NATIONAL ENERGY EFFICIENCY BEST PRACTICES STUDY

ENERGY EFFICIENCY BEST PRACTICES: WHAT'S NEW?

Submitted to

California Best Practices Project Advisory Committee
Rafael Friedmann
Contract Manager
Pacific Gas and Electric Company
P.O. Box 770000, N6G
San Francisco, CA 94177

Submitted by

PRIME CONTRACTOR
ITRON, INC.
1111 BROADWAY, SUITE 1800
OAKLAND, CA 94607

Volume WN1 Report Contractor – Itron, Inc.

July 2008

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ACKNOWLEDGEMENTS

The Best Practices Study team would like to gratefully acknowledge the participation of the following individuals and their organizations in this report:

- Commissioner Art Rosenfeld of the California Energy Commission
- Ralph Cavanagh of the Natural Resources Defense Council
- Neal Elliot, Marty Kushler, Dan York and Harvey Sachs of ACEEE
- Ann Peterson, the PIER Buildings End-Use Energy Efficiency program manager at the California Energy Commission
- Ed Vine of Lawrence Berkeley National Laboratory
- Mike McCormick and Nancy Whelan of California's Climate Change Action Registry
- George Edgar, the Director of Energy Policy at Wisconsin Energy Conservation Corporation
- Rebecca Foster, the Residential Lighting Program Manager at the Consortium for Energy Efficiency
- John Taylor, the Residential Programs Manager at the Consortium for Energy Efficiency
- Don Aumann of the California Lighting Technology Center
- Donald Gilligan, the Executive Director of NAESCO

These individuals participated in lengthy interviews in which they generously shared their expertise in new and emerging policies, strategies and technologies related to energy efficiency and climate change. Without their participation and the support of their organizations, this report would not have been possible.

We also thank the members of the Best Practices Study's Project Advisory Committee for their inspiration, insights, tireless review and thoughtful direction throughout the project:

- Rafael Friedmann – Pacific Gas and Electric Company
- Pierre Landry – Southern California Edison Company
- Rob Rubin – Sempra Utilities
- Peter Lai – California Public Utilities Commission, Energy Division
- Don Schwartz – California Energy Commission

Finally, these reports benefited greatly from the tireless production efforts of Alex Kang.

CONTACT INFORMATION

Rafael Friedmann
Best Practices Study Contract Manager
Pacific Gas and Electric Company
P.O. Box 770000, N6G
San Francisco, CA 94177
415-972-5799
RAF1@pge.com

Jennifer Fagan and Mike Rufo
Best Practices Study Prime Contractor Leads
Itron, Inc.
1111 Broadway, Suite 1800
Oakland, CA 94607
608-235-1314, 510-844-2800
jennifer.fagan@itron.com
info@eebestpractices.com

Bruce Mast
WN1 What's New Report Lead
Frontier Associates LLC
1515 S. Capitol of Texas Highway
Austin, TX 78746-6544
510.845.0472, ext.111 (Phone)
Bruce@BuildItGreen.org

Christopher Dyson
WN1 What's New Researcher
KEMA, Inc.
122 West Washington Avenue
Suite 1000
Madison, WI 53703
(608) 259-9152

ES. EXECUTIVE SUMMARY

This report summarizes findings from research on new program and technology approaches and related best practices, conducted as part of the second phase of a national best practices study of energy efficiency programs. Pacific Gas & Electric Company managed this study on behalf of the California Public Utilities Commission (CPUC). The project's management advisory committee included staff from the other California IOUs, the California Energy Commission, and the CPUC. As part of this effort, the research team interviewed national energy efficiency experts from a wide range or organizations and reviewed a substantial body of secondary sources.

ES.1 TECHNOLOGY AND MARKET TRENDS

Several broad cultural, market, and economic trends are strongly influencing building energy efficiency, both positively and negatively:

- Increased concerns about climate change, air quality, and related environmental issues associated with the production of electricity and consumption of natural gas are spurring greater efforts to promote energy efficiency. California's adoption of Assembly Bill 32 puts it at the forefront of state-level initiatives by committing the state to reduce its global warming emissions to 80% below 1990 levels by 2050.

- Population growth and economic development patterns are shifting to hotter inland areas of California and the Southwestern United States, resulting in increased energy consumption and costs, peak demand spikes, and compromised grid reliability.

- Mere specification of high-efficiency equipment is increasingly recognized as an inadequate solution. Systems and equipment frequently perform less efficiently than predicted due to sub-optimal integration of subsystems and components, improper installation, poor maintenance, and limited ability to diagnose performance issues.

- The digital revolution has opened up new, more affordable opportunities for energy savings and peak demand management in buildings but the proliferation of entertainment and information systems has also significantly increased plug loads.

Innovations in Lighting Technology

In the lighting arena, a combination of emerging technology developments, recent public policy initiatives, and a renewed push from manufacturers and large retailers could spell the end of incandescent lamps as the staple residential lighting technology. Royal Philips Electronics is the first lighting manufacturer in North America seeking to phase-out production of incandescent light bulbs and Wal-Mart Stores, Inc. has announced a campaign to sell 100 million CFLs by the end of 2007.

Light-Emitting Diode (LED, also known as solid-state) technology is getting a lot of attention because it is extremely energy efficient and it allows better light distribution than standard CFL or fluorescent technologies. Recent innovations are bringing the technology cost down and now feature the capability to generate blue light, which enables engineers to produce the full spectrum of lighting colors by mixing red, green, and blue. LED technology is opening up a new research area in hybrid technologies—combining two different light sources for different applications[1].

In the nonresidential sector, research is underway to develop more sophisticated lighting controls that are virtually self-commissioning and simpler from the user's perspective. The emergence of new high-intensity fluorescent lighting fixtures have made fluorescent lighting the most cost-effective choice for lighting high indoor spaces. These HIF systems are more energy-efficient than HID solutions and feature lower lumen depreciation rates, better dimming options, virtually instant start-up and restrike, better color rendition, and reduced glare.[2]

Innovations in HVAC Technology

New and underutilized technologies are coming on the market to challenge the primacy of compressor-based cooling: night-time ventilation and cooling, evaporative condenser-based air conditioners, direct-indirect evaporative cooling systems, and ductless mini-split heat pumps. Some of these technologies are new; others have experienced significant market barriers to wider adoption and acceptance.

Evaporative condenser-based air conditioners replace the air-cooled condenser with an evaporatively-cooled condenser to achieve an energy efficiency rating of 17.5 EER. Test results have shown 50 percent energy savings compared with 13 SEER units with air-cooled condensers.

Night-time ventilation and cooling technology exploits large differences between daytime and nighttime temperatures to maintain home comfort through ventilation-only strategies. On the nonresidential side, advanced economizer technologies are also improving the ability to maintain comfort levels through ventilation.

Innovations in Hot Water Technology

The Super Efficient Gas Water Heater Appliance Initiative (SEGWHAI) aims to bring to market a storage gas water heater that is 30% better than currently available models. The proposed SEGWHAI unit must also be installed as a simple, quick replacement for existing small storage water heaters.[3] As an alternative to storage hot water heaters, tankless water heaters eliminate

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[1] Some good additional sources on hybrid technologies can be found at http://www.energy.ca.gov/pier/final_project_reports/CEC-500-2005-141.html

[2] Esource (2007), "Lighting: HID Versus Fluorescent for High-Bay Lighting", *ESource Building Energy Advisor*, http://www.esource.com/BEA/demo/PDF/P_PA_46.pdf

[3] http://www.segwhai.org

standby energy losses because they only use energy when the hot-water is turned on.[4] This work was initiated by California's PIER program and is now being led by the Consortium for Energy Efficiency's natural gas committee

CEC-funded research into hot water distribution design has identified a number of design issues that result in significant waste of resources, along with cost-effective alternative design strategies to dramatically reduce the waste.[5]

Other Technology Innovations

PIER has invested in several projects to explore residential load control technologies and energy efficient power supplies. PIER-funded research has also led to the development of prototype colored asphalt shingles with solar reflectances of up to 0.35. Raising the solar reflectance of a roof from 0.10 (typical of a conventional dark roof) to 0.35 (typical of a cool dark roof) can reduce building cooling energy use by more than 10 percent. Colored metal, clay tile, and concrete tile roofing materials with solar reflectances of 0.30 to 0.60 are currently sold in California.[6]

U.S. DOE estimates that advanced framing techniques that to reduce the amount of lumber used in construction can improve overall building shell energy efficiency by about 5% while resulting in a structurally sound home with lower material and labor costs than a conventionally framed house.[7]

ES.2 EMERGING TRENDS IN CODES AND STANDARDS

A combination of public policy challenges is spurring higher energy efficiency standards at the state and federal level. The most significant changes typically involve strategies to increase the scope and importance of field verification to assure that quality construction practices are implemented.

Regulators are also recognizing the possible disincentive higher standards can pose for continued cost-effective energy efficiency programs and are taking steps to recognize and reward the role utility programs play in advancing building standards and commercializing emerging technologies.

ES.3 INNOVATIONS IN PROGRAM DESIGNS AND INCENTIVE STRUCTURES

Shrinking energy efficiency gains through technological improvements, particularly for HVAC technologies, are pushing energy efficiency program managers to

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[4] Ibid.

[5] http://www.cuwcc.org/res_hot_water.lasso

[6] http://www.energy.ca.gov/pier/final_project_reports/CEC-500-2006-067.html

[7] http://www.eere.energy.gov/consumer/your_home/designing_remodeling/index.cfm/mytopic=10090, accessed June 18, 2007

- Focus greater attention on performance and installation quality, particularly in the areas of insulation, HVAC, and lighting controls

- Explore replacement technologies and design strategies that deliver substantial energy benefits (e.g., advanced evaporative cooling and night ventilation instead of refrigerated AC systems)

- Emphasize non-energy benefits to expand the market share for energy efficiency

- Better measure baseline market conditions to understand the potential efficiency gains attributable to incomplete code enforcement

An emerging area of focus is on learning to quantify the indirect energy efficiency impacts that derive from non-energy interventions. For example, the California PUC is exploring ways to quantify the embedded energy associated with water conservation. The California Energy Commission is examining the energy implication of land use planning decisions. These research areas are opening up new opportunities to more thoroughly integrate resource-efficiency programs to accomplish multiple policy objectives.

Integration of energy and non-energy policy objectives is also expanding opportunities for collaboration between energy efficiency programs and a broad array of stakeholders. Local governments are an increasingly visible ally due to their commitment to energy efficiency as a component of their greenhouse gas reduction strategies. Diverse industry stakeholders are promoting green building practices for the combined benefits of energy and water efficiency, resource conservation, and indoor environmental quality. U. S. Green Building Council's Leadership in Energy and Environmental Design (LEED) rating system has become the de facto national green building standard for new residential and nonresidential buildings.

Programs targeting energy efficiency in existing homes are devoting increased attention to home performance. Home Performance Contracting has been found to reduce energy use in existing homes by 50% or more by emphasizing a comprehensive, performance-based analysis of home shell and mechanical systems. Customer acceptance is driven by a variety of market drivers, including comfort, durability, health and safety, along with energy efficiency.[8] New information feedback technologies also show promise for improving home performance by simplifying home energy management, providing real-time feedback on energy consumption and price signals, and delivering low-cost end-use monitoring results.

Performance is also a primary theme in the evolution of nonresidential programs. In the new construction arena, programs remain focused on influencing design decisions at the earliest stages and momentum behind USGBC's LEED standard has helped move commissioning into the mainstream. Nonresidential lighting programs are also focusing on performance by offering hybrid performance-based models that link incentives to both energy efficiency performance and lighting quality.

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[8] Rogers, Michael, Megan Edmunds, Robert Knight, (2006) "Home Performance with ENERGY STAR®: Delivering Savings with a Whole-House Approach" 2006 ACEEE Summer Study on Energy Efficiency in Buildings (2.229¬–2.241)

Retrocommissioning practices are also making inroads for the existing building stock. Recent applications have combined established retrocommissioning protocols with permanent building energy system monitoring. At least one industry expert sees tremendous potential to capture even greater savings from existing building stock by combining the latest retrocommissioning practices with advanced building controls, smart meters, and flexible rate design.

Lighting programs and national initiatives such as ENERGY STAR and CEE play a continuing role in ensuring that the transition to a CFL-based lighting market is smooth and painless from the consumer's perspective. Key areas of focus include

- Commercialization of the GU-24 universal base;
- Push for a broader array of attractive and energy-efficient fixture designs through design competitions and co-op marketing with manufacturers and distributors;
- Performance standards to ensure that low-cost CFLs coming on the market meet consumer expectations for light output and quality, longevity, and functionality; and
- Research and development to address concerns of mercury toxicity.

