

### Quick Facts

- Energy use in residential buildings accounts for about 17 percent of U.S. greenhouse gas emissions. Half of these emissions are due to two of the largest energy end uses—heating, ventilation, and air conditioning (HVAC) equipment and lighting. This factsheet focuses on the remaining 50 percent of emissions that are due to a variety of appliances, such as water heaters and refrigerators.
- An investment in end-use energy efficiency increases the availability of system-wide electricity generation and transmission capacity for other uses; as such, end-use efficiency can be considered a resource, often described in terms of “negawatts,” that provides energy savings comparable to the electricity generated by power plants.
- U.S. residential per household electricity consumption has increased 39 percent since 1970, reflecting the overall trend toward larger homes and a greater variety of appliances and electronics in each home. However, there is evidence of recent trends towards more energy efficient new homes and stabilization of home sizes.

### Background

Residential buildings account for about 17 percent of U.S. greenhouse gas (GHG) emissions measured in carbon dioxide equivalents (CO<sub>2</sub>e) (including both direct emissions, such as from residential furnaces, and the indirect emissions from generating the electricity consumed in these buildings).<sup>1</sup> The large share of residential building energy consumption attributable to space heating and cooling varies with climate conditions.<sup>2</sup> Energy consumed by the roughly 110 million residential buildings<sup>3</sup> in the United States is used to power various end uses, each of which require different technological improvements or behavioral changes to increase energy efficiency and conservation. Improving residential end-use energy efficiency is a challenge given the long lifetimes of appliances, such as refrigerators and ovens, and the preferences and usage patterns of households.<sup>4</sup>

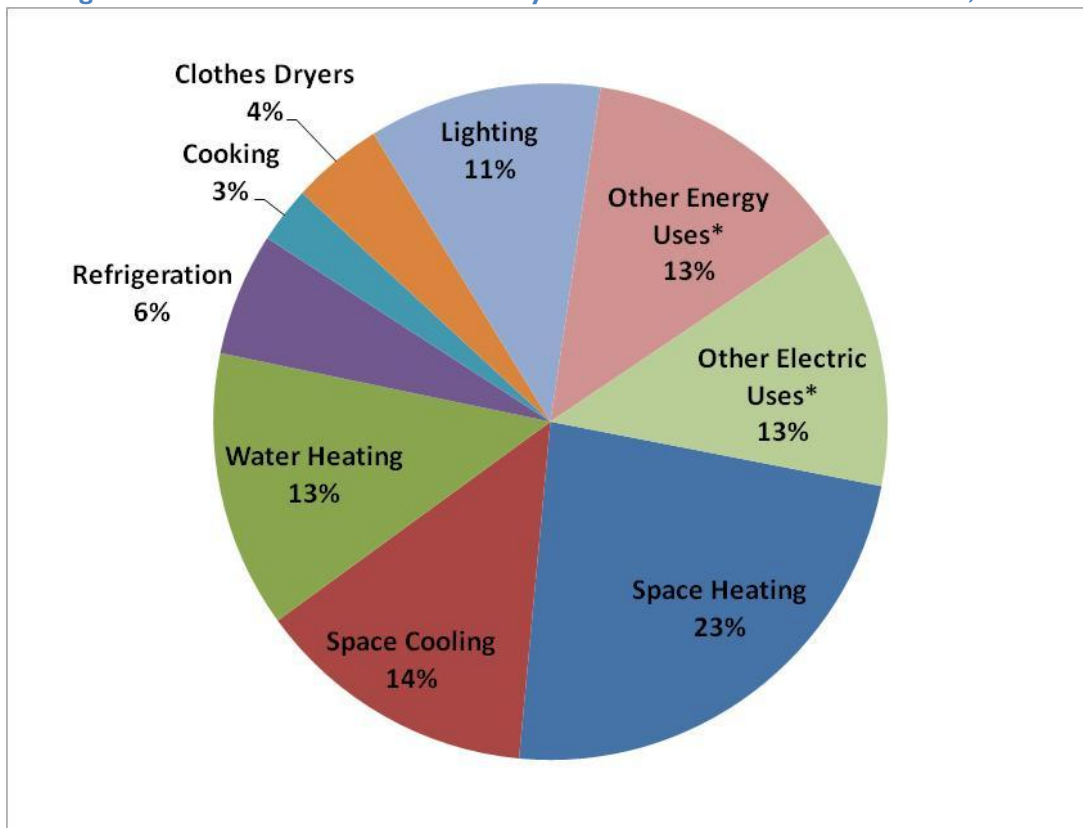
An investment in end-use energy efficiency increases the availability of system-wide electricity generation and transmission capacity for other uses. Thus, end-use energy efficiency can be considered a resource, often referred to as a “negawatt,” available to balance electricity supply and demand, just as is done with other resources such as coal or wind power generation. Like these other resources, “negawatts” from end-use energy efficiency are available in varying amounts at different levels of investment. When considering costs over the lifetime of an investment, end-use energy efficiency can be one of the lowest-cost means of meeting energy demand and of reducing GHG emissions.

