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ENERGY EFFICIENCY IN THE NORTH AMERICAN EXISTING BUILDING STOCK

IEA INFORMATION PAPER

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ACRONYMS

AC	Air Conditioner
ACEEE	American Council for an Energy-Efficient Economy
AEO	Annual Energy Outlook
AFUE	Annual Fuel Utilization Efficiency
AHAM	Association of Home Appliance Manufacturers
BTU	British Thermal Unit
CBECS	Commercial Buildings Energy Consumption Survey
CEC	California Energy Commission
CECO	Commercial Energy Conservation Ordinance
CEE	Consortium for Energy Efficiency
CFL	Compact Fluorescent Lamp
CHP	Combined Heat and Power
CPU	Central Processor Unit
DOE	US Department of Energy
DVR	Digital Video Recorder
EER	Energy-Efficiency Ratio
EERS	Energy Efficiency Resource Standard
EF	Energy Factor
EIA	Energy Information Administration
EPA	US Environmental Protection Agency
EPAct	Energy Policy Act
EPBD	European Directive on the Energy Performance of Buildings
FEMP	Federal Energy Management Program
FTC	Federal Trade Commission
GDP	Gross Domestic Product
GW	Gigawatt
GWh	Gigawatt-hour
HDTV	High Definition Television
HERS	Home Energy Rating System
HH	Household
HP	Heat Pump
HUD	US Department of Housing and Urban Development
HVAC	Heating, Ventilation, and Air Conditioning
IEA	International Energy Agency
KWh	kilowatt-hour
LBNL	Lawrence Berkeley National Laboratory
LCD	Liquid Crystal Display

LED	Light Emitting Diode
MBTU	Million British Thermal Units
MEF	Modified Energy Factor
MMT	Million Tons
MT	Market Transformation
NAECA	National Appliance Energy Conservation Act
NEMA	National Electrical Manufacturers Association
NRCan	Natural Resources Canada
NRDC	Natural Resources Defense Council
NREL	National Renewable Energy Laboratory
NYSERDA	New York State Energy Research and Development Authority
O&M	Operation and Maintenance
OECD	Organization for Economic Cooperation and Development
PC	Personal Computer
PJ	Petajoule
PNNL	Pacific Northwest National Laboratory
QUADS	Quadrillion British Thermal Units
RCX	Retrocommissioning
RD&D	Research, Development and Deployment
RECO	Residential Energy Conservation Ordinance
RECS	Residential Energy Consumption Survey
SEER	Seasonal Energy-Efficiency Ratio
TWh	Terawatt-hour
VSD	Variable Speed Drive

EXECUTIVE SUMMARY

The building stock in the USA and Canada accounts for approximately 600 MToe of primary energy consumption. While much attention has been focused on policies and measures to improve the energy efficiency of new buildings, less has been directed at the existing building stock due to the inherent and perceived difficulties in improving their energy performance. Although freedom for action is constrained, there is growing evidence that much can be achieved through targeted policies to encourage better energy management, cost-effective upgrades of energy-using equipment, and building fabric refurbishment.

There are many reasons that energy use is growing despite improvements in the efficiency of specific technologies. There are a wide variety of new electric appliances in use that were unheard of or very rare twenty, or even five, years ago. Typical North American households have dramatically more consumer electronics than ever before, meanwhile the ownership and usage rates of more traditional appliances has continued to increase and is not expected to slow down in the near future without new policies for efficiency. Furthermore, the saturation and use of air conditioning equipment, especially central air conditioning, continues to grow, as consumers can afford lower cost comfort systems that improve their quality of life.

This report presents the findings of a new assessment of the techno-economic and policy-related efficiency improvement potential in the North American building stock conducted as part of a wider appraisal of existing buildings in member states of the International Energy Agency. It summarizes results and provides insights into the lessons learned through a broader global review of best practice to improve the energy efficiency of existing buildings. At this time, the report is limited to the USA because of the large size of its buildings market. At a later date, a more complete review may include some details about policies and programs in Canada. If resources are available an additional comprehensive review of Canada and Mexico may be performed in the future.

Energy Use and Existing Loads

The building sector is the largest consumer of energy in the United States, using approximately 40.3 quadrillion Btus (quads) of energy in 2002 – around 41 percent of total US energy use. The 107 million households comprising the residential sector account for the largest portion of building sector energy use (20.9 quads), followed by 4.6 million commercial buildings (17.4 quads), and industrial buildings (2.0 quads). Most of the energy used in buildings is consumed by equipment that transforms fuel or electricity into end uses such as space heating or air conditioning, light, hot water, refrigeration, laundry cleaning, information management, and entertainment.

Figures ES1 and ES2, respectively; show the breakdown of energy end uses for the US residential and commercial buildings sectors. The large (and growing) portion of energy contributing to "other uses" in both sectors, along with challenges in trying to reconcile different official data sources, point out the need for more detailed end-use surveys and forecasts that better quantify the energy use and savings potential for these other uses.

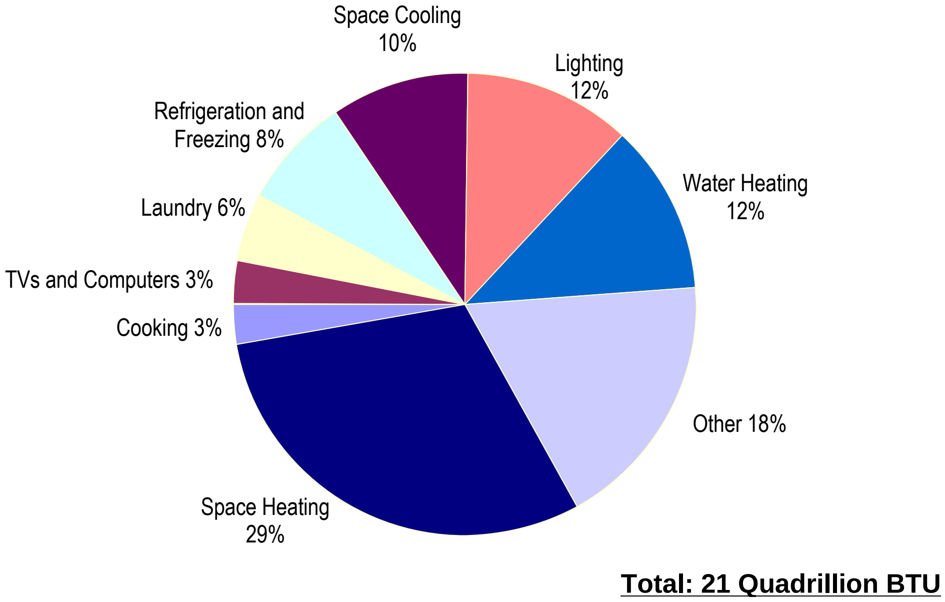

Figure ES1. Primary Energy Use in U.S. Residential Buildings, 2004

Note: Other uses include furnace fans, dishwashers, pool pumps/heaters, other small electric devices, heating elements and motors.
Source: EIA, 2006: Annual Energy Outlook.

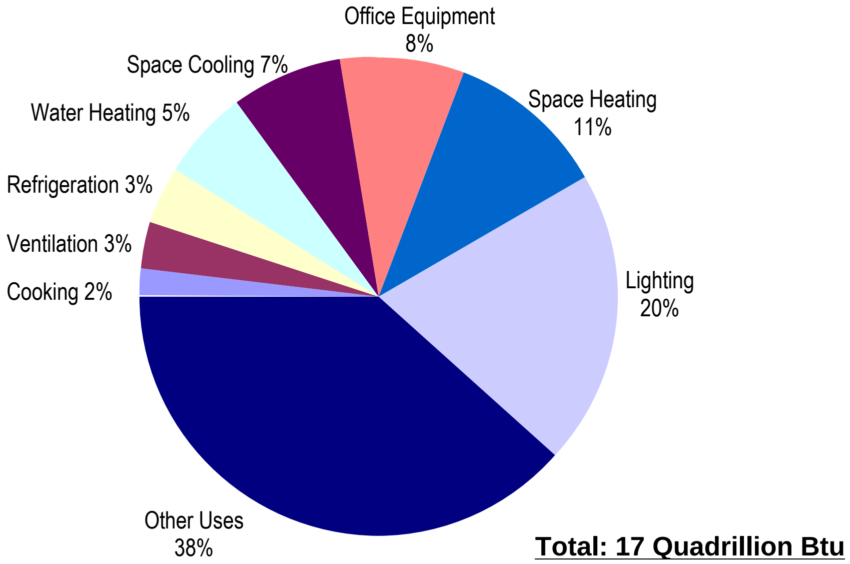

Figure ES2. Primary Energy Use in U.S. Commercial Buildings (2004)

Note: Other uses include service station equipment, teller machines, telecommunications, medical equipment, pumps, emergency generators, combined heat and power systems, manufacturing and residual fuel use. Source: EIA, 2006: Annual Energy Outlook.

A wide variety of technical options exist for further efficiency improvements. These options are discussed in the full report with a focus on end-use technologies in buildings. The report does not address promising net energy savings technologies such as combined heat and power, district energy systems, or micro-cogeneration options, as these technologies are intended to address supply-side instead more than end-use efficiency.

Review of Current and Historic Buildings Energy-Efficiency Programs and Their Effectiveness

The potential for energy savings in the existing buildings sector is large and the opportunities for capturing savings through increased adoption of new and under-utilized technologies and practices are well established. Nevertheless, cost-effective investments in energy-efficiency improvements are often ignored by businesses, governments, and individual consumers. A number of barriers are responsible for the widespread underinvestment in energy efficiency in existing buildings. A great deal of research and deliberation has focused on identifying these barriers and devising ways to address them through policy measures and programmatic initiatives.

A recent IEA project (Prindle 2007) quantifying the effects of market failures in end-use energy consumption summarizes the key barriers to greater investment in energy efficiency as:

- Principal-agent barriers
- Information/transaction cost barriers
- Externality cost barriers
- Other barriers and economic forces

In the existing buildings sector, *principal-agent barriers* are common in lease properties where a split incentive exists between the landlord or the owner's agent (who purchases or specifies what energy consuming equipment will be installed in the building) and the tenant (who typically pays the utility bill). This issue arises in both the commercial leasing market and in rental housing. Similarly, a split incentive exists for homeowners and businesses that do not expect to hold a property long enough to realize the full financial benefit of an investment in energy-efficiency measures. Recent estimates suggest that as much as 50% of residential energy use in the USA is affected by principal-agent barriers (Prindle 2007).

Information/transaction cost barriers arise when the consumer lacks sufficient information or expertise to make purchasing decisions that optimize their overall cost and energy savings. The asymmetry of information available to the consumer versus other market actors can create confusion and distrust thereby discouraging adoption of new technologies or services. Consumers may also face higher transaction costs associated with the additional time, effort, and inconvenience necessary to identify and purchase efficient products and services.

The large environmental and health impacts associated with energy production and transmission lead to large *externality cost barriers* such that the price of energy does not reflect its true cost to society. Addressing this requires broad level policy changes that are beyond the scope of this study, yet these issues need to be kept in mind when considering the benefits accruing from reduced energy consumption.

Several characteristics of the buildings sector result in *other barriers and economic forces* that impede adoption of cost-effective efficiency measures. The building industry is very fragmented making it difficult to identify the appropriate contractor(s) to provide needed services including retrofits that can improve building energy performance. Once improvements are identified, the customer may have to manage the efforts of multiple contractors. In commercial buildings, institutional practices and organizational structures can inhibit investment in cost-effective energy-efficiency projects. The process for approving capital and non-capital (operations and maintenance) projects, the methods for crediting energy cost savings within the organization, the level at which decisions are made, and the financial criteria used to judge proposed projects all have an impact on the decision-making process and can result in missed opportunities to invest in cost-effective energy-efficiency projects. In the residential and small business sector, additional cognitive and behavioral barriers including bounded rationality (or “satisficing”), decision-making difficulties, uncertainty and risk aversion, and the value of non-energy benefits can play a role in individual purchasing decisions involving energy-consuming products and services.

Through this project, we reviewed a range of policy instruments enacted at the federal, state, and local levels, and energy-efficiency programs operated by utilities, market transformation organizations, manufacturers, and other private program implementers as well as a number of government-sponsored efficiency programs. Using program data, reported results, and evaluation studies, we examined program and policy impacts to determine the effectiveness of each approach in terms of energy savings and longer-term market impacts. Details of our review are included in the full report.

In reviewing the effectiveness of initiatives toward improving the energy efficiency of existing buildings, there are two principal indicators that seem to summarize the overall impacts of the policy or program: the amount of energy saved and the degree of market transformation that they cause. Each of these can be further broken down into additional sub-indicators. Table ES1 summarizes the qualitative review of effectiveness for a range of policies and programs.

Some “terms of art” are not always widely understood and can be used to mean different things; for this report we have a specific meaning for the following terms:

Market Transformation: initiatives intended to cause lasting market changes through strategic interventions in existing market channels.

Resource Acquisition: activities to procure demand-side energy savings instead of supply alternatives; often procured on a performance basis.

Retrocommissioning: or "existing building commissioning," is a systematic investigation of how a building's subsystems are being operated and maintained, and it is used to identify and solve optimization and integration issues. Retrocommissioning usually excludes retrofit solutions or major equipment replacements, although such recommendations may be offered.

Table ES1. Energy-Efficiency Initiatives and Indicators of Effectiveness

Initiatives	**Energy Saved**			**Market Transformation Effects**		
	Magnitude	**Permanence/ Sustainability**	**Remaining Savings**	**Drive Innovation**	**Replication/ Free Drivership**	**Potential for Backsliding**
Federal Policies						
Equipment standards	VH	VH	H	M	L	L
Building codes/regulations	H	H	H	M	M	M
Government purchasing, procurement, facility mgmt	M	M	M	M	M	M
Tax incentives	M	M	H	H	H	M
Research & Development	M	M	H	H	L	L
State and Local Policies						
High Level Policy Goals	H	H	H	H	M	M
Building codes/regulations	VH	H	H	H	M	L/M
Equipment standards	H	M	M	M	H	L
Funding of public benefits programs/activities/ Demand Side Resource acquisition	VH	H	VH	M	M	M
Government purchasing, procurement, facility mgmt	M	M	M	M	M	M
Tax incentives	M	L	H	M	H	M
Programs						
Product Replacement Incentives:						
– Independent programs	H	M	H	M	L	H
– Coordinated efforts	H	H	H	H	H	M
Market Transformation Initiatives:						
– Information/Education	H	L	H	L	M	M
– Training	M	M	H	L	M	M
– Manufacturer/Retailer incentives	M	M	M	H	M	M
– Golden carrot programs (combined R&D, incentives, and standards)	H	VH	H	H	M	L
– Financing assistance	L	M	M	L	L	M
– Performance contracts	H	M	H	L	L	M
Manufacturer Programs	L	M	M	H	M	M
Peak Load/ Demand Response	L	L	M	M	L	M
Government Programs						
Energy Star	H	M	M	M	H	M
Weatherization	H	M	H	M	L	M
Partnerships for Home Energy Efficiency	M	M	H	M	M	M

Notes: VH = very high; H = high; M = medium; L = low

Potential New Policies and Measures to Improve Energy Efficiency in Buildings

There has been a wide range of policy and programmatic activity in North America in recent years to address energy efficiency in existing buildings. Moving forward, new and changing drivers are encouraging a greater level of interest in improved building energy performance. The emergence of new drivers highlights the need for a different set of policies and actions that build on tried-and-tested approaches combined with promising new policies and measures. Chief among these new and evolving drivers are:

- Increasing concern over global climate change
- Greater emphasis on demand reduction in light of energy supply and capacity constraints
- Societal trends toward an expectation of greater "creature comforts" and amenities
- Significant progress addressing the energy efficiency of building subsystems and specific end-use technologies

New Initiatives Toward Existing Buildings Energy Efficiency

New California Initiatives Targeting Existing Buildings

In 2001, the California State Legislature directed the California Energy Commission (CEC) to "investigate options to reduce wasteful peak load energy use in California's existing residential and nonresidential buildings." Following a three year investigation period, the CEC published the Commission Report "Options for Energy Efficiency in Existing Buildings" in December 2005,[1] which included a number of recommendations and strategies to increase energy efficiency in existing buildings in the State. Specific strategies identified are time-of-sale information disclosure, an information gateway, integrated whole building diagnostic testing and repair, assistance to affordable housing, equipment tune-ups for the residential sector, and benchmarking and retrocommissioning for the commercial sector.

Expanded Energy Efficiency Resource Standards

Energy Efficiency Resource Standards are a simple, market-based mechanism to encourage energy efficiency in electricity and natural gas use. Utilities are given set savings targets, often with the flexibility to achieve the targets through a market-based trading system. Resource Standards are currently in place in several US states and other countries.

In the USA, Texas led the way with a requirement in their electricity restructuring law that electric utilities offset 10% of their demand growth through end-use energy efficiency. The Texas utilities have had no difficulty meeting these targets and are currently exceeding them. A number of other states, including Hawaii, Nevada, Connecticut and California have established energy savings or regulatory targets for utilities, and other states are exploring them. A summary of activity toward energy efficiency resource standards was recently prepared[2] demonstrating significant savings potential from expansion of these sorts of standards among states, as well as consideration of a national energy efficiency resource standard.

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[1] "Options for Energy Efficiency in Existing Buildings" California Energy Commission Report CEC-400-2005-039-CMF. December 2005. Available at: http://www.energy.ca.gov/ab549/documents/index.html

[2] Nadel, Steven 2006. Energy Efficiency Resource Standards: Experience and Recommendations. ACEEE Report E063. March 2006.

Experience from European Buildings Policies

The European Directive on the Energy Performance of Buildings (EPBD), adopted in 2002, includes a number of requirements aimed toward improving the energy performance of existing buildings, specifically mandatory energy certification of all buildings with each change in occupancy, mandatory inspection and assessment of heating and cooling installations, adoption of a comprehensive whole-building energy assessment methodology and issuance of building energy performance codes for all new buildings, but also for all existing buildings where more than 1 000m^2 (~11 000 sq. ft.) is being retrofit. One of the more important requirements for existing buildings is the mandatory public display of energy performance for all public buildings over 1 000 m^2 (approximately 11 000 sq. ft.). Furthermore, the European Directive on Energy Services (2006/32/EC) requires EU Member States to install accurate time of use metering systems. In some cases individual Member States are opting for advanced metering systems which will enable users to better know where and how they are using energy and take more informed decisions. Many of the requirements of these Directives are just beginning to come into effect in most European member countries and bear close watching to see what might be applicable in North America.

Promising Potential Policies

We have also reviewed several policy options that have not yet been tried or that have seen limited use. These include:

1) *Time of Transfer Ordinances*

A property sale or change of occupancy represents an ideal time for implementing efficiency upgrades in existing buildings. Several tools can be used to encourage – or even mandate – efficiency improvements as part of the transaction.

- **Mandatory labeling or Home Energy Rating System (HERS) rating.** A mandatory labeling program for existing homes or a requirement that existing homes be given a HERS rating prior to sale would provide buyers a means to compare the energy performance of homes under consideration, thereby making energy use a more salient feature in the home purchase decision. Mandatory certification of non-residential buildings would allow for even greater consideration of a building's energy performance at the time of purchase, through an appraisal process that can more accurately monetize the increased property valuation from lowered utility costs.
- **Mandatory codes.** Residential and Commercial Energy Conservation Ordinances (RECOs and CECOs) have been implemented by a handful of municipalities as a way to bring the existing building stock closer in line with the energy code requirements for newer buildings.
- **Mandatory disclosure of EEMs at time of mortgage application.** Many US lenders offer EEMs, but their use has been limited by a general lack of awareness and limited marketing. Mandatory disclosure would require that applicants receive notice that Energy-Efficient Mortgages (EEMs) are available to finance energy upgrades.

2) *Zero-Energy (or zero-carbon) New Buildings*

The growing interest and technical capacity for designing and constructing zero-energy new buildings could be leveraged to improve the efficiency of existing buildings. As a condition of service for utilities, new buildings connecting to the utility system would be required to achieve zero-energy performance via onsite energy efficiency and renewable energy generation. Any remaining energy use in new buildings would be offset by credit purchases in a "white tags" market driven by Energy Efficiency Resource Standard requirements.

3) *Oil Savings Programs*

   Oil use is small compared to electricity and natural gas in the US buildings sector, but it is fairly large in the Northeast and Midwest regions and is expected to increase somewhat over the coming decade. Several options hold promise for reducing oil use in buildings:

   - **End-use efficiency improvements.** Many of the same types of market transformation programs targeted toward electric and gas appliances and equipment could be used to reduce oil consumption. In particular, loans, technical assistance, financial incentives, and education/awareness programs could be implemented with similar effects.
   - **Fuel switching and retrofits as offsets in carbon cap-and-trade programs.** Carbon emission reduction policies that focus on the power sector can use non-electricity energy savings as offsets.
   - **Loan programs for oil dealers.** Members of Congress have considered a federal loan program to help dealers finance their inventories, and it has been suggested that such a program could include conditions requiring dealers to use part of such funds to finance boiler and furnace replacements as well as other efficiency measures.
   - **Energy services contracting.** In this program design, building owners would be offered lower energy costs in exchange for giving over the operation of their energy-using systems to energy services contractors. Some utility affiliates and others have explored variants of this approach in seeking to provide refrigeration, chilled water, steam, or other customer energy services. This approach works primarily in large commercial and residential buildings where the service provider takes over ownership of building energy systems assets and sells energy services back to building occupants.

4) *"Smart" metering or real-time metering and benchmarking*

   The development and widespread proliferation of metering and communications technologies now allows for real-time metering of building energy use and sharing of energy use data with utilities, government, efficiency programs, and the public at large. The ready availability of the data allows for aggregation and benchmarking of individual building performance against that of similar structures which enables users to readily see what level of improvement can be realized. Furthermore, advanced metering allows users to see where they are using energy and, when coupled with appropriate interfaces, the impacts of any efficiency improvements they choose to invest in.

Analysis of Potential Savings from Different Policy Scenarios

Despite the plethora of studies done in recent years, there has not been any recent comprehensive national or North American end-use level review of savings potential in existing buildings. Given the wide variety of building types and uses, vintages of construction, and energy-consuming equipment installed, the energy intensity and improvement potential of different buildings varies dramatically, giving rise to a broad range of savings potentials for different building classes. A comprehensive review would be a great addition to the policy debate.

The most comprehensive national review of buildings (and other energy using sectors) was done in 2000 as part of *Scenarios for a Clean Energy Future*, prepared by a group of National Laboratories under DOE sponsorship.[3] This national study reviewed technologies available at the

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[3] Interlaboratory Working Group. 2000. Scenarios for a Clean Energy Future (Oak Ridge, TN; Oak Ridge National Laboratory and Berkeley, CA; Lawrence Berkeley National Laboratory), ORNL/CON-476 and LBNL-44029, November.

time of the study, and found that dramatic savings could be achieved, at very low costs compared with supply alternatives. The study reviewed two scenarios: *moderate*, which presumed modest progress toward new policies, and *advanced*, which assumed a significant implementation effort beyond the moderate case. The average technology costs to achieve the 10–12% savings relative to business as usual, $4–6 per MBtu, are significantly less than current energy prices of $11 to $28 per MBtu (based on EIA 2006 national average costs for natural gas and electricity, respectively).

Scenarios Studied for this Project

For this project, a simplified analysis of current energy use in existing buildings, tied to the expected base case forecast contained in the US Energy Information Administration's *Annual Energy Outlook 2007* (AEO 2007) forecast,[4] has been developed to study the potential savings from the following scenarios:

- *Base Case:* No increased policy activity, energy use as forecast in AEO
- *Increased Policy Activity:* Nationwide adoption of what is happening in leading states/regions; dramatically increased funding toward energy efficiency in existing buildings
- *Aggressive Policies:* Substantial push toward rapid implementation of lowest life cycle cost technologies and practices replacing standard equipment in all existing buildings; use/demonstrations of some currently untested policies to push the policy envelope, in line with the most aggressive policies now being pursued at US state level

The base case energy use forecast contained in the AEO shows the contribution to the energy use forecast from buildings already in place, and those that will be constructed during the forecast period. The relative magnitude of these different portions is shown in Figure ES3.

Our simplified model rolls the US building stock up into number of households and floor space of commercial buildings to forecast impacts of improvements to energy efficiency at different saturations and replacement rates for varied policy scenarios. The model compares current "typical existing buildings" with an "energy-efficient" building that utilizes currently available technologies and practices. This "energy-efficient building" is not intended to be a demonstration of the most efficient building or the lowest overall life cycle cost, but instead representative of what a major portion of the existing building stock might reasonably achieve through cost-effective measures within the next 20 years. As such, there is a level of conservatism built into the analysis.

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[4] All AEO forecast data used in this section were obtained in mid-December 2007 from the Energy Information website (http://www.eia.doe.gov/oiaf/aeo/index.html), where the forecast is called Annual Energy Outlook 2007 with Projections to 2030 (Early Release).

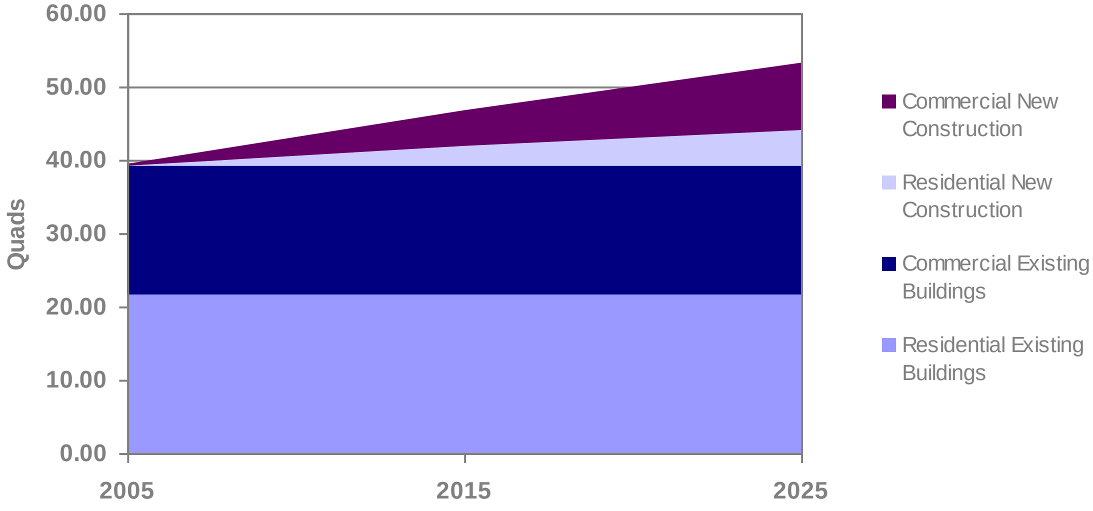

Figure ES3. Base Case Energy Use

For the different policy scenarios, we then assume different speeds over the forecast period in moving from current typical buildings to the more efficient ones, or increasing the saturation of energy-efficient buildings among the overall stock. For both the residential and commercial sectors, the increased policy activity scenario assumes that in 20 years 40% of the stock moves to the efficient base; the aggressive scenario assumes that 70% reaches the target.

Buildings already exist that are much more efficient than this prototype energy-efficient building, thus the savings potential could go deeper than what is projected in this analysis. Many residential buildings, both small and large, currently operate at energy use levels below the energy-efficient building described. For example, even with a 33% reduction in lighting energy use, the 1 400 kWh per year allocated for lighting in our model is much higher than averages in Europe and in many homes in the USA. The analysis is intentionally conservative.

For the commercial sector, with a much wider variety of building and space types and much less homogenous end-use mixes, it is more challenging to construct a similar end-use level comparison of a current typical building to an energy-efficient building. From our review of detailed studies and discussions with practitioners, we assume an overall 30% reduction over current typical practice is easily possible. Again, more efficient buildings exist that consume less than this prototype energy-efficient building, but the analysis is intentionally conservative.

While this simplified analysis has many limitations, it is effective in illustrating the potential savings available in existing buildings. It should be noted that some simplification is embodied in the “flat” projection of energy intensity for existing buildings; in reality many buildings will experience increased energy using equipment density (new products, and some with higher energy use per unit), while there is offsetting reduction due to renovations and improvements to efficiency of products as they are replaced.

Findings of Analysis

As shown in Table ES2 and Figure ES4, under the aggressive policies scenario, in 2025 overall existing buildings energy use would be 23% less than the current business as usual forecast, or just over one percent per year average annual efficiency improvement. The energy savings of 9 quads are equivalent to the current energy use of all residential buildings in the seven states with highest energy consumption (Texas, Florida, California, New York, Pennsylvania, Illinois and Ohio) combined, or the total combined current energy use of all office, retail and educational buildings in the USA.