Over the longer term, residential lighting program managers may need to reassess their technology portfolios. If current lighting technology and market trends hold, then incandescent lamps will cease to be the baseline technology and replacing them with CFLs will no longer be a cost-effective strategy for reaching energy efficiency goals.

1. INTRODUCTION

This report summarizes findings from research on new program and technology approaches and related best practices, conducted as part of the second phase of a national best practices study of energy efficiency programs. Pacific Gas & Electric Company managed this study on behalf of the California Public Utilities Commission (CPUC). The project's management advisory committee included staff from the other California IOUs, the California Energy Commission, and the CPUC. These findings build on the first phase of the study, completed in 2005, which benchmarked approximately 100 programs in order to identify and compare energy efficiency best practices at the program component level. The results of this first phase of the study are reported on the project website, www.eebestpractices.com.

As part of this effort, the research team interviewed national energy efficiency experts from a wide range or organizations. Phone interviews, approximately 30-45 minutes in length, focused on new program and technology approaches and related best practices that have emerged since Phase 1 was completed. The research also involved review of a substantial body of secondary sources.

This report places particular emphasis on emerging program and technology trends in California. While sources and industry experts nationwide were consulted, we focused particular attention on several key California-based sources because (1) California is at the forefront in many areas such as climate change, new technology RD&D, advancement in building codes, and energy efficiency deployment; and (2) the funders of this report are California energy efficiency portfolio administrators who seek a California context and framework for their decision-making. Despite this regional focus, we hope and expect that decision-makers around the country will find this report both useful and informative.

1.1 TECHNOLOGY AND MARKET TRENDS

U. S. energy policy is at a crossroads. For the last six years, national energy policy has focused heavily on expanding and diversifying energy supplies. For the years 2006–2010, Energy Information Administration projects an 8.8% increase in overall electricity generation capacity relative to the 2005 baseline. New coal-fired plants account for almost 30% of the total expected growth and more than 60% of the projected growth in 2009 and 2010.[9]

Continued focus on expanding energy supplies could have significant consequences for energy efficiency efforts. One possible outcome is that the utility industry will return to a scenario similar to the 1980s, with utilities experiencing overcapacity of supply and being able to argue that any additional capacity in the form of energy efficiency would be redundant. Nevertheless, recent events suggest a more optimistic outcome for energy efficiency efforts. At the national level, the policy debate has shifted toward energy efficiency and renewable sources, driven by

[9] http://www.eia.doe.gov/fuelelectric.html, accessed July 19, 2007

inter-related concerns of energy security, trade imbalances, economic efficiency, and environmental protection.

A more tangible sign of a shift in policy direction on energy efficiency is the emerging consensus among regulators and around the National Action Plan for Energy Efficiency (NAPEE). Recognizing that energy efficiency remains a critically underutilized resource in the nation's energy portfolio, more than 50 leading electric and gas utilities, state utility commissioners, state air and energy agencies, energy service providers, energy consumers, and energy efficiency and consumer advocates have formed a Leadership Group, together with the U.S. Department of Energy (DOE) and the U.S. Environmental Protection Agency (EPA), to address the issue. Together, they have crafted NAPEE as a call to action to create an aggressive, sustainable national commitment to energy efficiency.

The push for greater emphasis on energy efficiency has been aided by the emerging focus on environmental issues associated with production of electricity and natural gas: in particular, air quality and climate change. The connection between climate change and building energy efficiency is exemplified by Architecture 2030's "2030 °Challenge."[10] According to Architecture 2030, the building sector contributes to 40% of the GHG emissions. Stabilizing these emissions, and then reversing them to acceptable levels over the next ten years, is key to keeping global warming to approximately a degree centigrade (°C) above current levels. To accomplish this goal, the 2030 °Challenge proposes that greenhouse gas emissions attributable to energy consumption in existing buildings be reduced by 50% and emissions attributable to new buildings be reduced by 100% (i.e., carbon neutral) by 2030.

While federal policy-makers have responded cautiously thus far, state and local policy-makers have been more aggressive. California's adoption of Assembly Bill 32 puts it at the forefront of state-level initiatives by committing the state to reduce its global warming emissions to 2000 levels by 2010 (11% below business as usual), to 1990 levels by 2020 (25% below business as usual), and 80% below 1990 levels by 2050. AB 32 directs the California Air Resources Board (CARB) to develop appropriate regulations and establish a mandatory reporting system to track and monitor global warming emissions levels.[11] California's high level of commitment to energy efficiency as a means to address global warming is further exemplified by its energy resource loading order, which identifies energy efficiency and demand response as its preferred means of meeting growing energy needs, and its current $2 billion level of funding for programs implemented by the state's investor owned utilities during the 2006-2008 period.

Local governments are also responding proactively, as exemplified by the expanding roster of public agencies addressing climate change under the International Council for Local Environmental Initiatives (ICLEI) umbrella. ICLEI's Cities for Climate Protection® (CCP) campaign is designed to educate and empower local governments worldwide to take action on climate change. CCP is a performance-oriented campaign that offers a framework for local governments to reduce greenhouse gas emissions and improve livability within their municipalities. As of April, 2007, ICLEI counted 53 public agency members in California and

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[10] http://www.architecture2030.org/open_letter/index.html, accessed March 26, 2007

[11] http://www.arb.ca.gov/cc/cc.htm

almost 250 nationwide, representing approximately 25% of total U.S. greenhouse gas emissions.[12]

Beyond climate change, a number of economic, demographic, and technology trends are influencing the design of energy efficiency programs. California Energy Commission's Public Interest Energy Research (PIER) program provides an apt summary of eight key issues it considers in the process of making research portfolio investment decisions. For the most part, these issues mirror market and industry trends nationwide.[13]

- Issue 1. Population growth and economic development trends in hot inland areas will change California's energy consumption patterns, resulting in substantially increased energy consumption and costs, as well as increased peak demand spikes and compromised grid reliability.

- Issue 2. Customers do not have affordable and effective tools, technologies, controls, and strategies to respond to future time dependent price structures for electricity.

- Issue 3. Because affordability is the primary driver for building equipment purchase decisions, development of lower first-cost options for energy efficient products, as well as lower operational costs for energy consuming systems, are essential for increasing the adoption of energy efficiency measures in California.

- Issue 4. Decisions regarding building components, systems, and operations are generally made based on non-energy considerations, but understanding and addressing the substantial energy impacts of key non-energy considerations such as health, safety and productivity are critical to improving energy efficiency in California's buildings.

- Issue 5. New construction accounts for only a few percent of California's building energy usage each year. Although opportunities to impact energy use in existing buildings are more limited than for new buildings, the existing building sector is so large that efficient replacement products, improved operational strategies, and appropriate intervention tactics that can reach the existing building market are critical.

- Issue 6. Systems and equipment frequently perform less efficiently than predicted due to sub- optimal integration of subsystems and components, improper installation, poor maintenance, and user's inability to detect and diagnose equipment performance degradation, thereby reducing the equipment life and increasing energy costs.

- Issue 7. Technologies, products, strategies and business models developed for national markets do not adequately address California's unique building energy needs, and do not take advantage of state organizations, programs, and initiatives which can help facilitate improved building energy efficiency.

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[12] http://www.iclei.org/index.php?id=1118

[13] Ann Peterson, PIER Buildings End-Use Energy Efficiency program manager, personal communication, January 5, 2007

- Issue 8. The digital revolution has opened up new, more affordable opportunities for energy savings and peak demand management in buildings, but the proliferation of entertainment and information systems has also significantly increased plug loads.[14]

1.2 EMERGING TRENDS IN CODES AND STANDARDS

A combination of public policy challenges, including climate change and the continuing risk of energy shortages, has pushed the California Public Utility Commission to set aggressive performance targets for utility energy efficiency programs. Those same challenges have pushed the California Energy Commission to significantly raise the bar for building energy efficiency in 2005. In other words, utility program managers have faced shrinking margins for cost-effective energy efficiency gains beyond the baseline set by code at the same time that they have been asked to hit higher targets.

The PUC has recognized the inherent tension between higher performance targets and higher efficiency standards. It has also recognized the important role utility energy efficiency programs have played in advancing building standards by demonstrating the feasibility and cost-effectiveness of proposed measures. To encourage that ongoing role and mitigate any disincentive higher standards pose for continued cost-effective energy efficiency programs, the Commission has established a mechanism for assigning regulatory credit for energy savings attributable to utility participation in the standards revision process. Heschong Mahone Group has estimated that utility program contributions to the 2005 standards revisions will generate more than 600 GWh in annual energy savings by 2014.[15]

1.3 INNOVATIONS IN PROGRAM DESIGNS AND INCENTIVE STRUCTURES

While advances in communication, information, and entertainment technologies are reshaping business practices, lifestyles, and building load profiles, the rate of technological innovation on the energy efficiency front may be slowing. Incremental improvements in the efficiency of existing technologies are getting smaller and more expensive. As one program manager observed, "When you look at the technologies that are out there, we certainly have improved energy efficiency technologies, but some of those are getting to limits on what they will be able to achieve in an application."[16] Program managers are responding by:

- Focusing greater attention on performance and installation quality, particularly in the areas of insulation, HVAC, and lighting controls

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[14] http://www.energy.ca.gov/pier/buildings/description.html

[15] McHugh, Jonathan, Douglas Mahone, Steve Blanc, Patrick Eilert, and Gary Fernstrom (2006) "2008 California Codes and Standards Progress: Expanding and Consolidating Efficiency Gains", 2006 ACEEE Summer Study on Energy Efficiency in Buildings, pp. 8.165–8.178

[16] Personal communication, George Edgar, Director, Energy Policy, Wisconsin Energy Conservation Corporation (Phil Audet interviewer), March 9, 2007

- Exploring replacement technologies and design strategies that deliver substantial energy benefits (e.g., advanced evaporative cooling and night ventilation instead of refrigerated AC systems) that the market has been slow to adopt

- Emphasizing non-energy benefits to expand the market share for energy efficiency

The convergence of energy and non-energy benefits has provided particularly fruitful ground for program innovations. For example, utility power plants have long been the subject of Clean Air Act regulations to limit the formation of ozone, particulate matter, nitrous and sulfur dioxides, and other pollutants. However, only recently have utilities and the EPA established a direct policy link between energy efficiency and pollution reduction. Texas is the first example of the application of EPA-approved procedures for incorporating the air emissions reductions associated with utility energy efficiency programs into the State Implementation Plan (SIP) for attaining national ambient air quality standards. In other regions, government and utility officials as well as large energy consumers are examining ways to use emissions credits associated with energy efficiency projects to address non-compliance issues, or to participate in emissions markets. To fully realize the value of these emissions benefits, increased standardization of EM&V protocols across regional and state boundaries will likely be required.

Like air quality, climate change offers substantial potential to generate non-energy benefits through energy efficiency. As Lawrence Berkeley National Laboratory's Ed Vine points out, "Climate change has the potential to raise the profile of energy efficiency and create political will for expanded goals and increased funding."[17]

California's Climate Change Action Registry offers one of the more promising mechanisms for linking climate change and energy efficiency. The Registry is private-public partnership formed by the California legislature in 2000. It provides a registry of greenhouse-gas emissions (GHGs) from emitters in California, the nation, and internationally. Members report emissions they own and control, as well as indirect emissions. Reported emissions are certified by independent third parties; the Registry publishes only certified data. Through CARROT, the Registry's online GHG reporting and calculation tool, participants are able to document the GHG emissions attributable to their energy use and reductions in emissions due to energy efficiency. For participants in industries that are ripe for future regulation, voluntary emissions reporting is a prerequisite for claiming future credit for emissions reductions achieved prior to adoption of regulatory requirements.[18] Since the Registry's launch in 2002 with 23 charter members, the Registry has grown to 273 members, including more than 100 members reporting for the first time in 2007. The membership roster includes strong representation from the oil and gas sector, utilities, public agencies, manufacturing and solid waste.