### Description

Four options for increasing energy efficiency and reducing greenhouse gas emissions from the residential sector include (1) incorporating high-efficiency or renewable on-site power generation to displace less efficient and/or more carbon-intensive grid power; (2) reducing whole building energy consumption through well-designed energy codes and standards including, but not limited to, those involving the building’s “envelope,” which consists of the structural materials, fenestration (e.g. windows and doors), air sealing, and insulation (see [Climate TechBook: Building Envelope](#));(3) improving end-use appliance energy efficiency; and 4) educating homeowners about their home’s operation and maintenance as related to energy. As Figure 1 shows, two of the largest residential end-uses – heating, ventilation, and air conditioning (HVAC) equipment and lighting – are responsible for just under 50 percent of direct and indirect residential GHG

emissions. The remaining residential energy end uses are the focus of this factsheet and are described below.

**Figure 1: Greenhouse Gas Emissions by End Use in the Residential Sector, 2007**



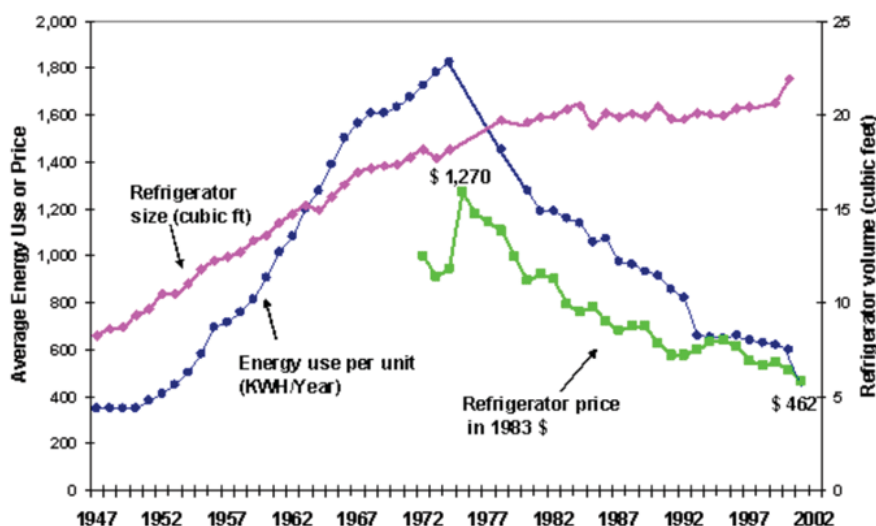
Source: Energy Information Administration (EIA) [Annual Energy Outlook](#), 2009.

\*Note: "Other Energy Uses" includes small electric devices, heating elements, and motors; such appliances as swimming pool and hot tub heaters, outdoor grills, and outdoor natural gas lighting; wood used for primary and secondary heating in wood stoves or fireplaces; and kerosene and coal. "Other Electric Uses" includes color TVs (6%), PCs (2%), furnace fans (2%), dishwashers (1%), freezers (1%), and clothes washers (1%).

- **Hot water heaters** are the second largest end use of electricity in households, contributing 13 percent of total residential GHG emissions. Water heating efficiency can be improved through the use of technologies such as heat pumps, integrated HVAC-water heating systems which make use of waste heat, and tankless water heaters.<sup>5</sup>
- **Electric plug loads** (other electric uses) include a variety of devices such as: personal computers and peripherals (e.g., printers, scanners, and speakers); television and other audiovisual equipment; personal care appliances such as hair dryers and electric toothbrushes; and kitchen appliances such as coffee makers, toasters, and microwaves. Energy use by these devices has historically accounted for about 10 percent of total residential GHG emissions, but this share is increasing. Means to improve the energy efficiency of these devices include energy efficiency standards for the power supplies of these devices, or the devices themselves.

