U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Quadrennial Technology Review: The Building as a System

U.S. Department of Energy

Executive Summary

The DOE deploys energy efficiency using three strategies that build a self-reinforcing efficiency ecosystem

- Research and develop new technologies;
- Prime the market for technology adoption; and
- Use codes and standards to “clean up”.

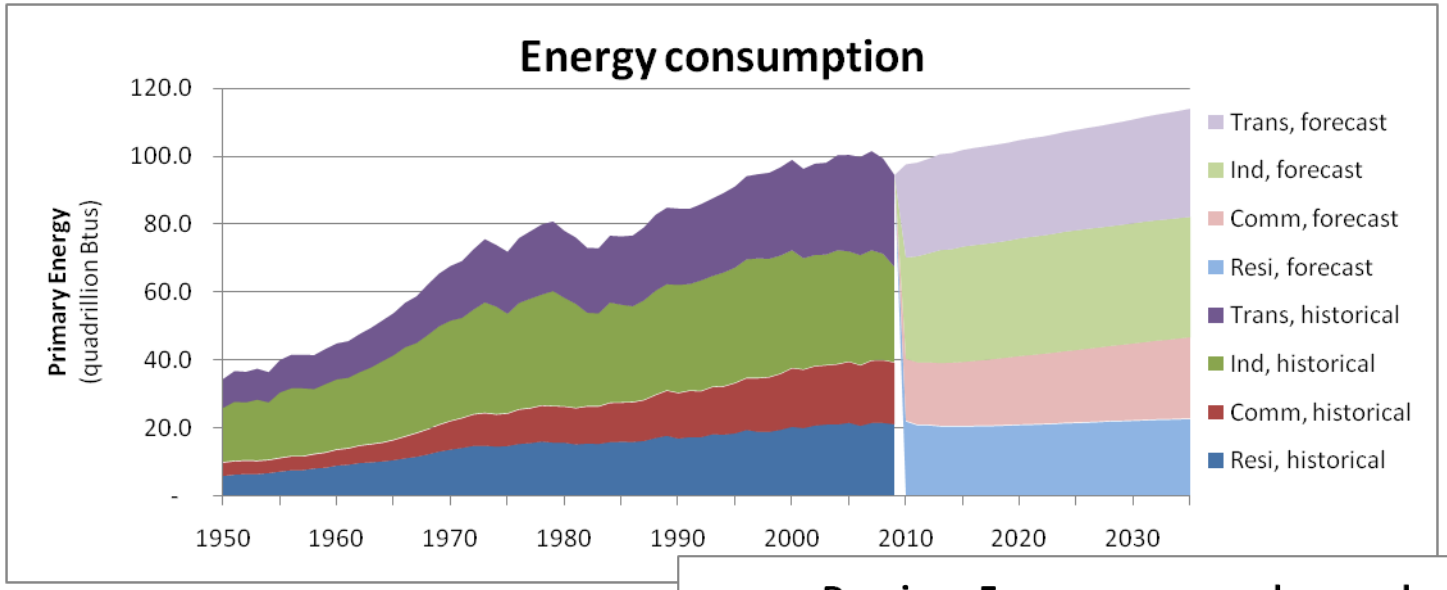
Buildings account for over 40% of energy consumption with meaningful opportunities for reduction through enduse-specific and cross-cutting opportunities; we present these opportunities viewed on four horizons