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[17] Personal communication, Ed Vine, Lawrence Berkeley National Laboratory (Bruce Mast interviewer), February 1, 2007

[18] Personal communication, Mike McCormick and Nancy Whelan, Climate Change Action Registry (Bruce Mast interviewer), January 17, 2007

As a first step in more closely linking GHG emissions and energy efficiency, the Registry is working with Southern California Edison. The Registry markets energy efficiency to its members; SCE, in turn, markets Registry membership to its program participants. If a program participant saves 1–3 million kWh per year and made process changes in 2007, then SCE pays for up to 50% of project installation, 50% of certification cost, and pays 100% of registry dues. The Registry contributes 40 hours of marketing and PR services. If savings exceed 3 million kWh, SCE also pays 100% certification cost.[19]

Over the longer term, the potential exists for strengthening the linkage between energy efficiency and both air quality and climate change by monetizing the value of GHG and air pollutant reductions through cap and trade mechanisms. However, several policy issues remain to be resolved. A threshold question for monetizing the value of GHG or emissions credits from energy efficiency is to determine who owns them. According to Registry staff, utilities will get credit for decarbonizing the electricity supply and implementing energy efficiency programs. As proposed, utilities would get credit for both shareholder investments and for DSM paid with PGC funds.[20] Monetizing emissions reductions is also a challenge because emissions vary by time of day. Base generation may be hydro-power or coal, whereas peak generation may be gas turbine or diesel. So it is important to know the generation fuel mix and scheduling.[21]

Beyond climate change, there are other opportunities to optimize multiple policy issues as well. For example, the California PUC is looking at the embedded energy associated with supplying water. Water conservation saves energy needed for water transport, purification, and waste treatment. The PUC has asked utilities to partner with water utilities and develop programs that look at embedded energy.[22]

Programs to promote more efficient land use are also beginning to involve utilities. "Smart Growth," sustainable development, and green building programs may act as catalysts to integrate land use, renewable energy, and energy efficiency programs. LBNL and the California Energy Commission are currently collaborating on the Sustainable Urban Energy Planning project to examine the energy implications of land use planning decisions.

A final area of program innovation is through increased integration of related energy resource programs. For example, there is increased convergence, particularly in California, between renewable energy and energy efficiency programs. To qualify for a solar incentive under California's New Solar Homes Program, a home must now perform 15% better than the state energy standard and ENERGY STAR appliances and high efficacy lighting must be installed throughout (except the dining room and small rooms). The incentive level is tied to expected

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[19] Personal communication, Mike McCormick and Nancy Whelan, Climate Change Action Registry (Bruce Mast interviewer), January 17, 2007.

[20] Ibid.

[21] Personal communication, Ed Vine, Lawrence Berkeley National Laboratory (Bruce Mast interviewer), February 1, 2007

[22] Ibid.

system performance, which requires a HERS Rater to field-verify the installation's azimuth and tilt.

Closer program integration is also a theme in Wisconsin, this time between energy efficiency and load management programs. As Wisconsin Energy Conservation Corporation's George Edgar reports, "We're looking for more effective integration for multiple objectives at the same time. In particular, we're trying to avoid instances where demand response becomes a substitute for doing the energy efficiency on the underlying measure itself. An example of an integrated solution might be that instead of necessarily paying the customer for their demand response when an interruption may occur, we front-load some of those payments so that the customer can buy higher incremental-cost equipment."[23] Another example of this synergy is that buildings which are being evaluated for demand response programs will often receive a tune-up and/or retrocommissioning of specific equipment commissioned that results in both energy and peak demand savings. ACEEE also sees a growing interest in bundling delivery of energy efficiency with demand response and views it as a smarter way to market to end-users in order to realize the joint benefits of both types of programs. [24] [25]

Another opportunity for integration is with smaller residential and commercial customers. Efficiency providers utilize a "whole building" approach which accesses a comprehensive menu of program services. These smaller customers are being offered a package of services and which considers all their end uses.. This is often being done through a single point of contact to better coordinate services and minimize small participant confusion.[26]

A final area that is ripe for further integration is utility and non-utility energy efficiency initiatives. Opportunities for integration exist at both the portfolio planning and marketing levels. Wisconsin Energy Conservation Corporation reports it is pursuing a more integrated marketing approach for its larger customers to help them leverage additional resources, including DOE funds and emission credits.[27] State tax credit programs present similar integration opportunities. Oregon Department of Energy offers a noteworthy Business Energy Tax Credit (BETC) program, which targets investments in energy efficiency, recycling, renewable energy resources, and less-polluting transportation fuels. The 35% tax credit is taken over five years. For the period 2000–2005, the program reported savings of 121.7 trillion BTUs over and above savings obtained through utility energy efficiency programs.[28]

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[23] Personal communication, George Edgar, Director, Energy Policy, Wisconsin Energy Conservation Corporation (Phil Audet interviewer), March 9, 2007

[24] Personal communication, Marty Kushler, ACEEE (Christopher Dyson interviewer) , January 2007

[25] York and Kushler, 2005, "Exploring the Relationships Between Demand Response and Energy Efficiency: A Review of Experience and Discussion of Key Issues", ACEEE

[26] Personal communication, Dan York, ACEEE (Christopher Dyson interviewer) , January 2007

[27] Ibid.

[28] http://egov.oregon.gov/ENERGY/CONS/BUS/BETC.shtml, accessed April 27. 2007

2. FINDINGS BY PROGRAM AREA

2.1 RESIDENTIAL NEW CONSTRUCTION

2.1.1 Technology and Market Trends

Several general trends outlined in the Introduction have particular prominence in the new construction arena, both residential and nonresidential:

- The emerging focus on environmental issues associated with production of electricity and consumption of natural gas, particularly climate change
- Concentrations of population growth and economic development trends in hot regions
- The continued domination of installation cost and non-energy considerations, which are the primary drivers for building equipment purchase decisions
- Sub-optimal integration of subsystems and components and improper installation

Climate change considerations are spurring local governments to adopt green building policies and incentives. Build It Green, a California-based nonprofit organization that focuses on residential green building, has documented 20 public agencies in California with green building-related ordinances or Conditions of Approval requirements and 22 offering some kind of financial incentive or technical assistance for residential new construction.[29] ICLEI's Cities for Climate Protection® (CCP) campaign incorporates a five-milestone structure that participating local governments work through: (1) establish a baseline; (2) set a target; (3) develop a local action plan; (4) implement the local action plan; and (5) measure results. Green building is often a core element of local action plans because it reduces GHG emissions through multiple integrated strategies:

Green building element	GHG reduction mechanism
Improved building energy efficiency	Reduced electricity generation and natural gas consumption
More compact, transit-oriented development patterns	Reduced vehicle miles traveled
Construction waste diversion	Reduced methane and other GHG emissions from landfill
Improved water efficiency	Reduced energy needs for water transport, treatment, storage, and post-treatment

[29] Build It Green (2007), "Building Green and Proving It", PowerPoint Presentation to 2007 Housing California Conference, April 25, 2007 (unpublished)

Some local communities have begun to consider energy issues in land use and have included energy considerations in their general plans. The cities of Chula Vista, Pasadena, Pleasanton, and Santa Monica; the counties and cities of San Francisco and San Luis Obispo; the County of Humboldt; and the San Diego Association of Governments and Southern California Association of Governments are some of the local governments that have taken significant action in furthering smart growth.[30]

In the technology arena, Sacramento Municipal Utilities District has identified a number of currently available or emerging technologies that are capable of making zero peak homes a reality, but a number of them must either be further developed or made acceptable to production builders.[31] These include:

- Building shell technologies that are better insulated and/or incorporate large amounts of exposed thermal mass that can be thermally "charged" during off-peak hours
- Improved HVAC technologies such as indirect-direct evaporative cooling, radiant heating and cooling, and ductless mini-split systems
- Passive solar architectural features
- New demand response strategies such as off-peak overcooling, appliance load control, and the use of the battery storage in plug-in hybrid vehicles when they are garaged
- High-efficacy lighting fixtures for all types of lighting
- Lower-cost and higher-performance PV systems, including PV materials that are made using semi-conventional printing processes, carbon nanotubes, modular rooftop concentrators, PV fabrics, and hybrid PV/space heating systems

Lighting Controls. According to the CEE, residential program managers are demonstrating increased interest in lighting controls and daylighting.[32] That interest is spurred in part by the October 2005 revision to California's energy efficiency standards, which mandate the use of high-efficacy light fixtures in certain areas, or controls such as dimmers and vacancy sensors. In response, new technologies are coming on the market and industry initiatives are renewing interest in home automation, especially lighting control. Typically, the technology will add less than $5 or $10 to the cost of a device. Wireless lighting control protocols have been developed and are becoming increasingly economical, which will greatly increase their market

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[30] California Energy Commission, "2006 California Integrated Energy Policy Report Update," p. 81 (http://www.energy.ca.gov/2006publications/CEC-100-2006-001/CEC-100-2006-001-CMF.PDF)

[31] Bruce Ceniceros and Bruce Vincent, 2006 ACEEE Summer Study on Energy Efficiency in Buildings, pp. 1.36–1.47

[32] Personal communication, Rebecca Foster, Residential Lighting Program Manager, Consortium for Energy Efficiency (Phil Audet interviewer), March 12, 2007

penetration.[33] Additional lighting technology trends are described under the Residential Lighting Program Area findings.

Mechanical ventilation. Mechanical ventilation is becoming an increasing important residential design issue. Mechanical ventilation is uncommon in U.S. single-family homes because until recently it was thought that residential buildings were leaky enough and windows were opened frequently enough to provide adequate air exchange. However, as homebuilding materials and practices have changed, air infiltration levels have decreased, and it has become obvious that mechanical ventilation is a residential design issue. Additional key HVAC technology trends are described under the Residential HVAC Program Area findings.

Super-efficient storage gas water heaters. The Super Efficient Gas Water Heater Appliance Initiative (SEGWHAI) is a PIER-funded program to bring to market a storage gas water heater that is 30% better than currently available models. The SEGWHAI challenge is to achieve this level of efficiency, while making the unit as good as or better than a conventional storage gas water heater. The proposed SEGWHAI unit must also be installed as a simple, quick replacement for existing small storage water heaters.[34] [35]

Hot water distribution design. The California Energy Commission is spearheading research into the energy and water efficiency implications of hot water distribution design through the Task Force on Residential Hot-Water-Distribution Systems. The research has identified a number of design issues that result in significant waste of resources, along with cost-effective alternative design strategies to dramatically reduce the waste.[36] Reducing distribution losses through better design and return loop plumbing is one promising strategy to reduce energy use.[37]

Drain heat recovery water heaters. Drain heat recovery water heater technology replaces vertical sections of building drainpipes and, in most applications, captures as much as 60 percent of the heat from the wastewater for reuse. As hot wastewater flows through the drain, incoming cold water passes through a coil of copper supply pipe wrapped around the drain, capturing the heat from the wastewater. Use of the technology is limited to times when wastewater is generated. Applications include motels and hotels, dormitories, health clubs, and single and multifamily residences.[38]

Tankless water heaters. Also called instantaneous or on-demand water heaters, tankless water heaters use less energy because they do not store water in a tank. Tankless water heaters only

[33] Julie Jacobsen, "Top 5 Trends: Lighting and Home Automation," CE Pro, January 2006, pp. 84-88

[34] http://www.segwhai.org

[35] Personal communication, Harvey Sachs, ACEEE (Christopher Dyson interviewer) , January 2007

[36] http://www.cuwcc.org/res_hot_water.lasso

[37] Personal communication, Harvey Sachs, ACEEE (Christopher Dyson interviewer) , January 2007

[38] Buckley, Rachel Reiss (2006) "A Roulette Wheel of Energy-Efficiency Technologies", Association of Energy Service Professionals

use energy when the hot-water is turned on, and the energy used is proportional to the volume of hot water used. Electric and natural gas tankless water heaters are available and have lifetimes twice those of tank-type water heaters. In most cases, tankless water heaters have a nine-year payback.[39]

Cool-colored roofs. Solar reflective, thermally emissive (cool) roofs decrease demand for building air conditioning power, lower the ambient air temperature, and, by promoting lower ambient air temperatures, retard the formation of smog. For example, raising the solar reflectance of a roof from 0.10 (typical of a conventional dark roof) to 0.35 (typical of a cool dark roof) can reduce building cooling energy use by more than 10 percent. The PIER program has sponsored research to develop ENERGY STAR® qualifying cool-colored roofing products with a solar reflectance of at least 0.25. This project has led to the development of prototype colored asphalt shingles with solar reflectances of up to 0.35. Colored metal, clay tile, and concrete tile roofing materials with solar reflectances of 0.30 to 0.60 are currently sold in California.[40]

Advanced Framing. Research conducted on behalf of the California Energy Commission has found that wood framing comprises approximately 27% of the net exterior wall area of new homes in California.[41] This percentage is referred to as the framing factor. High framing factors detract from the overall energy efficiency of the building shell because heat transfer is much higher through wood studs than through insulation. U.S. DOE estimates that advanced framing techniques that to reduce the amount of lumber used in construction can improve overall building shell energy efficiency by about 5% while resulting in a structurally sound home with lower material and labor costs than a conventionally framed house.[42]

Energy-efficient power supplies. Most office equipment and consumer electronic devices use external power supplies to convert high-voltage alternating current (AC) into the low-voltage direct current (DC) that they need to operate. While the best power supplies are more than 90% efficient, some are only 20 to 40% efficient, wasting the majority of the electricity that passes through them.[43] These power supplies consume about 2 percent of all electricity produced in the United States. To encourage research on advanced, energy-efficient designs from power-supply manufacturers, the California Energy Commission and ENERGY STAR sponsored an international design competition, which resulted in more efficient, more compact, and, in many cases, dramatically smaller power supplies than typically found on the market. Improvements were especially dramatic among low-wattage power supplies, which tend to be less efficient than higher-power units.