- **Refrigeration and Freezers** are responsible for about 7 percent of GHG emissions from the residential sector, and are among the biggest success stories for energy efficiency standards (see Figure 2). Since the 1970s, refrigerators and freezers have increased in size by a third while consuming two-thirds less energy at one-third the price.
- **Dishwashers, clothes washers, and dryers** contribute 6 percent of residential GHG emissions. For these appliances, optimal usage patterns such as running full loads and using efficient settings can improve energy efficiency. In terms of technology, appliance research has led to the development of modern dishwashers which consume about half as much energy as models from the 1970s,<sup>6</sup> and front-loading (horizontal axis) clothes washers which use 60 percent less energy and 40 percent less water than top-loading washers.<sup>7</sup> There is little variation among the efficiencies of clothes dryers, but natural gas-powered dryers tend to be cheaper to operate than electric clothes dryers because natural gas has usually been cheaper than electricity.<sup>8</sup>
- **Cooking** through the use of electric or natural gas ovens and ranges contributes about 3 percent of residential GHG emissions. Self-cleaning, convection, natural gas, and models without pilot lights tend to be the most efficient ovens, with possible energy savings of as much as 20 percent with convection ovens.<sup>9</sup> However, cooking practices such as using copper, flat-bottomed cookware on ranges and glass or ceramic pans in ovens, matching cookware size to range top size, and using smaller appliances to cook small dishes are more important than technology advances to achieve further gains in energy efficiency.<sup>10</sup>
- **Other energy uses** include miscellaneous consumption in the household through small electric devices, heating elements, and motors; such appliances as swimming pool and hot tub heaters, outdoor grills, and natural gas outdoor lighting; wood used for primary and secondary heating in wood stoves or fireplaces; and kerosene and coal. These end uses are responsible for as much as 13 percent of residential GHG emissions.

Figure 2: Household Refrigerators/Freezers Average Electricity Use by Year of Purchase



Source: National Research Council, 2009<sup>11</sup>

### Environmental Benefit / Emission Reduction Potential

In 2003, researchers estimated that residential end-use energy efficiency standards for appliances and HVAC systems could achieve 8-9 percent reductions in primary energy<sup>12</sup> consumption and associated CO<sub>2</sub> emissions<sup>13</sup> by 2020 compared to a “business-as-usual” scenario which extrapolated historical market-induced energy efficiency improvements from the mid-1980s.<sup>14</sup> These cumulative reductions translate to 1.4 gigatons (Gt) of CO<sub>2</sub>-e by 2020, equivalent to the lifetime emissions from four-and-a-half 1000 megawatt (MW) coal power plants, or 4.4 Gt of CO<sub>2</sub>-e by 2050, equal to the lifetime GHG emissions from fourteen 1000 MW coal power plants.<sup>15</sup>

A 2009 analysis by McKinsey and Company estimated that a 27 percent reduction in residential primary energy consumption and associated GHG emissions in 2020 is possible with profitable (positive net present value) energy efficiency investments in lighting, end-use appliances, and building envelop upgrades in new, existing, and low-income homes.<sup>16</sup> McKinsey calculated that about 30 percent of total residential primary energy reductions could be achieved through more efficient electronics and end-use appliances, equal to 1.8 quadrillion BTUs of primary energy.

Since 2003, two energy bills (the Energy Policy Act of 2005 and the Energy Independence and Security Act of 2007) have imposed new energy efficiency standards. The 2009 federal economic stimulus bill (American Recovery and Reinvestment Act) also included funding for state energy efficiency programs and assistance for low-income homeowners, which may accelerate the pace of energy efficiency improvements. In addition, climate change bills considered by the U.S. Congress also include appliance efficiency provisions. The net effect of these recent pieces of legislation will be to realize a significant portion of the potential GHG emission reductions possible from residential energy efficiency.

### Cost

When considering costs over the lifetime of an investment, residential end-use energy efficiency can be one of the lowest-cost means of meeting energy demand and of reducing GHG emissions. For example, analysts from McKinsey and Company estimated that energy efficiency improvements in residential electronics would have a net savings of \$101 per metric ton of CO<sub>2</sub> (tCO<sub>2</sub>) avoided and that improvements in water heater efficiency would have a net savings of \$11/tCO<sub>2</sub> when considering lifecycle costs.<sup>17</sup> These analysts argue that incremental capital costs are minimal for energy efficiency improvements in residential appliances.<sup>18</sup> These estimates consider the economic potential for energy efficiency investments, and do not take into account behavioral changes, or regulatory, market or demographic factors that may affect the levels of energy efficiency practically achievable through appliance investments in the residential sector.