Table ES2. Savings from Three Scenarios (energy use in Quads)

	Base Case – BAU			Increased Policy Activity			**% Savings in 2025**	Aggressive Policies			**% Savings in 2025**
	2005	2015	2025	2005	2015	2025		2005	2015	2025	
Residential	21.69	21.69	21.69	21.69	20.55	18.65	14%	21.69	19.41	16.38	24%
Commercial	17.89	17.89	17.89	17.89	17.08	15.74	12%	17.89	16.28	14.13	21%
Total	39.58	39.58	39.58	39.58	37.63	34.39	13%	39.58	35.69	30.51	23%

These overall savings results are consistent with other models developed for specific states or regions or for specific end uses, and also fit in the range of savings that a variety of experts consulted during this project felt were attainable. They fall well within the estimates found in the different technical, economic and achievable potential studies cited above.

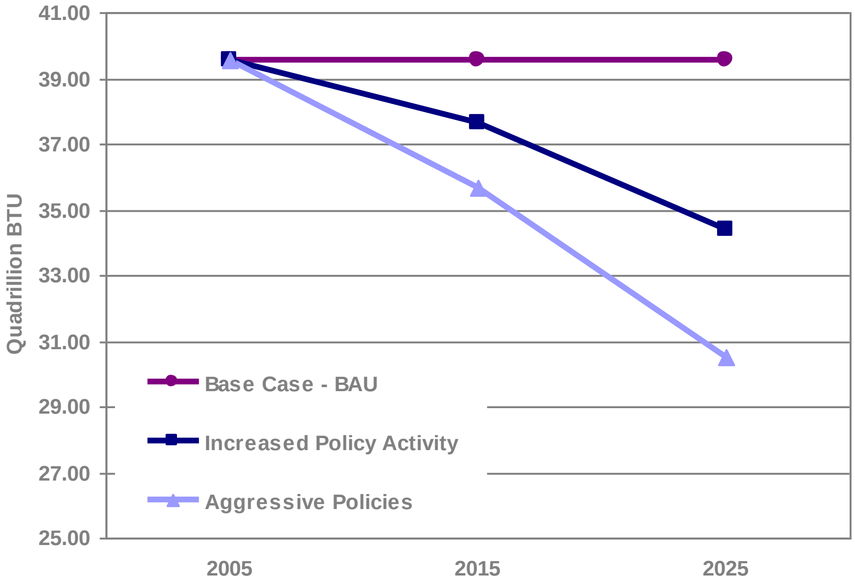

Figure ES4. Reduction in Energy Use from Three Scenarios

Moreover, these levels of savings are very similar (even conservative) when compared to what a number of states have set as state policy goals for energy savings. Three states in particular – Vermont, California and Connecticut – have established targets for 1.0 to 1.5% annual energy savings in buildings and other sectors. In Vermont, for example, the energy-efficiency utility that administers the state's public benefits programs is currently achieving energy use reductions of approximately 1% per year. With recent increases in program funding, the utility is in the process of determining how much beyond 2% savings per year is attainable for the coming decade.[5] California and Connecticut, both long time leaders in energy-efficiency policies, have targets for 1% per year savings, despite the fact that their building stock is already more efficient than most other states in the nation.

Estimated Value and Cost-Effectiveness of Savings

Determining the cost and cost-effectiveness of these projected savings is a challenge, but it is possible to use the results of some of the more detailed studies described above to make an estimate of the value. While detailed cost-effectiveness studies have been done in conjunction with savings potential projects in a variety of states, these are not easily extrapolated to national savings estimates.

The most detailed national analysis of the costs and savings of different energy scenarios can be found in *Scenarios for a Clean Energy Future* (Interlaboratory Working Group 2000) which estimated that the "technology cost," or cost of the conserved energy, ranged from $4.00 to $6.19 per MBtu saved. Using a median value of $5.10, it is possible to compare the projected technology cost to the current AEO 2007 forecast national weighted average price for buildings consumers in 2025 of $18.21/MBtu (in 2005 dollars). This price difference of just over $13 per MBtu, when multiplied by the 9 Quads of energy savings projected for the aggressive scenario in 2025, is worth almost $120 billion in 2025. The cost to achieve the savings is approximately $45 billion, but with savings from reduced consumption of nearly $165 billion, the net cost savings are very significant.

Electricity use in existing buildings in 2025 under the aggressive scenario is projected to be reduced by approximately 20 percent – from 3 730 TWh to 2 980. The 750 TWh of savings, at national average building sector electric load factors, avoids the need for about 200 GW of generation capacity, or avoided capital cost of approximately $130 billion at the current average new capacity cost of $650 per kW for new gas-fired generation.

Suggested Mix of Policies and Measures for the North American Building Stock

Rationale for Suggested Mix: Organizing Principles

The appropriate mix of policies and measures to generate the greatest level of efficiency improvements in North American buildings needs to account for regional and local differences in experience and commitment to energy efficiency, the technology development and deployment cycle, and the diversity of stakeholders involved in decisions that influence energy policy, efficiency programs and energy use. Strong policy intervention is justified in the existing buildings sector to overcome barriers identified earlier that prevent markets from performing at their economic optimum.

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[5] Steve Nadel personal communication with Blair Hamilton of Efficiency Vermont, November 2006.

In certain parts of North America, a well-organized and reasonably comprehensive mix of policy and program activity is already underway. The suggested mix that we are recommending is intended to work in regions where strong and active policy structures are already in place as well as in regions where activity might be more limited or just getting started. The specifics can be tailored to suit local circumstances as needed.

Similarly, we recognize that some efficient technologies and practices are already making great progress in the marketplace, while others are struggling. The recommended strategy mix allows for this, and recognizes that different technologies and practices face different barriers and will be adopted at different paces.

Finally, it is critical to recognize that a wide variety of policy stakeholders influence the way in which energy-efficiency policy and program activity is developed and implemented: federal, state and local government policy makers, as well as utilities and other energy suppliers, energy consumers, and a range of different advocacy and industry groups that all bring different perspectives to the mix.

Recommended Comprehensive Strategy/Mix of Policies and Measures

Achieving significant cost-effective energy savings in existing buildings requires the design and implementation of a comprehensive, long-term strategy encompassing the following five closely coordinated elements:

1. Regularly updated and ambitious equipment efficiency standards to lock-in the savings from market transformation and resource acquisition efforts and to ensure that these savings are available to all end users
2. Improved building energy codes for existing buildings that apply at the time of substantial renovation, sale or change of occupant
3. Resource acquisition activities and incentives to cover the initial incremental costs of these higher efficiency technologies and practices in a wide range of applications
4. Market transformation initiatives, including the training of practitioners, to bring energy-efficient technologies and practices into the broader marketplace
5. Aggressive research, development & deployment (RD&D) of promising energy saving technologies and practices.

Each of these five elements requires significant funding at federal, state and/or local levels. R&D incentives encourage companies and entrepreneurs to bring new technologies to market, while resource acquisition and market transformation initiatives increase the share of efficient technologies and use of best practices in existing buildings. Regulatory activities such as codes and standards are necessary to prevent any technology backsliding if other programs are scaled back due to competing priorities.

More specific recommendations for each element follow.

Minimum Efficiency Standards

- Update existing standards regularly to capture savings in improved products.
- Expand standards to cover new products.
- Update test protocols, with an eye toward global harmonization, to accommodate new products, new designs and new features on existing products.

- Establish new standards for installation, testing and system correction at time of equipment replacement.

The Appliance Standards Awareness Project runs a coordinated effort to identify options for new state and federal standards and to build grassroots support for both.

Energy Codes

- Research efforts to expand coverage of codes and standards to a greater number of existing buildings, including time of transfer activities.
- Direct research toward the most effective enforcement mechanisms for codes affecting existing buildings – some work has been done regarding new construction codes, but very little on existing buildings.
- Implement continual, regular updates to codes to lock in changes as new technologies become standard in the market.
- Improve code enforcement to ensure high levels of compliance and allow for more regular upgrades.
- Institute more aggressive advances to get codes equivalent first to Energy Star levels and then to the levels included in the 2006–07 tax incentive levels.

Resource Acquisition

- Implement well-funded, long-term programs to send appropriate market signals that the energy efficiency of buildings is an ongoing, high priority policy area.
- Target programs toward specific technologies that can be easily “acquired” and the savings accurately measured, such as lighting, high efficiency equipment, and residential retrofits where savings are easily calculated and replicable.
- Direct funding toward “hard to reach” sectors such as low-income housing and small business where progress is otherwise slow due to split incentives and other barriers to investment.
- Provide incremental cost incentives for new energy-efficient products and technologies to accelerate their market penetration and technology cost curve evolution to the point where they satisfy cost-effectiveness conditions for market transformation initiatives.
- Coordinate initiatives among different program providers to ensure maximum market effects.
- Expand energy efficiency portfolio standards to drive resource acquisition targets and set appropriate high level goals for implementers to achieve in the most cost-effective manner.

As an example, California has deemed energy efficiency the “resource of first resort,” or first in the “loading order” for any new growth in electricity demand. As such, electric utilities must exhaust all cost-effective efficiency resources before considering new generation capacity. This has resulted in $2 billion in approved investments in efficiency from 2006 through 2008 of which a large part targets the building sector. Likewise, Vermont is aggressively pursuing energy efficiency as a resource by establishing ambitious new targets.

Market Transformation

- Identify ambitious but achievable targets for efficiency and establish appropriate incentive mechanisms to get them to market.

- Identify barriers to greater adoption of energy-efficient technologies and practices and strategies to overcome them.
- Engage in training and capacity building to make all market actors aware of new technologies and practices and to remove existing knowledge and skills gaps.
- Launch coordinated marketing campaigns to educate consumers and others. Where possible this should strengthen existing energy-efficiency messaging and "branding" efforts such as Energy Star in order to maximize consumer uptake and minimize confusion.
- Coordinate with contractors, manufacturers, suppliers and others in the market supply chain to accelerate the deployment and market penetration of the most efficient building technologies and practices.
- Expand implementation of emerging "whole building" approaches, including retrocommissioning, benchmarking, energy performance disclosure and whole-building HVAC initiatives. As these practices have complex market channels, comprehensively planned and coordinated market transformation strategies are required.
- Provide appropriate performance-based fiscal incentives to increase uptake of the most efficient technologies and refurbishment practices.
- Pursue sector-based approaches targeting energy-efficient refurbishment in specific sectors of the buildings market, such as schools, hospitality, etc.

There are numerous national and regional organizations, such as the Consortium for Energy Efficiency, Northwest Energy Efficiency Alliance, Northeast Energy Efficiency Partnerships, and others, which participate in and support coordinated market transformation initiatives to promote common messages and build capacity to deliver energy efficiency in existing buildings. It is appropriate for those wishing to enhance the energy efficiency of existing buildings to make use of and contribute to the capacity of these organizations to deliver common market transformation objectives.

Research, Development and Deployment

- Increase funding and support for technology R&D for long range opportunities, as well as for currently available and evolving technologies and practices.
- Undertake ambitious demonstration activities to showcase these technologies and prove their market viability; for example, the refurbishment of public sector or utility buildings presents an excellent opportunity to exhibit leadership and stimulate market development in energy-efficient building.
- Establish and strengthen state- and utility-funded emerging technologies programs to support the development and demonstration of promising technologies and practices.

As an example, the New York State Energy Research & Development Authority (NYSERDA) has a strong R&D program that provides substantial funding for the development and deployment of new and promising energy-efficient technologies. Once viability is demonstrated these technologies are then fed into NYSERDA's broader public benefits funded market transformation and resource acquisition initiatives. This blend of strong R&D with broad-based market-building initiatives has enabled new technologies to penetrate the market more rapidly than would otherwise have been the case.

The Way Forward

For this recommended mix to have the desired impact, a handful of inputs will help "prepare the ground" for successful program and policy implementation. Among these inputs are:

1. Improved data on detailed end uses and enhanced modeling to better predict the impacts and benefits of energy-efficiency technologies and practices, as well as to monitor the progress of the policies and programs implemented.
2. Development of robust energy efficiency cost curves based on the cost of delivered energy savings in existing buildings rather than simple technology costs. These curves could inform policy decisions driving investment in all efficiency measures that are less than or equal to the marginal cost of new energy supplies, thus yielding the societal least life cycle cost. As policy priorities shift to a greater emphasis on abatement of carbon dioxide emissions, the value of carbon abatement could be included.
3. Ongoing training and capacity building on new technologies and practices, such that all market players are fully trained and informed and market barriers are minimized.
4. A better understanding of the links between building energy-efficiency policies and other policy goals, such as climate change, employment impacts of energy efficiency vs. supply options, and other key policy drivers that can help support the policies recommended in this report.
5. More research on the quality of equipment installations and ways to lower the cost of comprehensive buildings retrofits.
6. Periodic studies on the implementation and enforcement of codes toward existing buildings and ways to improve their effectiveness.

These inputs can improve the climate for adoption of a more robust mix of efficiency programs and policies in regions with a newfound interest in energy efficiency and in those where more aggressive and innovative policies will supplement a well-established set of efficiency programs.

INTRODUCTION

Purpose of Project

The International Energy Agency (IEA) works within the framework of the Organization for Economic Cooperation and Development (OECD) to facilitate energy cooperation among member countries. The IEA's role includes reviewing the opportunities for energy savings in a variety of different energy use sectors. The buildings sector is a significant energy user around the globe, and in particular, the existing stock of buildings – those already built and consuming energy for the foreseeable future – represents a large opportunity for potential savings.

The building stock in the USA and Canada accounts for approximately 600 MToe of primary energy consumption, some 39% of combined national energy use. While much attention has been focused on policies and measures to improve the energy efficiency of new buildings, less has been directed at the existing building stock due to the inherent and perceived difficulties in improving their energy performance. While freedom for action is constrained, there is growing evidence that much can be achieved through targeted policies to encourage better energy management, cost effective upgrades of energy-using equipment and building fabric refurbishment.

There has been a wide range of policy and programmatic activity in North America in recent years to address energy efficiency in existing buildings. Over the past year, the level of interest has grown due to higher energy prices and concerns about energy supply. Great progress has been made in improving the efficiency level of specific technologies and end uses (e.g. typical refrigerators now use around 25% of the energy of an average early 1970s model and commercial lighting systems provide much higher efficacy when measured in lumens of light output per watt of input power). It is only in recent years, though, that there has been more focus on systems and "whole building" approaches, both for residential and commercial buildings.

Despite the improvement in energy efficiency in specific products and end uses, the total energy use in buildings in the USA has grown significantly over the past two decades. While the energy intensity of residential buildings improved by 8% over the period, energy use in residential buildings grew from 8.9 to 10.4 quads during the period from 1985 to 2002, primarily due to 24% growth in the number of households. Commercial buildings have become significantly more energy intensive over the same period; a 12% increase in energy intensity, resulting in total commercial sector energy consumption more than 50% higher in 2002 than it was in 1985 (PNNL 2004).

There are many reasons that energy use is growing despite improvements in the efficiency of specific technologies. There are a wide variety of new electric appliances in use that were unheard of or very rare twenty, or even five, years ago. Typical North American households have dramatically more consumer electronics than ever before, meanwhile the ownership and usage rates of more traditional appliances has continued to increase and is not expected to slow down in the near future without new policies for efficiency. Furthermore, the saturation and use of air conditioning equipment, especially central air conditioning, continues to grow, as consumers can afford lower cost comfort systems that improve their quality of life.

In commercial buildings, the intensity growth is driven both by increased use of electronic equipment (computers, printers, and a variety of other systems) along with trends toward more sophisticated ventilation and space conditioning systems that are more energy intensive. In most regions of the USA, only a small percentage of new commercial construction is completed with operable windows for ventilation; standard practice now includes ventilation systems that consume significant electricity to move air (or other heat transfer fluids) as well as more energy for heating and cooling spaces.

In 2004, in anticipation of a broader global review of policies and programs intended to improve the energy efficiency of the existing building stock, the IEA commissioned a review of historical initiatives in North America to feed into the broader global review of best practices in policies and programs for existing buildings. In 2005, at the G8 Summit in Gleneagles Scotland, world leaders further directed the IEA to develop indicators to assess efficiency in buildings and identify policy best practices. The broader international review is in its early phases, but given the leading role of North America in the world economy, this review is an important contribution to the international best practices effort.

Description of Report

This report presents the findings of a new assessment of the techno-economic and policy-related efficiency improvement potential in the North American building stock conducted as part of a wider appraisal of existing buildings in member states of the International Energy Agency. The project team assessed, as comprehensively as possible, impacts of previous policies and programs on building energy use in North America, and developed estimates of future impacts of potential new efficiency policies for existing buildings. This report summarizes the results and provides insights into lessons learned though the broader global review of best practices to improve the energy efficiency of existing buildings.

The report builds on significant other efforts underway in North America, including a variety of efforts by US and Canadian national governments, as well as specific activities underway at regional, state, and local levels. A particularly relevant effort is the “AB 549” (Assembly Bill 549) initiative in California, where the California Legislature directed the California Energy Commission to “investigate options and develop a plan to decrease wasteful peak-load energy consumption in residential and non-residential buildings” and report the findings to the legislature.

At this time, the report is limited to an initial look at the USA because of the large size of the market. At a later date, a more complete review may include some details about policies and programs in Canada. If resources are available, an additional comprehensive review of Canada and Mexico may be performed in the future.

CHARACTERIZATION OF EXISTING BUILDING STOCK AND MARKET STRUCTURE

The existing building stock in the North American OECD member countries, Canada and the United States, represents approximately 119 million households and over 80 billion square feet of commercial building space. Table 1 shows the population, estimated number of households, and other information about the relative size of the US and Canadian buildings markets.

Table 1. Population, Household and Commercial Floor Area of North American Buildings

	2001 Population	2001 Estimated Number of Households	2001 Estimated Commercial Sector Floor Area (million m^2)	2001 Residential Energy Use (PJ)	2001 Commercial Energy Use (PJ)
Canada	31 021 000	12 517 000	520	1 338	1 061
United States	285 093 813	106 270 000	6 503	21 196	18 400
Total	316 114 813	118 897 000	11 703	22 434	19 461

Source: EIA 2003: Annual Energy Outlook 2003; NRCan 2005; US Census Bureau

For the USA, a range of more specific sector-by-sector data are available on buildings in several of the largest states and the four primary regions of the country (individually, the State of California and each of the four US census regions are larger energy users than the whole of Canada). Data on energy use, and average residential energy expenditures per capita for the four largest states and the four primary census regions are shown in Table 2 (all cost figures throughout this report are presented in US$).

Table 2. Regional Variations in Energy Use and per Capita Energy Expenditures

	2001 Population	2001 Estimated Number of Households	2001 Residential Energy Use (PJ)	2001 Residential Expenditures (Million US$)	2001 Residential Expenditures per Capita (US$)
Canada	31 021 000	12 517 000	1 338	na	na
United States	285 093 813	106 270 000	21 196	168 618	591
Total	316 114 813	118 897 000	22 434		
Four Largest US States					
California	34 533 054	12 300 000	1 446	15 503	449
Texas	21 340 598	7 700 000	1 570	12 999	609
New York	19 074 843	7 100 000	1 194	13 371	701
Florida	16 355 193	6 300 000	1 192	9 257	566
US Census Regions					
Northeast	59 935 435	20 200 000	3 280	35 260	588
Midwest	64 809 640	24 500 000	4 820	37 740	582
South	101 856 767	38 900 000	7 431	59 520	584
West	64 506 081	23 400 000	3 291	27 230	422

Source: EIA 2001: Residential Energy Consumption Survey (RECS); EIA 2003: Annual Energy Outlook 2003; NRCan 2005; US Census Bureau

Buildings in the USA are located in a diverse range of climatic conditions, some requiring significant heating, and others significant cooling, while some have lower energy requirements year round due to more advantageous weather conditions. Figure 1 shows the wide range of climate conditions in North America. As a result of this wide range of conditions, different regions of North America have widely varying heating and cooling loads. The southern states of the USA have negligible heating loads, while cooling energy use dominates. The marine climates of the west coast have dramatically lower heating and cooling loads due to the ocean current effects that moderate temperatures in that region.

Figure 1. Climatic Regions in North America
(Source: www.buildingscience.com)

The buildings sector has a very fragmented market structure, with a multitude of different market actors affecting energy-efficiency decisions. A summary of the more influential types of decision makers and stakeholders affecting energy use in buildings is shown in Figure 2.

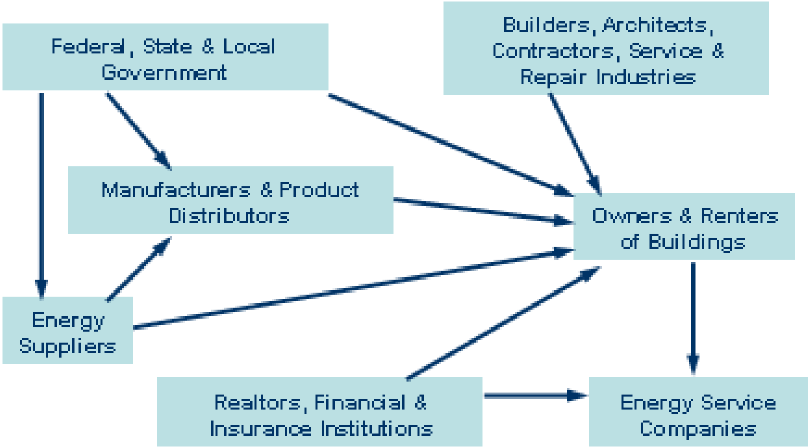


Figure 2. Stakeholders and Decision-makers in the Buildings Sector
(Source: Brown et al., 2005)

The remainder of this section provides a review of the US residential and commercial building stock and its market structure. Only high level summary information is presented – the references included in each subsection provide much more detail. The US Department of Energy (DOE) publishes an annual "Buildings Energy Data Book" which summarizes the very detailed information on building characteristics and energy use collected through the US Energy Information Administration's (EIA's) periodic Residential and Commercial Buildings Energy Consumption Surveys. Natural Resources Canada also publishes detailed surveys of building characteristics and energy consumption.

Residential Sector

The residential building sector includes a wide variety of different building styles and energy use characteristics. In 2001, there were approximately 107 million households in the USA, occupying almost 170 billion square feet of floorspace in 83 million buildings. The US population continues to grow at a healthy rate – the number of households is projected to increase by an additional 35% by 2025.

Types, Age and Ownership Characteristics of Residences

Distribution of the 107 million US households by ownership and housing type is shown in Table 3. The US residential market is dominated by single-family detached homes; multi-family buildings with 5 or more units are the next largest category of residence.

Table 3. Share of US Households by Housing Type and Ownership

Housing Type	Owned	Rented	Total	Millions of Units
Single-Family	59.1%	9.8%	68.9%	72.3
Detached	52.1%	6.9%	59.0%	61.9
Attached	7.0%	2.9%	9.9%	10.4
Multi-Family	3.6%	21.1%	24.8%	26.0
2–4 units	2.0%	6.9%	8.9%	9.3
5 or more units	1.7%	14.2%	15.9%	16.7

Source: DOE 2005: Buildings Energy Databook, Table 2.1.2

The distribution of dwellings by size (floorspace) and age are shown in Tables 4 and 5. It should be noted that there are wide variations in the average size of housing units in different parts of the USA.

Table 4. Distribution of Home Size in Square Feet

Square Footage	Percent of Total
<500	3.6%
500 – 999	20.4%
1 000 – 1 499	21.2%
1 500 – 1 999	15.5%
2 000 – 2 499	12.6%
2 500 – 2 999	8.7%
3 000 – 3 499	6.4%
3 500 – 4 000	3.8%
>4 000	7.7%
	100%

Source: EIA 2001: RECS

Table 5. Age of Residential Buildings

Year of Construction	Percent of Total
1949 or before	25%
1950 – 1959	13%
1960 – 1969	13%
1970 – 1979	18%
1980 – 1989	17%
1990 – 2001	14%
	100%

Source: EIA 2001: RECS

The average size of new residences has been growing consistently. Figure 3 shows the increase in the average size of newly constructed homes between 1990 and 2002. During that period, the average new single-family home has grown from 2 080 to 2 320 square feet; an increase of about 15%, while the average number of residents per household stayed essentially constant.

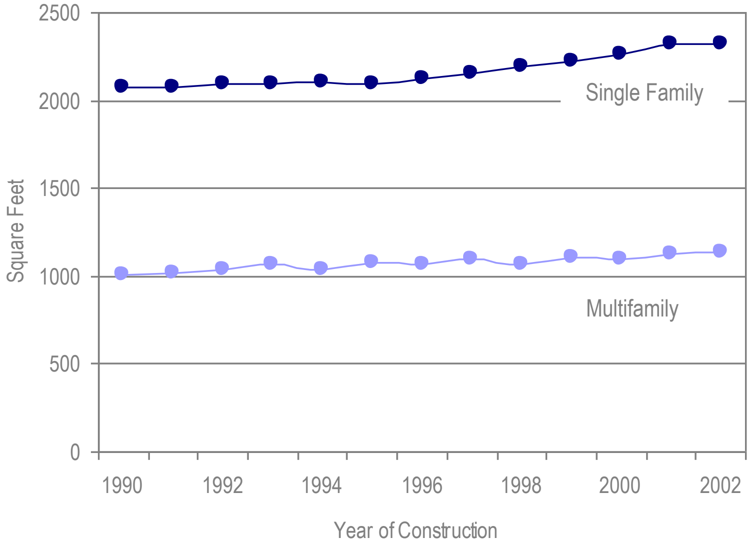


Figure 3. Trends in the Size of New Homes in the U.S.
(Data Source: DOE, 2005: Buildings Energy Databook)

Looking back further, the USA has experienced growth in home size as the average number of persons per household has been shrinking. A recent analysis of the average size of new houses and persons per household shown in Figure 4 demonstrates how the floor space per person has grown dramatically over the past 50 years.

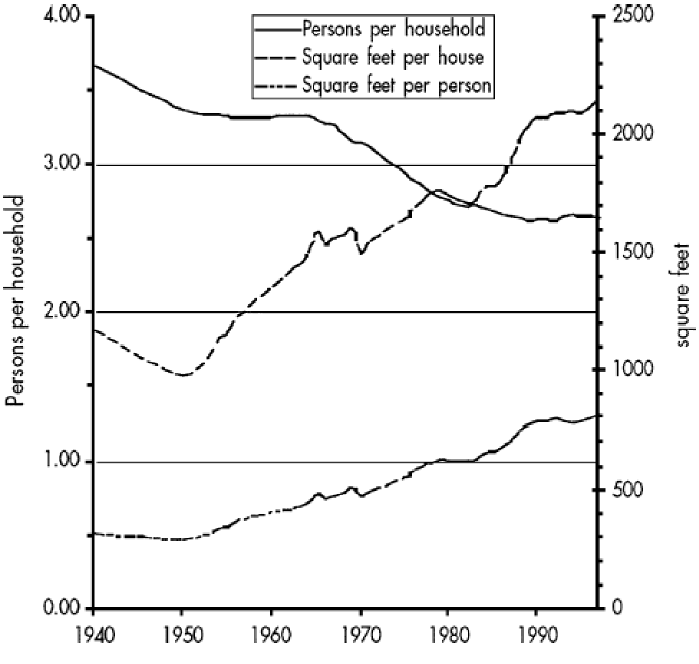


Figure 4. Trends in Average Home Square Footage and Family Size, 1940–2000
(Source: Wilson and Boehland, 2005)

Energy Expenditures by Residential Building Types and Regions

The different types of housing result in significantly different energy costs per household. Table 6 below shows the typical range in per household and per square foot costs for different housing types and different regions. In multi-family housing units, the total energy costs are lower, although the costs per square foot are higher as the non-heating uses are spread over a smaller building footprint. Mobile homes are generally built at the lowest first cost, and as a result are usually not particularly energy efficient. When viewing the expenditures by census region, the heavier heating climate of the Northeast is evident, while the marine climate on the west coast, with significantly lower heating and cooling degree days, results in lower energy expenditures.

Table 6. Energy Expenditures per Household and per Square Foot

	Per Household (US$2003)	Per Square Foot (US$2003)
By Housing Type		
Single-Family	**1 751**	**0.73**
Detached	1 780	0.73
Attached	1 580	0.72
Multi-Family	**998**	**0.96**
2–4 units	1 302	0.94
5 or more units	829	0.98
Mobile Home	**1 379**	**1.31**
By Census Region		
Northeast	1 797	
Midwest	1 591	
South	1 578	
West	1 206	

Source: DOE 2005a: Buildings Energy Databook 4.2.3–4

Commercial Sector

The commercial building sector includes a wide range of buildings, from high rise office and hotel buildings in centre cities, to large shopping malls, to small buildings spread throughout the country. A tremendous amount of information has been published about the building characteristics and energy use profiles of commercial buildings in both the USA and Canada: more comprehensive data than that available for any other region in the world.

In addition to the periodic *Commercial Buildings Energy Consumption Survey* (CBECS), conducted every four years by the US Energy Information Administration (EIA 2003), DOE commissioned a comprehensive study of the structure and operation of the commercial buildings market published in 2004: *Who Plays and Who Decides: The Structure and Operation of the Commercial Building Market* (Reed et al 2004). The data presented in this section are extracted from CBECS and the *Who Plays* reports.