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[39] Buckley, Rachel Reiss (2006) "A Roulette Wheel of Energy-Efficiency Technologies", Association of Energy Service Professionals

[40] http://www.energy.ca.gov/pier/final_project_reports/CEC-500-2006-067.html

[41] http://www.energy.ca.gov/pier/final_project_reports/500-02-002.html

[42] http://www.eere.energy.gov/consumer/your_home/designing_remodeling/index.cfm/mytopic=10090, accessed June 18, 2007

[43] http://www.efficientpowersupplies.org

The ENERGY STAR program will soon begin labeling products—such as cell phones, PDAs, digital cameras, and camcorders—that are manufactured with ENERGY STAR–qualified power supplies. Eventually, more products— including laptop computers, cordless phones, and office equipment—will carry the label. Qualifying power supplies will also be sold separately as replacement products. To qualify initially, a power supply's average efficiency must fall in the top 25 percent of units on the market.[44]

2.1.2 Emerging Trends in Codes and Standards

Title 24 energy efficiency standards underwent significant revision in 2005, making it more challenging for residential new construction programs to be cost effective. A key change in the 2005 standards was to increase the scope and importance of field verification to assure that quality construction practices are implemented to maximize the home's ultimate energy performance. Ten measures in the 2005 standards now require Home Energy Rating Systems (HERS) field verification and diagnostic testing:[45]

System	Title 24 Measure
Ducts	Duct Sealing (res. & nonres)
	Supply Duct Location
Air Conditioners	Refrigerant Charge
	TXV
	Adequate Air Flow
	Air Handler Fan Watt Draw
	High EER
	Maximum Cooling Capacity
Building Envelope	Building Envelope Sealing
	Quality Insulation Installation

Research that supports Title 24 is a high priority for California Energy Commission's PIER program. The program is currently evaluating 23 different proposals for changes to the 2008 standards, including proposals that address cool roofs, ventilation, attic modeling, water heating, and fault detection for HVAC. California's investor-owned utilities are the primary client for this research. Their energy efficiency programs are a channel for commercializing

[44] http://www.energy.ca.gov/publications/displayOneReport.php?pubNum=CEC-500-2006-012-FS

[45] California Energy Commission (2004) *Residential Alternative Calculation Method (ACM) Approval Manual For Compliance with California's 2005 Energy Efficiency Standards*, 400-03-003F, http://www.energy.ca.gov/title24/2005standards/residential_acm/index.html

research results through emerging technologies demonstration programs. The PIER program has proposed 15 products and technologies to move into utility energy efficiency programs.[46]

2.1.3 Innovations in Program Designs and Incentive Structures

Residential new construction programs have been particularly challenged by the combination of higher program performance targets, stricter building energy efficiency standards, and the lack of dramatic technological breakthroughs for greater and more cost-effective energy efficiency gains. Programs are responding in several ways:

- Focusing greater attention on performance and installation quality, particularly in the areas of insulation, HVAC, and lighting controls, and retrocommissioning
- Exploring replacement technologies and design strategies that deliver substantial energy benefits (e.g., advanced evaporative cooling and night ventilation instead of refrigerated AC systems)
- Emphasizing integrated program design such as green building and Zero-Energy New Homes that deliver multiple resource benefits to expand the market share for energy efficiency and enhance the program's overall cost-effectiveness

In California, there has been a recent convergence between utility energy efficiency programs and renewable energy. The Energy Commission implements the New Solar Homes Partnership (NSHP) in coordination with the California Public Utilities Commission (CPUC) in the overall California Solar Initiative. The CEC envisions turning over program administration to the electric utilities or a third-party administrator by mid-2007. The NSHP seeks to achieve 400 MW of installed solar electric capacity in California by the end of 2016. Starting in 2007, homes must perform better than Title 24 to qualify for incentives:

- Tier 1: Exceed Title 24 by 15%
- Tier 2: Exceed Title 24 by 35% with AC performance 40% better than Title 24 minimums

In addition, high efficacy lighting must be installed throughout (except dining and small rooms) and all appliances must be ENERGY STAR. Incentives are now performance-based and require HERS verification of azimuth and tilt.[47]

Greater convergence between energy efficiency, renewable energy, and load management is also a theme in SMUD's efforts to redesign its residential new construction program to focus more directly on long-term performance goals. The resulting program design will promote a unique combination of energy-efficient design features, roof integrated photovoltaics with net metering, automated peak shifting strategies and built in demand response capabilities. This

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[46] Ann Peterson, PIER Buildings End-Use Energy Efficiency program manager, personal communication, January 5, 2007

[47] California Energy Commission (2006), New Solar Homes Partnership: Final Guidebook, CEC-300-2006-017-CMF (http://www.gosolarcalifornia.ca.gov/documents/CEC-300-2006-017-CMF.PDF)

design is expected to deliver demand-side benefits to homeowners, the utility and the environment that are much greater than possible from conventional utility new construction incentive programs, which focus only on energy efficiency.[48]

Nationwide, the convergence between energy efficiency and renewable energy is most evident in the emergence of Zero-Energy Homes (ZEH) initiatives under the auspices of U.S. Department of Energy's (DOE's) Building America Program.[49] DOE defines a net zero energy building as "a residential or commercial building with greatly reduced needs for energy through efficiency gains, with the balance of energy needs supplied by renewable technologies." A Zero Energy Home combines state-of-the-art, highly energy-efficient designs and equipment with on-site renewable energy generation (which typically includes a solar hot water production system and a rooftop photovoltaic, or PV, system) to return as much energy to the utility as it takes on an annual basis.[50]

A key rationale for integrating energy efficiency and renewable energy is that energy efficiency is generally a more cost-effective resource than renewable energy generation. By maximizing building energy efficiency first, the renewable energy system can be greatly downsized, while still getting the building to zero net-energy use. A key methodological issue then is to determine at what point increased energy efficiency becomes less economical than increased renewable energy capacity. National Renewable Energy Laboratory and University of Colorado have tackled this issue by developing the BEopt (Building Energy Optimization) analysis method. This method evaluates the costs and benefits of different combinations of energy efficiency and renewable-energy options targeting the development of homes with zero peak cooling demand. The optimization approach conducts a sequential search of a large number of possible option combinations. It then uses the most cost-effective alternatives to generate a least-cost curve to achieve home-performance levels ranging from a Title 24-compliant home to a home that uses zero net source-energy on an annual basis. By evaluating peak cooling load reductions on the least-cost curve, it is then possible to determine the most cost-effective combination of energy efficiency and renewable-energy options that both maximize annual energy savings and minimize peak-cooling demand.[51]

The results indicate that it is possible to build a 2,592 square foot home in Sacramento at an incremental cost of about 5% relative to a standard Title 24 home that will achieve zero peak cooling demand, reduce total annual heating energy use by 70%, reduce annual cooling energy use by 60%, and reduce total source-energy use by 60%. The examples presented in this study are representative of what can be accomplished using currently available materials, components, and equipment options. However, to achieve these benefits, several energy-saving

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48 Bruce Ceniceros and Bruce Vincent, 2006 ACEEE Summer Study on Energy Efficiency in Buildings, pp. 1.36–1.47

49 http://www.eere.energy.gov/buildings/building_america/pdfs/29915_zeb_path.pdf

50 http://www.toolbase.org/PDF/CaseStudies/ZEHPotentialImpact.pdf

51 Anderson, Ren, Craig Christensen, Scott Horowitz (2006), "Program Design Analysis Using BEopt (Building Energy Optimization) Software: Defining a Technology Pathway Leading to New Homes With Zero Peak Cooling Demand," 2006 ACEEE Summer Study on Energy Efficiency in Buildings (2.23¬–2.35)

strategies must be done right and must also be done in the right combination. Residential energy programs that provide direct support to production builders and minimize the risks associated with changing current construction practices are required to maximize broader benefits to California, including reducing requirements for construction of additional energy generation, transmission, and distribution capacity.[52]

2.2 RESIDENTIAL HVAC

2.2.1 Technology and Market Trends

A key market trend that poses an ongoing challenge to the design of HVAC programs is the highly aggregated nature of the market. Despite the fact that HVAC needs vary widely by climate, the industry is dominated by a handful of manufacturers who produce equipment for national and international markets. "There have been some efforts to get specific HVAC designs that perform well in various micro-climates. Thus far, whenever we've raised that type of opportunity with both the trade associations and with the individual manufacturers, it comes back that it would be completely contradictory to their current production and marketing methods to start having products that are differentiated by climate."[53] Nevertheless, given the increasing challenges of improving the energy efficiency of compressor cooling, the focus of technology research and development appears to be shifting toward alternatives to compressor cooling that exploit regional climatic conditions.

Night-time ventilation and cooling. California Energy Commission's PIER program has funded research and development of a nighttime ventilation and cooling strategy ("Nightbreeze") that exploits the high diurnal temperature swings (cool nights) typical of most California climates. An outside air damper delivers up to 2100 CFM of filtered outside air and vents indoor air to the attic or outdoors. A control system integrates heating, air conditioning, ventilation cooling, and fresh air ventilation functions and optimizes the amount of ventilation cooling required to maximize energy savings and offset A/C use.

Evaporative condenser-based air conditioners.[54] Freus offers a 17.5 EER air conditioner for residential and commercial applications up to 10 tons. This unit currently possesses the highest efficiency of any equipment on the market. The next best EER for residential units is 14 and next best for small commercial units is 11.8. The Freus unit uses an evaporatively-cooled condenser instead of an air-cooled condenser; i.e., it evaporates water off the coil to remove heat instead of blowing air across the coil. Unlike other evaporative coolers it does not add moisture to air. It also maintains efficiency under hot conditions better than air-cooled units. Test results from Sacramento Municipal Utility District have shown 50 percent energy savings

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[52] Anderson, Ren, Craig Christensen, Scott Horowitz (2006), "Program Design Analysis Using BEopt (Building Energy Optimization) Software: Defining a Technology Pathway Leading to New Homes With Zero Peak Cooling Demand," 2006 ACEEE Summer Study on Energy Efficiency in Buildings (2.23¬–2.35)

[53] Personal communication, John Taylor, Residential Programs Manager, Consortium for Energy Efficiency (Phil Audet interviewer), March 9, 2007

[54] Buckley, Rachel Reiss (2006) "A Roulette Wheel of Energy-Efficiency Technologies", Association of Energy Service Professionals

compared with 13 SEER units— the federal minimum efficiency standard—and 40 percent energy savings compared with 16 SEER units. The CEE HVAC committee is currently evaluating the evaporatively-cooled condenser technology to determine if it is widely applicable in hot climates or applicable primarily in hot dry climates.