A 1998 report from researchers at the Lawrence Berkeley National Laboratory estimated that the cost of energy savings<sup>19</sup> for many efficient appliances mandated by standards was below residential market electricity rates of 5-9 cents per kilowatt-hour (kWh), from as low as 0.15 cents per kWh for energy saved with clothes washers, 3.5-4.9 cents per kWh for dishwashers, and 5.0-5.8 cents per kWh for refrigerators, to as high as 7.3 cents per kWh for clothes dryers using a 7 percent discount rate.<sup>20</sup>

Energy efficiency cost estimates are highly dependent on the choice of household discount rate. Consumers have been observed to use 20-100 percent discount rates in making residential appliance purchases.<sup>21</sup> The social discount rate is usually much lower than the private discount rate, meaning that more projects appear socially beneficial than privately beneficial. Other researchers argue that the cost-efficiency relationship for

appliances is unclear, and that the incremental costs are substantial for efficient appliances, especially when bundled with other costly premium features.<sup>22</sup>

### Current Status

U.S. residential per household electricity consumption has increased 39 percent since 1970, reflecting the overall trend toward larger homes and a greater variety of appliances and electronics in each home.<sup>23</sup> However, there is evidence of recent trends towards more energy efficient new homes and stabilization of home sizes. The U.S. Department of Energy Smart Home Scale shows today's new homes are 30 percent more energy efficient than the existing housing stock, and U.S. Census data show that their median size stabilized between 2005 and 2007 and subsequently has been trending downward.<sup>24,25</sup> Efficient residential end-use appliances are becoming more common in the market through the use of energy efficiency standards and the ENERGY STAR® voluntary labeling program. Energy efficiency standards increase the average efficiency of products sold on the market by banning the sale of products that are less efficient than the standard. Minimum energy efficiency standards for residential end-use appliances are regularly updated at the federal and state levels as technology advances or with new legislation. The Energy Independence and Security Act of 2007 (EISA) established higher energy efficiency standards for refrigerators, freezers, dishwashers, and power supplies for electric plug loads. The U.S. Department of Energy is also currently updating standards for water heaters and clothes washers and published new standards for cooking ranges in 2009. ENERGY STAR® labels are applied to the appliances in different categories that rank in the top 25 percent of those available on the market in terms of energy efficiency. The market penetration of ENERGY STAR® products varies by end use, from as high as 95 percent for new LCD screens to as low as 16 percent for battery charger systems sold in 2007.<sup>26</sup>

### Obstacles to Further Development or Deployment

- **Lack of a price on GHG emissions**  
Electricity prices that do not reflect the full societal cost of GHG emissions from traditional fossil fuel power generation limit the incentive to invest in energy efficiency by reducing the cost savings possible with efficient appliance upgrades and increasing payback periods for such investments. Without a price on GHG emissions, the private benefits of investing in energy efficiency are less than the societal benefits of such investments.
- **Lack of Awareness and Information**  
Many consumers and building developers are unaware of the energy efficiency of the appliances in their buildings, and do not have knowledge about the best-in-class technology available for many end uses or the potential cost and energy savings from such devices.
- **Behavioral Barriers**  
Households do not always make rational choices about appliance investments. They may use simplistic financial measures such as payback periods which ignore the possibility of future fuel price increases, they choose from a subset of appliances which may not contain the optimal appliances because of time- or resource-constraints, they are biased toward the status quo, and they are more willing to take risks to avoid losses than to achieve gains in making economic decisions. Behavioral economics research points to monetary and non-monetary/information-based interventions that can address this barrier.<sup>27</sup>

- **Split Incentives**

In the highly fragmented buildings industry, those who pay energy bills may not make decisions about the specifications and purchase of large household appliances. For example, in the market for newly constructed homes, builders may not install the most efficient appliances if they are not sure that the incremental cost of the appliance will be reflected in the selling price of the house, while buyers must pay the higher lifetime energy bills from less efficient appliances. In the rental market, which accounts for almost a quarter of residential energy use,<sup>28</sup> owners may have the capital to invest in energy efficient appliances, but have limited incentive to do so because tenants pay electricity bills. This effect varies by appliance; for example, 90 percent of buyers of new homes obtained their dishwashers and cooking ranges through their builders, while 60 percent of buyers purchased their refrigerators themselves through a retailer.<sup>29</sup>

- **Ownership Transfer Issues**

Residential end-use energy efficiency improvements often yield savings and payback periods longer than most homeowners are likely to stay in a particular house. Since residential housing markets do not always capitalize energy efficiency investments in home prices,<sup>30</sup> benefits accrue to future owners through lower energy bills. This factor mainly affects purchasing decisions for less portable appliances with long lifetimes such as refrigerators, laundry equipment, and ovens.