Types and Age of Buildings

Table 7 shows types of commercial sector buildings broken down by floorspace, number of buildings, and percentage of total sector energy consumption. The three principal building types of office, mercantile, and education account for almost half of commercial sector energy use. As shown in Table 8, a substantial portion of commercial floorspace was built prior to 1980 and a large number of buildings built in the first half of the 20th century are still in operation and consuming energy.

Table 7. Share of Commercial Buildings by Type and Primary Energy Consumption

Building Type	Total Floorspace	Total Buildings	Primary Energy Consumption
Office	18%	16%	22%
Warehouse/Storage	16%	13%	8%
Mercantile	15%	14%	15%
Education	13%	7%	10%
Public Assembly	7%	7%	6%
Lodging	7%	3%	7%
Service	5%	10%	6%
Health Care	4%	3%	8%
Food Service	3%	7%	7%
Public Order/ Safety	2%	2%	1%
Food Sales	1%	4%	4%
Vacant	8%	12%	2%
Other	2%	2%	3%
	100%	100%	100%

Source: DOE 2005a: Buildings Energy Databook, Table 2.2.2

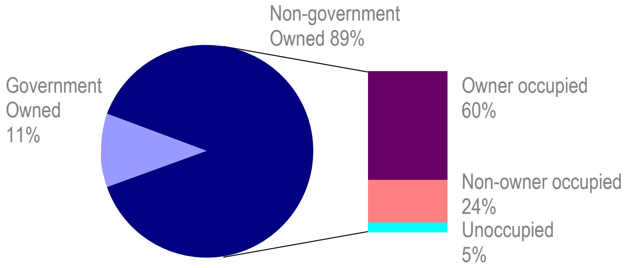
Table 8. Commercial Building Vintage

Year of Construction	Percent of Total Floorspace
Prior to 1919	6%
1920 – 1959	23%
1960 – 1979	34%
1980 – 1989	21%
1990 – 1999	16%
	100%

Source: DOE 2005a: Buildings Energy Databook, Table 2.2.6

Ownership Characteristics

Figures 5 and 6 show the ownership of commercial buildings in the USA, first in terms of the number of buildings owned and then as a percentage of the floor area of the entire commercial buildings sector. Figure 7 breaks down government versus private ownership for each type of commercial sector building.



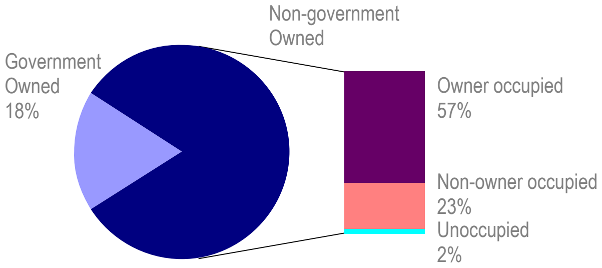


Figure 5. Ownership of Commercial Buildings by Number of Buildings

Figure 6. Ownership of Commercial Buildings by Square Feet

Source: DOE 1999: EIA Commercial Buildings Energy Consumption Survey (CBECS)

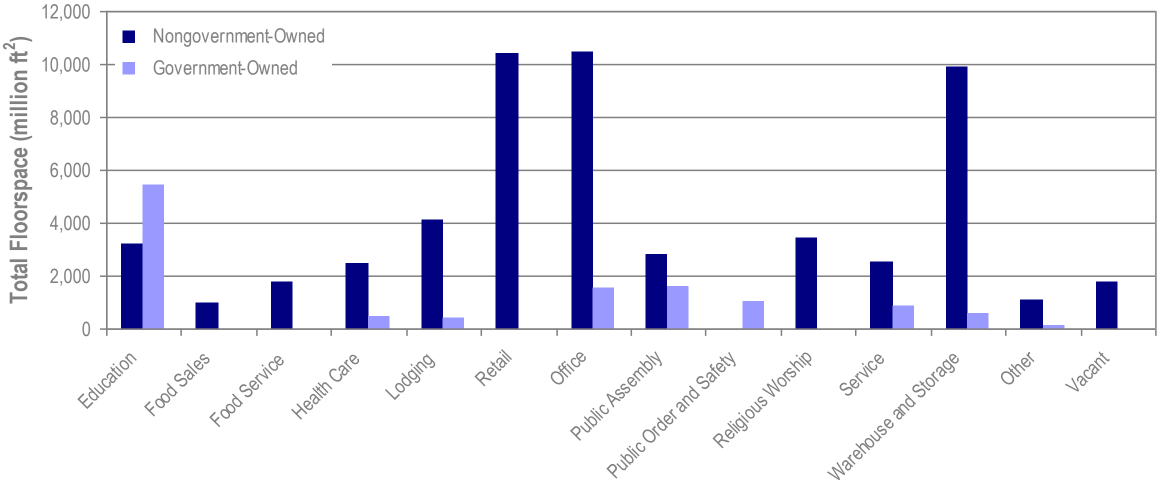


Figure 7. Ownership Characteristics of Different Building Types
Source: EIA, 1999: Commercial Buildings Energy Consumption Survey (CBECS)

ANALYSIS OF SECTORAL ENERGY USE AND EXISTING LOADS

The building sector is the largest consumer of energy in the United States, using approximately 40.3 quadrillion Btus (quads) of energy in 2002 – around 41 percent of total US energy use. The 107 million households comprising the residential sector account for the largest portion of building sector energy use (20.9 quads), followed by 4.6 million commercial buildings (17.4 quads), and industrial buildings (2.0 quads) (Brown et al 2005). Most of the energy used in buildings is consumed by equipment that transforms fuel or electricity into end uses such as space heating, air conditioning, lighting, hot water, refrigeration, laundry, information management, and entertainment.

The periodic detailed RECS and CBECS surveys, as well as building surveys from Natural Resources Canada, provide a wealth of information about building energy use and loads. In addition, a number of studies are available with specific data on individual end-use technologies, detailed surveys of equipment and appliance usage patterns, and building characteristics, although these studies generally cover specific geographic regions. Unless otherwise stated, the data presented in the remainder of this section are for the USA based on data collected through RECS and CBECS.

Residential Sector

Residential Energy Usage

In the residential sector, a significant fraction of overall energy consumption is for space heating and air conditioning (around 40% of primary energy use, and over 55% of delivered energy use). An additional 12% is used for water heating and a further 12% for lighting. The remainder of home energy consumption goes to appliances, electronics, and other purposes. Figure 8 shows the breakdown of end uses for the US residential buildings sector.

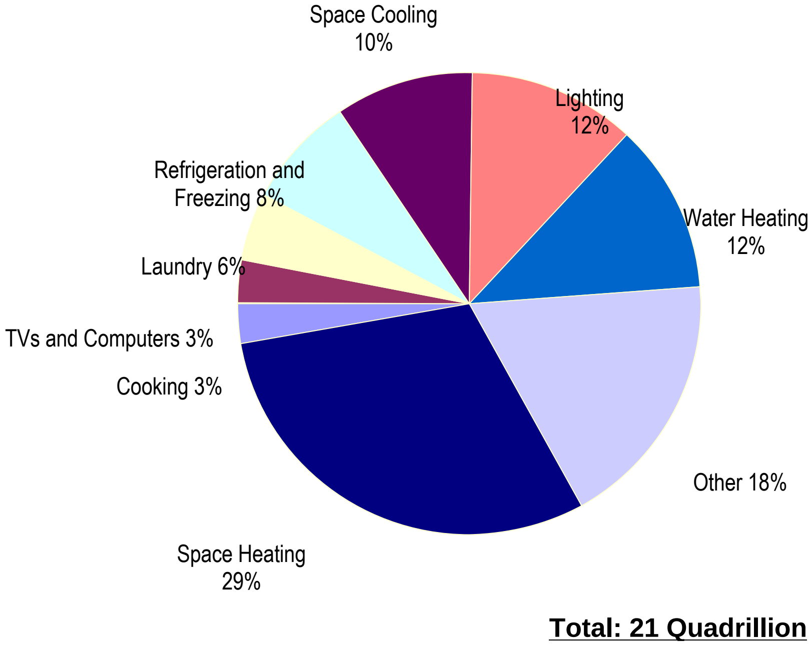


Figure 8. Primary Energy Use in U.S. Residential Buildings, 2004

Note: Other uses include furnace fans, dishwashers, pool pumps/heaters,
other small electric devices, heating elements and motors.
Source: EIA, 2006: Annual Energy Outlook.

The energy intensity of residences in the USA has improved over the past two decades due to a significant drop in heating energy use per household following the energy price shocks in the 1970s as shown in Figure 9. More recently, though, appliance energy use has grown rapidly as a result of increases in the types and saturation of consumer electronics.

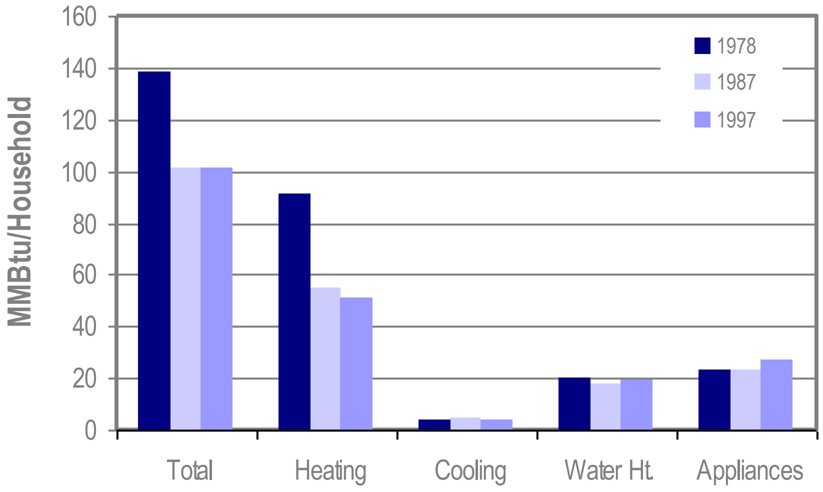


Figure 9. Delivered Energy per U.S. Household by Total and End Use
(Source: EIA (RECS) 1978, 1987, 1997)

Usage by End Use and Fuel Type

As noted above, heating and cooling use vary regionally based on climatic conditions. Table 9 shows delivered energy use for average households in the four US census regions and demonstrates how households in the Northeast and Midwest use dramatically more energy due to space heating. This drives total energy use higher in those regions than the warmer climates of South and West regions.

Table 9. 2001 Delivered Energy Use for an Average Household, by Region (MBtu/Household)

End Use	Northeast	Midwest	South	West	National
Space Heating	63.1	66.8	27.7	29.7	43.9
Space Cooling	3.3	5.1	11.5	5.4	7.7
Water Heating	18	17.4	13.9	15.1	15.8
Refrigeration	4.2	4.9	6.0	4.0	5.0
Other Appliances and Lighting	20.1	23.7	24.3	20.2	22.5
Total	106.6	116.7	82.5	70.1	92.2

Source: DOE 2005: Buildings Energy Databook, Table 7.3.1

Natural gas is the main fuel for space heating in US homes, but electricity has captured a larger share of space heating over the past few decades. Table 10 shows heating fuel and system types used in US households. Fuel oil and propane heating are in decline, while use of electricity (largely for heat pumps) is growing, in part explained by the fast growth in housing in the less harsh climates of the South and West compared to the Northeast and Midwest.

Table 10. Main Residential Heating Equipment

	Percent of Total Households			
Equipment Type	**1987**	**1993**	**1997**	**2001**
Natural Gas	*55%*	*53%*	*53%*	*55%*
Central Warm-Air Furnace	35%	36%	38%	42%
Steam or Hot-Water System	10%	9%	7%	7%
Floor/Wall/Pipeless Furnace	6%	4%	4%	3%
Room Heater/Other	4%	3%	4%	3%
Electricity	*20%*	*26%*	*29%*	*29%*
Central Warm-Air Furnace	8%	10%	11%	12%
Heat Pump	5%	8%	10%	10%
Built-In Electric Units	6%	7%	7%	6%
Other	1%	1%	2%	2%
Fuel Oil	*12%*	*11%*	*9%*	*7%*
Steam or Hot-Water System	7%	6%	5%	4%
Central Warm-Air Furnace	4%	5%	4%	3%
Other	1%	0%	0%	0%
Other	*13%*	*11%*	*9%*	*8%*
	100%	100%	100%	100%

Source: DOE 2005: Buildings Energy Databook, Table 5.6.12

Heating, Air Conditioning, and Ventilation Loads, by System Type and Fuel

Just as the fuel mix for residential heating systems has changed over the past several decades, there has also been a shift away from hot water and steam systems toward warm air systems. This change has been driven in part by growth in the number of households in Southern and Western regions, but also by the very significant increase in the penetration of central air-conditioning systems throughout the country. Once ducts are installed for central air conditioning, many water and steam systems are swapped out for warm air systems. Figure 10 shows the increase in air-conditioning use nationally and highlights the dramatic growth in the use of air-conditioning in the all regions.

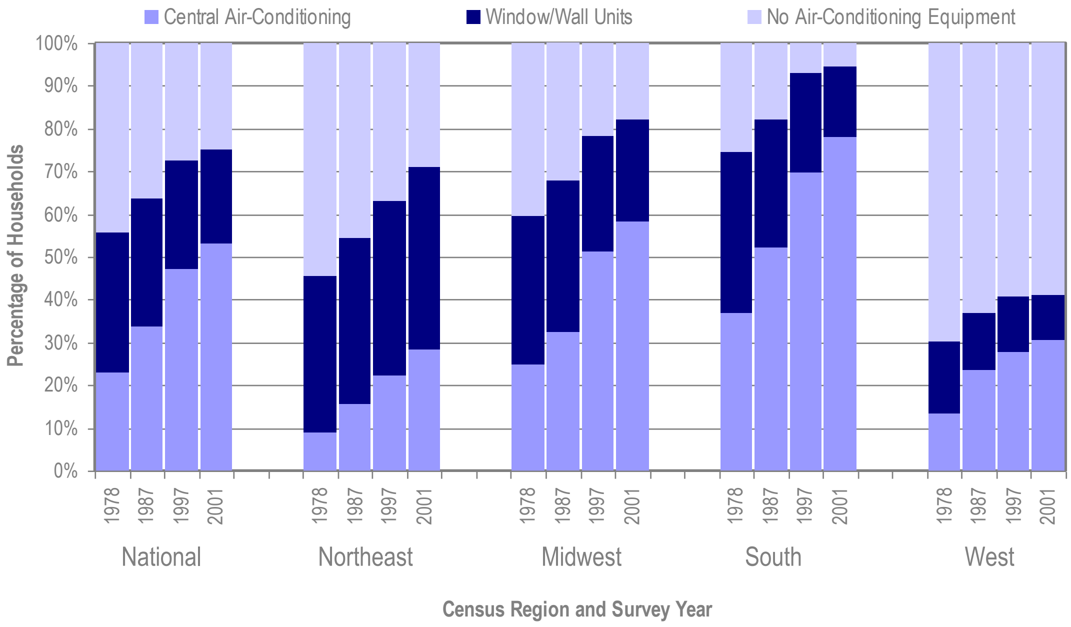


Figure 10. Delivered Energy Use Per U.S. Household by Total and End Use
(Source: EIA (RECS) 1978, 1987, 1997, 2001)

Types of Thermal Distribution Systems

As central AC systems become standard in most new homes, the use of forced air heating systems has also become the norm in residential new construction so that a single thermal distribution system can supply both heating and cooling. Table 11 shows the current breakdown.

Table 11. Residential Heat Distribution System by Region

	Number of Houses (million units)	
	Northeast & North Central	South &West
Single-Family		
Forced-Air	22.2	18.1
Unconditioned Space	6.6	14.9
Partially Conditioned Space	7.6	2.7
Conditioned Space	8.0	0.5
Hydronic	7.2	1.8
Built-in Electric	1.0	1.8
Other or None	4.6	14.4
Multi-Family		
Forced-Air	5.9	10.5
Hydronic	5.8	(3)
Built-in Electric	0.6	1.1
Other or None	(3)	(3)
Mobile Home		
Forced-Air	1.1	1.8
Other or None	0.8	1.4

Source: EIA RECS Web site

Building Envelope Characteristics: Insulation and Glazing

Residential building heating and cooling loads are a function of climate conditions, the type and efficiency of the heating and/or cooling systems, and the characteristics of the building envelope. Since the energy crises of the 1970s, there has been a big push toward building energy codes throughout North America, with regulations in most jurisdictions requiring better insulation levels and more efficient windows.

With increased energy code regulation that often applies to window and wall replacement or building remodels (in addition to new construction), the saturation of more energy-efficient windows and higher levels of wall and ceiling insulation are slowly improving the efficiency of the built stock over time. In addition, with a growing emphasis on more efficient windows for new construction and renovation projects, the availability of single glazed windows is shrinking, and the percentage of the existing housing stock with newer technologies, including low-e glass, continues to grow. Great effort has also been put toward "weatherization" of existing homes to reduce air leakage and cut energy loss.

Domestic Water Heating Use

Domestic water heating is typically the second largest residential energy end use, following space heating or cooling (depending on which climate dominates in the given region). Domestic water heating is made up predominately of natural gas or electric storage water heating systems. There had been more use of centralized domestic water heating systems in older, urban multi-family housing in the USA, but with a trend toward individual metering and billing, separate storage systems now go into virtually all new single- and multi-family units and many multi-family units have been retrofit with standalone systems. Instantaneous, tankless gas and electric water heaters are just beginning to develop any significant market share, primarily in new construction. Figure 11 below shows the breakdown by fuel for water heating in US homes.

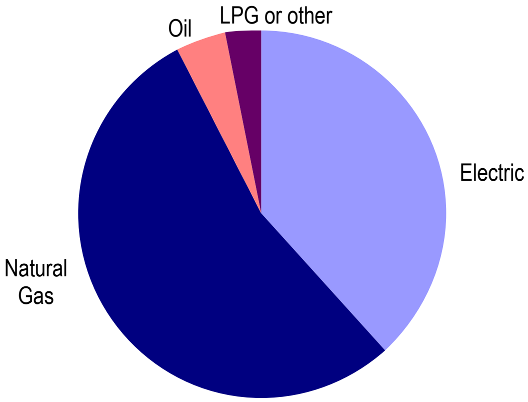


Figure 11. Average Residential Water Heating Fuel Use
Source: EIA, 2001: Residential Energy Consumption Survey (RECS)

Lighting Use: Types of Lamps and Fixtures, Hours of Usage

The vast majority of lighting used in residential buildings is incandescent lighting with substantial opportunities for efficiency improvement. Table 12 shows the distribution of US residential lighting electricity consumption and total light output (in lumen hours) for a range of incandescent and more efficient technologies, as estimated through a detailed survey of lighting energy use in 2002 (Navigant 2002). There are some signs that the penetration of more efficient technologies are beginning to take hold, though not yet affecting the majority of existing households.

Table 12. Distribution of US Residential Lighting Electricity Consumption

Technology	Percent of Lighting Electricity	Percent of Light Output
Incandescent	*90*	*69*
Standard – General Service	76	60
Standard – Reflector	11	5
Halogen – General Service	1	1
Halogen – Reflector	1	1
Fluorescent	*10*	*31*
Screw-in Compact Fluorescent	1	1
Misc. Fluorescent	9	29

Source: Navigant 2002

Appliance Usage: Saturation Levels, Market Shares, Trends

Appliance energy use has been growing steadily in recent years as a variety of new products have been introduced and widely adopted. Table 13 shows household saturation levels for a variety of electric and gas appliances. It is evident that several energy-intensive appliances, such as clothes dryers, are growing in popularity as disposable incomes rise and more families seek out appliances that are perceived as time-saving conveniences.

Table 13. Appliances in US Households, Selected Years, 1980–2001

Survey Category	**Survey Year**								
	1980	**1981**	**1982**	**1984**	**1987**	**1990**	**1993**	**1997**	**2001**
Number of Households (millions)	82	83	84	86	91	94	97	101	107
Electric Appliances									
Clothes Dryer	47%	45%	45%	46%	51%	53%	57%	55%	57%
Clothes Washer	74%	73%	71%	73%	75%	76%	77%	77%	79%
Computer, Personal	NA	NA	NA	NA	NA	46%	23%	35%	56%
Dehumidifier	9%	9%	9%	9%	10%	12%	9%	NA	11%
Dishwasher	37%	37%	36%	38%	43%	45%	45%	50%	53%
Freezer, Separate	38%	38%	37%	37%	34%	34%	35%	33%	32%
Oven, Microwave	14%	17%	31%	34%	61%	79%	84%	83%	86%
Refrigerator (one)	86%	89%	86%	88%	86%	84%	85%	85%	83%
Refrigerator (two or more)	14%	13%	13%	12%	14%	15%	15%	15%	17%
Television (any type)	98%	98%	98%	98%	98%	99%	98%	NA	NA
Television (b/w)	51%	48%	46%	43%	36%	31%	20%	NA	NA
Television (color)	82%	83%	85%	88%	93%	96%	98%	99%	99%
Gas Appliances									
Clothes Dryer	14%	16%	15%	16%	15%	16%	15%	16%	17%
Outdoor Gas Grill	9%	9%	11%	13%	20%	26%	29%	NA	NA
Range (stove-top burner)	46%	46%	47%	45%	43%	42%	38%	39%	39%

Source: EIA 2001; Regional Energy Profiles, Appliance Reports

The biggest appliance energy user in most homes is the refrigerator. There has been dramatic improvement in the per unit energy consumption for refrigerators in North America in recent years (a 75% reduction in energy use over 25 years), much of it driven by minimum standards as demonstrated in Figure 12. Despite the reduction in energy use by the typical refrigerator, overall energy consumption from refrigerators has been more level, declining by approximately 1% per year for the past ten years (Deumling 2004). Population growth, larger refrigerators with new energy-using features, and higher saturations as more households use a second refrigerator all contribute to these trends.

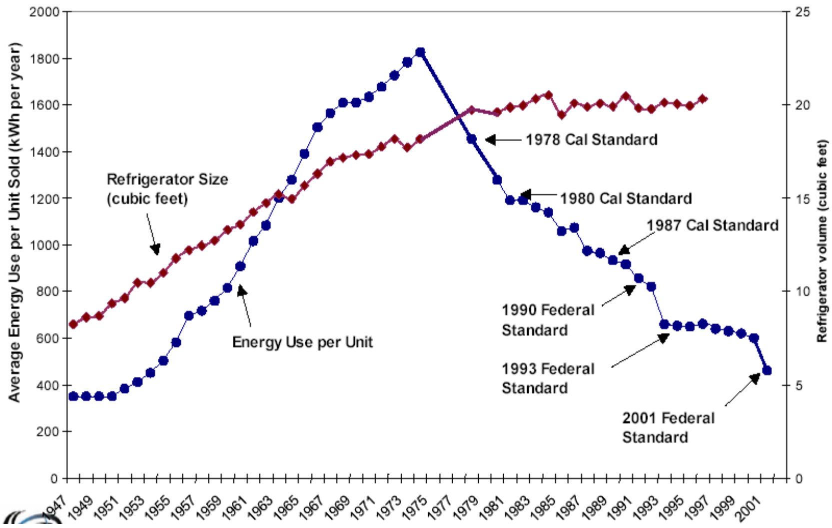


Figure 12. U.S. Refrigerator Energy Use 1947 – 2002

Note: Annual drop from 1974 to 2001 = 5% per year.
Deumling, 2004

The largest growth in appliance energy use stems from increasing saturations of new consumer electronics products, many of which were not in use or available a decade ago. Table 14 shows the top most demanding electronic end uses in US households along with their power use in active and standby modes, total unit annual consumption, and estimated national usage.

Table 14. Most Demanding Consumer Electronics End Uses in US Homes (2004)

Product	Number of Units (millions)	Avg. Active Usage (watts)	Avg. Standby Usage (watts)	Avg. Unit Energy Use (kWh/ year)	Total US Energy Use (TWh/ year)	Percent of Total Residential Consumption[f]
Color Television[b]	228	150	4	275	62.7	4.69%
Desktop PC[a]	85	75	4	230	19.5	1.46%
VCR/DVD[a]	200	17	3	78	16	0.99%
Digital Cable Box[c]	65	23	22	130	8.5	0.63%
Computer Monitor[a]	85	45	2	91	7.7	0.58%
External Power Supplies[d]	200			25	5.0	0.37%
Satellite Box[c]	32	17	16	110	3.5	0.26%
Laptop PC[a]	36	25	2	72	2.6	0.19%
Digital Video Recorder[a]	10	27	25	225	2.2	0.16%

Sources: (a)TIAX 2006; (b)NRDC 2005a; (c)NRDC 2005b; (d)Wilson, Thorne and Morrill 2004; (e)EIA 2001; (f)EIA 2006: Annual Energy Outlook.

Trends in Whole Building Usage Over Time

While there have been dramatic improvements in the efficiency of specific technologies and end uses, other factors such as increasing house size and appliance saturation characteristics are negating much of the efficiency improvement. Figure 13 shows the impact of these factors and their effect on residential energy intensity (primary BTU per household) over the past two decades.

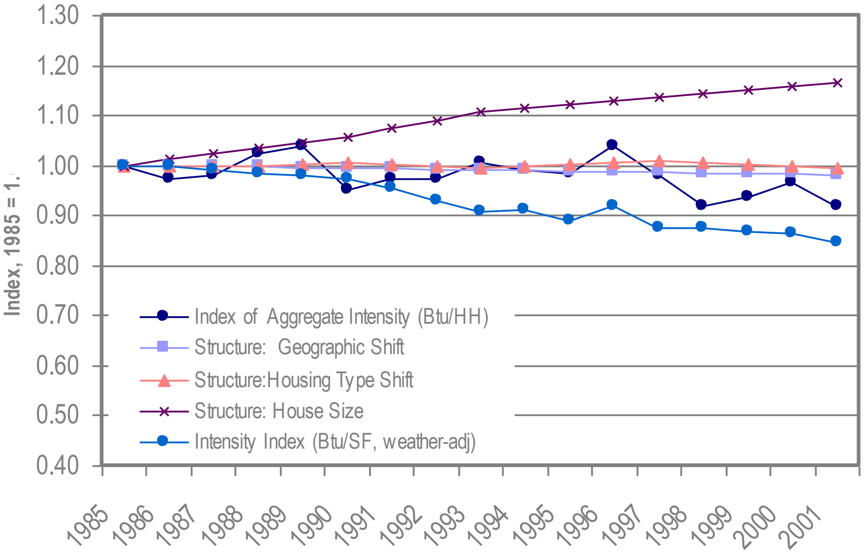


Figure 13. Residential Intensity for Delivered Energy and Structural Changes
Source: DOE: Indicators of Energy Intensity (http://intensityindicators.pnl.gov/)

Commercial Sector

The commercial sector includes a tremendous variety of different building types, operating in a wide range of climatic conditions, and as such, there is great variation in how energy is used in commercial buildings. Nationally, the largest end use for energy is for lighting (20 percent); lighting and office equipment (8 percent) drive “internal loads” in commercial buildings that make their total energy use less dependent on climatic conditions than residential buildings. Air conditioning/space cooling requires almost as much energy nationally as space heating, caused in part by the need to offset the heat generated by lighting and other electric equipment. The remainder of energy use in commercial buildings is for water heating, refrigeration, and other purposes.

Commercial sector energy use has been growing at a rapid pace, in partially due to economic trends and the shift from manufacturing to services. Figure 14 shows the growth in commercial sector energy use in the USA over the past five decades.

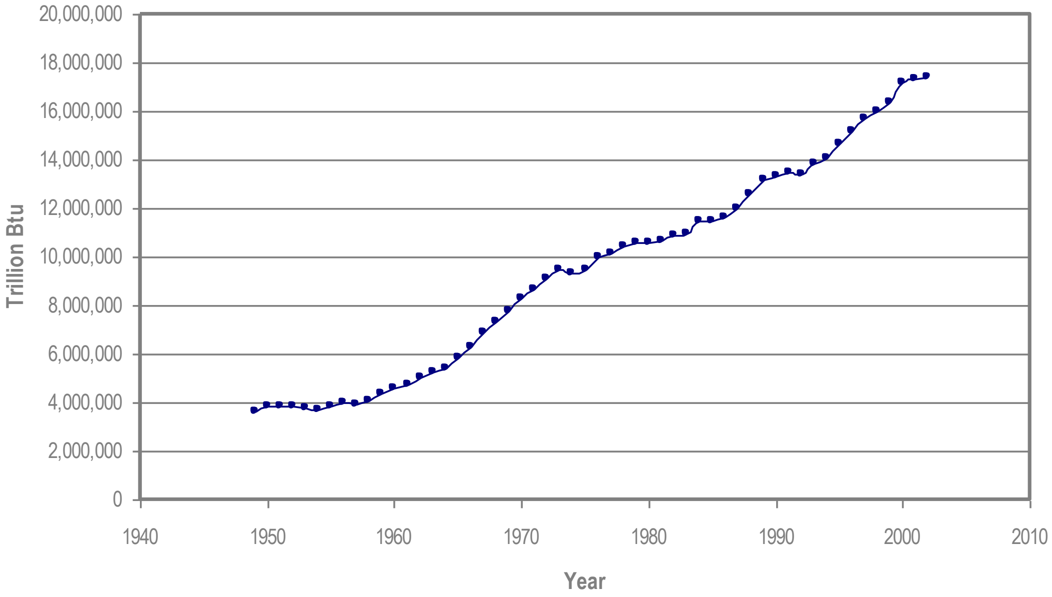


Figure 14. Commercial Sector Energy Use 1948–2000

Source DOE: Indicators of Energy Intensity (http://intensityindicators.pnl.gov/)

Commercial Sector Energy Usage

The breakdown of commercial sector energy use in the USA is shown in Figure 15. Figure 16 shows the wide variety of building types and energy intensity, and Figure 17 shows how energy intensity has changed for specific building types over the past twenty-five years.