Direct-Indirect Evaporative cooling systems. Newer indirect/direct evaporative coolers can achieve comfort in a wider range of climate zones than can conventional evaporative coolers. These units represent an alternative to DX systems in parts of California, since they are capable of delivering air that is several degrees below wet bulb temperature, and which is drier than the air delivered by conventional evaporative coolers. Newer systems incorporate variable speed motors.[55]

Ductless mini-split heat pumps. Ductless mini-split heat pumps provide a unique solution to bringing central air conditioning into homes that lack forced air ducts. In ductless systems, there is (usually only) one outdoor unit serving multiple indoor units (each containing a refrigerant coil and blower). Refrigerant is piped from the outdoor unit through small-diameter insulated refrigerant lines directly to individual rooms or zones. Cooled air is blown into the room by a fan in the individual evaporator units. The term "mini" is used to describe the small indoor units located in each room or zone. While distribution energy losses in conventional systems have been estimated as high as 30 percent, distribution losses for ductless systems are about one to five percent.[56] According to CEE, the incorporation of ductless mini-split technologies into ENERGY STAR and utility energy efficiency programs has been complicated by the lack of an acceptable test procedure, which has limited the manufacturers' ability to make the case for the value of the energy savings.[57]

2.2.2 Emerging Trends in Codes and Standards

Federal energy standards for HVAC changed in 2006 to 13 SEER. ENERGY STAR is expected to raise its standard for labeled units in 2009. Manufacturers are responding by trying to get higher SEER ratings (15 SEER and higher) from single-speed units. However, these higher performance units are still relatively expensive and, according to one observer, "industry is consistently stating that they are hitting theoretical limits in terms of SEER, EER and HSPF, the conventional metric for energy efficiency."[58] In the absence of readily available higher efficiency equipment, the increase in SEER standard has significantly reduced the savings potential for conventional residential HVAC programs because the energy standards generally serve as a proxy baseline. One response from utilities has been to devote resources to better measuring the actual baseline conditions in the field. "We know there is an opportunity, we

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55 Bisbee, Dave (2005) "Customer Advanced Technologies Program Technology Evaluation Report: The OASys", Sacramento Municipal Utility District, available at http://www.smud.org/education/cat/cat_pdf/OASys.pdf

56 http://www.toolbase.org/Technology-Inventory/HVAC/ductless-mini-split-heat-pumps

57 Personal communication, John Taylor, Residential Programs Manager, Consortium for Energy Efficiency (Phil Audet interviewer), March 9, 2007

58 Ibid.

know there is energy savings out there, and we can even show what a good installation does, in terms of energy savings against an expected baseline. A consistent issue that comes up is proving that the baseline is as low as we think it is, because of the fact that codes are often suggesting that it is much higher than in reality it is, since the codes aren't enforced."[59]

2.2.3 Innovations in Program Designs and Incentive Structures

The lack of breakthrough cooling technologies, combined with increasing federal standards, is driving program designers to focus increased attention on installation quality. According to Robert Mowris, "High efficiency air conditioners can only capture 13% of potential HVAC savings due to sizing and installation problems."[60] At the national level, ACCA/ANSI has recently completed a Quality Installation Specification that goes above and beyond even Title 24. ENERGY STAR is exploring the opportunity to launch an ENERGY STAR installation program that would involve a label/endorsement of a quality installation. On the technical side, the key threshold question that remains to be worked out is a verification method that provides the needed degree of rigor and credibility without imposing additional costs that overwhelm the expected benefit of the quality installation. On the market side, ENERGY STAR is currently evaluating the market's readiness for having an installation program, what expectations should be for participation, how much weight the ENERGY STAR brand brings to that market, and what kind of requirements program partners will be expected to meet. Current projections are that these issues will be addressed and a program will be ready for launch in 2008.[61]

One expected challenge in developing an ENERGY STAR installation program is that different utilities around the country may need to strike a compromise in what ENERGY STAR should require, because requirements that produce good savings in California may be so ambitious that they stifle participation in other states. According to CEE, California has a major advantage in terms of having turn-key, successful, relatively cost-effective quality installation programs. The fact that both utility energy efficiency programs and the Title 24 energy standards reward installers for third party-verified quality installation has pushed California's HERS raters into becoming quality HVAC installation verifiers. In addition, the utility programs have also attracted market players like Proctor Engineering Group (Check Me!®), Portland Energy Conservation Inc. (AirCare Plus) Robert Mowris and Associates (Verified™), Enalasys, and Honeywell (HVAC Service Assistant), who offer third-party turn-key verification of HVAC installation quality.[62]

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59 Personal communication, John Taylor, Residential Programs Manager, Consortium for Energy Efficiency (Phil Audet interviewer), March 9, 2007

60 http://www.pge.com/docs/pdfs/rebates/program_evaluation/advisory_group/2nd_HVAC_Report_Out_April29.pdf, accessed July 5, 2007

61 Personal communication, John Taylor, Residential Programs Manager, Consortium for Energy Efficiency (Phil Audet interviewer), March 9, 2007

62 Ibid.

2.3 RESIDENTIAL LIGHTING

2.3.1 Technology and Market Trends

A combination of emerging technology developments, recent public policy initiatives, and a renewed push from manufacturers and large retailers could spell the end of incandescent lamps as the staple residential lighting technology. If these trends hold, then residential lighting program managers may need to reassess their technology portfolios. Incandescent lamps would cease to be the baseline technology and replacing them with CFLs would no longer be a cost-effective strategy for reaching energy efficiency goals.

The public policy debate around incandescent lamps is being spurred by efforts to address climate change. California Assembly Bill 722, introduced by Assembly Member Levine on February 22, 2007, would prohibit the sale of general service incandescent lamps in the state after January 1, 2012.[63] Similar legislation is under consideration in Connecticut (SB1432), North Carolina (HB838), and Rhode Island (SB806). Minnesota legislation, SF1442, would place a 25 cent tax on each incandescent bulb sold. Connecticut's bill also includes a 10 cent "surcharge" on any incandescent lamp.[64]

At the federal level, Senator Mark Pryor (D-Ark.) and Congressman Don Manzullo (R.-Ill.) have joined the Lighting Efficiency Coalition in calling for technology-neutral performance standards that will phase out the least efficient products from the market such as the 128-year old incandescent-style lamps.[65] Congresswoman Jane Harman (D-Calif.) has introduced legislation (HR 1547) that would require all lamps to produce 60 lumens-per-watt by January 2012; 90 lumens-per-watt by January 2016; and 120 lumens-per-watt by January 2020.[66] These state and federal initiatives follow on the heels of incandescent bans that have recently been enacted in Australia and in Ontario, Canada.[67] While their prospects for passage in 2007 are unclear, the idea of an incandescent ban or a new performance standard that would effectively disqualify current-generation incandescent technology is clearly gaining traction.

Regardless of the outcome of the political debate, several key players in the residential lighting market have recently announced new initiatives to spur CFL sales or phase out incandescent lamps entirely. According to PR Newswire, Royal Philips Electronics is the first lighting

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63 http://www.leginfo.ca.gov/pub/07-08/bill/asm/ab_0701-0750/ab_722_bill_20070222_introduced.html (accessed April 25, 2007)

64 http://ncel.net/newsmanager/news_article.cgi?news_id=171 (accessed April 25, 2007)

65 http://www.prnewswire.com/news/index_mail.shtml?ACCT=104&STORY=/www/story/03-14-2007/0004545992&EDATE= (accessed April 25, 2007)

66 http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=110_cong_bills&docid=f:h1547ih.txt.pdf (access April 25, 2007)

67 http://www.cbc.ca/canada/toronto/story/2007/04/18/ontario-lightbulb-ban.html#skip300x250 (accessed April 25, 2007)

manufacturer in North America seeking to phase-out production of incandescent light bulbs.[68] The world's three largest light bulb makers, General Electric, Siemens and Royal Philips Electronics, have jointly announced that they will push European consumers to switch to energy-saving bulbs in a bid to cut carbon dioxide emissions that are believed to contribute to global warming.[69]

Wal-Mart Stores, Inc. has taken the highest profile stance, announcing an ambitious campaign to sell 100 million CFLs by the end of 2007. The retailer estimates that this initiative will avoid the emission of 20 million metric tons of greenhouse gases.[70] As one of its marketing initiatives, Wal-Mart has teamed up with Yahoo!, AC Nielsen, the EPA, the Department of Energy, and Environmental Defense to promote CFL purchases through a campaign dubbed "18 Seconds," referring to the estimated time required to switch out an incandescent with a CFL (www.18seconds.org). One industry expert summed up the challenge and opportunity of Wal-Mart's initiative succinctly: "If Wal-Mart is able to pull this off, we may have two more years with a fairly robust CFL component, simply as a complementary effort, and during that period of time we really need to be developing other opportunities."[71]

Not all industry players are abandoning incandescent technology. General Electric in particular has announced that it is developing incandescent technology that will be twice as efficient as current incandescents (i.e., approximately 30 lumens per watt) and ultimately comparable to CFLs in efficiency (approximately 60 lumens per watt).[72] However, the announcement is vague on the time frame for the new product release, raising questions as to whether the announcement's timing represents a true technology breakthrough or simply an attempt to forestall legislative efforts to ban incandescent technology. In either case, the announcement would appear to support the technical feasibility of establishing a performance-based standard of 60 lumens per watt for household lighting products.

Light-Emitting Diode (LED, also known as solid-state) technology is getting a lot of attention because it is extremely energy efficient and it allows better light distribution than standard CFL or fluorescent technologies. Standard lamps radiate light in all directions. This necessitates a fixture design to control light distribution, which reduces the effective lumens. A well-designed LED system can control light exactly where it needs to go, which maximizes fixture efficacy. The challenges have related to its cost, low levels of light output, and narrow wavelengths. Recent innovations are bringing the technology cost down and now feature the capability to generate blue light, which enables engineers to produce the full spectrum of lighting colors by

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68 http://www.prnewswire.com/news/index_mail.shtml?ACCT=104&STORY=/www/story/03-14-2007/0004545992&EDATE= (accessed April 25, 2007)

69 http://www.msnbc.msn.com/id/17364944/#storyContinued (accessed April 25, 2007)

70 http://www.walmartfacts.com/articles/4630.aspx (accessed March 25, 2007)

71 Personal communication, George Edgar, Director, Energy Policy, Wisconsin Energy Conservation Corporation (Phil Audet interviewer), March 9, 2007

72 http://www.geconsumerproducts.com/pressroom/press_releases/lighting/new_products/HE_lamps_07.htm (accessed April 26, 2007)

mixing red, green, and blue. Current research is focused on addressing heat dissipation issues on the back of the circuit chip. Improper heat dissipation changes the light color over time. [73]

LED technology is opening up a new research area in hybrid technologies—combining two different light sources for different applications. For example, the California Lighting Technology Center (CLTC) is conducting applied research on hybrid porch lights. Instead of the current strategy of operating a 15W CFL all night, CLTC is looking at providing low-level lighting all night long via 3 or 4 LEDs, coupled with an occupancy sensor that controls a higher wattage lamp for full lighting only when needed. CLTC is working with Hunter Lighting on such a product to release in 2007. CLTC is working with Guardco on a similar strategy for walkway lighting, combining low-watt LEDs, higher wattage CFLs, and occupancy sensors.[74]

2.3.2 Emerging Trends in Codes and Standards

As CFLs are poised to gain significant market share in the residential lighting market, concerns have mounted regarding their mercury content and the prospects of mercury contamination of groundwater supplies through improper disposal of household CFLs in local landfills.[75] In response, lighting manufacturers, through the National Electrical Manufacturers Association, have agreed to voluntarily cap the total mercury content in CFLs of less than 25 watts at 5 milligrams (mg) per unit. The total mercury content of CFLs that use 25 to 40 watts of electricity will be capped at 6 mg per unit.[76] Royal Philips Electronics has gone further and released a series of Extreme Low Mercury designated products, rated at 2 mg of mercury or lower.[77] According to David Nelson, AIA, "Low mercury fluorescent lamps can be disposed of in landfills in some states. In these states, lamps that have sufficiently low levels must pass the testing procedure known as the Toxic Characteristic Leaching Procedure (TCLP) test."[78, 79]

The primary challenge for emerging lighting technologies is the need to establish an efficacy testing protocol for LED lighting that permits direct comparison to CFLs and other technologies. This issue is particularly important for determining suitability for the ENERGY STAR label, which is the accepted standard for energy-efficient lighting. ENERGY STAR testing protocols for CFLs currently evaluate the lamp and ballast independently of the fixture.