- **Capital Constraints**

Residential homeowners often apply high discount rates of 20-100 percent or higher for energy efficiency improvements, higher than rates of return for most financial investments.<sup>31</sup> Compared to commercial or industrial decision-makers, residential households tend to be more risk-averse and have greater sensitivity to initial capital costs because they lack liquidity and have a higher cost of capital or limited access to capital. This effect is more pronounced in lower-income and capital-constrained households. Streamlined loan approval processes, favorable loan terms, and direct rebates can help to address this barrier.

- **Rebound Effects**

Rebound effects describe the partial increases in energy consumption due to energy efficiency investments that can occur either by making an appliance less expensive to use and thereby encouraging greater use of it, or by reducing overall electricity prices in wholesale markets, leading to greater electricity consumption in general. The rebound effect may erode some of the estimated energy savings and emission reductions possible with residential end-use energy efficiency. Researchers have estimated that 10-40 percent of water heater efficiency gains are negated by increased water heater usage, but little to no increase in energy consumption is seen in other appliance markets, though indirect effects due to the purchase of larger appliances with premium features were not measured.<sup>32</sup>

- **Additionality**

A danger with energy efficiency programs is that the financial incentives for energy efficiency are partially captured by individuals who would have made these investments even in the absence of policy interventions. If this occurs, it limits the extent to which programs improve energy efficiency and decreases the cost-effectiveness of the program.

- **Unequal Treatment of Energy Efficiency and Supply-Side Resources**

In general, utilities have more incentive to invest in power generation or transmission upgrades than in energy efficiency because their profits are often tied to electricity sales and capital cost recovery.

### Policy Options to Help Promote Residential Energy Efficiency

- **A Carbon Price**  
A price on carbon, such as that which would exist under a GHG cap-and-trade program (see [Climate Change 101: Cap and Trade](#)), would make energy efficiency a more cost-effective option compared to electricity from traditional fossil fuel generation.
- **Energy Efficiency Resource Standards (EERS)**  
An EERS is a market-based mechanism to encourage more efficient generation, transmission, and use of electricity and natural gas. State public utility commissions or other regulatory bodies set electric and/or gas energy savings targets for utilities, often with flexibility to achieve the target through a market-based trading system. All EERS's include end-use energy savings improvements. 19 states have an EERS (see the Pew Center's EERS [web page](#)).
- **Policies to Promote Smart Grid Deployment**  
Smart grid technologies, including communication networks, advanced sensors, and monitoring devices, form the foundation of new ways for utilities to generate and deliver power and for consumers to understand and control their electricity consumption at the building level and at the level of individual electronic appliances (see Smart Grid factsheet).
- **Appraisal Practices**  
Appraisal practices and standards should accurately reflect the financial benefits provided by more energy efficient homes and buildings.
- **Innovative Financing and Subsidies**  
Financing mechanisms whose rates and limits reflect the benefit of more energy homes or buildings and leasing arrangements – such as loans with favorable terms, rebate programs, and green mortgages – would lower the up-front capital required for consumers to invest in end-use energy efficiency. For example, in 1995, Congress mandated a national energy efficiency mortgage program which insures loans for energy efficiency investments incorporated into new or refinanced mortgages administered through the U.S. Department of Housing and Urban Development.<sup>33</sup>
- **Low-Income Weatherization Assistance**  
Subsidies for energy efficiency investments can share the welfare benefits of energy efficiency improvements among all segments of society.
- **Point of Sale and Rent Interventions**  
These policies can address ownership transfer issues. Information dissemination or requirements and incentives for energy audits or appliance upgrades during home sales or new rental contracts can encourage households to improve residential end-use efficiency.<sup>34</sup>
- **Decoupling of Utility Profits from Electricity Sales**  
By ensuring cost-recovery for initial incremental capital costs and a rate of return for energy efficiency investments equal to returns on power generation and transmission investments, state

regulators can make utilities indifferent between energy efficiency investments and power generation investments.<sup>35,36</sup> Decoupling programs can also serve to adjust electricity rates periodically to maintain stable utility revenues despite increases or decreases in electricity consumption (see Pew factsheet on [Decoupling](#)).

- **Utility-Based Incentive Programs**

Several states have adopted different models of utility-based direct energy efficiency incentive programs which disseminate efficiency information, subsidize energy audits, provide incentives for energy efficient new residential construction, or offer rebates for efficient equipment. For example, electricity consumers in northern California face a “systems benefit charge” which is pooled and administered by distribution utilities for system-wide energy efficiency investments. Vermont has created an independent energy efficiency utility to administer energy efficiency projects. States such as New York, Wisconsin, and Ohio administer energy efficiency investments through state agencies.