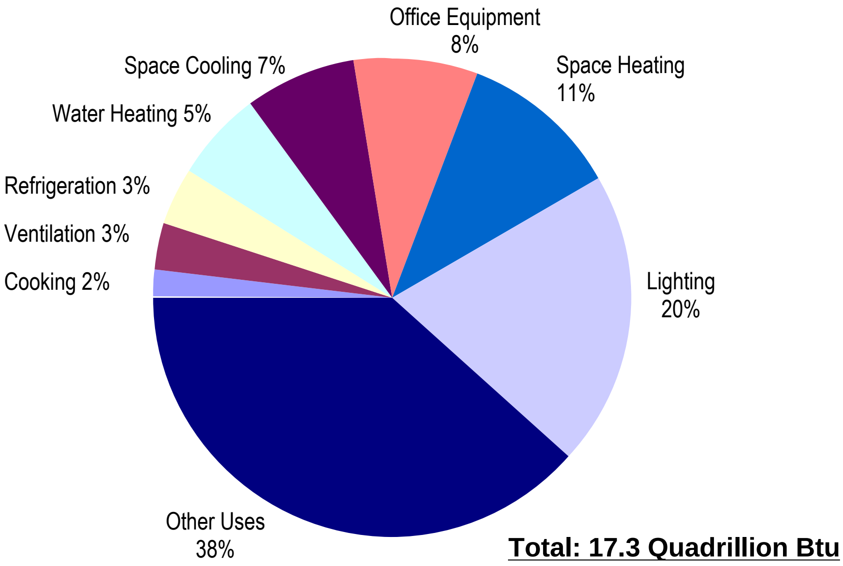


Figure 15. Primary Energy Use in U.S. Commercial Buildings (2004)
Note: Other uses include service station equipment, teller machines, telecommunications, medical equipment, pumps, emergency generators, combined heat and power systems, manufacturing and residual fuel use.
Source: EIA, 2006: Annual Energy Outlook

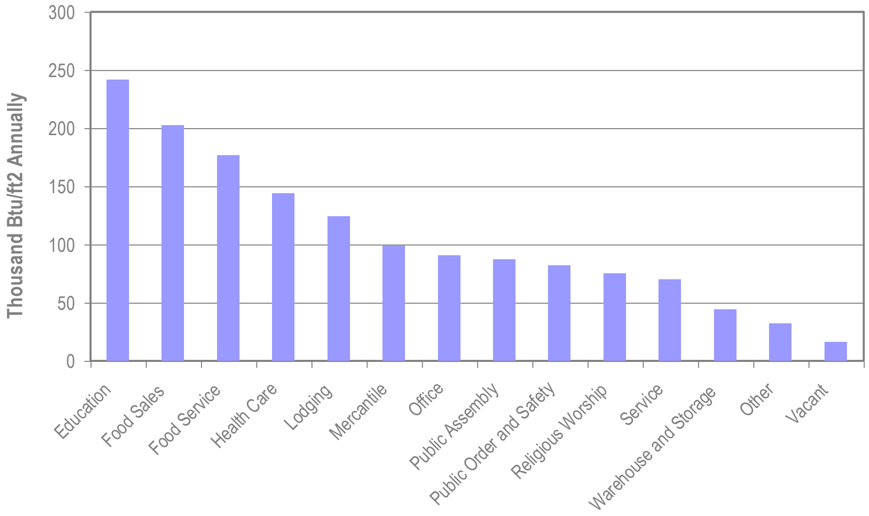


Figure 16. Energy Intensity of Different Commercial Building Types
Source: EIA, 1999: Commercial Buildings Energy Consumption Survey (CBECS)

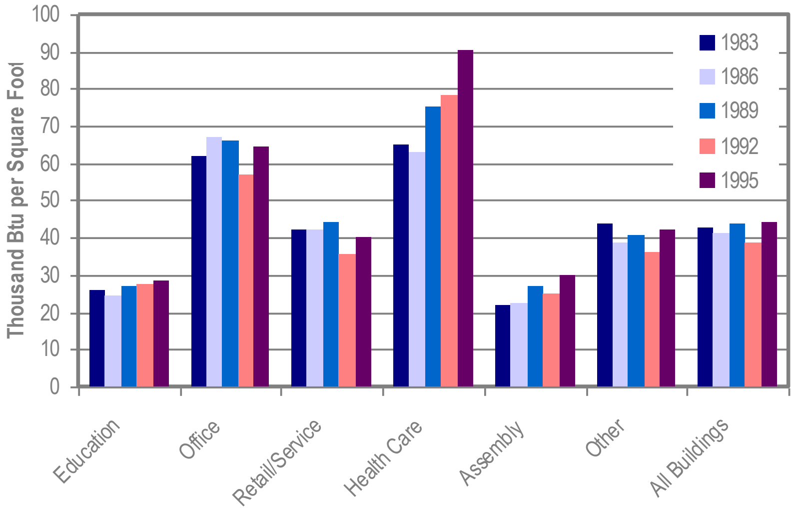


Figure 17. Changes in Energy Intensity of Selected Building Types
Source: EIA, 2003: Commercial Buildings Energy Consumption Survey (CBECS)

Heating, Air Conditioning, and Ventilation Loads, by System Type and Fuel

The type of HVAC system and equipment in a commercial building is largely dependent on the building type, as well as other characteristics (number of stories, total building size, etc). There has been a significant trend in recent years toward “packaged” heating and AC units, often rooftop units, to simplify installation and maintenance of the systems. The penetration of the most common HVAC system types and equipment, demonstrating the shift in system types, is shown in Table 15.

Table 15. Main Commercial Heating and Cooling Equipment as of 1995 and 1999 (Percent Total Floorspace)

Heating Equipment	1995	1999	Cooling Equipment	1995	1999
Packaged Heating Units	29%	38%	Packaged AC Units	45%	54%
Boilers	29%	29%	Individual AC	21%	21%
Individual Space Heaters	29%	26%	Central Chillers	19%	19%
Furnaces	25%	21%	Residential Central AC	16%	12%
Heat Pumps	10%	13%	Heat Pumps	12%	14%
District Heat	10%	8%	District Chilled Water	4%	4%
Other	11%	6%	Swamp Coolers	4%	3%
			Other	2%	2%

Source: DOE 2005a: Buildings Energy Databook, Table 5.6.13

Types of Thermal Distribution Systems

Like the primary heating and cooling equipment, types of thermal distribution systems vary by building type. Table 16 shows the types of distribution systems in different building types; office buildings have the greatest variety of system types, while warehouse/storage buildings, and food sales and service are almost exclusively served, if at all, by packaged distribution systems.

Table 16. Conditioned Floorspace in Commercial Buildings by Building and System Type

	Cooling System (million square feet)						
Building Type	**Individual AC**	**Packaged AC**	**Central VAV**	**Central FCU**	**Central CAV**	**Not Cooled**	**Total**
Education	805	2 204	551	466	212	3 522	7 760
Food Sales	0	534	0	0	0	20	554
Food Service	83	1 100	0	0	0	64	1 247
Health Care	134	557	401	334	802	159	2 387
Lodging	1 669	283	85	707	85	779	3 608
Mercantile and Service	333	5 820	1 081	831	249	2 507	10 821
Office	1 257	4 450	2 322	484	1 161	561	10 231
Public Buildings	371	3 337	847	0	751	2 168	7 464
Warehouse/Storage	119	1 482	0	0	102	2 285	3 988
Totals	4 771	19 767	5 287	2 822	3 352	12 065	48 064

Source: DOE 2005a: Buildings Energy Databook, Table 5.7.1

Lighting Use: Energy Intensities, Types of Lamps and Systems

Lighting levels, and resulting lighting energy use, vary greatly in different types of commercial buildings. Table 17 shows the different lighting end-use intensities for a range of commercial building types, along with estimates of how much each building type contributes to both annual lighting energy, and percent of the total lighted commercial floorspace.

Table 17. Commercial Lighting Use and Intensity by Building Type

Building Type	**Percent of Total Lighted Floorspace**	**Percent of Total Annual Lighting Energy**	**Annual Lighting End-Use Intensity per Total Lighted Floorspace (kWh/ft^2)**
Education	13.6%	10.1%	4.6%
Food Sales	1.1%	1.8%	9.9%
Food Service	2.4%	4.2%	10.8%
Health Care	4.1%	7.7%	11.5%
Lodging	6.4%	7.0%	6.8%
Mercantile and Service	22.4%	24.8%	6.9%
Office	18.6%	24.5%	8.2%
Public Buildings	7.0%	7.2%	6.4%
Public Order and Safety	2.3%	1.7%	4.8%
Warehouse/Storage	14.0%	6.9%	2.9%
Other	1.8%	2.2%	7.8%
Vacant	6.2%	1.9%	1.3%

Source: DOE 2005a: Buildings Energy Databook, Table 5.9.4

Since lighting is such a significant end use, and the heat generated by lighting in commercial buildings often must be removed by air-conditioning systems, much attention in recent years has been paid to commercial lighting energy efficiency. Significant progress has been made in market transformation toward more efficient lighting systems and products (such as electronic ballasts and more efficacious lamps), but with trends toward higher artificial lighting levels and greater percentages of total floor space lit to these higher levels, lighting energy use continues to grow. Use of natural light through daylighting practices is growing in commercial buildings, but remains most prevalent and widely used in older buildings built early in the twentieth century.

Building Envelope Characteristics: Building Skin and Glazing

Similar to residential buildings, there have been substantial improvements in levels of building insulation and glazing efficiency since the energy price shocks of the 1970s. In commercial buildings, however, building types are generally more “load-dominated” than “skin-dominated,” in that total building energy use is less dependent on climatic conditions and building envelope characteristics than on equipment loads inside the building.

The key envelope characteristic in most commercial buildings is glazing, and thus, limiting heat gain is the primary opportunity for energy savings. Energy codes and regulations in many jurisdictions regulate insulation levels and the amount and type of glazing. As a result, the existing commercial building stock is moving toward higher levels of building fabric efficiency as a greater percentage of buildings affected by codes become part of the existing building stock.

Domestic/Service Water Heating Use

Water heating energy use in commercial buildings is a very small percentage of total energy consumption for many building types (office, public assembly, warehouse/storage), and a substantial portion for others (lodging, health care, and food service). For buildings with low domestic water use, electric water heating predominates, but only represents a small percentage of total commercial sector domestic water heating energy use. Natural gas is the fuel of choice for most buildings that have high water heating demand; fuel oil, propane, and district heat make up a small share.

Office Equipment Energy Usage: Saturation Levels, Market Shares, Trends

A large portion of the increase in electrical energy use intensity in commercial buildings is the proliferation of new electronic computer and information technology equipment that has blossomed over the past two decades. Computer use in buildings has grown dramatically, though the energy intensity of office equipment appears to have peaked, with new equipment being less energy intensive than models in use several years ago (e.g., flat screen LCD panels have replaced more energy intensive CRTs for computers). Table 18 shows the change in saturation of computers in the USA over the period from 1992 to 1999; similar changes have occurred for a variety of other electronic office equipment such as copiers, printers and fax machines.

Table 18. Change in the Number of Computers in Commercial Buildings, 1992–1999

	Computers (thousand)			Computers per Thousand Employees			Computers per Million Square Feet		
	1992	**1995**	**1999**	**1992**	**1995**	**1999**	**1992**	**1995**	**1999**
All Buildings	29 752	43 003	57 864	431	571	707	463	732	859
Principal Building Activity									
Assembly	845	1 763	1 654	167	258	526	102	262	377
Education	6 004	8 046	11 914	877	847	1 335	710	1 039	1 377
Food Sales	85	206	247	101	316	252	113	321	249
Food Service	146	276	557	65	118	138	98	204	301
Health Care	1 128	2 549	3 652	334	569	587	641	1 092	1 252
Lodging	651	1 296	1 884	322	472	800	225	358	417
Mercantile and Service	2 478	4 021	5 044	157	308	639	201	316	780
Office	15 451	21 173	27 642	599	797	954	1 319	2 021	2 295
Large (>50 000 ft^2)	9 746	13 341	17 437	674	833	963	1 566	2 380	2 459
Small (<50 000 ft^2)	5 705	7 831	10 205	502	743	939	1 040	1 607	2 061

Source: EIA 1999; Commercial Buildings Energy Consumption Survey (CBECS)

Trends in Whole Building Energy Usage Over Time, and by Year of Construction

Energy use in commercial buildings has been growing increased quite rapidly over the past two decades as a result of large growth in total commercial floorspace and increases in numbers and usage of computers and other information technology. Figure 18 shows how these factors have affected commercial building energy use since 1985.

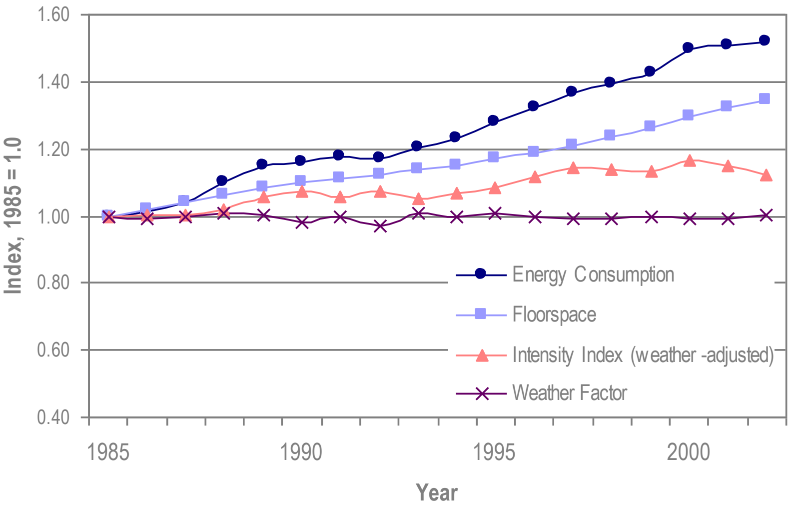


Figure 18. Changes in Energy Intensity of Selected Building Types
Source: DOE: Indicators of Energy Intensity (http://intensityindicators.pnl.gov/)

Disappointingly, newer buildings as a whole are no more efficient than older ones. Figure 19 shows energy use intensity levels for buildings by year of construction. It appears that commercial buildings constructed from prior to 1919 through 1959 use, on average, appreciably less energy per unit of floorspace than more recent construction. Differences in service levels, types of equipment in place, and building use may explain some of this phenomenon, but overall it appears that new designs are not matching energy performance expectations, and the impact of energy codes is not necessarily showing up in the average stock of new construction.

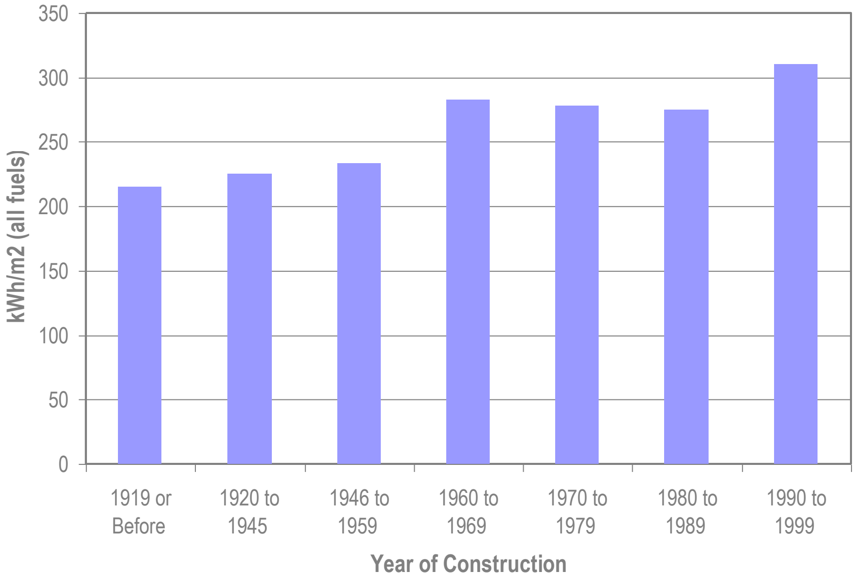


Figure 19. U.S. Commercial Building Energy Intensity by Year of Construction
Source: EIA 1999: Commercial Buildings Energy Consumption Survey (CBECS)

DETERMINATION OF EXISTING FABRIC AND EQUIPMENT EFFICIENCIES AND TECHNICAL OPTIONS TO IMPROVE ENERGY EFFICIENCY

A closer look at trends in the energy efficiency of residential and commercial sector equipment and building envelopes demonstrates where the greatest progress has been made in improving the efficiency of the existing building stock. An assessment of the technical options for further efficiency improvements shows where the greatest opportunities lie. The remainder of this section, while not exhaustive, summarizes the current fabric and equipment efficiencies in the existing building stock for major building systems and leading energy end uses. Promising technical options for improving efficiency are noted.

Residential Sector

Building Envelope: Insulation and Glazing

The effectiveness of a house's outer shell determines how airflow, moisture and heat gain or loss is regulated within the living space. According to 2001 EIA data, over 50% of US residents report unceasing drafts in their homes during winter months, while another 34% reported experiencing drafts "most of the time," suggesting significant room for improvement in building shell efficiency.

Walls. In a standard North American home, energy transfer through walls account for about 19% of heating load and 10% of cooling load. Fiberglass batts are the most common form of residential insulation. Although polyurethane and other rigid foam materials offer high performance per inch of thickness, the higher cost of these products has limited their adoption. A wall's resistance to heat flow depends on the type of insulation as well as the thickness of the wall frame and any layering of materials. In North American homes, which tend to be fairly well insulated, much of the air leakage occurs because of awkward or irregularly shaped wall segments that are incorrectly insulated. Spray-applied cellulose insulation is one of the most effective technologies available for sealing walls in existing homes.

Windows. In homes of more recent vintage, windows comprise 10%-25% of the exterior wall space. In heating-dominated climates, windows can account for over a quarter of a home's total heat losses in winter. Likewise, in cooling-dominated climates, the solar energy that is transmitted through windows can account for up to one third of a house's cooling load.

Over the past 10–15 years, window performance has improved dramatically due to the development of low-emissivity (low-e) glazing, tints, inert or low-conductance gas fills, insulating spacers, improved weather stripping, and tighter frame design. Since 1990, the use of wood and aluminum windows in new construction has declined in favor of vinyl and other materials. More advanced insulation technologies for residential windows in cold climates include suspended low-e films that create more inter-pane airspaces, vacuum windows and aerogels. Windows incorporating these technologies (also known as "superwindows") currently account for less than 1% of the North American market. With estimated savings of up to 20% of heating energy use in cold climates above 5 500 heating degree days a year, these windows present a great opportunity for cost-effective energy savings.

Roofing. Roofs are a major source of unwanted heat loss and gain. In winter months, heat from the interior living space escapes to the attic and through the roof, accounting for 12% of total heat losses. During the summer, radiative and conductive heat transfer through roof and ceiling materials amount to 14% of a house's cooling load. Improved attic insulation can cut these energy losses.

A large majority of residential roofs are covered with asphalt shingles, which typically reflect 4%-12% of incoming solar energy. Other types of shingles, clay tiles, and metal products are fairly common on steep-sloped residential roofs. More reflective light-colored materials, which are common on flat-roofed commercial buildings, have not gained much appeal in residential applications due to aesthetic preferences. ENERGY STAR qualified roofing materials, which require 25% solar reflectance on steep roofs, achieved 6% of sales in 2004.

Pigments that provide high-reflectance in standard colors have recently been developed for the residential market. Although they are not yet cost-competitive, these materials produce a 60% reduction in heat gain, resulting in an average 20% cooling-load energy savings, depending on climate and building characteristics. The aesthetic characteristics of these new products should improve their marketability.

Space Heating

In the USA, residential heating systems and primary heating fuel vary by region and age of the home. Roughly 56% of US households depend on natural gas to fuel furnaces or boilers, particularly residents living in the Midwest and the South. Of the 8% of households that depend on fuel oil, the vast majority (75%) are in northeastern homes with steam or hot water boilers. Another third of the country depends on electricity, over half of whom live in western states.

Two thirds of US households use a central warm-air furnace powered by electricity, natural gas, or another fuel such as propane. Boilers for hot water or steam circulation account for another 12% of the residential heating market. Non-furnace electric equipment is less common, with 10% of households equipped with an electric air or ground-source heat pump and another 6% using built-in baseboard and other electric resistance units. Wood-fired stoves are the primary heat sources for 2% of the residential heating market.

The annual fuel utilization efficiency (AFUE) of standard furnaces and boilers sold in the US ranges from 0.80 to 0.95. Sales of high-efficiency condensing gas furnaces that are ENERGY STAR qualified (AFUE 0.90 or higher) are on the rise, however, accounting for 37% of sales in 2005. Virtually all oil-fired boilers on the market today are ENERGY STAR-qualified (AFUE 0.85 or higher), while oil furnaces lag with most of the market consisting of non-condensing units with AFUE of 0.83 or lower.

Condensing furnaces have achieved market success primarily in cold climates, where they save at least 11% of fuel use, and account for a large majority of furnace sales. The price differential is lower – about $400 – in regions where there is high penetration and a competitive market, as in Wisconsin.

Recent research on furnace performance has explored the benefits of improving system installation and maintenance (including duct leakage) and the electrical efficiency of the air handling system. Numerous studies estimate savings from reduced duct leakage at 15% of heating energy use (with even higher cooling season savings in climates with high cooling loads).

ACEEE estimates that the savings potential of installing an advanced residential furnace fan would be 500 kWh per year during the heating cycle alone.

Cold climate air-source heat pumps incorporating multiple compressors and intelligent controls can drastically reduce the amount of supplemental resistance heating needed, yielding savings of 14% in residences that rely on electric heat. Ground-source heat pumps offer even greater savings for electrically heated homes – roughly 40–60% savings compared to standard air-source heat pumps. These systems currently account for less than 5% of residential heat pumps sales and less than 1% of the overall residential heating market.

Further down the road, advances in distributed energy technologies that are being developed today may make residential on-site heat and power co-generation a reality. Installing small-scale and simple power sources, such as Sterling engines or fuel cells on the customer end of the electrical grid would provide low-cost and more reliable power and heat, saving 40–50% of the primary energy currently used for residential heat and power. With further R&D, thermally activated cooling technologies could expand the potential of distributed generation to capture more savings from cooling end uses.

Air Conditioning

Air conditioning demands the largest percentage of residential electricity in many regions of the country. Overall, air conditioning consumes a total of 190 billion kWh each year or 10% of residential sector electricity use, accounting for more than 2% of total US energy use.

According to 2001 government data, roughly 76% of US households use electric air conditioning regularly. Of these households, around two-thirds use a split-system central air system. Another 15%, largely in cooler climates, use an air-source heat pump. Over one-fourth of households rely on at least one window- or wall-mounted air conditioner for their primary cooling needs.

As the use of air conditioners has increased, equipment efficiency has improved. In 1992, US federal law required that air conditioners and heat pumps meet a minimum of SEER 10. Through the use of more precise refrigerant control valves, variable speed blowers, improved coil design and better motors, central air conditioner efficiency has increased by 22% since 1990, while room air conditioner performance has improved by 12%.

By 2002, the average central AC unit was already well beyond SEER 10, prompting the government to revise the standard to SEER 13, effective 2006. Currently, an array of air conditioners and heat pumps from SEER 13 to 17 are readily available on the market.

Despite the successes of federal regulations, field studies of residential air conditioners and heat pumps have found that most units do not live up to the efficiency levels implied by their SEER ratings. Deficiencies are due primarily to installation and sizing issues as well as the SEER rating method itself, which does not account for regional climatic variations. In the absence of an improved rating system, adding advanced features to produce a single “robust” AC system immune to such shortfalls or undertaking coordinated efforts to improve installation and maintenance could result in 33% energy savings while enhancing health and comfort.

Water Heating

Water heating is the third largest energy end use in the US residential sector and the second largest use for natural gas after space heating. Home water heaters use around 1.15 quadrillion

Btu (quads) of natural gas each year, or roughly 20% of total residential natural gas usage. They also account for 8–9% of residential electricity use (EIA 2006). The average annual energy consumption per unit is difficult to gauge for water heaters due to a lack of comprehensive data as well as variance in type, tank size and fuel source.

Of the 99.9% of households that contain at least one water heater, 38% run on electricity, 55% are gas-fired, and 7% use petroleum gas or distillate fuel (EIA 2006). Conventional storage or tank-type water heaters are by far the most prevalent type of water heating equipment in US homes. Wall-mounted tankless or “instantaneous” water heaters may be 30–35% more efficient than conventional storage water heaters, but they currently represent no more than 2% of the residential water heating market (Energy Trust 2005).

Revised federal efficiency standards for water heaters, effective in 2004, raised the energy factor for a typical 40-gallon gas-fired unit to 0.59 and a typical 50-gallon electric unit to 0.90. The average gas-fired unit in operation today has an EF of 0.55, while the average electric unit has an EF of 0.88 (EIA 2006).

Despite increased domestic standards and the wide acceptance of high-efficiency tankless and solar water heaters in other countries, water heater performance in the USA has not changed dramatically in the past 15 years due to high upfront costs, design constraints, other manufacturer concerns, and a lack of product support. Within the past two years, however, new research initiatives involving manufacturer and utility input in California and at the federal level are beginning to explore other ways to help high-efficiency water heaters penetrate the market.

Several approaches exist for increasing water heater efficiency. In addition to instantaneous water heaters, promising technologies include high-efficiency condensing natural gas water heaters (EF of 0.89), heat-pump water heaters (EF of 2.0 and higher), solar water heaters, and devices that recover wasted heat from water heater and air conditioning systems. Improved distribution systems also present an opportunity for reducing water heating energy use in homes with storage water heaters.

Home Appliances

Home appliances, including white goods, consumer electronics and home office equipment, are responsible for nearly 25% of the energy used in the home and 3.5% of US total primary energy consumption (E-Source 2001). According to the Association of Home Appliance Manufacturers (AHAM), there are over 750 million appliances currently used in US homes and businesses, and shipments of major residential appliances has grown 60% over the past 10 years (AHAM 2003). Electricity is increasingly the dominant energy source for appliances such as ranges and clothes dryers, which used to be predominantly fueled by natural gas. The residential electricity load is also responding to rising use of home office and entertainment equipment and portable electronics.

Refrigerators and Freezers. Food storage appliances, including refrigerators, refrigerator-freezers and freezers, have an installed base in the USA of approximately 200 million units and together consume roughly 195 billion kWh annually or 17% of total residential sector electricity use. Refrigerators (including refrigerator-freezers and compact refrigerators) are the second largest end use for electricity in the home, next to air conditioning. On average, refrigerators that are in use today consume around 734 kWh of electricity per year.

Virtually every US household contains at least one refrigerator, while nearly 20% of homes have a second unit (EIA 2001). Most of these are either top-bottom refrigerator-freezers without an ice-dispenser, or side-by-side refrigerator-freezers including an ice dispenser unit. The use of compact refrigerators as a secondary refrigerator has grown remarkably over the past 10 years, from 11% saturation in 1996 to over 17% today (Appliance Magazine 2006).

Refrigerator efficiency improvements have been largely driven by federal standards over the past three decades, with the help of market transformation efforts and voluntary labeling programs such as Energy Star. Refrigerators sold today use 60% less energy on average than models sold in 1980. Efficiency improvements continue – Energy Star qualified models, which are at least 15% more efficient than the current federal standard, have increased their market share to over 33%, up from 27% in 2000. Other utility promotions and incentive programs have brought to market refrigerators that achieve efficiencies of 23–30% above federal law.

Technical improvements, however, have not offset increases in volume, use of more automated components, and overall refrigerator demand. Recent research shows that watts per cubic foot have been on a steady incline since refrigerators obtained 95% market share in 1957. Since 1980, average volume has increased 13% (Deumling 2004). Meanwhile, according to AHAM data, the number of refrigerator and freezer units shipped to retailers has grown 50% from 8.2 million units in 1993 to 12.3 million units in 2002 (AHAM 2003).

Significant cost-effective savings beyond current federal standards could be achieved either through continued incremental design changes (thicker walls) or major component modifications (such as vacuum panel insulation). By using better components available today, such as a high-efficiency compressors, high-efficiency fan motors for both the evaporator and condenser fans, and adaptive defrost control, a refrigerator 15% more efficient than the 2001 standard would be feasible with an incremental cost to the consumer of $35 (DOE 2005). The same study found that meeting a 25% increased federal standard would require a more substantial re-design, resulting in a much higher incremental cost of over $100.