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73 Personal communication, Don Aumann, California Lighting Technology Center (Bruce Mast interviewer) February 2, 2007

74 Ibid.

75 http://www.energystar.gov/ia/partners/downloads/meetings/CFLMercuryConundrum_RecyclingProject_Fulbright.pdf (accessed April 25, 2007)

76 http://www.nema.org/gov/ehs/committees/lamps/cfl-mercury.cfm (accessed April 25, 2007)

77 http://www.lighting.philips.com/gl_en/news/press/sustainability/archive_2006/reduction_in_mercury.php?main=global&parent=4390&id=gl_en_news&lang=en (accessed April 25, 2007)

78 See EPA SW-846, "Test Methods for Evaluating Solid Waste (Physical/Chemical Methods)", Chapter 7, "Toxicity Characteristic Leaching Procedure," Section 7.4

79 http://www.wbdg.org/design/efficientlighting.php (accessed April 25, 2007)

According to CEE's Rebecca Foster, there are unresolved questions as to whether that approach is appropriate for LED lighting. One issue is photometrics. The ability of a luminaire to effectively deliver light to a work surface is partly a function of fixture design. LEDs provide greater flexibility in this respect, an advantage that is discounted if the luminaire is considered separately from the fixture. More importantly, the ability of an LED luminaire to perform as designed depends on the fixture's ability to dissipate heat. Poor heat dissipation can affect light output and color rendition. Thus an evaluation of a luminaire in isolation may not give an accurate assessment of the luminaire's actual performance in a particular fixture.[80]

2.3.3 Innovations in Program Designs and Incentive Structures

The residential lighting industry is clearly in a state of flux. The combination of emerging technology developments, new public policy initiatives, and the commitment from leading manufacturers and large retailers to flex their marketing muscle promises substantial energy efficiency improvements in the mix of lighting products commonly available to consumers. These market changes promise to radically alter the market baseline and associated cost-effectiveness for residential lighting programs.

In the meantime, utility programs and national initiatives such as ENERGY STAR and CEE play a continuing role in ensuring that the transition to a CFL-based lighting market is smooth and painless from the consumer's perspective. Key areas of focus include

- Commercialization of the GU-24 universal base;
- Push for a broader array of attractive and energy-efficient fixture designs through design competitions and co-op marketing with manufacturers and distributors;
- Performance standards to ensure that low-cost CFLs coming on the market meet consumer expectations for light output and quality, longevity, and functionality; and
- Research and development to address concerns of mercury toxicity.

While Wal-Mart's marketing muscle shows great potential for expanding the role of CFLs in lighting America's homes, the lack of market penetration to date has not been simply a marketing issue. Screw-in CFLs are incompatible with many incandescent fixtures and hard-wired CFL fixtures suffer from an array of incompatible pin configurations and limited fixture design choices.

To address the pin incompatibility issue, the American Lighting Association and the U.S. EPA have spearheaded development of a universal line voltage socket, called the GU-24 base. According to Foster, et al. (2006), "the GU-24 base is now well integrated into the ENERGY STAR fixture program. EPA reports that approximately one-third of all new qualified products use the base… and several manufacturers told us 'this is what makes it possible for us to produce ENERGY STAR fixtures.' Further, the base type is currently moving through the ANSI

[80] Personal communication, Rebecca Foster, Residential Lighting Program Manager, Consortium for Energy Efficiency (Phil Audet interviewer), March 12, 2007

standardization process, which should further bolster its position as the accepted universal line voltage socket type for ENERGY STAR fixtures."[81]

The new ballasts are expected to simplify the technology choices from the consumer's perspective and provide greater flexibility to change a fixture's wattage and lumen output. Replacement lamps should also be easier to find. The universal base should simplify the design process from the manufacturer's perspective and bring down fixture costs. On the efficiency side, those interested in long-term savings through the promotion of energy-efficient fixtures can have a guarantee that those fixtures will not be used with incandescent light sources, because the GU-24 is only approved for CFLs or solid-state sources.[82]

To expand the array of lighting design choices, the American Lighting Association, U.S. DOE (represented by Pacific Northwest National Laboratory) and the Consortium for Energy Efficiency (CEE) joined forces in 2002 to organize "Lighting for Tomorrow", an annual design competition for energy-efficient, ENERGY STAR-qualified fixture families.

The design competition promotes the development of "showroom quality" energy-efficient lighting by requesting elegant, energy-efficient designs and recognizing designers and prototype manufacturers with monetary awards and promotional efforts including press releases, announcements at conferences, use of websites, and promotion through LFT partners. Judges for the 2006 competition considered nearly 60 indoor and outdoor lighting fixture families—complementary lighting products that can be purchased as a set—from which they selected 26 fixture families. In the indoor category, 7 designs were selected as 2006 Lighting for Tomorrow winners, while 12 additional designs were awarded honorable mention. In the outdoor category, 3 designs were designated as winners, with 4 others earning honorable mention.[83] According to Foster, et al. (2006), the competitions have received excellent media coverage by the residential lighting trade press, as well as Sunset Magazine, HGTV, and local news outlets. About 50% more fixture manufacturers displayed ENERGY STAR fixtures at the January 2006 Dallas Market, compared to the 2005 market.[84]

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[81] Foster, Rebecca, Kelly Gordon, Terry McGowan (2006), "Lighting for Tomorrow: What Have We Learned and What About the Day After Tomorrow?" *2006 ACEEE Summer Study on Energy Efficiency in Buildings* (6.88–6.99)

[82] Personal communication, Rebecca Foster, Residential Lighting Program Manager, Consortium for Energy Efficiency (Phil Audet interviewer), March 12, 2007

[83] http://www.lightingfortomorrow.com/2006/pdf/2006_lft-pk.pdf (accessed April 25, 2007)

[84] Foster, Rebecca, Kelly Gordon, Terry McGowan (2006), "Lighting for Tomorrow: What Have We Learned and What About the Day After Tomorrow?" *2006 ACEEE Summer Study on Energy Efficiency in Buildings* (6.88–6.99)

2.4 RESIDENTIAL COMPREHENSIVE

2.4.1 Technology and Market Trends

Nationwide, on a per household basis, residential gas usage is decreasing and electric usage is increasing.[85] The "other appliance" or "miscellaneous" end use, which encompasses all end uses except HVAC, refrigeration, water heating, lighting, cooking, dishwashing, and clothes washing/drying is now the largest residential end use, and continues to grow at a faster rate than all other residential end uses. Miscellaneous uses are becoming relatively more important because some of the conventional uses of energy have become much more efficient and because people are buying more energy-using appliances that fall into the miscellaneous category.[86]

Technology trends that were previously described under Residential New Construction, Residential HVAC and Residential Lighting also apply to this category. Residential water heating is gaining increasing attention as an opportunity for energy efficiency gains (see Residential New Construction for discussion of specific technologies). Other promising new technologies that deserve mention are those that (1) combine waste heat from one end use to provide input heat to another use; (2) expand load control capabilities to residential end uses; or (3) address the growing power demands of plug loads. PIER is investing in research projects to explore residential load control technologies and energy efficient power supplies.

Emerging Trends in Codes and Standards

Emerging trends in codes and standards trends were previously described under Residential New Construction, Residential HVAC and Residential Lighting.

Innovations in Program Designs and Incentive Structures

Two innovations in program designs are worth noting:

- Increased focus on overall home performance
- Programs that incorporate new information feedback technologies to influence consumer behavior

Home Performance Contracting has emerged as a significant market opportunity to use building-science based approaches to improve existing homes. Practitioners in the field estimate that this approach can reduce energy use in existing homes by 50% or more of total energy use. The approach emphasizes a comprehensive, performance-based analysis of home

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[85] http://www.marketresearch.com/product/display.asp?productid=1334536&xs=r&SID=75943189-382826906-307737743&curr=USD&kw=&view=abs (accessed May 3, 2007)

[86] http://enduse.lbl.gov/projects/resmisc.html (accessed May 3, 2007)

shell and mechanical systems. Customer acceptance is driven by a variety of market drivers, including comfort, durability, health and safety, along with energy efficiency.[87]

Two new information feedback technologies show particular promise for influencing consumer behavior. The first, GoodWatts, is an advanced, two-way, real-time, comprehensive home energy management system field tested as part of California's Automated Demand Response System (ADRS) pilot program. Via the Internet, homeowners with GoodWatts can

- set climate control and pool or spa pump runtime preferences and view these settings at any time both locally and remotely
- program desired thermostat and pool/spa responses to changes in electricity prices
- view whole-house or end-use specific demand in real time and display trends in historical consumption

Customers with ADRS technology and subject to dynamic, critical peak pricing rates successfully achieved load reductions compared to control customers without ADRS technology on standard tiered rates. The load reductions were substantial and stable across a range of days and temperatures. Where present, pool pumps made a significant contribution to reduction of Super Peak and peak period load.[88]

The second emerging information feedback technology consists of low cost monitoring systems to determine the relative energy intensity of various household energy end uses. Parker, et al., (2006) document the potential to reduce energy consumption by 10–15 percent via instantaneous feedback on household electrical demand and provide case study evaluations of two such feedback devices, *The Energy Viewer* and *The Energy Detective*. While lacking the programmable control functionality of GoodWatts, these devices provide guidance on profitable areas to reduce household electrical demand. The technology is particularly useful for identifying opportunities to deploy targeted power strips and occupancy-based controls to significantly reduce electricity use associated with household entertainment centers, home office equipment and rechargeable devices.[89]

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[87] Rogers, Michael, Megan Edmunds, Robert Knight, (2006) "Home Performance with ENERGY STAR®: Delivering Savings with a Whole-House Approach" 2006 ACEEE Summer Study on Energy Efficiency in Buildings (2.229¬–2.241)

[88] Wang, Katherine, and Joel Swisher (2006) "Are Smart Homes More Efficient? Energy Impact of California's Residential Automated Demand Response Program", 2006 ACEEE Summer Study on Energy Efficiency in Buildings (2.297–2.308)

[89] Parker, Danny, David Hoak, Alan Meier, and Richard Brown (2006), "How Much Energy Are We Using? Potential of Residential Energy Demand Feedback Devices" 2006 ACEEE Summer Study on Energy Efficiency in Buildings (1.211–1.222)

2.5 NONRESIDENTIAL NEW CONSTRUCTION

2.5.1 Technology and Market Trends

General trends outlined in the Residential New Construction chapter apply to nonresidential new construction as well:

- The emerging focus on environmental issues associated with production of electricity and consumption of natural gas, particularly climate change
- Concentrations of population growth and economic development trends in hot regions
- The continued domination of installation cost and non-energy considerations as the primary drivers for building equipment purchase decisions
- Sub-optimal integration of subsystems and components. and improper installation

As discussed in the context of residential new construction, green building is emerging as an integrated approach to addressing multiple environmental impacts related to the built environment. U. S. Green Building Council's Leadership in Energy and Environmental Design (LEED) rating system has become the de facto national green building standard for nonresidential buildings. As of May, 2007, USGBC counted 8,957 member companies and organizations, representing a four-fold membership increase over the last five years. USGBC estimated the annual U.S. market in green building products and services to be over $7 billion in 2005 and projects that to increase to $12 billion in 2007. Over 630 buildings have been LEED certified as of May 2007 and almost 4,800 buildings have been registered but not certified.[90] Twenty-two states and more than 75 local governments reference LEED as the basis for a green building initiative for state-owned or private nonresidential projects.[91] In-depth analysis of 21 LEED certified buildings documented energy savings on the order of 27 percent compared to modeled baseline values.[92]

Executive Order S-20-04, signed by California's Governor Schwarzenegger on Dec. 14, 2004, cites USGBC's LEED rating system in calling for aggressive action to reduce state building electricity usage for facilities owned, funded or leased by the state. The order establishes a goal of 20% gains in energy efficiency by 2015. The order also directs the California Public Utilities Commission (CPUC), the Energy Commission, the Public Employees and State Teachers

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[90] http://www.usgbc.org/DisplayPage.aspx?CMSPageID=225 (accessed May 14, 2007)

[91] https://www.usgbc.org/FileHandling/show_general_file.asp?DocumentID=691 (accessed May 14, 2007)

[92] Diamond, Rick, Mike Opitz, Tom Hicks, Bill Von Neida, Shawn Herrera, (2006) "Evaluating the Energy Performance of the First Generation of LEED-Certified Commercial Buildings" 2006 ACEEE Summer Study on Energy Efficiency in Buildings (3.41–3.52)

Retirement Systems, and the Division of the State Architect to use their respective authorities to contribute toward meeting the 20% goal.[93]

In the technological arena, key areas of focus are on strategies to better capture the benefits of integrated design and performance testing to ensure that design strategies are properly implemented.

Design. A common challenge in designing buildings for energy efficiency is that conventional energy performance simulation software requires detailed specification of the building parameters in order to model building energy efficiency and test design alternatives. Thus, most designers do not consider the energy use of a building design until very late in the process when many energy efficiency strategies are no longer cost-effective to implement. To address this challenge, Green Building Studio was developed as a web-based analysis tool to help architects quickly analyze building energy performance trade-offs at the conceptual design phase of a project. The tool integrates with 3D-CAD/BIM applications and facilitates data sharing between design and engineering personnel.