- **Energy Efficiency Standards**

Efficiency standards have been mandated at the federal level for a wide variety of residential products.<sup>37</sup> Industry associations often develop voluntary energy efficiency standards as a way to stay ahead of federal regulations and identify premium products.<sup>38</sup> Energy efficiency standards have been one of the two largest sources of CO<sub>2</sub> emission reductions in the buildings sector.<sup>39</sup> Some analysts argue that efficiency increases due to energy standards are modest compared to energy efficiency gains that can be realized through higher energy prices, which can be achieved through a price on carbon. For example, in an econometric study, researchers found a 5 percent increase in water heater efficiency due to high prices during the oil crises in the 1970s, compared to a 2 percent increase due to energy standards in 1990.<sup>40</sup>

- **Voluntary Labeling**

Labeling systems such as the ENERGY STAR® program can lower information gaps in the residential sector. The ENERGY STAR® program is one of the two largest sources of CO<sub>2</sub> emissions reductions in the buildings sector.<sup>41</sup> Voluntary labeling and information dissemination programs can provide clear financial and technical information useful for household decision-making, such as simple financial analyses and identification of a subset of best-in-class products from which consumers can choose.

- **Non-Monetary Interventions**

Programs such as the Sacramento Municipal Utility District (SMUD)’s ) “smiley face” experiment may help to address behavioral barriers. SMUD included smiley faces on bills of customers whose usage was low relative to nearby households, and frowning faces on households with high usage. This induced an energy savings of approximately 2 percent relative to households with standard bills. These and other interventions which increase access to information, or use framing, social pressure, or default options can help to change behaviors to improve end-use energy efficiency.<sup>42,43</sup>

- **Behavioral Response Research**

There is limited empirical data on the behavioral response to policy interventions to improve energy efficiency; such data can be used to design better policies to lower behavioral barriers to energy efficiency.

### Related Business Environmental Leadership Council (BELC) Company Activities

- [AEP](#)

- [Dow](#)
- [DTE Energy](#)
- [Duke Energy](#)
- [Energy](#)
- [GE](#)
- [Hewlett-Packard Company](#)
- [Intel](#)
- [PG&E](#)
- [PNM Resources](#)
- [Whirlpool](#)
- [Wisconsin Energy Corporation](#)

### **Related Pew Center Resources**

#### 10-50 Workshop Energy Efficiency Papers

Gilbert Metcalf, Tufts University (Overview) ([pdf](#))

Lynn Price and Ernst Worrell, Lawrence Berkeley National Laboratory ([pdf](#))

Vivian Loftness, Carnegie Mellon University ([pdf](#))

Richard Newell, Resources for the Future ([pdf](#))

[Appliances and Global Climate Change: Increasing Consumer Participation in Reducing Greenhouse Gases](#), 2000.

Brown, M. A., Southworth, F., and Stovall, T. K. 2005. [Towards a Climate-Friendly Built Environment](#).

[The U.S. Electric Power Sector and Climate Change Mitigation](#), 2005

What's Being Done in the States:

[Appliance Efficiency Standards](#),

[Energy Efficiency Resource Standards](#)

### **Further Reading / Additional Resources**

American Council for an Energy-Efficient Economy (ACEEE). [Consumer Guide To Home Energy Savings](#).

U.S. Department of Energy (DOE), Energy Efficiency and Renewable Energy Program.

- [Appliances and Commercial Equipment Standards](#).
- [ENERGY STAR®](#)

Dubin, J. A. 1992. "[Market Barriers to Conservation: Are Implicit Discount Rates Too High?](#)" California Institute of Technology Working Paper.

Electric Power Research Institute. 2009. [Assessment of Achievable Potential from Energy Efficiency and Demand Response Programs in the U.S.](#) Technical Report # 1016987. January.

Gillingham, K., Newell, R., and Palmer, K. 2009. [Energy Efficiency Economics and Policy](#). Resources for the Future Discussion Paper # 09-13. April.