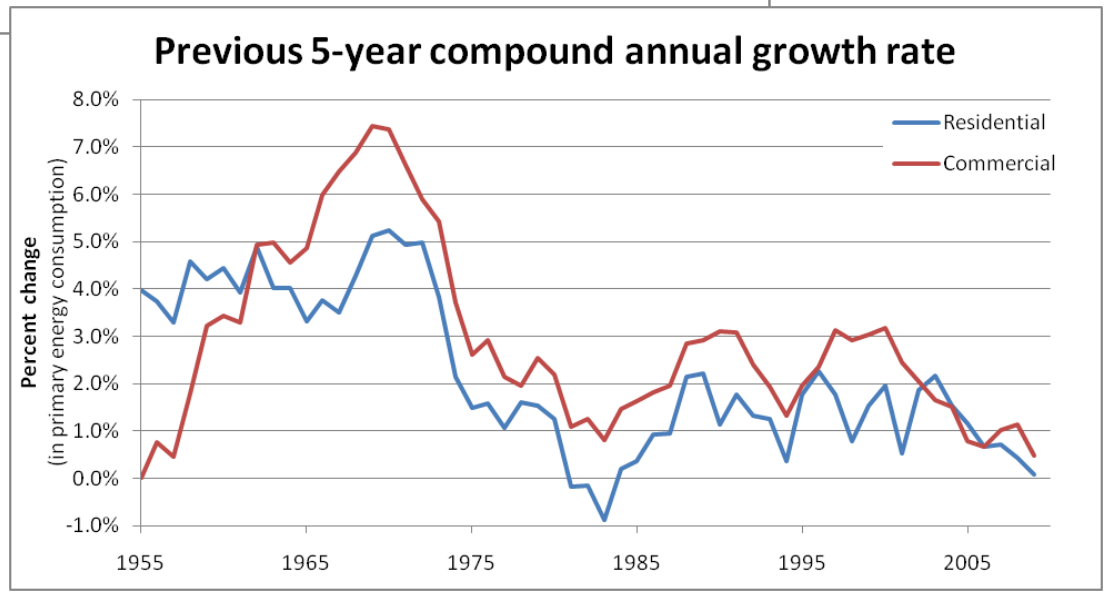
- Deploy today’s technology;
- Research emerging technologies;
- Advance cross-cutting component technologies; and
- Explore not-in-kind advances.

Researching emerging technologies offers considerable benefits in major systems (e.g., windows and wall); and

Advancing systems approach provides savings through systems integration, improved envelope, sensors and controls and building modeling.

Energy use has grown overtime, but that growth is slowing

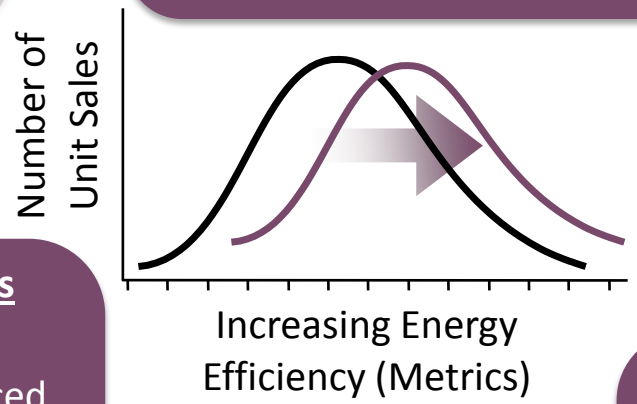




DOE deploys energy efficiency using three strategies that build a self-reinforcing efficiency ecosystem

R&D

- Advance innovative technologies for appliances, equipment, and products
- Integrated building systems