Daylighting. Daylighting is gaining in both market share and technology sophistication, combining good shell design and good controls. For example, designers are now specifying view windows separate from daylighting windows. Low windows let in less light and glare but still allow occupants to see out. Higher daylight windows get light into the interior of the building space. Light shelves and light louvers (highly reflective mini-blind applications) help transmit and diffuse light throughout the space.[94]

Commissioning. The practice of building commissioning and retrocommissioning has advanced significantly in recent years, particularly in the Pacific Northwest through the efforts of Portland Energy Conservation Inc. The practice has gained momentum since USGBC made it a prerequisite for obtaining LEED certification for new commercial construction and major renovation projects. More recently, the non-profit California Commissioning Collaborative was established to bring together California utilities and state agencies to promote commissioning practices in the state. The Collaborative provides training and education, develops case studies of commissioning success stories, and conducts market research. A key research focus is to develop the "Cx Database" as a tool for analyzing and demonstrating the costs and benefits of commissioning services.[95]

2.5.2 Innovations in Program Designs and Incentive Structures

The Energy Policy Act of 2005 provides a tax incentive of up to $1.80 per square foot for the installation of qualifying technologies that are designed to reduce the total annual energy and power costs with respect to the interior lighting systems, heating, cooling, ventilation, and hot

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[93] See http://www.governor.ca.gov/state/govsite/gov_htmldisplay.jsp?sTitle=Executive+Order+S-20-04&sFilePath=/govsite/executive_orders/20041214_S-20-04.html&sCatTitle=Exec+Order, accessed July 5, 2007.

[94] Personal communication, Don Aumann, California Lighting Technology Center (Bruce Mast interviewer) February 2, 2007

[95] See http://www.cacx.org, accessed July 5, 2007.

water systems of the building by 50 percent or more relative to ASHRAE/IESNA Standard 90.1-2001 (as in effect on April 2, 2003).[96]

Since 2004, six states and three additional collaborators have joined forces to promote building commissioning with funding from U.S. Department of Energy's State Technologies Advancement Collaborative (STAC). The STAC program seeks to streamline commissioning practices by addressing two widely recognized barriers to the adoption of commissioning: (1) the need for tools and technologies that standardize and simplify commissioning approaches and reduce implementation costs; and (2) the uncertainty about cost savings and other benefits from commissioning.[97]

Energy efficiency programs are devising new ways of integrating USGBC's LEED-NC rating system into their program designs. For example Energy Trust of Oregon offers up to $200,000 in incentives for new construction projects that meet energy performance targets and earn specified Energy & Atmosphere Credit points as part of LEED-NC certification.[98]

2.6 NONRESIDENTIAL HVAC

2.6.1 Technology and Market Trends

As in the residential sector, nonresidential HVAC equipment may be approaching the technical and economic limits of performance, which has spurred greater interest in installation quality. The complexity of large HVAC systems creates additional opportunities and challenges related to system controls and proper system design.

Eugene Water & Electric Board (EWEB) has developed "premium" economizer requirements that result in increased economizer savings in the field. Several field studies have found that more than half of outside air economizers on packaged rooftop cooling units are not providing optimal savings, either because dampers or controls have failed, changeover is set incorrectly, or the improper type of controls for the local climate have been installed. Analysis of economizer operation indicates that, at best, only one third of potential savings is being achieved. EWEB's field monitoring showed that properly operating premium economizers provide more savings than standard economizers. Results also supported increased focus on commissioning to improve economizer reliability. Reliance on contractor training and a

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96 U.S. Green Building Council (2005), *Analysis of the Conservation and Energy Efficiency Tax Provisions in the Energy Policy Act of 2005*, prepared by Van Ness Feldman, https://www.usgbc.org/FileHandling/show_general_file.asp?DocumentID=1123

97 Khan, Aleisha, Martha Brook, Tudi Haasl, Hannah Friedman, David E. Claridge, Philip Haves, and Malcolm Verdict (2006) "Plugging Holes: Uncovering Critical Resource Gaps Needed for Commissioning to Thrive" *2006 ACEEE Summer Study on Energy Efficiency in Buildings* pp. 4.160–4.171.

98 Mauldin, Tom, Lynn Hoefgen, Greg Stiles, Charlotte Rollier, Cathy Chappell (2006), "Encouraging Efficiency in an Already Efficient Market" 2006 *ACEEE Summer Study on Energy Efficiency in Buildings* pp. 4.219–4.229.

specified field checkout (visual inspection only) did not result in better economizer reliability. [99]

A new angle on retrocommissioning is monitoring-based commissioning, which combines permanent building energy system monitoring with established retro-commissioning protocols to achieve and maintain high performance and low energy use. The University of California (UC), California State University (CSU), and California's investor-owned utilities have all collaborated to pilot-test monitoring-based commissioning on 30 buildings at 25 university campuses. The pilot involved the upgrade of permanent energy meters and other instrumentation, augmentation of energy information systems, benchmarking of building energy performance, assistance with initial commissioning efforts, and training of in-house staff. Preliminary results from 13 sites significantly exceeded program performance targets: the projects represented 32% of total funding, while producing 66% of aggregate energy and cost savings goals for the overall program, with aggregate simple payback period of 2.3 years.[100]

To further advance this effort, Lawrence Berkeley National Laboratory has developed a specification guide for performance monitoring systems to assist commercial and institutional building owners in specifying what is required to obtain the information necessary to initiate and sustain an ongoing commissioning activity. The primary purpose of the performance monitoring system is to provide facility managers and operators with the means to easily assess the current and historical performance of the building/facility as a whole, and its significant energy consuming systems and components. The performance monitoring system includes not only the needed sensors, wiring and data acquisition devices, but also the software tools to analyze system performance from both an energy efficiency and comfort perspective.[101]

Pacific Northwest National Laboratory has also contributed to performance monitoring efforts in the form of the Whole-Building Diagnostician (WBD), a modular diagnostic software system that provides detection and diagnosis of common problems associated with the operation of heating, ventilating, and air-conditioning (HVAC) systems and equipment in buildings. The WBD tracks overall building energy use, monitors the performance of air-handling units, and detects problems with outside-air control. The Whole-Building Energy (WBE) module provides a graphical record of building energy performance over time, enabling users to identify major changes in energy consumption. The Outdoor Air Economizer (OAE) diagnostic module monitors the performance of air-handling units and can detect over 20 different basic operation problems with outside-air control and economizer operation.[102]

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[99] Hart, Reid, Dan Morehouse, and Will Price (2006) "The Premium Economizer: An Idea Whose Time Has Come" *2006 ACEEE Summer Study on Energy Efficiency in Buildings*, pp. 3.104–3.105

[100] Brown, Karl, Mike Anderson, Jeff Harris (2006), "How Monitoring-Based Commissioning Contributes to Energy Efficiency for Commercial Buildings" *2006 ACEEE Summer Study on Energy Efficiency in Buildings*, pp. 3.27–3.40

[101] Lawrence Berkeley National Laboratory (2007) *A Specifications Guide for Performance Monitoring Systems*, http://cbs.lbl.gov/performance-monitoring/specifications/

[102] http://www.buildingsystemsprogram.pnl.gov/fdd/wbd/index.stm, accessed July 10, 2007.

2.6.2 Emerging Trends in Codes and Standards

The Energy Policy Act of 2005 establishes new minimum energy efficiency thresholds for commercial package air conditioning and heating equipment (air-cooled). These thresholds affect all equipment manufactured on or after January 1, 2010. Standards for residential-sized HVAC systems are 13 SEER for split system and single package air conditioners, and 13 SEER, 7.7 HSPF for split system and single package heat pumps, effective January 23, 2006.[103]

Table 1
2010 Federal Efficiency Standards for Commercial Package Air Conditioning and Heating Equipment (Air-cooled)

Size category	Equipment Type	Min. Efficiency
Small (65,000–135,000 Btu/h)	Air conditioners	11.2 EER
	Heat pumps (cooling mode)	11.0 EER
	Heat pumps (heating mode)	3.3 COP
Large (135,000–240,000 Btu/h)	Air conditioners	10.8 EER
	Heat pumps (cooling mode)	10.6 EER
	Heat pumps (heating mode)	3.2 COP
Very large (240,000–760,000 Btu/h)	Air conditioners	10.0 EER
	Heat pumps (cooling mode)	9.5 EER
	Heat pumps (heating mode)	3.2 COP

[103] As specified by the National Appliance Energy Conservation Act of 1987 (10 CFR Part 430) and amended by the U. S. Department of Energy on April 2, 2004. See http://www.eere.energy.gov/buildings/appliance_standards/residential/pdfs/ac_fr_081704.pdf

At the state level, California's 2005 revisions to Title 24 add new requirements for nonresidential HVAC systems. The changes focus heavily on installation quality and improved controls.[104]

- **Acceptance Requirements.** Mandatory measures for basic building commissioning for HVAC equipment and controls

- **Demand Control Ventilation.** Mandatory requirement to include sensors that measure CO_2 levels and adjust ventilation rates in spaces with varying occupancy such as conference rooms, dining rooms, lounges and gyms.

- **Duct Efficiency.** In unconditioned or indirectly conditioned space, mandatory requirement for R-8 duct insulation. Prescriptive approach requires duct sealing with field verification.

- **Efficient Space Conditioning Systems.** Prescriptive requirements to improve HVAC system efficiency, including variable speed drives, electronically commutated motors, better controls, and efficient cooling towers. For large systems (greater than or equal to 300 tons in installed capacity), there are limitations on the use of air-cooled chillers.

- **Compliance Credits.** Adds procedures for gas cooling and underfloor ventilation.

Proposed 2008 revisions to Title 24 include multiple HVAC-related changes, including provisions for Fault Detection Diagnostics (FDD) for air handling units, VAV boxes, and rooftop air conditioners.[105]

2.6.3 Innovations in Program Designs and Incentive Structures

According to Moore, et al. (2006), retrocommissioning is gaining recognition as a cost-effective strategy for improving building performance, reducing energy use, and enhancing indoor air quality. On average, retrocommissioning projects save 15 percent of total building energy costs, with a simple payback averaging less than one year. The San Diego Retrocommissioning Program provides a successful program model that is expected to influence the design of retrocommissioning programs statewide. The program targeted large commercial buildings (>250,000 square feet) in the SDG&E utility territory and incorporated innovative features to establish a long-term commissioning infrastructure in California. To ensure quality retrocommissioning services and persistence of retrocommissioning benefits over time, the program developed retrocommissioning protocols, commissioning provider trainings, building

104 http://www.energydesignresources.com/docs/end-44.pdf

105 http://www.energy.ca.gov/title24/2008standards/documents/2007-06-13-15_workshop/presentations/070613%20Eley%20Workshop%20Summary%20Slides.pdf

operation monitoring guidelines, and innovative, leveraged marketing efforts.[106] Similar efforts are underway in New York and elsewhere.

2.7 NONRESIDENTIAL LIGHTING

Emerging energy efficiency trends in the nonresidential lighting arena reflect an interesting mix of emerging technologies, more sophisticated controls, and greater focus on design practices, installation quality, and commissioning.

2.7.1 Technology and Market Trends

Reduced-wattage fluorescent lamps. Manufacturers are promoting a reduced-wattage T8 lamp that may draw as little as 25 watts, compared to the more typical 32 watts for standard T8s. According to ESource, these lamps provide higher efficacy, longer life, and better color quality than standard T8s. Manufacturers report that these versions now account for about 10 percent of all 4-foot T8 lamps sold.[107]

LED Lighting. LED lighting technology is extremely energy efficient and it allows better light distribution than standard CFL or fluorescent technologies. Whereas, standard lamps radiate light in all directions, a well designed LED system can direct light exactly where it needs to go, which maximizes fixture efficacy. The challenges have related to its cost, low levels of light output, and narrow wavelengths. Recent innovations are bringing the technology cost down and now feature the capability to generate blue light, which enables engineers to produce the full spectrum of lighting colors by mixing red, green, and blue. Current research is focused on addressing heat dissipation issues on the back of the circuit chip. Improper heat dissipation changes the light color over time. Federal lighting technology investment is exclusively focused on LEDs.[108]

Hybrid Technologies. An important technology research area for the California Lighting Technology Center, hybrid technologies combine two different light sources for different applications. Typical combinations involve low-watt and higher-wattage lamps with controls such as an occupancy sensor or timer. The approach is being developed and field-tested for an array of applications, including

- Ambient night lighting for hotel bathrooms
- Combined ambient and task lighting for offices

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[106] Moore, Emily, Amanda Potter, Tudi Haasl, and Don Frey (2006), "Marketing Retrocommissioning to Large Commercial Building Owners: Lessons Learned from the San Diego Retrocommissioning Program" *2006 ACEEE Summer Study on Energy Efficiency in Buildings*, pp. 4.242–4.251.