- Greening, L. A., Greene, D., Difiglio, C. 2000. "Energy efficiency and consumption - the rebound effect - a survey." *Energy Policy*. Vol 28, p. 389-401.
- Howarth, R. B., Haddad, B. M., Paton, B. 2000. "The economics of energy efficiency: insights from voluntary participation programs." *Energy Policy*. Vol. 28, page 477-486.
- Koomey, J. G., Mahler, S. A., Webber, C., and McMahon, J. 1998. [\*Projected Regional Impacts Of Appliance Efficiency Standards For The U.S. Residential Sector\*](#). LBNL-39511.
- Kushler, M., York, D., Witte, P. 2006. [\*Aligning Utility Interests with Energy Efficiency Objectives: A Review of Recent Efforts at Decoupling and Performance Incentives\*](#). ACEEE report # U061. October.
- McKinsey and Company, 2007. [\*Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost?\*](#) December.
- McKinsey and Company, 2009. [\*Unlocking Energy Efficiency in the U.S. Economy\*](#). July.
- Meyers, S, McMahon, J. E., McNeil, M., and Liu, X. 2003. "Impacts of US Federal Energy Efficiency Standards for Residential Appliances," *Energy*. Vol 28, June: 755-67.
- Newell, R., Jaffe, A. and Stavins, R. 1998. "The Induced Innovation Hypothesis and Energy-Saving Technological Change," *Resources for the Future*, Discussion Paper, October.
- Train, K. 1985. "Discount Rates in Consumers' Energy-Related Decisions: A Review of the Literature." *Energy* Vol. 10, No. 12: 1243-1253.

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<sup>1</sup>U.S. Environmental Protection Agency. 2009 *U.S. Greenhouse Gas Inventory Report*.  
<http://epa.gov/climatechange/emissions/usinventoryreport.html>

<sup>2</sup> In contrast, commercial building electricity consumption is largely driven by the size of lighting, computer, and other electronic loads. Brown, M. A., Southworth, F., and Stovall, T. K. 2005. [\*Towards a Climate-Friendly Built Environment\*](#). page ES-iv.

<sup>3</sup> U.S. Census Bureau. [\*American Housing Survey\*](#).

<sup>4</sup> Brown et al. 2005.

<sup>5</sup> Brown et al. 2005, page 31.

<sup>6</sup> American Council for an Energy-Efficient Economy (ACEEE). [\*Consumer Guide To Home Energy Savings\*](#).

<sup>7</sup> U.S. Department of Energy. [\*Appliance Success Stories\*](#).

<sup>8</sup> Flex Your Power. 2009. [\*Clothes Dryers Product Guides\*](#).

<sup>9</sup> ACEEE. 2007. [\*Consumer Guide to Home Energy Savings: Cooking\*](#).

<sup>10</sup> ACEEE, *Cooking*, 2007.

<sup>11</sup> NRC (National Research Council). 2009. *Realistic Prospects for Energy Efficiency in the United States*. Washington, D.C.: National Academies Press.

<sup>12</sup> Primary energy is defined as the energy contained in the fuels (e.g., coal, natural gas, and petroleum) consumed directly or indirectly by the household. The delivered energy is the energy actually consumed by the household and will reflect conversion and transmission losses from the primary energy. The delivered energy from natural gas used directly in a household is about the same as the primary energy from natural gas, except for any losses from transportation. In contrast, the primary energy of electricity is often 2-3 times higher than the delivered energy of electricity used by the household, depending on the resource mix (of coal, natural

gas, nuclear, renewable, etc.) used to produce the electricity and taking into account the energy losses that occur during the generation and grid transmission of electricity. For example, in the case of coal-fueled electricity, the primary energy is the energy value of the coal used in the power plant. The delivered energy is the energy value of electricity delivered to a home, which will be less than the primary energy because power plants convert only a fraction of the primary energy to electricity and then electricity is lost during transmission and distribution.

<sup>13</sup> The GHG emissions associated with a unit of primary energy (measured in quadrillion British thermal units (Btus) or quads) depends on the fuel mix. For example, as U.S. electricity generation becomes less carbon-intensive through the use of more renewables, nuclear, and natural gas instead of coal, the GHG emissions per unit of primary energy will decrease.

<sup>14</sup> S. Meyers, J. E. McMahon, M. McNeil and X. Liu, "Impacts of US Federal Energy Efficiency Standards for Residential Appliances," *Energy* 28 (June 2003): 755–67. See also S. Meyers, J. E. McMahon, M. McNeil and X. Liu, "Realized and Prospective Impacts of U.S. Energy Efficiency Standards for Residential Appliances," Lawrence Berkeley National Laboratory, LBNL-4950, June 2002.

<sup>15</sup> Assumes a 73.8 percent capacity factor (source: [EIA](#)), and 50-year lifetime for a coal power plant, and a CO<sub>2</sub> emissions rate equal to the U.S. coal fleet average emissions rate, calculated from the [EPA Emissions Inventory](#) and the Energy Information Administration's *Electric Power Annual 2007* report ([http://www.eia.doe.gov/cneaf/electricity/epa/epa\\_sum.html](http://www.eia.doe.gov/cneaf/electricity/epa/epa_sum.html))

<sup>16</sup> McKinsey and Company, 2009. [Unlocking Energy Efficiency in the U.S. Economy](#). July.