Cooking Appliances. Over the past few decades, the market for cooking equipment has diversified considerably along with evolving consumer preferences and more advanced technologies. Today's consumers are presented with a greater variety of electric cooking equipment, combination appliances with advanced features, and new cooktop elements and designs. On average, cooking currently accounts for 50% of the natural gas consumed by residential appliances, and it is responsible for 8% of total residential electricity consumption nationwide. (DOE 2007; EIA 2001)

Virtually every US household has an oven and cooktop, either combined in a single range or as separate cooktop and wall oven components. Based on DOE's most recent field usage data, a typical electric range consumes around 510–540 kWh/year, including 275–304 kWh used by the oven and 235 kWh/year used by the cooktop. The most common unit, a gas range with electric ignition, consumes roughly 3 million Btu/year. Gas ranges with standing pilots use twice this amount, roughly 6.4 million Btu. The contribution of standing pilots to national gas use is declining since a 1990 federal standard banned their use on ranges with electric chords. Aside from this ruling, cooking appliance efficiency is so far unregulated in the USA although DOE is currently revisiting the issue.

Since 1990, electric ranges have grown in use relative to gas ranges, now accounting for 60% of the market. Electricity has further taken over the kitchen as microwaves have become nearly as common as ranges. Since penetrating over 50% of the market in the mid-1980s, microwave oven saturation grew to 95% in 2003 and annual shipments have climbed to over 13 million, an 80% increase since 1992 (AHAM 2003).

Perhaps the most notable recent trend in US kitchens, along with microwave use, is an overall decrease in cooking activity. According to a 2001 EIA study, the number of households who reported cooking at least once a day declined four percentage points between 1993 and 2001. In addition to eating out more, people are increasingly relying on smaller food preparation equipment for their daily needs, including rice cookers, toaster ovens, electric grills and coffee makers.

Dishwashers. More than 69 million residential dishwashers are currently installed in US homes, accounting for 2.5% of the total electricity used in the residential sector (EIA 2001). Most dishwashers on the market today consume 350–530 kWh of electricity per year.

The use of dishwashers has grown only slightly over the last 10 years, from a saturation level of 55% in 1996 to roughly 60% today. When coupled with housing growth over the past fifteen years, the number of dishwashers sold has increased more than 44% over the same time frame (AHAM 2003). At the same time, the typical household uses the dishwasher to clean fewer loads per year.

The efficiency of a dishwasher is reported as an energy factor (EF), which takes into account the energy used by both the dishwasher and the water heater. The federal efficiency performance standard of EF 0.46 has been effective since 1993. With an average lifespan of 9 years, this suggests most units currently in operation have an efficiency rating of at least 0.46 to 0.48.

Today, efficiency gains by dishwasher manufacturers have far outpaced federal regulations. By total shipment-weighted averages, dishwashers sold today are 58% more efficient than those sold in 1980 and use on average 28% less energy than the federal requirement (AHAM 2003). These gains are in a large part due to ENERGY STAR labeling and non-regulatory incentive programs that have encouraged manufacturers to market dishwashers with advances that lower hot water use per cycle.

The ENERGY STAR program in particular has had a dramatic impact on the sale of high-efficiency dishwashers over the past 10 years. In 1998 alone, market share of Energy Star qualified dishwashers doubled from 13% to 26%. By 2006, roughly 80% of nationwide dishwasher sales met Energy Star specifications, which are at least 25% more energy-efficient than standard models. These high-efficiency models save on hot water by incorporating improved insulation along with better spray arms, filtering systems, pumps, and motors. Opportunities for enhancing dishwasher efficiency also include improving the electrical efficiency of controls and standby mode consumption. New Energy Star specifications taking effect in 2007 (0.65 EF) should encourage further adoption of these improvements.

Laundry Equipment. About 35 billion loads of laundry are washed and dried annually in the USA, accounting for around 7% of total residential electricity use (EIA 2001). Laundry equipment is now found in around 85% of US households. Overall, sales of washers over the past 15 years have increased roughly 35% while dryer sales are up more than 50% (AHAM 2003). The sale of electric dryers accounts for two-thirds of this growth, while gas dryers have maintained a relatively flat share of the market. Average volume has also risen 18% since 1980 as households wash more clothes per cycle.

Energy savings in laundry equipment is ultimately determined by the amount of hot water used and the amount of moisture removed by the washer during each cycle, which lowers drying time. The average clothes washer in use today (a typical 1999 model) uses roughly 875 kWh of electricity per year, assuming 392 loads per year (AHAM 2003). Water heating accounts for roughly 85–90% of this total.

Revised federal efficiency standards for clothes washers most recently took effect in 2004 with a second tier level scheduled to take effect in 2007. In 2004, Energy Star washers, which average 50% higher efficiency than the current federal standard, accounted for 27% of all sales in the USA. When the new federal standard takes effect, new Energy Star criteria will require a higher MEF and incorporate a water factor requirement for the first time.

Over the past 25 years, washers have seen a 70% gain in efficiency as manufacturers have equipped their units with more rinse options, improved sensors, motors and mixing valves resulting in less hot water used. Units sold today use roughly 18% less energy per cycle on average than the units sold 25 years ago (AHAM 2003). Dryer efficiency has increased with washer efficiency, as drying time is lowered and other components such as automatic dryer shut-off and electric ignition systems are increasingly employed. More advanced technologies determining spin speed and advanced electronic controls continue to advance in international and, to a lesser extent, North American markets.

Residential Lighting

Lighting accounts for roughly 15% of residential electricity consumption, costing each household \$50–\$150 each year and accounting for over 100 billion kWh of electricity (EIA 2001). Replacing the five highest use fixtures in a home with high-efficiency lamps can dramatically cut energy use and costs.

Over 85% of the lamps in US homes are standard, screw-in, incandescent bulbs. An estimated 2.95 billion of these lamps are currently installed in homes across the country, along with another 660 million fluorescent lamps. While the use of incandescent halogen lamps, particularly standing torchiere lamps grew rapidly over the past ten to fifteen years, recent federal standards ban the sale of the most common halogen torchieres which draw 300–500 watts.

Energy use in residential lighting depends on architectural features as well as the type of lighting system installed. Several federal and state incentive programs are currently in place to encourage the purchase of improved fixtures, lamps, sensors and controls. US market penetration of compact fluorescent lamps hovers around 2% (Navigant 2002), but sales have been increasing for over a decade. In California, incentive programs have helped CFLs achieve 5% market share, with a cumulative penetration of over 20% in existing fixtures (Sathaye and Murtishaw 2004).

Despite their inefficiencies, incandescent lamps have maintained a stronghold in the market because of their compatibility with conventional fixtures and control features that have become commonplace. High costs and aesthetic concerns have helped to keep CFLs from gaining wide acceptance. There are several technologies being developed and brought to market today that help improve the versatility and persistence of the CFL. Among the most promising are portable lamps with pin-based CFL fixtures that are incompatible with incandescent bulbs, recessed downlights that are increasingly popular in new homes, and dimming control devices that work with incandescent, CFL and halogen lamps. Because they encourage a wider and more persistent use of CFLs, each of these technologies could present between 60% and 70% lighting energy savings in their respective applications.

Consumer Electronics and Home Office Equipment

A vast array of electronic and home office products are used in US homes, most of which use energy in both standby and active power modes. Efforts to characterize and control energy have until very recently focused on standby power consumption. The average US household continually consumes 50–70 watts of standby and off-mode power, amounting to around 450 kWh per year, or 5% of average residential electricity consumption. VCRs, TVs, and set-top boxes account for over half of this load. More recently, however, the growing use and variety of portable and plug-in electronic equipment has led research to shift toward controlling active mode energy consumption.

An estimated 3.1 billion power supplies currently in use today in the USA account for 3–4% of the nation's annual electricity bill (Foster and Horowitz 2004). Six to 10% of US electricity is converted from high-voltage AC to low-voltage power by external and internal power supplies in electronic appliances and portable tools. Many of these power supplies are only 50–70% efficient, wasting much of their delivered energy as heat while converting high-voltage ac to low-voltage dc power.

Televisions and set-top boxes are becoming an important target for research into active mode efficiency improvements. With virtually all US households owning at least one television and 40% containing two or more, there are an estimated 227 million televisions currently in use. The Natural Resources Defense Council (NRDC) estimates that television usage will grow by 50% over the next 3–5 years. The scheduled 2009 conversion to digital broadcasting is already driving increased sales of high-definition televisions (HDTV) and high-resolution, flat-panel LCD and plasma screens, which can draw considerably more power than conventional analog equipment.

Along with increased television use is a rapidly changing market for set-top boxes, which provide televisions with cable programming, recording options and video game capabilities. Roughly 95% of households use at least one DVD or VCR and 89% also receive cable or satellite television (Ostendorp, Foster and Calwell 2005). Sales of digital video recorders (DVRs) have ballooned over the past few years. Currently installed in 14% of US households, DVR market penetration is expected to reach 50% by 2010.

Cable/satellite boxes and multi-function boxes with recording and high-definition features present tremendous potential for energy savings because they are virtually always on or in ready modes, drawing 10–50 watts at any given time. ACEEE estimates that set-top box energy use accounted for 1.3% of residential electricity use as of 2003 (Amann 2004). If current trends continue, this figure will rise to 4% by 2010.

Personal computers and printers continue to take hold in a growing percentage of households with current saturation at roughly 66% (Appliance Magazine 2006). Residential personal computer sales are currently at 55 million a year, and are poised to surpass sales to the commercial sector in annual growth (Dunn 2005).

Technical options for reducing the energy demand of consumer electronics and home office products include improving the efficiency of internal power supplies and creating more advanced power mode controls so that units spend more time asleep or off. For set-top boxes, these features could be adopted at a modest incremental cost to the consumer. For certain less-demanding appliances such as TVs, VCRs, cordless phones and other portable tools, 1-watt standby power is within reach for many manufacturers. Estimated annual savings varies product to product, but for roughly 21% of common household appliances using standby power, reducing standby consumption could result in 60% per product energy saving, or 49 TWh of total electricity savings by 2020.

For many high-demand products, controlling active power consumption is also within reach. New designs that increase power supply efficiency to 73–95% are already in the market. ENERGY STAR currently provides specifications for computer monitors that are based on active power energy consumption. For TVs in particular, NRDC reports that there is sufficient variation in power usage among products with similar screen size and picture quality to warrant an ENERGY STAR specification based on active power. Cutting television active mode power consumption 25% could save 10 billion kWh of electricity per year in the USA once widely implemented.

Table 19. Options to Improve Residential Building Efficiency By End Use

End Use		% of Total Residential Energy	Technology Options	Savings Potential
Space Conditioning	Walls	51%	• Improved insulation for attics, walls, floors	M
	Windows		• Low-e glazing • Tints • Inert or low-conductance gas fills • Improved weather stripping • Tighter frame design	M
	Roofing		• High-reflectance pigments for standard colored shingles	L
	Space Heating		• High-efficiency condensing gas furnaces advanced furnace fan motors • Reducing duct leakage • Cold climate air-source heat pumps with multiple compressors • Ground-source heat pumps • Boiler controls	H
	Space Cooling		• More precise refrigerant control valve • Improved installation practices • Variable speed blowers • Improved coil design and better motors	H
Water Heating		12%	• Tankless water heaters • High-efficiency condensing natural gas WHs • Heat-pump WH • Solar WH	M
Appliances	Refrigerators and Freezers	12%	• High-efficiency fan motors and adaptive defrost control • Major component modification (vacuum panels)	M
	Dishwashers		• Improved insulation, better spray arms, filtering systems, pumps and motors • Better standby modes	M
	Laundry Equipment		• Washers with more rinse options, improved sensors, motors and mixing valves resulting in less water used • Dryers with automatic shut-off and electric ignition systems. • Advanced electronic controls	M
Residential Lighting		12%	• Pin-based CFLs • Recessed downlights • Dimming control devices • LEDs • Better fixture efficacy	H
Consumer Electronics		10%	• Improving internal power supplies, more advanced power modes to save standby power • Reducing active mode energy consumption of TVs and monitors	M

Savings: L (Low) is <15% of end-use energy; M (Medium) is 15–25%; H (High) is >25%.

Commercial Sector

Building Envelope: Insulation and Glazing

Energy performance in the commercial sector often focuses on improving the efficiency of the heating, cooling or lighting equipment. However, optimizing these systems depends also on the thermal properties of a building's outer shell. Improvements made to the windows, walls, ceilings and roof of a commercial building reduce energy cost while also reducing mold and other moisture problems, equipment breakdown, and discomfort.

Walls. A wide variety of materials are used in the construction of commercial buildings, providing more variance in building shell efficiency than in the residential sector. For instance, many large commercial office buildings are constructed with steel, which can dramatically increase the thermal conductivity of a building's shell without proper insulation. On average, thermal conductivity and air infiltration through walls account for 21% of total heat losses from commercial buildings during heating months (DOE 2005a).

Although insulation upgrades can save considerable energy at relatively low cost in many buildings, commercial building owners tend to focus on equipment upgrades. Over the past 25 years, insulation upgrades have been installed in 5% of the existing building stock. The retrofit rates for lighting and HVAC systems are roughly three times as high (EIA 2003).

Windows. Windows are a major factor in commercial energy use, responsible for 22% of a building's total heat losses in winter and 32% of cooling loads from solar heat gain in the summer. For decades, commercial buildings have incorporated reflective or tinted glass to reduce the solar heat gain attributed to windows. Today, the use of "spectrally selective" glass is becoming more common, allowing for greater use of daylighting techniques which can cut down on electric lighting needs, thereby reducing both electricity use and cooling costs. Around 10% of existing buildings have installed window replacements within the past 25 years, thus capturing savings from window replacements will be a long-term challenge.

Roofs. About two thirds of all commercial rooftops incorporate asphalt shingles or asphalt and gravel layering. Another 20% are surfaced with metal sheeting. Because most commercial roofs are flat or near-flat and have a large surface area, light-colored, "cool" treatments have achieved greater success than in the residential sector. For the average commercial building, roofs account for only 1% of total heat gains during summer months. In colder conditions, however, heat losses through the roof are similar to other buildings, accounting for 12% of the total heating load (DOE 2005a). Cool roofs can reduce building energy use and cut peak cooling demand by 10% to 15% while reducing building contributions to the urban heat island effect.

Air Conditioning

In non-industrial commercial buildings, air-conditioning is responsible for 11% of the total on-site energy use (DOE 2005a). Together, US institutions and businesses consume roughly 1.4 quads of primary energy to cool their buildings (EIA 2006). Based on total floorspace cooled, nearly 40% of this load is used to meet cooling demand in southern states, while another 25% is used in Midwestern states (EIA 2003).

Over 75% of commercial buildings – approximately 57 million square feet of floorspace – have air-conditioning systems. Packaged rooftop air conditioning units are the most common, present in nearly one half of commercial buildings. Another third of the market uses residential-type split-system air conditioners or heat pumps. Most large commercial buildings and campuses depend on a central chiller as part of a “built-up” heating and cooling system. In addition, many large buildings are equipped with more than one cooling system, including 16% that house individual room air conditioners.

Over the past 30 years, new technologies have advanced the performance of air conditioning equipment considerably. Packaged equipment has seen a gradual increase in energy efficiency through federal regulations, industry codes and other efficiency rating systems. Significant advances include better compressors and high-efficiency modulating air handler fans, which boast an estimated 20% market share. Heat pump efficiency has almost doubled through the development of more precise refrigerant valves, variable speed blowers, improved coil design and better motors. (NREL 2001) Variable speed drives that closely regulate chiller pump and air handler operations have also contributed to performance enhancements in built-up systems.

As of January 2006, federal standards for commercial packaged equipment increased from a minimum energy-efficiency ratio (EER) of 8.9 to EER 10.3. Research into high-efficiency rooftop-packaged air conditioners has been popular at the state and federal level. By incorporating advanced controls and integrated economizers to provide up to EER 13 efficiency levels, advanced rooftop units could provide 23% savings in 70% of buildings that already contain a packaged system.

Building Performance

Maximizing energy savings from building envelope upgrades in commercial buildings requires integrating these solutions with better controls for lighting, heating, cooling and ventilation subsystems. For existing buildings, advanced whole-system commissioning strategies have been developed and their adoption is growing. To correct for general performance deficiencies without making capital improvements, retrocommissioning can be a highly cost-effective way to save on energy commonly wasted through simple construction mistakes and sub-optimal operations practices. For relatively new buildings over 100 000 square feet, retrocommissioning usually pays for itself after 1–4 years and results in 10% annual energy savings.

Space Heating

Heating commercial buildings in the United States requires roughly 2 quads of energy each year, 2% of the nation’s overall primary energy consumption. In terms of on-site energy consumed, space heating is responsible for around 20% of the energy used in commercial buildings (EIA 2006).

The type of heating system used in a commercial building depends primarily on the building’s size. Large offices, schools and retail facilities (greater than 50 000 square feet) comprise 5% of the building stock but 50% of the total commercial floor space in the USA (EIA 2003). For most of these large buildings, heat is provided by a “built-up” system that includes a hot water boiler. Rooftop packaged heating and cooling systems provide heat for another third of commercial spaces, commonly in buildings between 5 000 and 50 000 square feet. Another 25–30% of US commercial spaces depend on a residential-type split-system furnace or heat pump.

Natural gas dominates the commercial heating market, used to fuel furnaces and boilers on site in over half of the building stock. Electricity provides for one quarter of on site heating demand, and the remaining segment is split among district heat (steam), fuel oil, and propane.

Over the past 15 years, 25% of commercial buildings have replaced their heating systems. Since 1980, another 10–15% of existing primary heating systems have undergone retrofits (EIA 2003). Optimizing heating system efficiency in commercial buildings depends largely on the size of the building and type of system. Because large buildings produce a lot of heat internally, significant savings are hard to find with upgrades to core heating equipment. Opportunities for savings are often found in the sizing and insulation of air ducts and pipes, the electrical efficiency of fans and pumps, and sophisticated system controls that optimize how heating, cooling and lighting systems are synergized.

In smaller commercial buildings, opportunities for improving core heating equipment are similar to those in the residential sector. Ground-source heat pumps have been more successful in the commercial sector, and they offer energy savings of 37% on average. Despite their good market potential, high installation costs and a lack of informed designers and contractors limit their competitiveness.

Recent advances in distributed power generation have created the long-term potential for small-scale commercial combined heat and power (CHP). By using reciprocating engines, microturbines or fuel cells on site, small-scale CHP can reduce energy costs and primary fuel use while increasing power reliability. Although the technologies are still in the development stage, small-scale CHP could yield 60–70% energy savings with committed government and utility support. For most buildings, savings will be highly dependent on the ability to use waste heat from the power source for other building loads.

Lighting

Commercial lighting accounts for over 3% of total US primary energy consumption, totaling just under 3.5 quads (EIA 2006). In non-industrial commercial buildings, it accounts for nearly a quarter of all on-site energy use (DOE 2005a). According to CBECS (2003), half of America's commercial floorspace remains lit after the space has been closed for the night.

Most commercial spaces depend on several types of lighting, including ambient lighting, task lighting, architectural "mood" lighting, or display lighting. Standard 4' tubular (T8 and T12) fluorescent lamps are the most common variety used in commercial buildings, from offices and retail stores to churches, schools and hospitals. Overall, there are an estimated 1.5 billion fluorescent lamps installed in commercial buildings, supplying 78% of the total light (Navigant 2002).

Incandescent and halogen lamps account for 22% of commercial sector lighting stock. Although they supply only 8% of the light output, they contribute over 30% to the total electricity consumed by commercial lighting. The average installed wattage of each incandescent lamp in commercial spaces is over twice that for fluorescents.

Compact fluorescent and ceramic metal halide lamps are versatile and efficient alternatives to bright halogen lighting for downlights, sconces, wall-washes, and more focused spot-lighting. Ceramic metal halide spot lamps, which currently account for 1% of the commercial lighting market, are offered by all major manufacturers and provide more attractive, warmer light quality than fluorescents.

Excess heat emitted by interior light fixtures is responsible for 42% of a commercial building's required cooling load (EIA 2005a). Thus, using high-efficiency lamps reduces electricity costs from both lighting and cooling.

Several different approaches exist for reducing commercial lighting energy use. Whole-building design approaches reduce the use of light fixtures by increasing the amount of natural daylight in interior spaces. Improved performance of existing equipment and the use of advanced controls are important for existing lighting systems. Just over 1% of commercial buildings currently use an energy management and control system for lighting. In addition to controls, innovative lighting technologies, such as scotopic, LED or hybrid solar lighting, can replace conventional systems or be applied to new construction.

High-efficiency "Super T8" fluorescent systems, which provide an efficacy of 92–95 lumens per watt, have achieved over 2% market penetration in recent years and are heavily promoted by California utilities and preferred under building code regulations. These lamps can provide 27–36% energy savings when replacing conventional T12 fluorescents, the most common commercial lamp type. Advanced lighting controls that can be programmed according to the particular daylighting and occupancy characteristics of different spaces is particularly useful in classrooms, retail, health care and office spaces. Compared to using standard T8 fixtures, fully integrated daylighting controls would add an incremental cost of 50 cents per square foot, with a 46% energy savings.

Hybrid solar lighting, especially useful for low-rise commercial buildings, uses roof-top solar collectors, optical fibers and special luminaires to augment fluorescent lighting systems with direct sunlight. Installing a typical hybrid system costs an average of $4 700, but provides over 50% energy savings. For Sunbelt states, payback time would be a reasonable 4 years, compared to almost double that in northern states.

Water Heating

Water heating uses a considerable amount of energy in the commercial sector. On average, 9% of the energy delivered to commercial buildings is used to heat water. For hotels, hospitals and restaurants, water heating accounts for a much larger share of total on-site energy use, around 20–30%. Nationally, commercial water heating is responsible for a total of 1.06 quads of primary energy each year (EIA 2006).

The market for commercial water heating fuel is about evenly split between electricity and natural gas. Three quarters of commercial buildings with hot water depend on a centralized system with a large boiler and storage tank (EIA 2003). In contrast to single-family homes, commercial-scale central systems provide hot water via a re-circulation loop that continually distributes water to each end use. Heat losses from these pipes into the walls can account for a considerable amount of wasted energy depending on the level of hot water demand in the building. In distributed or "point-of-use" systems, smaller tank-type or instantaneous units are located close to where hot water is needed. Because water isn't heated until there is a demand signal, this system can be more efficient than central systems. Such systems are currently used in 22% of commercial buildings with hot water (EIA 2003).

The market for commercial hot water has not changed much over the years, although federal regulations and promotions have somewhat helped to improve unit efficiency. Several state policies encourage the purchase of high-efficiency and solar water heaters, but market success of advanced commercial units has remained limited, with less than 3 000 units sold per year. For perspective, each year 600 000–900 000 gas and electric resistance units are sold to US businesses.

Commercial heat pump water heaters are one promising high-efficiency alternative to conventional commercial equipment. These units can supply 2.5 times the amount of heat per kWh than most electric resistance units (Sachs 2002). Another key opportunity for cost-effective savings comes from installation of water-saving fixtures and devices, particularly in high water use facilities such as restaurants.

Office Equipment

Office equipment currently consumes 10% of commercial sector electricity according to US federal estimates. With the emergence of the computer and more advanced networking devices, this share has grown. Over the past 10 years, the amount of electricity consumed by office computers alone has doubled, from 0.07 quads to 0.14 quads between 1994 and 2004 (EIA 1996; EIA 2006).

On average, desktop computers require 125–150 kWh per unit per year (Dunn 2005), depending on the capacity of the system, the efficiency of the power supply and the number of hours the machine is left in active, sleep, or standby mode. In most offices, 64% of desktop computers are left on after work-hours, only 6% of which are in sleep mode (Roberson et al. 2004). Along with computers, desktop-derived servers are now commonplace in office spaces for network management. Because these units have large capacities and are often left on 24 hours a day, they can consume 3–5 times the energy of desktop computers.

A typical power supply is 60–70% efficient, wasting 30–40% of its energy as heat. In office buildings, this heat output is a major contributor to cooling loads. In one case study conducted by Ecos Consulting, raising the efficiency of 5 000 desktop computers to 80% saved one organization over $95 000 in energy costs (Dunn 2005).

With 36 million desktop computers and 2.1 million servers added to the commercial sector each year (Dunn 2005), there is substantial opportunity for energy savings. Until recently, efforts to control the energy consumption of office equipment have focused on standby power usage since many electronic appliances spend a majority of their time idle. But as use increases and most office appliances now easily comply with current federal energy use specifications, active mode power specifications are under development.

ENERGY STAR is currently revising its specification for laptops, workstations, desktop computers and desktop-derived servers. Likely to be implemented in 2007, the new specification includes a minimum power supply efficiency of 80% for desktop computers and 75% to 83% for servers. Currently, ENERGY STAR specifies maximum on-mode power usage for monitors only. Qualified ENERGY STAR office products that have low standby power usage advertise an electricity savings in the range of 40% to 60%.

Often computer networks in commercial office buildings use considerably more energy than necessary because the network software being used may not support low-power modes, even when computers are on standby. While many tools are available to control the power used by networked computer monitors, software that helps manage central processor unit (CPU) energy use is not widely available. Incremental savings from CPU management is 100–400 kWh/year.

Table 20. Options to Improve Commercial Building Efficiency by End Use

End Use		% of Total Commercial Energy	Technology Options	Savings Potential
Space Conditioning	Walls	30%	- Improved Insulation	L
	Windows		- Spectrally specific glass	M
	Roofing		- Light-colored "cool" treatments - Upgraded roof insulation	M
	Space Heating		- Large buildings: efficient fans and pumps, systems to synergize heating, cooling and lighting - Small buildings: similar to residential options - Small-scale CHP	H
	Space Cooling		- Better compressors, high-efficiency modulating air handler fans - More precise refrigerant valves, variable speed blowers, improved coil designs, better motors - Advanced controls and integrated economizers for rooftop units - Improved O&M	M
	Ventilation		- Higher efficiency fans and filters, heat recovery	M
Lighting		20%	- Compact fluorescent and ceramic metal halide lamps - Scotopic, LED, "Super T8" fluorescent fixtures - Fully integrated daylighting controls - Hybrid solar lighting	H
Office Equipment		15%	- Both standby and active mode power reductions for computers - CPU management	H
Water Heating		5%	- "Point-of-use" systems - Commercial Heat Pump Water Heaters	M

Savings: L (Low) is <15% of end-use energy; M (Medium) is 15–25%; H (High) is >25%.

REVIEW OF CURRENT AND HISTORIC BUILDINGS ENERGY EFFICIENCY PROGRAMS

The potential for energy savings in the existing buildings sector is large and the opportunities for capturing savings through increased adoption of new and under-utilized technologies and practices are well established. Nevertheless, cost-effective investments in energy-efficiency improvements are often ignored by businesses, governments, and individual consumers. A number of barriers are responsible for the widespread underinvestment in energy efficiency in existing buildings. A great deal of research and deliberation has focused on identifying these barriers and devising ways to address them through policy measures and programmatic initiatives.

A recent IEA project (Prindle 2007) quantifying the effects of market failures on end-use energy consumption summarizes the key barriers to greater investment in energy efficiency as:

- Principal-agent barriers
- Information/transaction cost barriers
- Externality cost barriers
- Other barriers and economic forces

In the existing buildings sector, *principal-agent barriers* are common in lease properties where a split incentive exists between the landlord or the owner's agent (who purchases or specifies what energy consuming equipment will be installed in the building) and the tenant (who typically pays the utility bill). This issue arises in both the commercial leasing market and in rental housing. Similarly, a split incentive exists for homeowners and businesses that do not expect to hold a property long enough to realize the full financial benefit of an investment in energy-efficiency measures. Recent estimates suggest that as much as 50% of residential energy use in the USA is affected by principal-agent barriers (Prindle 2007).

Information/transaction cost barriers arise when the consumer lacks sufficient information or expertise to make purchasing decisions that optimize their overall cost and energy savings. The asymmetry of information available to the consumer versus other market actors can create confusion and distrust thereby discouraging adoption of new technologies or services. Consumers may also face higher transaction costs associated with the additional time, effort, and inconvenience necessary to identify and purchase efficient products and services.

The large environmental and health impacts associated with energy production and transmission lead to large *externality cost barriers* such that the price of energy does not reflect its true cost to society. Addressing this requires broad level policy changes that are beyond the scope of this study, yet these issues need to be kept in mind when considering the benefits accruing from reduced energy consumption.