Codes & Standards

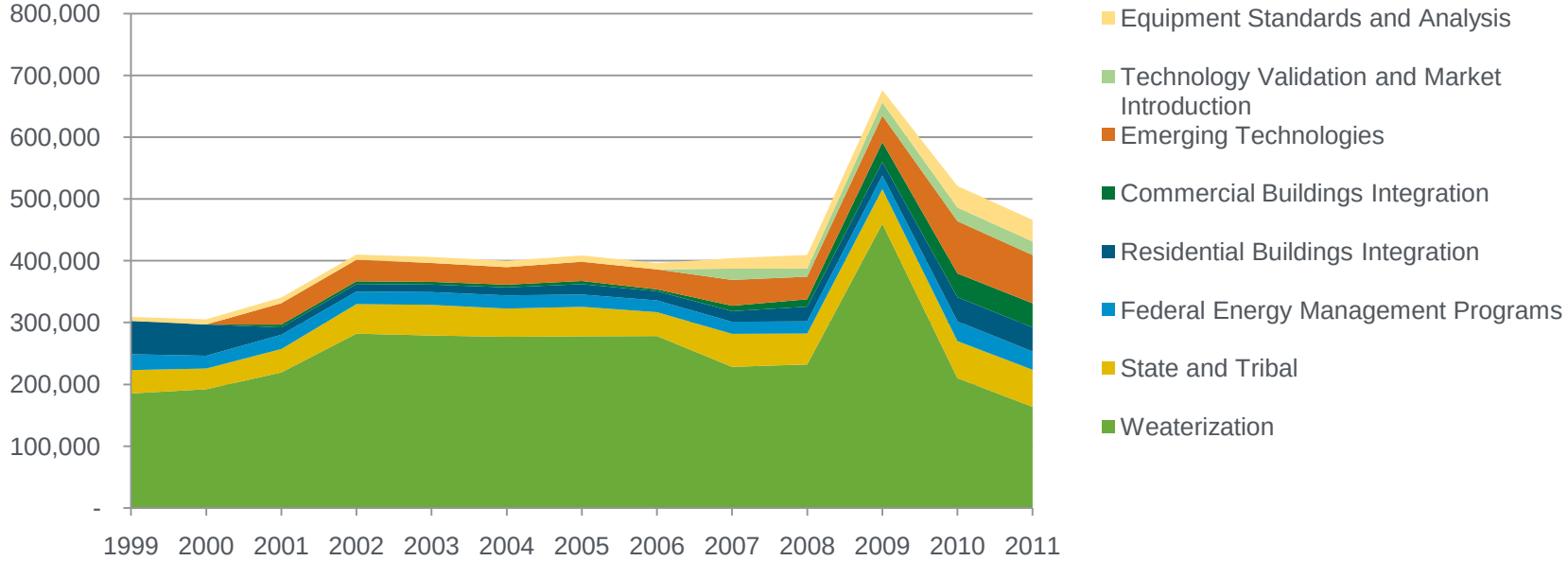
- Leverage market priming and advanced technologies
- Broaden coverage and update frequently to capture savings opportunities

Market Priming

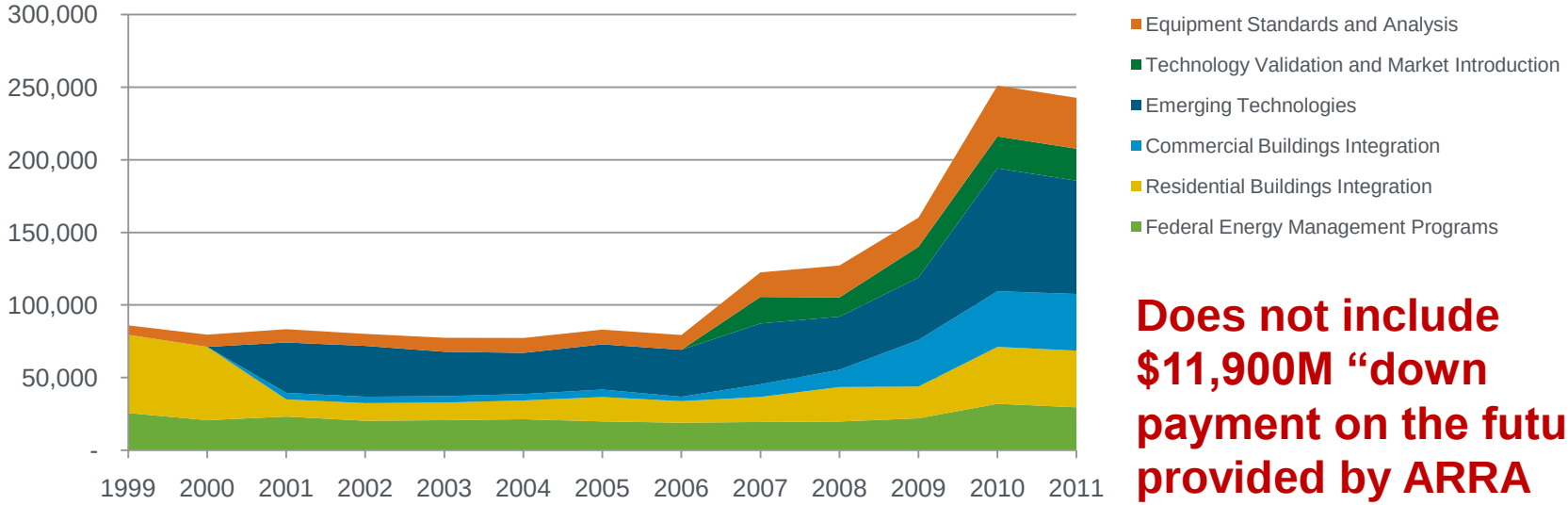
- Pull new products, practices and services into market faster at scale
- Technical support to ENERGY STAR / new higher tier