[107] Buckley, Rachel Reiss (2006) "A Roulette Wheel of Energy-Efficiency Technologies", Association of Energy Service Professionals

[108] Personal communication, Don Aumann, California Lighting Technology Center (Bruce Mast interviewer) February 2, 2007

- Bi-level lighting for audio-visual presentations (e.g., classrooms, conference rooms)
- Stairwell lighting
- Parking lots

Lighting controls. Developing effective lighting controls remains an industry challenge. A large-scale study of 123 buildings with daylight-responsive lighting controls found that more than half had non-functional controls. Nevertheless, the energy savings potential from effective controls is substantial. The same study found that the top quartile of controls were achieving 82% of their design savings targets reducing lighting energy consumption by 51% and lighting power density by 65%.[109] Lighting control research at the California Lighting Technology Center focuses on developing more sophisticated lighting controls that are virtually self-commissioning and simpler from the user's perspective. Researchers are also looking at demand-response lighting as a way to gradually dim lighting in response to peak load constraints without people noticing.[110]

High Intensity Fluorescent (HIF) Lighting. According to ESource, improvements in fluorescent lamps and the emergence of new HIF fixtures have made fluorescent lighting the most cost-effective choice for lighting high indoor spaces. These HIF systems are more energy-efficient than HID solutions and feature lower lumen depreciation rates, better dimming options, virtually instant start-up and restrike, better color rendition, and reduced glare.[111]

2.7.2 Emerging Trends in Codes and Standards

Proposed 2008 revisions to Title 24 include multiple lighting-related changes:[112]

- Test methods to determine wattage and efficacy for all light emitting diode (LED) lighting systems.
- New acceptance requirements for indoor lighting technologies, including manual and automatic daylighting controls, occupancy sensors, and timers.
- New acceptance requirements for outdoor lighting technologies, including motion sensor and shutoff controls

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[109] Howlett, Owen, Lisa Heschong, Jon McHugh, Abhijeet Pande, Gregg Ander, Jack Melnyk, Steve Blanc, David Cohan (2006) "Sidelighting Photocontrols Field Study", *2006 ACEEE Summer Study on Energy Efficiency in Buildings*, pp. 3.148–3.159.

[110] Personal communication, Don Aumann, California Lighting Technology Center (Bruce Mast interviewer) February 2, 2007

[111] Esource (2007), "Lighting: HID Versus Fluorescent for High-Bay Lighting", *ESource Building Energy Advisor*, http://www.esource.com/BEA/demo/PDF/P_PA_46.pdf

[112] http://www.energy.ca.gov/title24/2008standards/documents/2007-06-13-15_workshop/presentations/070613%20Eley%20Workshop%20Summary%20Slides.pdf

2.7.3 Innovations in Program Designs and Incentive Structures

Utilities in the New England states have moved away from a prescriptive approach to lighting energy efficiency and adopted a "Performance Lighting" program model. The program model incorporates hybrid performance standards for both energy efficiency and lighting quality (i.e., IES recommended lighting levels; premium efficiency illumination equipment; glare, color rendering, uniformity management). In this way, they ensure that participating projects exceed code requirements by at least 25% while avoiding projects that utilize outdated, inefficient technologies or achieve low LPDs by under-lighting spaces or "massaging" the calculation process.[113]

In a similar vein, the New York Energy $mart℠ Small Commercial Lighting Program (SCLP), implemented by The New York State Energy Research and Development Authority (NYSERDA), promotes effective, energy-efficient lighting through proper lighting design and deployment. The program has trained over 1,300 lighting practitioners (lighting contractors, distributors, designers, and manufacturers and their representatives), responsible for nearly 580 qualifying projects that have generated annual end-user energy savings in excess of 26 GWh. SCLP's lighting design model requires conformance with specific requirements for task light levels, lighting uniformity, glare, and color rendering and that the project lighting power density be 10% below that allowed by the State regulations.[114]

2.8 NONRESIDENTIAL LARGE COMPREHENSIVE

2.8.1 Technology and Market Trends

Developments on the technology side[115] include:

- ***Use of "disruptive" technologies – low-energy technologies that replace energy-intensive technologies and fundamentally change the way that things are manufactured.*** For example, the traditional welding process is highly energy intensive. An emerging low energy alternative is the use of adhesive bonding in place of welding. This could ultimately eliminate the use of traditional welding. Another emerging practice is the use of linear pneumatic positioning equipment instead of compressed air systems. This application offers the promise of eliminating compressed air completely from the manufacturing facility. These types of low-energy solutions represent technology shifts that fundamentally change how products are manufactured.
- ***Greater use of conditioned-based monitoring and other information-based "smart" technologies***. According to ACEEE, the largest opportunities from an emerging technology

[113] Birleanu Dan, Brian McCowan, Gary Epstein, Tom Butler, Tom Coughlin (2006), "A New High Performance Lighting Program Model: Outperforming Energy Codes while Mandating Premium Efficiency and Quality", *2006 ACEEE Summer Study on Energy Efficiency in Buildings,* pp. 4.1–4.15

[114] Dare, Marilyn J. and Bruce Appelbaum (2006), "The New York Energy $martSM Small Commercial Lighting Program: A New Model for Lighting Market Transformation Programs" *2006 ACEEE Summer Study on Energy Efficiency in Buildings,* pp. 4.76–4.87

[115] Personal communication, Neal Elliott, ACEEE Industry Program Director (Chris Dyson interviewer), January 2007

perspective are in the information technology area involving condition-based monitoring. For example, many U.S. manufacturers are now using remote reources to do the condition-based monitoring and subsequently dispatches a technician to do preventive maintenance on-site before the equipment fails. For manufacturing facilities, this type of preventative maintenance is highly valued because it reduces unplanned outages and associated production losses.

With respect to market trends, Energy Service Companies (ESCOs) are key providers of energy efficiency services to large nonresidential customers and account for a significant portion of their custom energy efficiency projects. An important distinction between ESCOs and other energy efficiency providers is that ESCOs offer a comprehensive service that includes energy audits, design engineering, installation and financing of the equipment (through third parties) and M&V of the savings. According to Donald Gilligan, Executive Director of the National Association of Energy Service Companies (NAESCO), the majority of the ESCO market is still in public facilities, whether state, federal or local, because these facilities lack the financing mechanisms and streamlined decision-making processes to tackle projects on their own. ESCOs are able to offer a combination of technical expertise, upfront financing, and long-term engagement in the project to see it through from planning to fruition (typically 12 to 18 months). They are able to handle large projects with complex development requirements, long timelines, and a degree of performance risk, at least as perceived by the customer.[116]

Looking forward, NAESCO sees a tremendous resource in under or poorly utilized building controls in existing buildings. The concept goes beyond retrocommissioning, combining the technical capabilities of building controls, smart meters, and flexible rate design. A significant research and development effort may be required to better define this resource and the best methods of deploying programs around it.

2.8.2 Emerging Trends in Codes and Standards

The move to stricter codes and standards, coupled with prior efficiency program success, has driven ESCOs to focus on the more complex and difficult-to-harvest efficiency resources. This shift has squeezed ESCO profit margins, pushed ESCOs to operate more efficiently, and forced them to carefully scrutinize the expected cost-effectiveness and risk versus reward of potential projects.

2.8.3 Innovations in Program Designs and Incentive Structures

The ESCO industry views the Standard Offer Program as the preferred model of effective resource acquisition. ESCOs consider standard offer programs to include any program model in which the value of a kW or kWh, or the measure that produces kW or kWh savings, is known. While “pay for performance” is seen as an effective model, inordinately stringent performance penalties may stifle ESCO participation if ESCOs find that the downside of non-performance is much greater than the potential upside of successful performance. Recent experience in New

[116] Personal communication, Donald Gilligan, NAESCO Executive Director (Bill Brooks interviewer), January 16, 2007

York suggests that a program without non-delivery penalties can deliver substantial benefits and even outperform a program with severe restrictions and non-delivery penalties

Whether the program model is standard offer, third-party, and direct rebate, an important factor in attracting ESCO participation is the degree of financial risk the program places on participants. In general, ESCOs are not high margin, operating on net profits in the high single digits. The successful ESCOs have developed very careful risk management procedures. Successful energy efficiency programs are those that give ESCOs a reasonable expectation of earning a return on investment with manageable risk.[117]

The more effective programs also recognize long planning cycles involved in large non-residential projects. Most ESCO projects have a 12 to 18 month development cycle, suggesting the need for as much as a 3-year program funding cycle to avoid contract and delivery problems. Longer funding cycles are one way of helping ESCOs manage risk. Many utilities, especially those with a long history of program delivery, recognize this.

A significant change in program design with direct implications for ESCOs is the pendulum swing in measurement and verification (M&V) requirements, mirroring the shift in regulatory philosophy. ESCOS were subject to strict monitoring and verification 15 years ago when program regulators focused on resource acquisition. The M&V focus shifted to deemed savings as regulators adopted a market transformation approach but more recently, the focus has reverted to resource acquisition, driven by a new wave of integrated resource planning on the part of utilities. According to NAESCO, "This means that a lot of these energy efficiency resources will really have to be solidly documented in a way that they never have been before, because you're talking to the supply people in the utility, not the energy efficiency managers. Their view of monitoring and verification is a revenue quality meter hardwired to the ISO headquarters with 4-second readings." One expected outcome is the development of a new generation of M&V techniques capable of delivering a degree of measurement precision in line with system planners' expectations, using technologies that were not available 10 or 15 years ago.[118]

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[117] Personal communication, Donald Gilligan, NAESCO Executive Director (Bill Brooks interviewer), January 16, 2007

[118] Personal communication, Donald Gilligan, NAESCO Executive Director (Bill Brooks interviewer), January 16, 2007

3. CONCLUSIONS AND RECOMMENDATIONS

This report has identified a number of positive trends and developments in the energy efficiency arena that can be considered as "best practices." Our general recommendation is to build on these successes and continually seek new opportunities to apply the lessons learned from these successes in innovative ways. These trends fall generally into two distinct categories: (1) market-oriented program design and (2) measurement and verification.

Energy efficiency program designers, portfolio managers, and regulators are all demonstrating increasingly sophistication in their understanding of market dynamics and the opportunities to leverage market forces to maximize energy efficiency gains.

- Program designers and authors of energy efficiency standards both recognize the limitations of relying purely on technological improvements and instead are focusing greater attention on performance and installation quality, particularly in the areas of insulation, HVAC, and lighting controls.

- National-level collaborations under the auspices of ENERGY STAR and CEE are developing the capacity to influence national-scale markets for lighting, HVAC, water heating and other technologies.

- Regulators are recognizing the central role utility programs and publicly-funded research initiatives play in bringing innovative technologies and practices to market. Researchers are collaborating with manufacturers and other private-sector stakeholders at all stages of research to facilitate commercialization of marketable innovations. These collaborations help ensure that non-energy considerations are thoroughly evaluated in the RD&D process, and that non-energy benefits are fully exploited in commercialization.

- Regulators are also recognizing the central role utility programs play in moving technologies and practices beyond the innovation stage and into standard practice. Utility-funded research is increasingly influential in identifying practices and technologies that are sufficiently well-established to merit codification in the energy standards. And utilities are starting to be rewarded for their efforts.

While a thorough understanding of market dynamics is required to maximize energy efficiency gains, detailed and rigorous measurement and verification is essential for energy efficiency to be treated as a resource on a par with supply-side options. At the same time the cost of more rigorous measurement and verification must be balanced against the value of the resource being quantified. Several positive trends have emerged in this arena.

- Program managers continue to refine their understanding of baseline market conditions to better understand the potential for further efficiency gains. Field testing and market research have also identified widespread performance issues with certain technologies and equipped program designers to address those issues in their program designs.

- New market research and quantitative analysis is helping to refine our understanding of the indirect energy efficiency impacts that derive from non-energy interventions. These research areas are opening up new opportunities to more thoroughly integrate resource-efficiency programs to accomplish multiple policy objectives. Integration of energy and non-energy policy objectives is also expanding opportunities for collaboration between energy efficiency programs and a broad array of stakeholders.

- New field measurement and feedback technologies show promise for improving field performance by simplifying energy management, providing real-time feedback on energy consumption and price signals, and delivering low-cost end-use monitoring results. Even greater savings from existing building stock may be possible by combining the latest retrocommissioning practices with advanced building controls, smart meters, and flexible rate design.