Several characteristics of the buildings sector result in *other barriers and economic forces* that impede adoption of cost-effective efficiency measures. The building industry is very fragmented making it difficult to identify the appropriate contractor(s) to provide needed services including retrofits that can improve building energy performance. Once improvements are identified, the customer may have to manage the efforts of multiple contractors. In commercial buildings, institutional practices and organizational structures can inhibit investment in cost-effective energy-efficiency projects. The process for approving capital and non-capital (O&M) projects, the methods for crediting energy cost savings within the organization, the level at which decisions are made, and the financial criteria used to judge proposed projects all have an impact on the decision-making process and can result in missed opportunities to invest in cost-effective energy-efficiency projects. In the residential and small business sector, additional cognitive and behavioral barriers including bounded rationality (or "satisficing"), decision-making difficulties, uncertainty and risk aversion, and the value of non-energy benefits can play a role in individual purchasing decisions involving energy-consuming products and services.

Through this project, we looked at policy instruments enacted at the federal, state, and local levels, and energy-efficiency programs operated by utilities, market transformation organizations, manufacturers, and other private program implementers as well as a number of government-sponsored efficiency programs. Using program data, reported results, and evaluation studies, we examined program and policy impacts to determine the effectiveness of each approach in terms of energy savings and longer-term market impacts. Here we provide a brief summary of the major categories of policies and programs reviewed.

Federal Policies

The federal government first enacted broad energy-efficiency policies in response to the energy crises of the 1970s. Among these were a number of far-reaching policy instruments directed toward energy efficiency in residential and commercial buildings. The federal government has had a tremendous impact on improving energy efficiency in the building stock through policies affecting products sold and buildings constructed in the USA and rules influencing the actions of the federal sector itself. Policies reviewed for this project include:

- Appliance and equipment efficiency standards
- Appliance labeling
- Building codes and standards
- Government purchasing and procurement and public sector facility management
- Tax incentives

Each of these policies is discussed in greater detail below, including an overview of policy activity to date and a summary of performance in terms of energy savings, cost-effectiveness, and market transformation effects.

Appliance and Equipment Efficiency Standards

Overview. One of the most effective federal policies by far has been enactment of mandatory minimum standards for appliances and equipment. Standards capture the technical improvements that allow for increased efficiency in some product models and spread those improvements throughout the product category. The least efficient products are eliminated from the market over time.

The federal government first adopted standards through the National Energy Conservation and Policy Act of 1978, however new standards developed under the legislation were quashed by the Reagan Administration. As states increasingly adopted their own standards (see discussion under "State and Local Policies"), interest in uniform federal standards emerged, leading to the adoption of national standards on most major appliances under the National Appliance Energy Conservation Act of 1987 (NAECA). Standards for commercial building equipment were added to federal legislation beginning with fluorescent ballasts in 1988 and a variety of lamps, motors, and commercial heating, cooling, and plumbing products with passage of the Energy Policy Act of 1992. Congress further expanded the scope of the standards program with passage of the Energy Policy Act of 2005 which mandated adoption of standards on an additional 16 products.

Table 21. Products Covered Under EPACT 2005

Product	Effective Date*	Standard
Residential		
Ceiling fan light kits	2007	Packaged with ENERGY STAR v2 screw-in CFLs or meet ENERGY STAR Residential Light Fixture v4 specification. Standard for specialized products determined by DOE by 1/1/07.
Dehumidifiers	Oct. 2007	ENERGY STAR v1 specification
Compact fluorescent lamps	2006	ENERGY STAR v2 specification
Torchiere lighting fixtures	2006	190 W maximum
Commercial		
Air-conditioners and heat pumps (unitary equipment 240–760k Btu/hr)	2010	Capacity — Minimum EER (AC/HP) 65–134k Btuh — 11.2/11.0 135–239 — 11.0/10.6 240–759 — 10.0/9.5 (EER 0.2 lower for units with integrated heating that is not electric resistance) For HP, also 3.2 COP@47°F except 3.3 for 65–134k Btuh equipment.
Clothes washers	2007	MEF at least 1.26 and WF no more than 9.5
Distribution transformers (low voltage)	2007	Meet NEMA standard TP-1-2002
Exit signs	2006	ENERGY STAR v2 specification
Fluorescent lamp ballasts (F34 and F96ES types)	2009	Closes loophole in DOE regulations so that these ballasts will be electronic, like other covered ballasts
Ice-makers (cube type, 50–2 500 lbs/day)	2010	California Energy Commission (CEC) standard, which is almost identical to Consortium for Energy Efficiency (CEE) Tier 1.
Mercury vapor lamp ballasts	2008	Bans sale of mercury vapor lamp ballasts
Pedestrian signals	2006	ENERGY STAR v.1.1 specification
Pre-rinse spray valves	2006	Maximum 1.6 gallon/minute
Refrigerators and freezers (packaged)	2010	California Energy Commission (CEC) standard, which is almost identical to ENERGY STAR specification
Traffic signals	2006	ENERGY STAR v1.1 specification
Unit heaters	Aug. 2008	Must be equipped with an intermittent ignition device and have power venting or an automatic flue damper

* Effective in January unless otherwise specified
Source: Nadel 2005

Performance. NAECA directs the US Department of Energy (DOE) to periodically review and revise existing standards. To date, DOE has revised standards on more than a dozen products, including multiple revisions of the refrigerator and clothes washer standards. Nevertheless, DOE has fallen woefully behind schedule on its standards revision responsibilities. Despite these lags, the standards program has been one of the most successful strategies for improving efficiency in the US building stock. Table 22 summarizes energy savings and carbon reductions from standards adopted to date. Standards have also proven to be an extraordinarily cost-effective policy instrument. With cumulative consumer savings of $234 billion through 2030, standards enacted to date have a benefit-cost ratio of approximately 3.0 to 1.0; consumer savings outweigh government expenditures on the program by more than 2 000 times (Nadel et al. 2006; Kubo, Sachs and Nadel 2001). This broad-based policy has yielded very large savings since the first federal standards were adopted in 1987; revised standards and newly adopted standards on an expanded list of products promise even greater savings over the coming years.

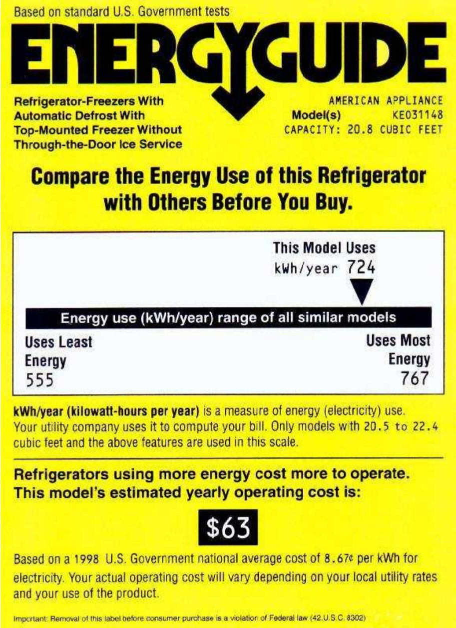
Table 22. Overall Savings from US Appliance Standards

Standards (Year Enacted)	Electricity Savings (TWh/yr)			Primary Energy Savings (Quads/yr)			Carbon Reduction (MMT)		
	2000	2010	2020	2000	2010	2020	2000	2010	2020
NAECA (1987)	8.0	40.9	45.2	0.21	0.55	0.61	3.7	10.0	10.1
Ballasts (1988)	18.0	22.8	25.2	0.21	0.27	0.29	4.4	5.0	5.0
NAECA updates (1989–91)	20.0	37.1	41.0	0.23	0.43	0.47	4.8	8.1	8.1
EPAct (1992)	42.0	110.3	121.9	0.59	1.51	1.67	11.8	27.5	27.9
NAECA updates (1997–2001)	0.0	42.0	107.7	0.0	0.5	1.19	0.0	10.4	23.4
EPAct 2005	0.0	14.7	53.0	0.0	0.21	0.65	0.0	3.7	11.5
TOTAL	**88**	**268**	**394**	**1.2**	**3.5**	**4.9**	**25**	**65**	**86**
% of projected US use	2.5%	6.9%	9.1%	1.3%	3.1%	4.0%	1.7%	3.6%	4.4%

Source: Nadel et al. 2006

Appliance Labeling

Overview. The Energy Policy and Conservation Act of 1975 required the US Federal Trade Commission (FTC) to develop a labeling program for home appliances. In 1980, the EnergyGuide label (Figure 20) first appeared on refrigerators, freezers, dishwashers, clothes washers, room air conditioners, storage water heaters, and furnaces. The program has since been expanded to cover central air conditioners, heat pumps, pool heaters, lighting products, plumbing products, and other types of water heaters. The label provides comparative information on the energy use or efficiency of competing models along with estimated annual operating costs for the white goods categories covered. Manufacturers are required to ship labels with each of their products and retailers are required to display the label on products showcased on the sales floor.



Based on standard U.S. Government tests

ENERGYGUIDE

Refrigerator-Freezers With
Automatic Defrost With
Top-Mounted Freezer Without
Through-the-Door Ice Service

AMERICAN APPLIANCE
Model(s) KE031148
CAPACITY: 20.8 CUBIC FEET

Compare the Energy Use of this Refrigerator with Others Before You Buy.

This Model Uses
kWh/year 724

Energy use (kWh/year) range of all similar models

Uses Least Energy 555

Uses Most Energy 767

kWh/year (kilowatt-hours per year) is a measure of energy (electricity) use. Your utility company uses it to compute your bill. Only models with 20.5 to 22.4 cubic feet and the above features are used in this scale.

Refrigerators using more energy cost more to operate. This model's estimated yearly operating cost is:

$63

Based on a 1998 U.S. Government national average cost of 8.67¢ per kWh for electricity. Your actual operating cost will vary depending on your local utility rates and your use of the product.

Important: Removal of this label before consumer purchase is a violation of Federal law (42.U.S.C. 8302)

Figure 20. U.S. EnergyGuide Label

Performance. The US experience with appliance labeling has been mixed. Although the distinctive yellow label is widely recognized as a source for energy use information, research has demonstrated a number of problems limiting use and effectiveness of the label (Thorne and Egan 2002). The US label has not had the same impact on the efficiency of products available and sold as labeling programs used in other regions including the European Union, Australia, and Thailand. The FTC is currently considering changes to the US label to improve its effectiveness; a final rule outlining any changes to the labeling program is expected in August 2007. ACEEE estimates savings from an improved label of roughly 0.25 quads per year once the appliance stock has turned over (Thorne and Egan 2002).

Building Codes and Standards

Overview. The greatest impact of building codes applies to new construction; however codes also require that additions and significant renovations to existing buildings meet minimum code requirements. Although specific energy codes for private buildings are enacted at the state level in the USA (see discussion under “State and Local Policies” below), the federal government plays an important role in stimulating the adoption and effective implementation of state-of-the-art energy-efficiency codes as instructed by the Energy Policy Act of 1992. This legislation also directs the Department of Energy to promulgate energy codes for federal buildings and assist federal agencies in implementing them.

Performance. DOE’s Building Energy Codes Program is engaged in activities to support code efforts around the country, working with a broad range of stakeholders. Key activities include:

- Support development of improved national model energy codes for residential and commercial buildings in conjunction with the International Code Council, the American

Society of Heating, Refrigeration, and Air-Conditioning Engineers, the Illuminating Engineering Society, and others
- Development of compliance tools and materials, including the widely used REScheck and COMcheck code compliance software
- Financial and technical assistance for state code adoption, implementation, and enforcement efforts
- Development of building energy codes for the Federal sector

DOE estimates energy bill savings of $1 billion per year as a result of the Building Energy Codes Program. Estimates of the proportion of these savings resulting from code-compliant renovations and additions to existing buildings are not available.

Government Purchasing and Procurement and Public Sector Facility Management

Overview. The government has also instituted policies to improve the efficiency of federal facilities. The federal government is the largest single energy user in the United States, spending over $4 billion in energy costs for federal buildings and facilities in 2003 (DOE 2005a). Government purchasing and procurement efforts establish recommended, and in some cases mandatory, specifications for federal purchases which total over $10 billion a year for energy-using products and services (FEMP 2006). The Federal Energy Management (FEMP) Program develops recommended product specifications, produces lists of qualifying products, and provides guidance to government procurement officials in all federal agencies. The Agency also administers provisions of the Energy Policy Act of 2005 requiring government agencies to purchase ENERGY STAR-qualified products and oversees implementation of Executive Order 13123 calling for reduction of federal buildings energy use by 35% from 1985 levels by 2010 and 13221 requiring federal agencies to seek out products with low standby power consumption. Through these efforts, the federal government is able to use its size to drive the market for more energy-efficient products.

Performance. In its most recent annual review highlighting its achievements, FEMP reported a 0.9% decrease in buildings and facility energy use in FY2003 relative to FY2002 performance – a one-year savings of $38.4 million and a reduction in buildings energy intensity of 24.8% in 2003 relative to the 1985 baseline, a significant step toward meeting the goals of Executive Order 13123 (DOE 2005a).

Tax Incentives

Overview. Over the past three decades, the federal government has offered a number of relatively short-term tax incentives to consumers, businesses, and manufacturers with the goal of stimulating the market for high-efficiency appliances, equipment, and building improvements. During the 1970s, incentives were made available for a handful of relatively conventional energy-efficiency measures. With the Energy Policy Act of 2005, Congress enacted a new set of tax incentives worth more than $2 billion. Unlike the earlier tax incentives, these manufacturer and consumer tax incentives cover a number of advanced energy-saving technologies and practices with the goal of stimulating the market for high-efficiency appliances, equipment, and building improvements. One major drawback is that the tax incentives are only available over the two-year period from 2006–2007; Congress is already under pressure to extend many of the provisions.

Performance. Although the 1970s-era tax credits were widely subscribed, costing the US Treasury nearly $10 billion in lost revenues, energy savings were modest. Research demonstrated a high level of free-ridership and limited impact in stimulating technological innovation (Geller

1999). For incentives in effect for 2006–2007, estimated annual savings are expected to reach 0.5 quads in 2020 (approximately 0.8% of US energy use) with cumulative savings through 2020 totaling 2.9 quads (Nadel 2005).

State and Local Policies

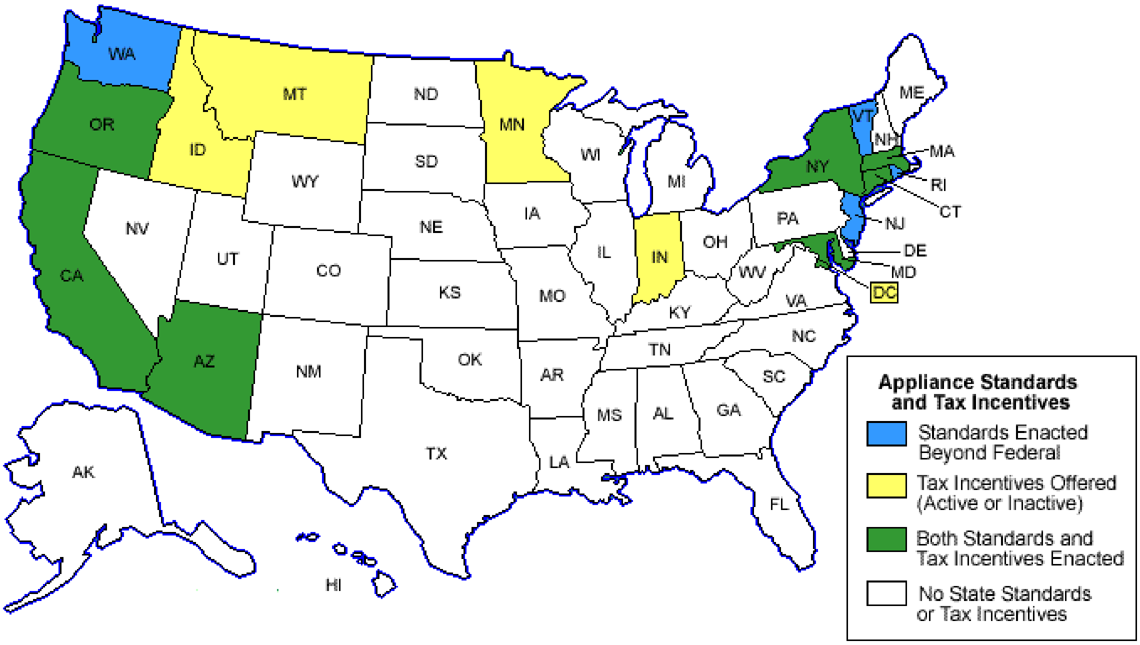
State and local governments have also been active in promoting improved energy efficiency through policy instruments – in many cases the same types of policies used at the national level. While individual state efforts cannot compare with the impact from federal policies, successful approaches first tried at the state and local level have been adopted at the federal level. The state and local policies covered include:

- Appliance and equipment efficiency standards
- Building codes and standards
- Government purchasing and procurement and public sector facility management
- Funding of public benefit programs/activities
- Tax incentives
- Existing building benchmarking

Appliance and Equipment Efficiency Standards

Overview. State action on appliance efficiency standards pre-dates federal standards. States first began setting minimum efficiency standards for products sold or installed in state in the mid-1970s. Action at the state level led to manufacturer support for the first federal standards in the 1980s. States remain free to set minimum efficiency standards for products that are not regulated at the federal level and to seek exemption from federal standards in cases where the state has a compelling reason to adopt stronger standards. The past few years have seen the resurgence in standards activity at the state level. A total of 10 states have passed standards on a wide range of products; a number of these standards were adopted at the federal level with passage of the Energy Policy Act of 2005. Map 1 shows states which have enacted standards that go beyond federal policy for at least one product. States, most notably California, are continuing their efforts to identify opportunities for further savings from appliance standards and to enact minimum standards for additional products.

Performance. Additional standards now under consideration in several states would yield annual energy savings of more than 641 trillion Btu in 2020 growing to more than 1.0 Quad in 2030 (Nadel et al. 2006). As noted above, state standards have played a critical role in garnering support for new federal standards, leveraging much greater savings.

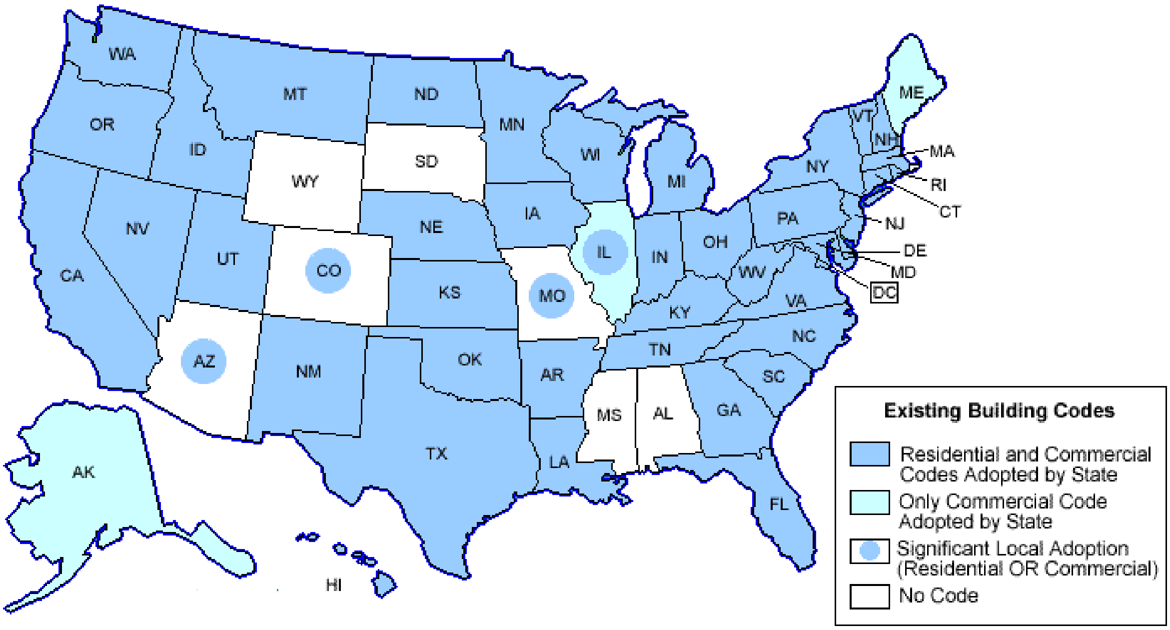


Map 1. States Which Have Implemented Efficiency Standards and/or Tax Incentives for Efficient Equipment and Upgrades

Building Codes and Standards

Overview. As noted above, states are responsible for enacting specific energy codes for residential and commercial buildings. States which have adopted either residential or commercial building codes are shown in Map 2. While building codes generally apply to additions and major renovations of existing buildings, the bulk of the energy savings from codes are found in new construction. To improve the efficiency of the existing stock of single- and multi-family homes, a handful of cities and states have enacted residential energy conservation ordinances (RECOs) and weatherization standards requiring homeowners and landlords to implement specific, low-cost efficiency measures at the time a property is sold or substantially renovated. Although the requirements are typically much less stringent than building codes for new construction, estimated energy savings for homes subject to RECO improvements are approximately 15% (Thorne 2001). Similar commercial energy conservation ordinances have been enacted in two US cities.

Performance. Data on energy savings associated with code requirements on new additions and major renovations to existing buildings are not widely available. However, anecdotal evidence on the enforcement of energy codes for these projects suggests that codes have had a limited impact on improvements in the existing buildings sector. RECOs, weatherization standards, and CECOs can complement energy codes and may be easier to enforce, but their limited adoption to date has kept their overall impact small.



Map 2. States Which Have Adopted Building Codes, Residential or Commercial

Government Purchasing and Procurement and Public Sector Facility Management

Overview. Like the federal government, states and municipalities have taken steps to reduce their own energy use through government purchasing and procurement policies and the use of performance targets for existing buildings. A number of states and municipalities have established financing mechanisms to help fund building upgrades and taken additional steps to ensure adequate staffing levels, technical assistance, and staff training to make the most of their purchasing, procurement, and building performance efforts.

Performance. The benefits to state and local governments vary depending on the types of programs and their level of investment. The opportunity in these facilities is tremendous with many state programs realizing savings of 20% in existing buildings. State buildings alone account for 5% of total US non-residential floorspace. Energy savings of 20% in these facilities would yield an overall reduction in non-residential building energy use on the order of 1%. In addition, these efforts not only save public dollars for core government missions, they can also promote local markets for energy-efficient products and build local capacity for energy-efficiency services.

Tax Incentives

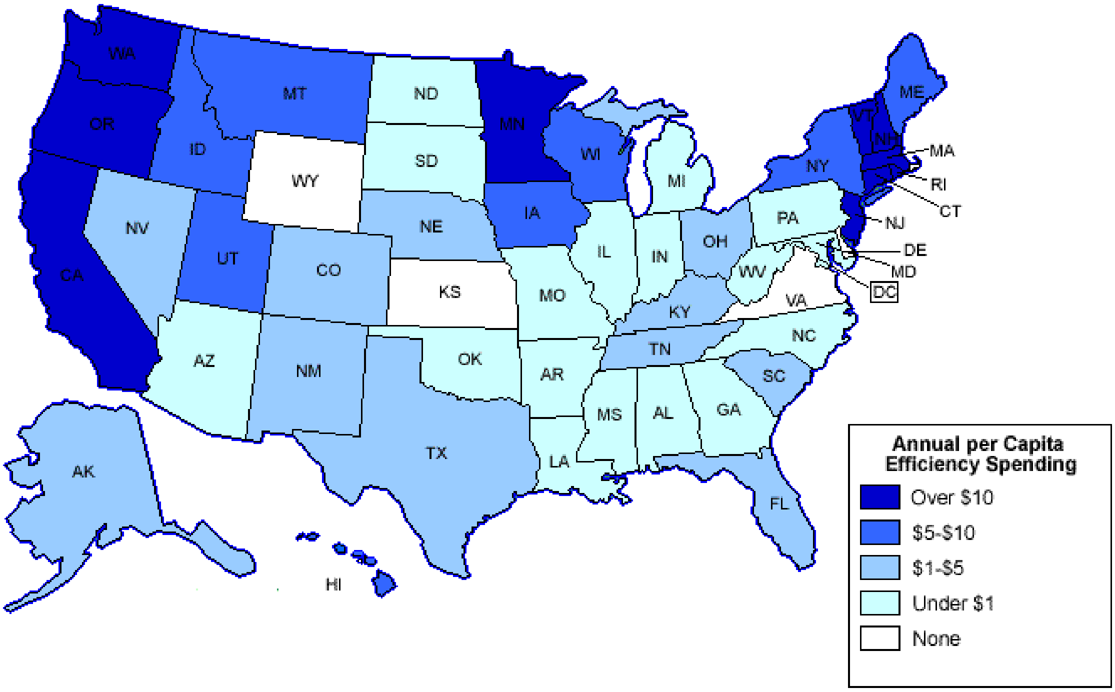
Overview. State governments have also instituted a variety of tax incentive measures to encourage consumers and businesses to invest in energy efficiency. The measures vary from state to state and include deductions or credits on state income taxes and elimination of state sales taxes on qualifying products. Oregon offers the longest-running and most comprehensive state tax incentive program in the USA, other states including California, Connecticut, District of Columbia, Hawaii, Idaho, Indiana, Maryland, Massachusetts, Montana Minnesota and New York have offered tax incentives for efficient technologies (including appliances, equipment, and building shell improvements) in recent years (note that some policies are now inactive). These states are shown in Map 1 alongside states that have been active in appliance standards.

Performance. Given its long-term involvement with tax incentives, Oregon has the most detailed information on the impact of a statewide tax incentive program. As of 2003, Oregon's programs had saved approximately 530 million kWh of electricity and 580 billion Btu of natural gas (Prindle et al. 2003). Scaling these savings up for an average size state would yield about 60% greater savings.

Funding of Public Benefit Programs/Activities

Overview. As the US utility industry faced a wave of restructuring through the 1990s, investments in ratepayer-funded efficiency programs dropped dramatically from a high of $1.8 billion in 1993 to about $900 million in 1998. Recognizing the ongoing need for these programs, many states have established new mechanisms for funding efficiency programs. The potential for expanded programs in additional states or adoption of a national public benefits fund is tremendous. Map 3 shows how states compare in terms of per capita efficiency funding, from York and Kushler (2005).

Performance. The adoption of "public benefits funds" (also referred to as "systems benefits funds," "public goods charges," or "systems benefits charges") together with renewed support for utility rate-payer funded programs has led to a rebound in efficiency program spending to a total of $1.35 billion in 2003 (York and Kushler 2005). Savings from these programs amounted to 1.9% of national electricity sales in 2003; however, the benefits are not evenly distributed. Twenty states account for 87% of the nationwide energy savings total.



Map 3. Annual per Capita Efficiency Spending by State (2004 data)
Source: York and Kushler (2005)

Private Sector Initiatives

Private institutions have sponsored a wide variety of energy-efficiency initiatives targeting residential and commercial buildings. Program sponsors include utilities, independent non-profit organizations, quasi-governmental agencies, manufacturers, and others. These programs can serve to complement government policies or to drive adoption of updated codes, standards, and procurement practices. The types of private initiatives reviewed for this study include:

- Resource acquisition programs
- Market transformation initiatives
- Manufacturer-based programs
- Peak load/demand response programs

Resource Acquisition Programs

Overview. Under the rubric of demand-side management, utilities began to operate resource acquisition programs as a way to eliminate or delay the need for additional electric generation capacity. A typical resource acquisition program offers financial incentives – often in the form of customer rebates – for purchase of high efficiency products and equipment. Common program targets include commercial lighting and HVAC equipment and residential appliances. Billions of dollars were invested in these programs in the 1980s and 1990s. While these programs are effective in securing energy savings for the sponsoring utilities, they do not include mechanisms to ensure that customers continue to purchase high efficiency products in the absence of program incentives or retailers and distributors continue to stock these products once the incentives are phased out. In the wake of capacity constraints and other challenges, there has been a resurgence of investment in resource acquisition programs in the years since 2003 as the value of these programs in a comprehensive energy savings and peak load reduction strategy is recognized.

Performance. A recent study of resource acquisition programs from around the country demonstrated typical program energy savings on the order of 1% of utility sales and demand reductions of 1% of peak load (Cook 2007). Greater savings can be expected in areas where greater investments are made in resource acquisition programs.

Market Transformation Initiatives

Overview. In response to the shortcomings of resource acquisition, a number of utilities and other efficiency organizations began to develop and implement market transformation initiatives designed to create lasting changes in the market for energy-efficient goods and services; changes that would persist after incentive programs were discontinued. To meet these goals, market transformation programs target all aspects of the product cycle, working with manufacturers, distributors, installers and other contractors, retailers, and consumers. Typical program activities include information and education campaigns, technical assistance and training programs for retailers and contractors, manufacturer and retailer incentives, financing assistance, customer rebates, and performance contracting, among others.

Performance. The impacts of market transformation can be hard to measure. The number and variety of initiatives that have been implemented around the country make it difficult to compile an aggregate estimate of energy savings. Individual programs have had varying degrees of success. One indicator of overall success is the adoption of new or more stringent mandatory energy-efficiency standards and building codes at the efficiency level first targeted by market transformation programs. Another is the widespread adoption of a technology or practice in response to market transformation activities. The Golden Carrot refrigerator program is a good example of successful market transformation. This comprehensive effort combined R&D, manufacturer incentives, and procurement activities toward significant improvements in refrigerator efficiency. Once the feasibility of these new levels had been demonstrated, the savings were captured through tighter efficiency standards. Likewise, efficiency improvements targeted through market transformation have been cemented in standards for traffic signals, motors, HVAC equipment, clothes washers, and many other products. Still, market transformation can take years and savings can be hard to attribute. More and more, program implementers are using market transformation as a long-term strategy to complement resource acquisition.