Building related funding has grown considerably over the past five years

Weatherization funding has traditionally dominated



BTP funding has more than doubled in the past five years



Does not include $11,900M "down payment on the future" provided by ARRA

Why a Systems Approach?

An integrated approach to building design and operation can provide increased energy savings

- Capture benefits through systems integration: buildings that incorporate component operations, deploying integrated control systems, and operating and maintaining the building using those systems;
- Improved building envelope: in addition to thermal insulation, envelope improvements can reduce energy consumption, improve occupant health and comfort, and durability;
- Deploy sensors, controls, and software: can automate systems, stimulate behavior change, and improve operations; and
- Whole building energy modeling: provide accurate and transparent estimates of energy use and savings opportunities.

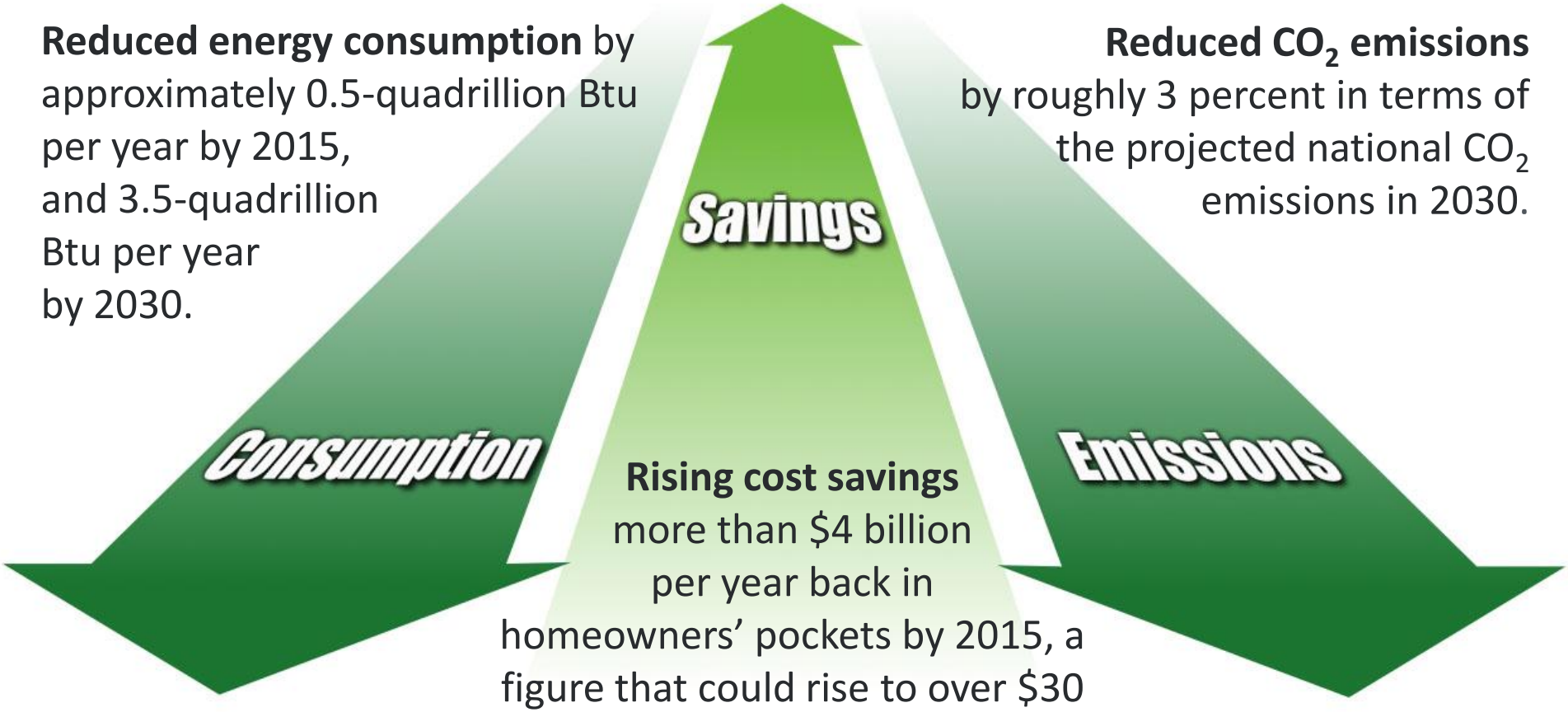
Systems Integration

- Design Guides
  - Advanced Energy Design Guides (AEDG) use energy models to “pre-calculate” solutions applicable to commercial buildings;
  - First set of AEDGs focused on a target reduction of 30% for smaller buildings lacking large engineering budgets and had broad market appeal; and
  - Next set of AEDGs will target 50% savings.
- Building Codes
  - Provided annual cost savings of approximately $3.2 billion/year;
  - Improved building efficiency to provide 260 trillion Btu savings annually in 2008; and