<sup>17</sup> Costs and emission reductions assessed from present to 2030 with a 7 percent discount rate (cost/savings in 2009\$). McKinsey and Company, 2007. [Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost?](#) December: p. ES-xiii. The [GDP deflator](#) was used to convert 2005 dollars to 2009 dollars..

<sup>18</sup> McKinsey and Company, 2009.

<sup>19</sup> Cost of conserved energy is an energy efficiency cost metric defined as the ratio between the incremental levelized annual cost for the efficient appliance and the annual electricity savings in comparison with a baseline appliance. Levelized annual costs are the sum of annual electricity and maintenance costs (if any) and amortized capital costs at a given discount rate.

<sup>20</sup> Koomey, J. G., Mahler, S. A., Webber, C., and McMahon, J. 1998. *Projected Regional Impacts Of Appliance Efficiency Standards For The U.S. Residential Sector*. LBNL-39511. Cost of conserved energy in 2009 calculated by escalating rates from 1995 by the [GDP deflator](#). All prices are in 2009 dollars.

<sup>21</sup> Train, K. 1985. "Discount Rates in Consumers' Energy-Related Decisions: A Review of the Literature." *Energy* 10(12):1243-1253.

<sup>22</sup> McKinsey and Co., 2009

<sup>23</sup> Calculated from residential end-use electricity consumption data from the Energy Information Administration's [Annual Energy Review](#) 2008, table 8.9: Electricity End Use, and the [U.S. Census Bureau](#) number of households data.

<sup>24</sup> U.S. Department of Energy [Smart Home Scale](#).

<sup>25</sup> U.S. Census. [New Residential Construction: Quarterly Starts and Completions by Purpose and Design](#).

<sup>26</sup> U.S. Environmental Protection Agency. 2008. [ENERGY STAR® Unit Shipment and Market Penetration Report: Calendar Year 2007 Summary](#).

<sup>27</sup> Gillingham, K., Newell, R., and Palmer, K. 2009. "Energy Efficiency Economics and Policy." [Resources for the Future Discussion Paper # 09-13](#). April.

<sup>28</sup> EIA, Residential Energy Consumption Survey (RECS), [Total Energy Consumption, Expenditures, and Intensities, 2005](#), Table US1.

<sup>29</sup> J.D. Power and Associates. [Press Release](#). 9 November 2005.

<sup>30</sup> Dubin, J. A. "Market Barriers to Conservation: Are Implicit Discount Rates Too High?" in *Economics of Energy Conservation*.

<sup>31</sup> Azevedo, I. L. "Energy Efficiency and Conservation: Is Solid-State Lighting A Bright Idea?" ECEEE paper, 2007.

<sup>32</sup> Greening, L. A., Greene, D., Difiglio, C. 2000. "Energy efficiency and consumption - the rebound effect - a survey." *Energy Policy*. Vol 28, p. 389-401.

<sup>33</sup> U.S. Department of Housing and Urban Development. [Energy Efficient Mortgages and FHA Mortgage Insurance](#).

<sup>34</sup> McKinsey and Co, 2009, page xi-Exhibit F.

<sup>35</sup> Kushler, M., York, D., Witte, P. 2006. "Aligning Utility Interests with Energy Efficiency Objectives: A Review of Recent Efforts at Decoupling and Performance Incentives." ACEEE report # U061.

<sup>36</sup> Solar Electric Power Association (SEPA). 2009. ["Decoupling Utility Profits From Sales."](#) SEPA Report # 03-09. February.

<sup>37</sup> [EERE](#)

<sup>38</sup> Examples of industry-led appliance standards programs include the [Association of Home Appliance Manufacturers' \(AHAM\) Standards program](#), and the [80 Plus Program](#) for 80% greater efficiency power supplies for plug loads developed by electric utilities,

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<sup>39</sup> Brown et al., 2005, page vi.

<sup>40</sup> Richard Newell, Adam Jaffe, and Robert Stavins, "The Induced Innovation Hypothesis and Energy-Saving Technological Change," Resources for the Future, Discussion Paper, October 1998, and Quarterly Journal of Economics 114, no.3, pp. 941–75.

<sup>41</sup> Brown et al., 2005, page vi.

<sup>42</sup> Kaufman, L. "Utilities Turn Their Customers Green, With Envy." *New York Times*. 30 January 2009.

<sup>43</sup> Ayres, Ian et al., 2009, *Evidence from Two Large Field Experiments that Peer Comparison Feedback Can Reduce Residential Energy Usage*, NBER Working Paper 15386.