Government Programs

The federal government, often in partnership with states and other entities, administers a number of other programs to promote energy efficiency. Examples include:

- ENERGY STAR® products and buildings
- low-income weatherization
- Partnerships for Home Energy Efficiency

ENERGY STAR®

Overview. The ENERGY STAR product labeling and building performance programs offer an easily recognizable symbol for consumers to identify energy-efficient products, while providing valuable tools, training and skills to contractors serving the residential and commercial buildings market, encouraging manufacturer investments in new technologies, and providing a common platform for the many agencies and organizations promoting energy efficiency at the federal, state, and local level. US EPA and DOE share responsibility for administration of the program.

Performance. In 2005, purchase of ENERGY STAR-qualified products and services yielded savings of 150 billion kWh (roughly $12.6 billion dollars in energy savings), double the program savings from 2000, along with 28 GW of peak power reductions. Cumulative benefits of the program from 1993 through 2015 (for ENERGY STAR activity through 2005) are estimated to total more than $125 billion (EPA 2006b). EPA anticipates program savings to double again over the period from 2005 to 2010.

Low-Income Weatherization

Overview. Through the low-income weatherization program, DOE works with state and local agencies to improve the efficiency of the existing housing stock, helping low-income residents save money while making their homes safer and more comfortable. Weatherization funds are allocated to the states which then administer programs, typically working with local contractors and/or non-profit organizations to conduct the weatherization upgrades.

Performance. Overall, the weatherization program meets its targets in terms of the number of homes weatherized and the amount of money invested in each home. Since its inception in 1976, the program has weatherized approximately 5.5 million homes with average energy savings of 30% per home, translating into energy bill savings of roughly $350 per year for residents (DOE 2007). However, the effectiveness of the program varies widely from state to state. The last comprehensive evaluation of the program was conducted in 1989. Since that time, the program has changed considerably. A large-scale evaluation is planned for 2007.

Partnerships for Home Energy Efficiency

Overview. In 2005, the Partnerships for Home Energy Efficiency was launched to coordinate the efforts of DOE, EPA, and the Department of Housing and Urban Development (HUD) with the goal of saving 10% or more of energy use in US homes over the next 10 years. The agencies will work together to improve coordination of existing programs and explore new opportunities for collaboration.

EFFECTIVENESS OF VARIOUS PROGRAMMATIC TYPES

As noted throughout this report, a wide variety of programs and policies have been implemented around the USA over the past three decades. Measuring effectiveness of these initiatives is a challenge, as there are many different drivers for the initiatives, and different perspectives support different goals and objectives. On some level, ongoing funding and support for a given policy or program is an indicator of its effectiveness, but this project has attempted to assess the effectiveness in a more systematic manner.

While there are a range of specific effectiveness and cost-effectiveness analyses for certain types of initiatives, particularly utility DSM programs and appliance standards projects, very little work has been done to holistically review a wide portfolio of different programs and policies toward recommending an ideal overall portfolio of initiatives. The most comprehensive review done to date was a 2004 report by Resources for the Future (RFF), "Retrospective Examination of Demand-Side Energy Policies" (Gillingham et al 2004). In that review, the authors describe well the challenge in reviewing effectiveness: "Assessing the overall and comparative effectiveness and cost-effectiveness of the collection of energy conservation programs reviewed here is a nearly impossible task given the limitations of existing information and the incompatibility of data from different programs."

Despite these challenges, the RFF report does attempt to distill down the various data sources into a summary of what has been achieved. Table 23 is based on their summary of all available data, where they state "…the effectiveness and cost-effectiveness picture for energy conservation programs is like a puzzle with many missing pieces."

Table 23. Summary of Estimates from Existing Studies of the Effects of Energy-Efficiency Programs in 2000 (adapted from Gillingham et al. 2004)

Program	**Energy Savings (quads)**	**Costs (billion $2002)**
Appliance Standards	1.2	$2.51
Utility DSM	0.62	$1.78
Energy Star	<0.93	$0.05
DOE Rebuild America	0.01	-
Weatherization Assistance Program	0.09	$0.14
Federal Energy Management Program	<0.07	$0.025
Total (includes some additional programs not aimed toward buildings)	<4.1	

The RFF study found that the bulk of savings to date come from appliance standards and utility DSM programs. The total estimated energy savings of 4.1 quads, when compared to the total building sector consumption of approximately 37 quads, suggests that the programs saved about 12% of residential consumption.

A big challenge in understanding overall effectiveness of the menu of policies and programs, as well as the relative effectiveness of different initiatives, is estimating what would have occurred in the absence of any of these programs. Additionally, ascribing attribution for savings to one initiative or another, when multiple programs or policies might be aimed toward a given end use or technology, presents a major challenge. Studies by the California Energy Commission and the Northwest Power Planning Council have made estimates of savings from utility programs versus codes and standards; no similar analyses have been done to estimate or attribute savings from the range of initiatives in place around the country.

The US Environmental Protection Agency (EPA) prepared a "Clean Energy-Environment Guide to Action: Policies, Best Practices, and Action Steps for States," intended as guidance for states considering new policies toward clean energy (EPA 2006a). In this report, EPA reviewed a range of policies and selected four "energy efficiency actions" for states to take based on the proven effectiveness and successful implementation by a number of states. The four policies that are reviewed in detail, with recommendations for implementation by states, are:

- Energy efficiency portfolio standards
- Public benefits funds for energy efficiency
- Building codes for energy efficiency
- State appliance efficiency standards

For utility DSM programs, a range of detailed reviews have been conducted in an effort to maximize the benefits gained from growing DSM program expenditures. With programs expanding significantly in California in recent years, the utilities there commissioned a "National Energy Efficiency Best Practices Study," which aimed to "develop a comprehensive and comparative understanding of energy efficiency program efforts throughout the United States" (Quantum Consulting 2004). The Best Practices Study reviewed program activity, organized around "Program Area Reports." Each program area report presents detailed comparative analyses of benchmarked programs and identification of best practices, associated rationales, key program category-specific issues, and lessons learned.

Effectiveness Comparison and Indicators

In reviewing the effectiveness of initiatives toward improving the energy efficiency of existing buildings, there are two principal indicators that seem to summarize the overall impacts of the policy or program: the amount of energy saved and the degree of market transformation that they cause. Each of these can also be further broken down into additional sub-indicators.

The "energy saved" indicator can be broken down into four metrics:

- The magnitude of the energy savings. It is nearly impossible to assign defensible, quantitative results to the indicators, so we present a range from "very high" (VH) down to "low" (L).
- The persistence/permanence of the savings. How lasting are the effects of the initiative, and is there likelihood for a reversal of the impacts?
- The savings to date from the initiative, and remaining savings potential.

Similarly, the market transformation effects can be measured by three subjective metrics: the ability to drive innovation in the targeted sector or technology; the spillover, or "free drivership" effects, where the initiative has effects beyond the specific intervention that is targeted; and, the potential for backsliding, or reversal of the progress once the intervention is stopped or removed.

It is difficult to view or measure the effectiveness of initiatives standing alone; it is really the mix of initiatives that pushes both energy savings and market transformation effects. For example, the magnitude of energy savings from product efficiency standards is very high, though product standards might remain stagnant and have little remaining efficiency potential without other market transformation programs driving innovation so that new, dramatically more efficient products come into the market that can eventually be considered for minimum standards. Similarly, a number of different types of initiatives feed into utility and other public benefit programs, so that the large amounts of funding available for these programs can be most effectively targeted to deliver significant energy savings and market transformation effects.

Table 24. Energy-Efficiency Initiatives and Indicators of Effectiveness

Initiatives	Energy Saved			Market Transformation Effects		
	Magnitude	Permanence/ Sustainability	Remaining Savings	Drive Innovation	Replication/ Free Drivership	Potential for Backsliding
Federal Policies						
Equipment standards	VH	VH	H	M	L	L
Building codes/regulations	H	H	H	M	M	M
Government purchasing, procurement, facility mgmt	M	M	M	M	M	M
Tax incentives	M	M	H	H	H	M
Research & Development	M		H	H	L	L
State and Local Policies						
High Level Policy Goals	H	H	H	H	M	M
Building codes/regulations	VH	H	H	H	M	L/M
Equipment standards	H	M	M	M	H	L
Funding of public benefits programs/activities/ Demand Side Resource acquisition	VH	H	VH	M	M	M
Government purchasing, procurement, facility mgmt	M	M	M	M	M	M
Tax incentives	M	L	H	M	H	M
Programs						
Product Replacement Incentives:						
– Independent programs	H	M	H	M	L	H
– Coordinated efforts	H	H	H	H	H	M
Market Transformation Initiatives:						
– Information/Education	H	L	H	L	M	M
– Training	M	M	H	L	M	M
– Manufacturer/Retailer incentives	M	M	M	H	M	M
– Golden carrot programs (combined R&D, incentives, and standards)	H	VH	H	H	M	L
– Financing assistance	L	M	M	L	L	M
– Performance contracts	H	M	H	L	L	M
Manufacturer Programs	L	M	M	H	M	M
Peak Load/ Demand Response	L	L	M	M	L	M
Government Programs						
Energy Star	H	M	M	M	H	M
Weatherization	H	M	H	M	L	M
Partnerships for Home Energy Efficiency	M	M	H	M	M	M

Notes: VH = very high; H = high; M = medium; L = low

Potential New Policies and Measures to Improve Energy Efficiency in Buildings

Drivers for New Policies

There has been a wide range of policy and programmatic activity in North America in recent years to address energy efficiency in existing buildings. Moving forward, new and changing drivers are encouraging a greater level of interest in improved building energy performance. The emergence of new drivers highlights the need for a different set of policies and actions that build on tried-and-tested approaches combined with promising new policies and measures. Chief among these new and evolving drivers are:

- Increasing concern over global climate change
- Greater emphasis on demand reduction in light of energy supply and capacity constraints
- Societal trends toward an expectation of greater “creature comforts” and amenities
- Significant progress addressing the energy efficiency of building subsystems and specific end-use technologies

Each of these drivers points to potential directions for new policies and measures. Growing climate concerns lead to a greater emphasis on reducing overall energy consumption rather than a sole focus on improved efficiency. As such, new policies must address broader societal trends such as population growth, development patterns, home (and household) size, geographic distribution, etc. Despite the improvement in energy efficiency in specific products and end uses, the total energy use in buildings in the USA has grown significantly over the past two decades. The energy use in residential buildings has grown from 8.9 to 10.4 quads during the period from 1985 to 2002, with the energy intensity of residential buildings improving by 8% over the period (the number of households in the country grew by over 24%). Commercial buildings have become significantly more energy intensive over the same period, with energy intensity increasing by 12%. As a result, total commercial sector energy consumption was more than 50% higher in 2002 than it was in 1985 (PNNL 2004). As the North American economy evolves and becomes increasingly service-driven, more and more GDP flows through commercial buildings, including a variety of new electrically intensive IT-based equipment and the added air-conditioning needed to remove added heat from this equipment and maintain desired comfort conditions.

Policies and programs designed to improve the efficiency of a given technology or end use have been successful in moving the market toward more efficient products. However, if overall energy use reduction and carbon emission constraints are the goal then effectiveness measures need to focus more on energy intensity, or total energy use per household or unit of commercial building floor area. With average house size growing, and the addition of lots of new electronic equipment in commercial buildings, there has been less progress toward this type of effectiveness metric: improving the overall energy intensity of the standard household or commercial building. Newer whole building approaches are a good start toward this type of metric, though these programs are relatively early in the maturation cycle.

Pressure on energy supplies and increasing capacity constraints require a greater attention to peak demand reduction in addition to energy efficiency and overall reductions in energy consumption. New policies and programs must address these concerns through innovative approaches to load management, ideally in conjunction with efficiency programming.

Great progress has been made in improving the efficiency level of specific technologies and end uses (e.g. typical refrigerators now use around 25% of the energy of an average early 1970s model, and commercial lighting systems provide much higher efficacy when measured in lumens of light output per watt input). It is only in recent years, though, that there has been more focus on systems and "whole building" approaches, both for the residential and commercial buildings sectors. Comprehensive whole building approaches encourage the adoption of a wider set of energy savings measures and can often reap interactive effects that aren't achieved from single technology-based upgrades.

There are many reasons that energy use is growing despite the improvements in efficiency in specific technologies. There is a wider variety of new electric appliances in use in buildings now than twenty, or even five, years ago. Many US households have dramatically more consumer electronics; the growth of new electronic entertainment devices continues to grow and is not expected to slow down in the near future. The saturation of air conditioning equipment also continues to grow, as consumers can afford lower cost comfort systems that improve their quality of life. As average house size has increased, the number of refrigerators and other energy-using products in the home has also grown. For example, more than 20% of US homes now have more than one refrigerator; wine chillers and other specialty appliances are increasingly common.

In commercial buildings, the intensity growth is driven both by increased use of electronic equipment (computers, printers, and a variety of other systems) along with trends toward more sophisticated ventilation and space conditioning systems that are more energy intensive. In most regions of the USA, only a small percentage of new commercial construction is completed with operable windows for ventilation; standard practice now includes ventilation systems that consume significant electricity to move air (or other heat transfer fluids) as well as more energy for heating and cooling spaces.

The recognition that a lot of potential for savings exists has led to some new initiatives. In California, which often serves as a model for other states and eventually the federal government, an effort has been underway over the past few years to examine potential strategies to capture the remaining energy savings potential. A variety of new initiatives have been proposed and state regulatory policies have provided significant funding for programs to drive these initiatives.

New Initiatives Toward Existing Buildings Energy Efficiency

New California Initiatives Targeting Existing Buildings

The California State Legislature (through Assembly Bill, or AB, 549, passed in 2001) directed the California Energy Commission (CEC) to "investigate options to reduce wasteful peak load energy use in California's existing residential and nonresidential buildings." Following a three year investigation period, the CEC published the Commission Report "Options for Energy Efficiency in Existing Buildings" in December 2005 (CEC 2005), which included a number of recommendations and strategies to increase energy efficiency in existing buildings in the State. As noted in the Executive Summary of the Commission Report:

> *"The strategies recommended in this report ... aim to fill 'gaps' identified in <current> efforts, focusing on the times – or 'trigger points' – that are the most likely opportunities to effect a significant change in a building's energy-consuming characteristics.*

> *Examples of these 'trigger points' include the sale of a property, a change in the leasehold on a property, the replacement of equipment and components installed on the premises, and refinancing, remodeling, renovation or rehabilitation events. Providing information about each specific building's energy efficiency potential and access to efficiency programs would be most effective at those times. These trigger points are also candidates for mandating the provision of relevant information and efficiency investments when appropriate.*
>
> *The strategies also capitalize on the availability of improved databases and diagnostic tools to identify individual buildings and building systems that offer the best opportunities for efficiency retrofits and improved energy utilization. Such activities not only identify targets for efficiency improvements, but also offer methods to convey to buyers, operators, and lenders information about the expected operating costs and market values of efficient or inefficient buildings."*

Specific strategies identified for implementation in California (some of which will require legislative action) are:

Residential Strategies

Time-of-Sale Information Disclosure By 2010, California should begin requiring disclosure of home energy ratings when a house is sold; the Energy Commission will work with industry and other stakeholders to be certain that the market is ready by this deadline.

Information Gateway Utilities will upgrade their efficiency information programs into a central clearinghouse, or gateway, to motivate consumers to take advantage of applicable programs and services.

Integrated Whole Building Diagnostic Testing and Repair Expand and transform the whole building diagnostic testing industry to detect flaws in building construction or operation, diagnose the causes, and facilitate, enable and verify their correction.

Assistance to Affordable Housing Improve and coordinate policies and procedures among utilities and State agencies toward affordable housing, particularly during trigger points of property rehabilitation and equipment replacements.

Equipment Tune-Ups Increase the capacity of the HVAC maintenance industry toward system tune-ups and maintenance services, connecting to time-of-sale events and leading to further standards requirements for testing and correction when equipment is replaced.

Commercial Strategies

Commercial Benchmarking By 2009, a California-specific benchmarking system will be available to all commercial buildings in the State, providing energy consumption information to building owners and operators so they can compare their buildings' performance to similar buildings; legislation will be sought to require that benchmarking be performed when a commercial building is financed or refinanced.

Retrocommissioning Expand the infrastructure to promote and facilitate retrocommissioning of existing buildings, in order to investigate the operation of energy consuming equipment, then detect, diagnose, and correct faults in the equipment and systems.

Most of these strategies, and the initiatives to implement other AB 549 recommendations, were just getting underway in 2006, and it is too early to measure their effectiveness or the level of success. However, given California's historic leadership in energy-efficiency programs and policies, it is highly likely that much of what is developed in the next year or two will be transferable to other parts of North America. Other leading states and regions are also currently investigating these strategies.

Expanded Energy Efficiency Resource Standards

An energy efficiency resource standard is a simple, market-based mechanism to encourage energy efficiency in electricity and natural gas. Utilities are given set savings targets, often with the flexibility to achieve the targets through a market-based trading system. Resource standards are currently in place in several US states and other countries.

In the USA, Texas led the way with a requirement in their electricity restructuring law that electric utilities offset 10% of their demand growth through end-use energy efficiency. The Texas utilities have had no difficulty meeting these targets and are currently exceeding them. A number of other states, including Hawaii, Nevada, Connecticut and California have established energy savings targets for utilities, and other states are exploring setting targets. A summary of activity relating to energy efficiency resource standards was recently prepared (Nadel 2006) demonstrating significant savings potential from expansion of these sorts of standards among states, as well as consideration of a national energy efficiency resource standard.

Experience from European Buildings Policies

The European Directive on the Energy Performance of Buildings (EPBD) was adopted in 2002, and includes a number of requirements aimed toward improving the energy performance of existing buildings, specifically mandatory energy certification of all buildings with each change in occupancy, mandatory inspection and assessment of heating and cooling installations, adoption of a comprehensive whole building energy assessment methodology, and issuance of building energy performance codes for all new buildings and all existing buildings where more than 1 000 m^2 (~11 000 ft^2) is being retrofit.

Perhaps the most important requirement for existing buildings is the mandatory public display of energy performance for all public buildings over 1 000 m^2 (approximately 10 000 sq. ft.). It is expected that this disclosure requirement will highlight lower performing buildings and dramatically raise awareness about the opportunities for energy performance improvement. Furthermore, the European Directive on Energy Services (2006/32/EC) requires EU Member States to install accurate time of use metering systems. In some cases, individual Member States are opting for advanced metering systems which will enable users to better know where and how they are using energy and make more informed decisions.

Denmark has led the way in Europe, with certain certification and labeling requirements in effect prior to the implementation of the EPBD, and with new energy certification requirements taking effect in 2006. Many of the EPBD requirements are just now beginning to take effect in most European member countries and bear close watching to see what might be applicable in North America. It will be valuable to watch the success of these new certification requirements, in comparison with the new initiatives in California, to study what will have the largest effect and what can be emulated by other states or regions.

Promising Potential Policies

In this section, we look at several policy options that have not yet been tried or that have seen limited use. Each of the policies described appears promising – further research and testing is warranted to determine if these policies can effectively deliver the expected energy savings with wider implementation.

1) *Time of Transfer Ordinances*

   A property sale or change of occupancy represents an ideal time for implementing efficiency upgrades in existing buildings. Several tools can be used to encourage – or even mandate – efficiency improvements as part of the transaction.

   - **Mandatory labeling or HERS rating.** In the current existing buildings market, potential buyers are at a disadvantage when it comes to information to help them identify energy-efficient properties. A mandatory labeling program for existing homes or a requirement that existing homes be given a HERS rating[6] prior to sale would provide buyers a means to compare the energy performance of homes under consideration, thereby making energy use a more salient feature in the home purchase decision. Mandatory certification of non-residential buildings would allow for even greater consideration of a building's energy performance at the time of purchase, as it will allow the appraisal process to accurately monetize the increased property valuation from lowered utility costs.
   - **Mandatory codes.** Residential and Commercial Energy Conservation Ordinances (RECOs and CECOs) have been implemented by a handful of municipalities as a way to bring the existing building stock closer in line with the energy code requirements for newer buildings. As noted earlier, such ordinances require building owners and landlords to implement certain efficiency improvements at the time a property is sold. While their impact to date has been limited, this policy option shows promise if implemented on a wider scale with more stringent requirements and greater enforcement.
   - **Mandatory disclosure of EEMs at time of mortgage application.** Just as all US mortgage applicants receive mandatory disclosures on fair housing laws and truth-in-lending information that lays out the full cost of the loan, applicants could receive notice that Energy-Efficient Mortgages (EEMs) are available to finance energy upgrades. Many US lenders offer EEMs, but their use has been limited by a general lack of awareness and limited marketing.

2) *Zero-Energy (or Zero-Carbon) New Buildings*

   The growing interest and technical capacity for designing and constructing zero-energy new buildings could be leveraged to improve the efficiency of existing buildings. As a condition of service for utilities, new buildings connecting to the utility system would be required to achieve zero-energy performance via onsite energy efficiency and renewable energy generation. Any remaining energy use in new buildings would be offset by credit purchases in a "white tags" market driven by Energy Efficiency Resource Standard requirements. Utilities would annually calculate the amount of energy offsets required, and would add increments to their EERS targets accordingly. This would drive new investment in existing

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[6] A Home Energy Rating System (HERS) Rating is an evaluation of the energy efficiency of a home as compared to a reference house. It provides objective, standardized information on the energy performance of a home. A HERS rating evaluates the performance of the thermal envelope, glazing strategies, orientation, HVAC system and other efficiency criteria, and is obtained by an on-site inspection. HERS rating calculations incorporate estimates of both annual energy performance and energy costs.

buildings to meet the added EERS requirements. Such policies could also be designed on a zero-carbon basis; the mechanisms would be similar, except that offsets could be obtained from renewable energy and other low-carbon markets. This approach has not been tested to date, but could be introduced in one of the states that have implemented an EERS.

3) *Oil Savings Programs*

Oil use is small compared to electricity and natural gas use in the US buildings sector, but it is fairly large in the Northeast and Midwest regions and is expected to increase somewhat over the coming decade, according to the Energy Information Administration. Reducing oil use helps address several important policy objectives (energy independence, security issues, global warming and other environmental concerns). To date, oil users have not had access to widespread efficiency programming of the type offered by electric and gas utilities. Several options hold promise for reducing oil use in buildings:

- **End-use efficiency improvements.** Many of the same types of market transformation programs targeted toward electric and gas appliances and equipment could be used to reduce oil consumption. In particular, loans, technical assistance, financial incentives, and education/awareness programs could be implemented with similar effects.
- **Fuel switching and retrofits as offsets in carbon cap-and-trade programs.** Carbon emission reduction policies that focus on the power sector can use non-electricity energy savings as offsets. In the seven-state Regional Greenhouse Gas Initiative,[7] reductions in heating fuel usage in existing buildings are eligible as such offsets. A major gas utility has also proposed conversion of oil to gas heat in existing buildings as an eligible measure for offsets. With stringent performance standards for the new systems, such an approach could save substantial heating fuels.
- **Loan programs for oil dealers.** Most fuel oil dealers are small businesses, and with the high price of heating oil, their inventory costs going into the heating season are substantial. Members of Congress have considered a federal loan program to help dealers finance their inventories, and it has been suggested that such a program could include conditions requiring dealers to use part of such funds to finance boiler and furnace replacements as well as other efficiency measures.
- **Energy services contracting.** In this program design, building owners would be offered lower energy costs in exchange for giving over the operation of their energy-using systems to energy services contractors. Some utility affiliates and others have explored variants of this approach in seeking to provide refrigeration, chilled water, steam, or other customer energy services. This approach works primarily in large commercial and residential buildings where the service provider takes over ownership of building energy systems assets and sells energy services back to building occupants.

4) *"Smart" metering or real-time metering and benchmarking*

The development and widespread proliferation of metering and communications technologies now allows for real-time metering of building energy use and sharing of energy use data with utilities, government, efficiency programs, and the public at large. The ready availability of the data allows for aggregation and benchmarking of individual building performance against that of similar structures which enables users to readily see what level of improvement can be realized.

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[7] The Regional Greenhouse Gas Initiative (RGGI or "ReGGIe") is a cooperative effort by 10 Northeast and Mid-Atlantic states to discuss the design of a regional cap-and-trade program initially covering carbon dioxide emissions from power plants in the region. In the future, RGGI may be extended to include other sources of greenhouse gas emissions, and greenhouse gases other than CO2.

Furthermore, advanced metering allows users to see where they are using energy and, when coupled with appropriate interfaces, see the impacts of any efficiency improvements they choose to invest in. The Danish Energy Saving Trust has implemented a web-based tool – Se-elforbrug ("watch electricity consumption") – to present data on electricity consumption in public and private buildings.[8] The website provides hour-by-hour consumption data for each facility as well as analysis reports breaking down average day, evening, and night usage and data on the past three months consumption. Individual building data can be compared to that of other buildings within the same market sector or to all other participating buildings. As of the end of 2006, 780 buildings representing 23 different workplace types were participating in the program. This program could serve as a useful model for development of national and/or statewide metering and benchmarking programs.

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[8] www.elsparefonden.dk/offentlig-og-erhverv/se-elforbrug

ANALYSIS OF POTENTIAL SAVINGS FROM DIFFERENT POLICY SCENARIOS

Review of Detailed Potential and Cost-Effectiveness Studies

Numerous detailed analyses and models of technical, economic, and achievable efficiency potential studies have been done in different states and regions of the USA in recent years, with most showing that there are very large energy savings to be tapped at much lower cost than that of new energy supplies. These studies range from simple compilations, analyses and literature reviews, to very detailed studies incorporating a sophisticated analysis by building type and vintage, end uses, and specific technological improvements. Most studies concentrate on electricity savings potential given the substantial incentives toward electric demand-side management initiatives.

Despite the plethora of studies done in recent years, there has not been any recent comprehensive national or North American end-use level review of savings potential in existing buildings. Given the wide variety of building types and uses, vintages of construction, and energy-consuming equipment installed, the energy intensity and improvement potential of different buildings varies dramatically, giving rise to a broad range of savings potentials for different building classes. A comprehensive review would be a great addition to the policy debate.

Detailed Potential and Cost-Effectiveness Studies

Several very detailed technical and achievable savings potential studies have been done for states or regions in the USA, which have included comprehensive analysis of the cost-effectiveness of the savings and specific measures. Most of these have studied electric end-use savings potential, often by specific measure or technical opportunity, with some more recent studies looking at natural gas potential in order to support major electric and gas efficiency program expenditures, generally at a state or utility service territory level. The cost recovery for these expenditures is justified through rate recovery mechanisms, and as such, detailed cost-effectiveness analyses and reviews are performed. Less study has been done on the unregulated fuels such as fuel oil and propane, though this has begun to change with recent higher oil prices.

The most comprehensive national review of buildings (and other energy using sectors) was done in 2000 as part of *Scenarios for a Clean Energy Future*, prepared by a group of National Laboratories under DOE sponsorship (Interlaboratory Working Group 2000). This national study reviewed technologies available at the time of the study, and found that dramatic savings could be achieved, at very low costs compared with supply alternatives. The study reviewed two scenarios: *moderate*, which presumed modest progress toward new policies, and *advanced*, which assumed a significant implementation effort beyond the moderate case. Table 25 shows a summary of buildings sector savings potential relative to a business as usual case from that study, as well as the costs to achieve those savings. The average technology costs to achieve the 10–12% savings relative to business as usual, $4–6 per MBtu, are significantly less than current energy prices of $11 to $28 per MBtu (based on EIA 2006 national average costs for natural gas and electricity, respectively).

Table 25. Summary of Buildings Sector Program Effectiveness and Costs, by Scenario and Fuel (from Scenarios for a Clean Energy Future)

Sector	Technoeconomic Potential % Savings Relative to Business as Usual		Achievable % of Technoeconomic Potential		Technology Cost	
	2010	2020	2010	2020	$/MBtu 2010	$/MBtu 2020
Residential – Moderate	14%	21%	24%	36%	5.23	4.88
Residential – Advanced	14%	21%	31%	55%	5.13	4.00
Commercial – Moderate	17%	25%	27%	37%	6.13	6.19
Commercial – Advanced	17%	25%	33%	48%	5.43	5.32

Source: Interlaboratory Working Group 2000

A study completed earlier in 2006 in California found that under the most aggressive scenario nearly 24 000 GWh of electric energy savings, and over 620 million therms of natural gas savings, could be achieved by 2016, with the majority of the savings being found in existing buildings (Itron 2005); these savings represent 28% of forecast electric use, and 11% of forecast gas use in 2016. This analysis included detailed end-use breakdowns and savings by measure and technology, a task well beyond the scope of this IEA project. For the residential building sector, detailed cost-effectiveness analysis was done for fifty-one different electric efficiency measures and practices and 14 gas measures and practices, all of which are currently commercially available. Similarly, eighty-two individual high efficiency measures were analyzed for the commercial buildings sector along with some additional emerging technologies.