  - Set buildings on a path to provide 1.7 Quadrillion Btu annual energy savings by 2030 through passage of ASHRAE 90.1-2010, expected passage of 2012 IECC, and state requirements and support to achieve 90% code compliance .
- Building Performance Labeling
  - Benchmarking and disclosing the energy performance of buildings have the potential to improve the understanding of the costs and benefits of efficiency and raise awareness of and demand for high performance buildings to “prime the market”; and
  - Labeling has proven successful through the EPA’s ENERGY STAR program and is common for commercial buildings in the UK and EU.

Building Codes: Benefits

Reduced energy consumption by approximately 0.5-quadrillion Btu per year by 2015, and 3.5-quadrillion Btu per year by 2030.

Reduced CO_2 emissions by roughly 3 percent in terms of the projected national CO_2 emissions in 2030.



Rising cost savings more than $4 billion per year back in homeowners' pockets by 2015, a figure that could rise to over $30 billion per year by 2030

Building Codes: Goals and Strategies

Model Energy Codes

- **50% Goal—for Increased Energy Savings**
  - Need to go beyond prescriptive approaches
  - Exploring performance-based options and alternative paths to compliance
  - Voluntary Codes: Submitted outcome and performance-based proposals
- **70% Initiative for Increased Adoption**
  - Comprehensive adoption strategy
  - Goal: 40 states to adopt ARRA target codes or most current model codes by 2015
  - Goal: 10 states to adopt the ARRA target codes or more efficient in FY2011
- **90% Compliance by 2017**
  - Continue technical and financial support to the states
  - Increase the number and availability of compliance guides and field measurement tools

