to support systems approaches to reducing building energy consumption.	4-3.1
Create test procedures and simulation programs relevant to various building systems, validated with field measurements.	4-5.4
State standard-setting bodies: Add minimum efficiency requirements for MEL devices to state standards.	1-6.2
ASHRAE: Add minimum requirements in building energy codes for control, monitoring and tracking of local MEL equipment.	1-6.4
ASHRAE: Develop improved end-use data and energy models to more reliably predict system-level energy savings potential from MELs (with DOE).	1-6.6
ASHRAE: Carry out modeling and develop case studies related to occupant engagement in MEL control/reduction measures (with DOE).	1-7.1
ASHRAE: Create a committee to identify changes needed in Standard 90.1 and other standards, as well as guidelines and training materials, to support DC power in new and existing commercial buildings.	2-5.2
ASHRAE and IECC: In future code development, explore coverage of additional building loads, enhancing sub-metering requirements and use of performance criteria for systems and whole-building energy use.	4-7.4

Recommendation Summary	Rec. #
Appliance and Equipment Manufacturers and Associations	
Work to enhance open-system protocols to facilitate the integration of MEL local controls with Building Management Systems.	1-6.5
Develop products and systems that offer a better performance/cost ratio for standardized DC solutions; are cost-effective from a system perspective; and provide at least the same capabilities as equivalent AC solutions.	2-3.1
Look for opportunities to build up B2G capabilities incrementally and in combination with systems designed around the non-energy benefits of connected devices and IoT.	3-7.4
Develop metrics to measure the performance of various building systems and subsystems, and to support systems approaches to reducing building energy consumption.	4-3.1
Provide designers and installers with guidance and training on the role of their components within the building system and the ideal configuration to optimize system efficiency.	4-6.1
NEMA: Complete work on and promote adoption of/compliance with new standards under development by the ANSI ASC C137 Lighting Systems Committee.	1-1.1
NEMA: Provide recommendations to DOE on alternative approaches for developing test procedures and setting standards for multi-component motor systems.	1-4.1
Industry Stakeholders and Efficiency Advocates	
Submit comments to DOE in applicable test procedure rulemakings to advocate revision of the test method to allow DC power input.	2-4.2
Work with DOE and code-setting bodies to review existing codes and standards to assess whether they are "DC-compatible."	2-5.1
Collaborate with DOE and other federal agencies to monitor developments outside the U.S. regarding DC power for HVAC and other building applications.	2-6.1

Recommendation Summary	Rec. #
In cooperation with DOE, states and utilities, undertake RD&D on ways smaller commercial and multi-family buildings can participate fully in B2G transactions.	3-7.2
In cooperation with DOE, states and utilities, undertake RD&D on ways to reduce building load given a percent reduction request from the utilities.	3-7.3
IEEE: Work with other organizations and industry groups to develop and disseminate training materials on the proper, safe and efficient application of DC power.	2-3.3
Voluntary energy rating program leaders: Update programs to include DC-input or hybrid products.	2-4.2
CLASP: Advocate for including DC-compatible test methods for appliance labeling and standards internationally.	2-4.2
Energy Services Companies	
Look for opportunities to build up B2G capabilities incrementally and in combination with systems designed around the non-energy benefits of connected devices and IoT.	3-7.4
Building Owners	
Look for opportunities to build up B2G capabilities incrementally and in combination with systems designed around the non-energy benefits of connected devices and IoT.	3-7.4
Building Owners' and Managers' associations: Educate members on the role of start-up and ongoing commissioning in advancing building performance; participate in long-term pilot programs; and support education and training of operations workforce to achieve design intent.	4-6.3

ALLIANCE
TO SAVE ENERGY

Using less. Doing more.