The California study combined customer data including energy usage profiles, specific segment data and adoption models, together with technology data such as characteristics and applicability by sector and specific cost and savings data. Results included energy impacts, individual utility impacts, and overall benefit/cost ratios. While this study is the most comprehensive analysis of existing building energy savings potential, the savings figures are conservative if extrapolated nationally, as California has a relatively moderate climate without large space conditioning loads and long standing policy leadership that makes California’s buildings among the most efficient in North America.

Similarly, in New York State, where heating loads are more dominant, the New York State Energy Research and Development Authority (NYSERDA) has conducted two detailed technical, economic and achievable potential studies, on electricity in 2003, and more recently looking at natural gas energy-efficiency potential (Plunkett et al 2003).

An analysis of studies on electricity savings potential in six New England states commissioned by Northeast Energy Efficiency Partnerships found that by 2013 an estimated 34 375 GWh of electricity savings is economically achievable, representing approximately 23% of the forecast electric load in that year (Optimal Energy 2004). The report found that this energy-efficiency improvement would cost 67% less than the cost of supplying the electricity. The report presented the major “reservoirs” of achievable potential by end use, as shown in Figure 21.

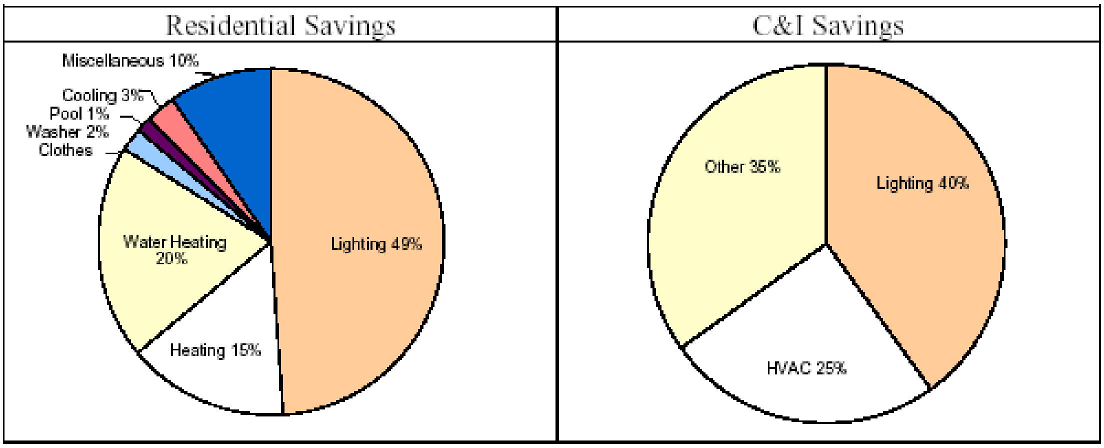

Figure 21. Major "Reservoirs" of Achievable EE Potential in 2013 by End Use
Source: Optimal Energy 2004

The most detailed review focusing on existing buildings is a savings analysis conducted as part of the California AB 549 Options for Energy Efficiency in Existing Buildings project. The final California Energy Commission Report issued in 2005 (CEC 2005) included savings and cost/cost-effectiveness for a number of new initiatives aimed specifically toward existing buildings (see "Potential New Programs" section for more information on these).

Studies Looking at Overall Savings Potential

With the number of technical, economic and achievable potential studies growing in recent years, a "meta-analysis" of recent studies was prepared in 2004. Generally, the potential studies are not limited to buildings, but include all end-use sectors. The meta-analysis of 11 studies found a median technical potential of 33% for electricity and 40% for gas, with a median achievable potential of 24% for electricity (an average of 1.2% per year) and 9% for gas (an average of 0.5% per year) (Nadel et al. 2004).

Some of these studies provide data on specific sectors, including residential and commercial buildings, while others do not contain that level of detail. A summary of the available studies based on the 2004 meta-analysis, updated by ACEEE staff with more recent data through mid-2006, is shown in Table 26. A fairly wide range of potential savings are found in the different studies, with a general finding that a higher percentage of technical and achievable savings are available in residential buildings than commercial, and significant savings are identified in all studies.

Table 26. Summary of Savings Potential (%) by Sector

				Residential			Commercial			Industrial			
Region	Year	Fuel	#Years	Tech	Econ	Ach	Tech	Econ	Ach	Tech	Econ	Ach	Notes
California	2003	Elec	10	21%	15%	10%	17%	13%	10%	18%	12%	11%	Max efficiency
Massachusetts	2001	Elec	5	NA	31%	NA	NA	21%	NA	Included in comm.			
New York	2003	Elec	20	40%	32%	NA	46%	40%	NA	21%	18%	NA	High avoided cost
Oregon	2003	Elec	10	28%	NA	NA	32%	NA	NA	35%	NA	NA	
Puget	2003	Elec	20	35%	19%	12%	39%	16%	12%	NA	NA	10%	Medium costs
Southwest	2002	Elec	17	NA	NA	26%	NA	NA	27%	NA	NA	33%	
US	2000	Elec	20	NA	NA	27%	NA	NA	22%	NA	NA	22%	Adv. Scenario
Vermont	2003	Elec	10	NA	NA	30%	NA	NA	32%	Included in comm.			Max achievable
Median				*32%*	*25%*	*26%*	*19%*	*19%*	*22%*	*21%*	*15%*	*14%*	
California	2003	Gas	10	NA	NA	NA	NA	21%	10%	NA	NA	NA	Comm., max case
Oregon	2003	Gas	10	69%	54%	NA	16%	8%	NA	NA	NA	NA	Res & comm.
Puget	2003	Gas	20	48%	19%	10%	20%	16%	8%	NA	NA	9%	Med/ High costs
US	2000	Gas	20	NA	NA	8%	NA	NA	8%	NA	NA	8%	Adv. scenario
Utah	2004	Gas	10	46%	27%	NA	29%	11%	NA	NA	NA	NA	Max achievable
Median				*48%*	*27%*	*9%*	*20%*	*14%*	*8%*	*NA*	*NA*	*9%*	

Note: This table only includes the longest time periods and most aggressive scenarios covered in each study.
Source: Nadel, Shipley, and Elliott 2004, updated by ACEEE staff with data through 2006

Studies Looking at Specific End Uses

In addition to these studies, a range of analyses have addressed the savings potential and cost-effectiveness of specific improvements and end uses.

A recent study on commercial building controls and performance diagnostics prepared for DOE (TIAX 2005) found that a combination of current, new and advanced building controls and diagnostic systems could reduce HVAC and lighting energy consumption in commercial buildings by approximately 40% on a national basis.

The Harvard School of Public Health published a report on insulation retrofits in existing housing (Levy, Nishioka and Spengler 2003), which found that bringing wall, ceiling and floor insulation levels in existing homes up to the modest levels required by the 2000 International Energy Conservation Code would save 800 TBtu, or approximately 12% of the space heating energy use from homes (Levy and Spengler 2003). This is just the savings estimated from insulation, while windows, air sealing and heating system improvements provide significantly higher savings potential.

Most of the detailed studies of energy-efficiency potential have been done for electricity with a small but growing number for natural gas, as these fuels are provided by regulated energy suppliers and are clear opportunities for publicly funded programs. With recent large increases in energy prices this has begun to change, and the first detailed look at fuel oil and propane savings potential in buildings was completed in 2006 as part of a study on potential oil savings from energy efficiency in several sectors (Elliott, Langer and Nadel 2006).

Scenarios Studied for this Project

For the purpose of this project, a simplified analysis of current energy use in existing buildings tied to the expected "business as usual" forecast contained in the US Energy Information

Administration's *Annual Energy Outlook 2007* (AEO 2007) forecast,[9] has been developed to study the potential from different scenarios:

- *Base Case:* No increased policy activity, energy use as forecast in AEO
- *Increased Policy Activity:* Nationwide adoption of what is happening in leading states/regions; dramatically increased funding for energy efficiency in existing buildings
- *Aggressive Policies:* Substantial push toward rapid implementation of lowest life cycle cost technologies and practices replacing standard equipment in all existing buildings; use/demonstrations of some currently untested policies to push the policy envelope, in line with policies now being pursued at the state level

The base case energy use forecast contained in the AEO shows the contribution to the energy use forecast from buildings already in place, and those that will be constructed during the forecast period. The relative magnitude of these different portions is shown in Figure 22.

Our simplified model rolls the US building stock up into numbers of households and floor space of commercial buildings, to forecast impacts of improvements to energy efficiency at different saturations and replacement rates for varied policy scenarios. The model compares current "typical existing buildings" with an "energy-efficient" building that utilizes currently available technologies and practices. This "energy-efficient building" is not intended to be a demonstration of the most efficient building or the lowest overall life cycle cost, but instead representative of what a major portion of the existing building stock might reasonably be able to achieve through cost-effective measures within the next 20 years. As such, there is a level of conservatism built into the analysis.

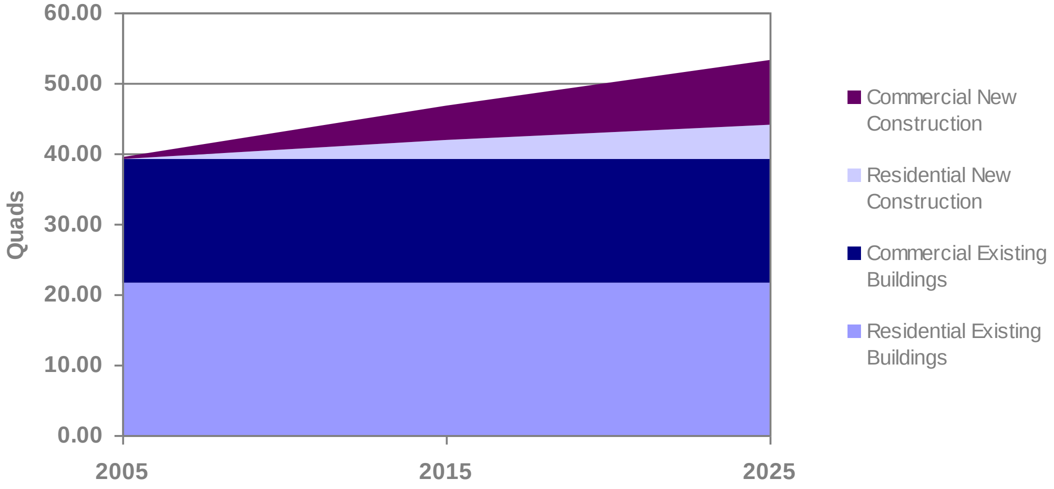

Figure 22. Base Case Energy Use

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[9] All AEO forecast data used in this section were obtained in mid-December 2007 from the Energy Information website (http://www.eia.doe.gov/oiaf/aeo/index.html), where the forecast is called Annual Energy Outlook 2007 with Projections to 2030 (Early Release).

Table 27. Comparison of Current Typical Residential Building with Energy-Efficient Case

Per Household (hh) Delivered Energy Consumption by End Use	**Current Typical Existing Building**		**Energy-Efficient Existing Building**		**% Savings**	**Assumptions**
	MBTU/ hh	kWh/ hh	MBTU/ hh	kWh/ hh		
Space Heating	49.4		27.2		45%	Energy Star (E*) windows, more ceiling insulation, sealing major air leaks, E* thermostat and efficient boiler/furnace
Space Cooling	5.8		3.5		40%	Similar mix as for space heating, but efficient AC equipment
Water Heating	14.8		10.4		30%	Efficient water heater, low flow showerhead, and E* wet appliances
Refrigeration	4.5	1 318	2.0	600	54%	Assume 475 kWh/yr E* refrig plus some % of homes with second refrig or freezer
Wet Appliances	0.5	146	0.5	132	10%	10% savings from E* Appliances (most savings counted in Water Heating)
Other Appliances	5	1 465	4.5	1 318	10%	10% savings from E* Appliances
Lighting	7.1	2 080	4.8	1 400	33%	Change half of sockets to E* CFL bulbs
Other Uses	14.2	4 161	12.8	3 745	10%	
Total Electricity		**9 171**		**7 195**		
Total Delivered Energy	**101.3**		**65.6**		**35%**	

While different end uses show significantly different levels of savings, the overall delivered energy savings potential is 35% when compared to the current typical building. This overall savings level is consistent with other more detailed analyses and a recent evaluation of large numbers of homes treated through the Home Performance with Energy Star program.[10]

For the different policy scenarios, we then assume different speeds over the forecast period for moving from current typical buildings to the more efficient ones, or increasing the saturation of energy-efficient buildings among the overall stock. For both the residential and commercial sectors, the increased policy activity scenario assumes that in 20 years 40% of the stock moves to the efficient base; the aggressive scenario assumes that 70% reach the target.

Buildings already exist that are much more efficient than this prototype energy-efficient building, thus the savings potential could go deeper than what is projected in this analysis. Many residential buildings, both small and large, currently operate at energy use levels below the energy-efficient

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[10] Analyses include Nadel et al 2004 (Meta-analysis) and Elliott et al 2006 (Reducing Oil Use); the recent evaluation was of over 13 000 homes retrofitted in New York through “Home Performance with Energy Star”, details can be found in Elliot et. al. 2006 or http://www.nyserda.org/Energy_Information/SBC/sbcmay06section5.pdf

building described. For example, even with a 33% reduction in lighting energy use, the 1 400 kWh per year allocated for lighting in our model is much higher than averages in Europe and in many homes in the USA. The analysis is intentionally conservative. While this simplified analysis has many limitations, it is effective in illustrating the potential savings in available in existing buildings.

For the commercial sector, with a much wider variety of building and space types and much less homogenous end-use mixes, it is more challenging to construct a similar end-use level comparison of a current typical building to an energy-efficient building. From our review of detailed studies and discussions with practitioners, we assume an overall 30% reduction over current typical practice is easily possible. For a typical office building at average national climate conditions, the end-use breakdown between the current typical building and the energy-efficient model is shown in Table 28. Again, more efficient buildings exist that consume less than this prototype energy-efficient building, but the analysis is intentionally conservative.

While this simplified analysis has many limitations, it is effective in illustrating the potential savings available in existing buildings. It should be noted that some simplification is embodied in the "flat" projection of energy intensity for existing buildings; in reality many buildings will experience increased energy using equipment density (new products, and some with higher energy use per unit), while there is offsetting reduction due to renovations and improvements to the efficiency of products as they are replaced.

Table 28. Comparison of Current Typical Commercial Building with Energy-Efficient Case

Per Floor Area (square foot) Delivered Energy Consumption by End Use	Current Typical Existing Building		Energy-Efficient Existing Building		% Savings	Assumptions
	MBTU/ sf		MBTU/ sf			
Space Heating	23.16		13.9		40%	Higher efficiency equipment and better controls; better insulation and windows
Space Cooling	5.68		3.4		40%	Higher efficiency cooling equipment and better controls; better windows
Water Heating	10.43		8.3		20%	Water heater and pipe insulation; faucet aerators and water use reduction
Ventilation	2.16		1.5		30%	Demand-Controlled Ventilation; higher efficiency fans and VSDs
Cooking	3.95		3.6		10%	More efficient cooking equipment
Lighting	15.13		6.8		55%	More efficient lamps and ballasts; better occupancy controls
Refrigeration	2.78		2.4		15%	Refrigeration case covers, better insulation and seals, and higher efficiency compressors
Office Equipment (PC)	2.25		1.7		25%	Energy Star office equipment; enabling sleep mode and other power management techniques
Office Equipment (non-PC)	4.61		3.5		25%	More efficient office equipment; better power management and energy management techniques
Other Uses	42.26		33.8		20%	More efficient electronic equipment (E* specs) and other
Total Delivered Energy	**112.41**		**78.8**		**30%**	

Findings of Analysis

As shown in Table 29 and Figure 23, under the aggressive policies scenario, in 2025 overall existing buildings energy use would be 23% less than the current business as usual forecast. The energy savings of 8.9 quads are equivalent to the current energy use of all residential buildings in the seven states with the highest energy consumption (Texas, Florida, California, New York, Pennsylvania, Illinois and Ohio) combined, or the total combined current energy use of all office, retail and educational buildings in the USA.

Table 29. Savings from Three Scenarios (energy use in Quads)

	Base Case - BAU			Increased Policy Activity			**% Savings in 2025**	Aggressive Policies			**% Savings in 2025**
	2005	2015	2025	2005	2015	2025		2005	2015	2025	
Residential	21.69	21.69	21.69	21.69	20.55	18.65	14%	21.69	19.41	16.38	24%
Commercial	17.89	17.89	17.89	17.89	17.08	15.74	12%	17.89	16.28	14.13	21%
Total	39.58	39.58	39.58	39.58	37.63	34.39	13%	39.58	35.69	30.51	23%

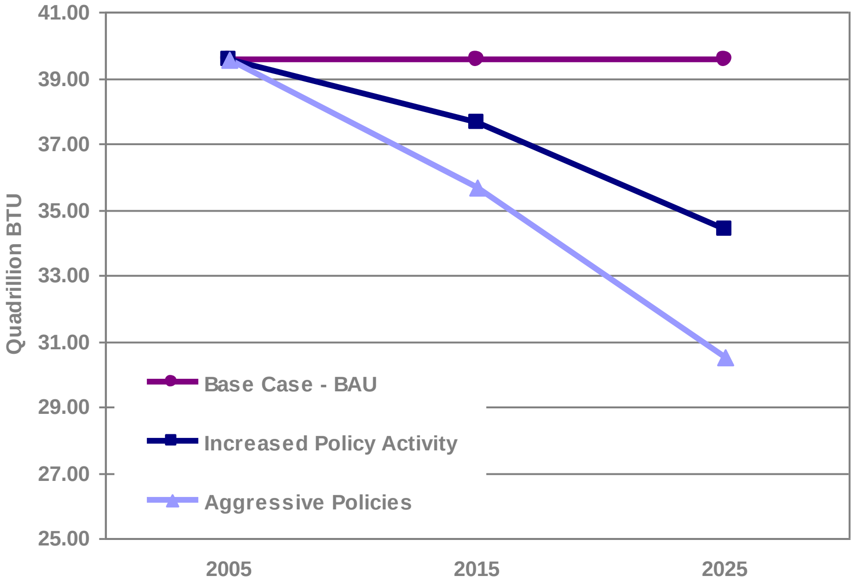

Figure 23. Reduction in Energy Use from Three Scenarios

These overall savings results are consistent with other models developed for specific states or regions or for specific end uses, and also fit in the range of savings that a variety of experts consulted during this project felt were attainable. They fall well within the estimates found in the different technical, economic and achievable potential studies cited above.

Moreover, these levels of savings are very similar to what a number of states have set as state policy goals for energy savings. Three states in particular – Vermont, California and Connecticut – have established targets for 1.0 to 1.5% annual energy savings in buildings and other sectors. In Vermont, for example, the energy-efficiency utility that administers the state's public benefits programs is currently achieving energy use reductions of approximately 1% per year. With recent increases in program funding, the utility is in the process of determining how much beyond 2% savings per year is attainable for the coming decade (Nadel 2006). California and Connecticut, both long time leaders in energy-efficiency policies, have targets for 1% per year savings, despite the fact that their building stock is already more efficient than most other states in the nation.

Estimated Value and Cost-Effectiveness of Savings

Determining the cost and cost-effectiveness of these projected savings is a challenge, but it is possible to use the results of some of the more detailed studies described above to make an estimate of the value. While detailed cost-effectiveness studies have been done in conjunction with savings potential projects in a variety of states, these are not easily extrapolated to national savings estimates.

The most detailed national analysis of the costs and savings of different energy scenarios can be found in *Scenarios for a Clean Energy Future* (Interlaboratory Working Group 2000) which estimated that the “technology cost,” or cost of the conserved energy, ranged from $4.00 to $6.19 per MBtu saved. Using a median value of $5.10, it is possible to compare the projected technology cost to the current AEO 2007 forecast national weighted average price for buildings consumers in 2025 of $18.21/MBtu (in 2005 dollars). This price difference of just over $13 per MBtu, when multiplied by the 9 Quads of energy savings projected for the aggressive scenario in 2025, is worth almost $120 billion in 2025. The cost to achieve the savings is approximately $45 billion, but with savings from reduced consumption of nearly $165 billion, the net cost savings are very significant.

Electricity use in existing buildings in 2025 under the aggressive scenario is projected to be reduced by approximately 20 percent, from 3 730 TWh to 2 980. The 750 TWh of savings, at national average building sector electric load factors, avoids the need for about 200 GW of generation capacity, or avoided capital cost of approximately $130 billion at the current average new capacity cost of $650 per kW for new gas-fired generation.

SUGGESTED MIX OF POLICIES AND MEASURES FOR THE NORTH AMERICAN BUILDING STOCK

Rationale for Suggested Mix: Organizing Principles

The appropriate mix of policies and measures to generate the greatest level of efficiency improvements in North American buildings needs to account for regional and local differences in experience and commitment to energy efficiency, the technology development and deployment cycle, and the diversity of stakeholders involved in decisions that influence energy policy, efficiency programs and energy use. Strong policy intervention is justified in the existing buildings sector to overcome barriers identified earlier that prevent markets from performing at their economic optimum.

In certain parts of North America, a well-organized and reasonably comprehensive mix of policy and program activity is already underway. The suggested mix that we are recommending is intended to work in regions where strong and active policy structures are already in place as well as in regions where activity might be more limited or just getting started. The specifics can be tailored to suit local circumstances as needed.

Similarly, we recognize that some efficient technologies and practices are already making great progress in the marketplace, while others are struggling. The recommended strategy mix allows for this, and recognizes that different technologies and practices face different barriers and will be adopted at different paces.

Finally, it is critical to recognize that a wide variety of policy stakeholders influence the way in which energy-efficiency policy and program activity is developed and implemented: federal, state and local government policy makers, as well as utilities and other energy suppliers, energy consumers, and a range of different advocacy and industry groups that all bring different perspectives to the mix.

Recommended Comprehensive Strategy/Mix of Policies and Measures

Achieving significant cost-effective energy savings in existing buildings requires the design and implementation of a comprehensive, long-term strategy encompassing the following five closely coordinated elements:

1. Regularly updated and ambitious equipment efficiency standards to lock-in the savings from market transformation and resource acquisition efforts and to ensure that these savings are available to all end users
2. Improved building energy codes for existing buildings that apply at the time of substantial renovation, sale or change of occupant
3. Resource acquisition activities and incentives to cover the initial incremental costs of these higher efficiency technologies and practices in a wide range of applications
4. Market transformation initiatives, including the training of practitioners, to bring energy-efficient technologies and practices into the broader marketplace
5. Aggressive research, development & deployment (RD&D) of promising energy saving technologies and practices.

Each of these five elements requires significant funding at federal, state and/or local levels. R&D incentives encourage companies and entrepreneurs to bring new technologies to market, while resource acquisition and market transformation initiatives increase the share of efficient technologies and the use of best practices in existing buildings. Regulatory activities such as codes and standards are necessary to prevent any technology backsliding if other programs are scaled back due to competing priorities.

More specific recommendations for each element follows:

Minimum Efficiency Standards

- Update existing standards regularly to capture savings in improved products
- Expand standards to cover new products.
- Update test protocols, with an eye toward global harmonization, to accommodate new products, new designs and new features on existing products.
- Establish new standards for installation, testing and system correction at time of equipment replacement.

The Appliance Standards Awareness Project runs a coordinated effort to identify options for new state and federal standards and to build grassroots support for both.

Energy Codes

- Research efforts to expand coverage of codes and standards to a greater number of existing buildings, including time of transfer activities.
- Direct research toward the most effective enforcement mechanisms for codes affecting existing buildings – some work has been done regarding new construction codes, but very little on existing buildings.
- Implement continual, regular updates to codes to lock in changes as new technologies become standard in the market.
- Improve code enforcement to ensure high levels of compliance and allow for more regular upgrades.

Institute more aggressive advances to get codes equivalent first to Energy Star levels and then to the levels included in the 2006–07 tax incentive levels.

Resource Acquisition

- Implement well-funded, long-term programs to send appropriate market signals that the energy efficiency of buildings is an ongoing, high priority policy area.
- Target programs toward specific technologies that can be easily “acquired” and the savings accurately measured, such as lighting, high efficiency equipment, and residential retrofits where savings are easily calculated and replicable.
- Direct funding toward “hard to reach” sectors such as low income housing and small business where progress is otherwise slow due to split incentives and other barriers to investment.
- Provide incremental cost incentives for new energy-efficient products and technologies to accelerate their market penetration and technology cost curve evolution to the point where they satisfy cost-effectiveness conditions for market transformation initiatives.
- Coordinate initiatives among different program providers to ensure maximum market effects.

- Expand energy efficiency portfolio standards to drive resource acquisition targets and set appropriate high level goals for implementers to achieve in the most cost-effective manner.

As an example, California has deemed energy efficiency the “resource of first resort,” or first in the “loading order” for any new growth in electricity demand. As such, electric utilities must exhaust all cost-effective efficiency resources before considering new generation capacity. This has resulted in $2 billion in approved investments in efficiency from 2006 through 2008 of which a large part targets the building sector. Likewise, Vermont is aggressively pursuing energy efficiency as a resource by establishing ambitious new targets.

Market Transformation

- Identify ambitious but achievable targets for efficiency and establish appropriate incentive mechanisms to get them to market.
- Identify barriers to greater adoption of energy-efficient technologies and practices and strategies to overcome them.
- Engage in training and capacity building to make all market actors aware of new technologies and practices and to remove existing knowledge and skills gaps.
- Launch coordinated marketing campaigns to educate consumers and others. Where possible this should strengthen existing energy-efficiency messaging and “branding” efforts such as Energy Star in order to maximize consumer uptake and minimize confusion.
- Coordinate with contractors, manufacturers, suppliers and others in the market supply chain to accelerate the deployment and market penetration of the most efficient building technologies and practices.
- Expand implementation of emerging “whole building” approaches, including retrocommissioning, benchmarking, energy performance disclosure and whole-building HVAC initiatives. As these practices have complex market channels, comprehensively planned and coordinated market transformation strategies are required.
- Provide appropriate performance-based fiscal incentives to increase uptake of the most efficient technologies and refurbishment practices.
- Pursue sector-based approaches targeting energy-efficient refurbishment in specific sectors of the buildings market, such as schools, hospitality, etc.

There are numerous national and regional organizations, such as the Consortium for Energy Efficiency, Northwest Energy Efficiency Alliance, Northeast Energy Efficiency Partnerships, and others, which participate in and support coordinated market transformation initiatives to promote common messages and build capacity to deliver energy efficiency in existing buildings. It is appropriate for those wishing to enhance the energy efficiency of existing buildings to make use of and contribute to the capacity of these organizations to deliver common market transformation objectives.

Research, Development and Deployment

- Increase funding and support for technology R&D for long range opportunities, as well as for currently available and evolving technologies and practices.
- Undertake ambitious demonstration activities to showcase these technologies and prove their market viability; for example, the refurbishment of public sector or utility buildings presents an excellent opportunity to exhibit leadership and stimulate market development in energy-efficient building.

- Establish and strengthen state and utility funded emerging technologies programs to support the development and demonstration of promising technologies and practices.

As an example, the New York State Energy Research & Development Authority (NYSERDA) has a strong R&D program that provides substantial funding for the development and deployment of new and promising energy-efficient technologies. Once viability is demonstrated these technologies are then fed into NYSERDA's broader public benefits funded market transformation and resource acquisition initiatives. This blend of strong R&D with broad-based market-building initiatives has enabled new technologies to penetrate the market more rapidly than would otherwise have been the case.

The Way Forward

For this recommended mix to have the desired impact, a handful of inputs will help "prepare the ground" for successful program and policy implementation. Among these inputs are:

1. Improved data on detailed end uses and enhanced modeling to better predict the impacts and benefits of energy-efficiency technologies and practices, as well as to monitor the progress of the policies and programs implemented.
2. Development of robust energy efficiency cost curves based on the cost of delivered energy savings in existing buildings rather than simple technology costs. These curves could inform policy decisions driving investment in all efficiency measures that are less than or equal to the marginal cost of new energy supplies, thus yielding the societal least life cycle cost. As policy priorities shift to a greater emphasis on abatement of carbon dioxide emissions, the value of carbon abatement could be included.
3. Ongoing training and capacity building on new technologies and practices, such that all market players are fully trained and informed and market barriers are minimized.
4. A better understanding of the links between building energy-efficiency policies and other policy goals, such as climate change, employment impacts of energy efficiency vs. supply options, and other key policy drivers that can help support the policies recommended in this report.
5. More research on the quality of equipment installations and ways to lower the cost of comprehensive buildings retrofits.
6. Periodic studies on the implementation and enforcement of codes toward existing buildings and ways to improve their effectiveness.

These inputs can improve the climate for adoption of a more robust mix of efficiency programs and policies in regions with a newfound interest in energy efficiency and in those where more aggressive and innovative policies will supplement a well-established set of efficiency programs.

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