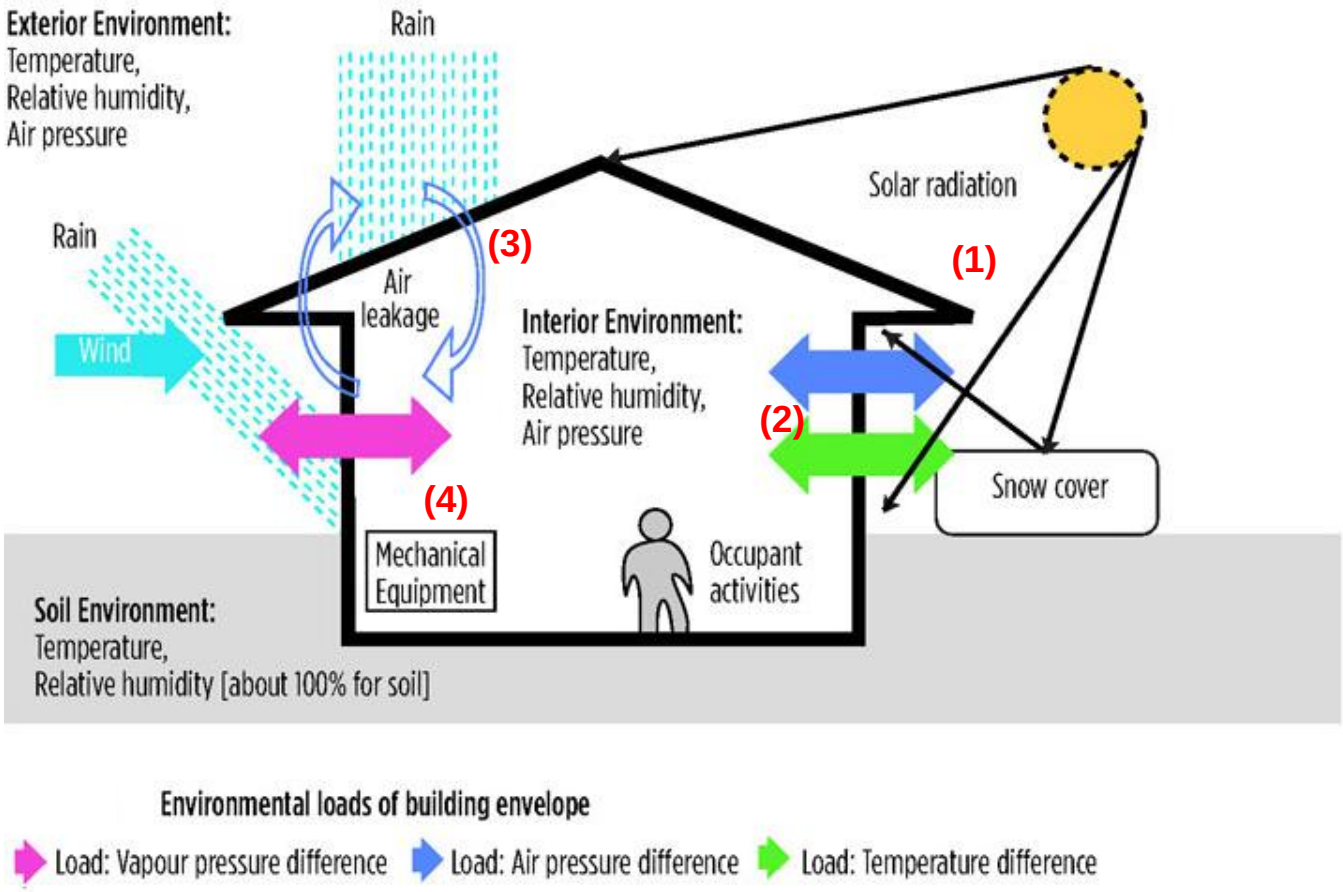
50% Better Codes
Proposed by 2015

70% Code Adoption
By 2015

90% Compliance
by 2017

Envelopes

Envelope should be considered an **integrated component** to manage solar heat gains (1), lighting (2), and ventilation (3); also highlights issues related to moisture (4), indoor air quality, building maintenance.



Envelopes: Opportunities for Improvements

- Advanced Roofing Designs
  - Next generation attic and roofing technologies (e.g., white roofs, above sheathing ventilation, radiant barriers, phase change materials, etc.) can increase roof insulation levels to >R-60

- Highly Insulating and Dynamic Windows
  - Low thermal conductivity (i.e., R-values of 5-10), low infiltration, and climate-appropriate infrared emissivity
  - Dynamic control of optical properties can manage summer solar gain and optimize winter gain to make windows a net provider of energy

Envelopes: Opportunities for Improvements

- Wall and Basement Building Retrofits
  - Cost reduction through improved installation techniques and business models of conventional insulation (e.g., “drill-and-fill”, exterior foam sheathing)
  - Demonstration of Exterior Insulation Fitting Systems (EIFS) for R-values of 40-60
- Highly Insulating Wall and Basement Approaches for New Buildings
  - New building codes will also draw on advanced approaches to framing and manufactured homes

- Daylighting Research
  - Reduce energy use with integration with controls
  - Solutions for commercial buildings include double-skinned, ventilated façades, dynamic shading, and 3-D window products

Building sensors, controls & diagnostics

- System Automation
  - Energy savings, increased convenience and operational simplicity, and decreased maintenance costs (e.g., inactivity-based timers, occupancy sensing, day lighting controls, and whole-home automation).
- Improved Data Use
  - Energy Information Systems: properly inform and motivate facilities operators to achieve expected performance; and
  - Advanced Billing Information: more detailed and timely usage information to homeowners through accepted channels such as energy bills.
- Retro-commissioning and “re-tuning”
  - Regular tune-ups to correct improper operations and save energy.
- Smart Grid
  - Dynamic information exchange between grid and building can improve the overall efficiency and reduce the cost of the power production and distribution system.

Modeling: enables building optimization and provides estimates of energy savings

An information platform of building energy use that:

- Is openly available and quality controlled, e.g., the National Energy Performance Data Warehouse;
- Identifies all opportunities for energy savings using accepted and standardized analysis;
- Modernizes EIA's data gathering with the RECs and CBECs surveys;
- Leverages the research and modeling capabilities of our National Labs to transform this database into a detailed national inventory of energy consumption and savings opportunities;
- Verifies with technology evaluation, model home testing, and real-world consumption data; and
- Remains evergreen through updates as new technologies are introduced and reliable data become available on a continual basis.

Building Commissioning: What is it?

Commissioning Process Overview

Pre-Design Phase

- Select a commissioning lead
- Pre-Design Phase commissioning meeting
- Begin developing *Owner's Project Requirements*
- Develop initial *Commissioning Plan* outline

Design Phase

- Design Phase commissioning meeting (If Pre-Design meeting didn't occur)
- Perform commissioning-focused design review
- Update *Commissioning Plan*
- Develop commissioning requirements for the specification
- Begin planning for verification checklists, functional tests, *Systems Manual*, and training requirements

Construction Phase

- Construction Phase kick-off meeting
- Review submittals, monitor development of *Shop and Coordination Drawings*
- Review *O&M Manuals*
- Perform ongoing construction observation
- Perform verification checks
- Perform diagnostic monitoring
- Perform functional testing
- Develop *Commissioning Report* and *Systems Manual*
- Develop *Recommissioning Plan*
- Verify and review training of owner's staff

Occupancy and Operations Phase

- Resolve outstanding commissioning issues
- Perform seasonal /deferred testing
- Perform near warranty-end review

Retrocommissioning Process Overview

Planning Phase

- Select the project
- Set project objectives and obtain support
- Select a commissioning lead
- Document the current operating requirements
- Perform an initial site walk-through
- Develop the *Retrocommissioning Plan*
- Assemble the retrocommissioning team
- Hold a project kick-off meeting

Investigation Phase

- Review facility documentation
- Perform diagnostic monitoring
- Perform functional tests
- Perform simple repairs
- Develop *Master List of Findings*
- Prioritize and select operational improvements

Implementation Phase

- Develop *Implementation Plan*
- Implement selected operational improvements
- Verify results

Hand-Off Phase

- Develop *Final Report*
- Compile a *Systems Manual*
- Develop *Recommissioning Plan*
- Provide training
- Hold close-out meeting
- Implement persistence strategies

Retrocommissiong: Opportunities in commercial buildings

Top faults causing energy inefficiencies in commercial buildings (Top 13 of 100+ faults identified)

	National Energy Waste (Quads, primary/year)	Electricity equivalent (BkWh/year)	Cost ($billion/year)
Duct leakage	0.3	28.6	2.9
HVAC left on when space unoccupied	0.2	19.0	1.9
Lights left on when space unoccupied	0.18	17.1	1.7
Airflow not balanced	0.07	6.7	0.7
Improper refrigerant charge	0.07	6.7	0.7
Dampers not working properly	0.055	5.2	0.5
Insufficient evaporator airflow	0.035	3.3	0.3
Improper controls setup / commissioning	0.023	2.2	0.2
Control component failure or degradation	0.023	2.2	0.2
Software programming errors	0.012	1.1	0.1
Improper controls hardware installation	0.01	1.0	0.1
Air-cooled condenser fouling	0.008	0.8	0.1
Valve leakage	0.007	0.7	0.1
Total (central estimate)	1.0	94.6	9.6
Total (range)	0.34-1.8	32.4-171.4	3.3-17.3

Adapted from Roth et al. (2005) assuming 10,500 BTU/kWh, and $0.10/kWh