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Addressing Market Barriers to Energy Efficiency in Buildings

David Austin

Congressional Budget Office

david.austin@cbo.gov

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Abstract

A large share of total U.S. energy consumption—40 percent—occurs in homes and buildings. Homes and buildings are less energy efficient than they would be if people could assess the value of energy savings more easily and correctly, and if energy prices provided them with stronger incentives to do so. This paper identifies three reasons why people undervalue energy savings: misperceived energy prices, imperfect information about energy efficiency, and biased reasoning about energy savings. The paper then examines four types of policy options for addressing those underlying market imperfections: prices that reflect the social costs of energy use, financial incentives, energy-efficiency standards, and better information about energy efficiency.

An Energy-Efficiency Gap in Buildings

Buildings in the residential and commercial sectors—houses, shops, schools, offices, and the like—account for about 40 percent of total U.S. energy consumption, including more than two-thirds of generated electric power. That is more energy than is consumed in transportation or in industry, the other two sectors of the economy. Therefore, any effort to limit carbon dioxide (CO₂) emissions and other social costs of energy production and consumption will probably involve achieving greater energy efficiency in building technologies: insulation, lighting, appliances, windows, and other equipment. Meaningful energy savings could be achieved if, at each opportunity to install or replace a building technology, decisionmakers chose the optimal level of energy efficiency, taking into account trade-offs in purchase price, performance, and social costs.

In this paper, however, I argue that imperfections—relating to misperceived prices, imperfect information, and biased reasoning—in markets for energy-using products interfere with people’s ability to make privately optimal decisions. The result is an energy-efficiency gap, or an “energy paradox”: Energy-efficient technologies with lower lifetime costs diffuse more slowly through the economy than would be expected given their cost advantages.

Because of energy’s social costs—not only regional pollutants (primarily particulates and oxides of sulfur and nitrogen) and global greenhouse gases (primarily carbon dioxide) from energy production and consumption, but also local pollution, traffic, and noise from resource extraction and transport—there are social benefits from policies that narrow the energy-efficiency gap. Growing concerns about global climate change have made it important to identify ways of reducing greenhouse-gas emissions at relatively low cost. Policies that address

imperfections in markets for energy efficiency can reduce polluting emissions at a cost that is relatively low compared with the benefits. With buildings responsible for a substantial share of U.S. energy consumption, such policies make buildings an important potential source of lower-cost emissions reductions.

Sources of Energy Demand and Energy Savings in Buildings

Energy use in buildings primarily supports space heating and cooling, ventilation, water heating, lighting, and refrigeration (see Table 1). Electricity is the primary energy source for most building functions, although natural gas is also a leading fuel for space heating, water heating, cooking, and clothes drying.¹

Examples of energy-saving building technologies include familiar products like programmable thermostats, low-energy lighting, and on/off timers for electrical outlets (to reduce energy use when equipment is in standby mode); durable technologies such as low-emissivity windows and variable-speed motors for furnaces and air conditioner systems; and spray-foam insulation of attics, reflective roofing materials, insulated-concrete foundation walls, and other construction technologies. Whether a technology's energy savings are worth a higher purchase price (relative to the price of a conventional technology) will depend on each potential adopter's particular circumstances. Thus, policies that preserve the choice of whether to adopt a technology—policies that create incentives or disseminate information rather than imposing mandates—are less likely to impose costs in excess of benefits. Still, there are circumstances in which mandates—minimum-efficiency standards and building energy codes—can be justified on a cost-benefit basis.

¹ Energy Information Administration, *Annual Energy Outlook 2010* (April 2010), [www.eia.doe.gov/oiaf/aeo/pdf/0383\(2010\).pdf](http://www.eia.doe.gov/oiaf/aeo/pdf/0383(2010).pdf), Tables A4 and A5.

**Table 1—U.S. Primary Building Energy Consumption by End Use,
Residential and Commercial Sectors, 2010**

End Use	Share (Percent) of Total Primary Energy Consumption *	
	Residential Sector	Commercial Sector
Space Heating	27.8	16.0
Space Cooling, Ventilation	15.1	23.6
Water Heating	12.9	4.3
Electronics & Computers	10.0	8.0
Lighting	9.7	20.2
Refrigeration	6.4	6.6
Wet Cleaning †	4.8	—
Cooking	3.7	1.4
Other ‡	3.6	14.5
SEDS Adjustment **	5.8	5.4
Total	100	100

Note: Shares of end uses for the residential sector do not add exactly to 100 because of rounding.

Source: Department of Energy, *2011 Buildings Energy Data Book*, Tables 2.1.5 and 3.1.4.

* Primary energy consumption by sector, as a share of the U.S. total: Buildings (40%: Residential 22.5%, Commercial 18.6%), Industrial (30.8%), Transportation (28.1%). (*2011 Buildings Energy Data Book*, Table 1.1.3)

† Includes clothes washers, dryers, and dishwashers. Does not include energy used by water heaters.

‡ “Other”: [Residential] - small electric devices, heating elements, motors, swimming pool heaters, hot tub heaters, outdoor grills, and natural gas outdoor lighting; [Commercial] - service station equipment, ATMs, telecommunications equipment, medical equipment, pumps, emergency electric generators, combined heat and power in commercial buildings, and manufacturing performed in commercial buildings.

** Energy not directly attributable to specified end uses. The Energy Information Administration’s SEDS (“State Energy Data System”) adjustment accounts for discrepancies between data sources.

The Size of the Building Energy-Efficiency Gap

Estimates of the size of the energy-efficiency gap vary widely. Even the best available estimates are accompanied by significant uncertainty. The Electric Power Research Institute (EPRI), a utility-sponsored research organization, estimates *technically feasible* savings based on a comparison of available energy-saving technologies. But it judges only some of those savings to be *economically feasible*, based on only those technologies whose savings would make up for higher purchase prices relative to the conventional alternatives. EPRI defines *achievable* savings as reflecting industry experts' judgments about how willing consumers would be to adopt the various energy-saving technologies and utility companies' recent experiences promoting energy efficiency to their customers.

EPRI finds that the maximum "achievable" energy savings by 2020 would be 10 percent (or 11 percent by 2030) if the most-efficient technologies available were adopted in new construction or to replace existing equipment at the end of its useful life, both at the most optimistic projected rates.² But EPRI estimates that, realistically, only about half of those maximum savings could be achieved by 2020 (or three-quarters of the savings by 2030) because of market barriers and adoption behaviors.

Other studies have produced estimates only of *technical* savings potential, without considering feasibility, in terms of adopters' costs and the gradual nature of technology diffusion. Those estimates tend to be much larger than EPRI's maximum achievable 10 percent savings:

² Electric Power Research Institute, *Assessment of Achievable Potential from Energy Efficiency and Demand Response Programs in the U.S.: 2010–2030* (January 2009). Savings would come from improved power supplies; maintenance of air ducts and heating, ventilation, and air conditioning equipment; insulation; reduced air infiltration (weatherization); programmable thermostats; reflective building materials; whole-house and ceiling fans; low-emissivity windows; water pipe insulation; and home energy-management systems.

- The National Renewable Energy Laboratory (NREL) has estimated that energy use in existing single-family houses would be 50 percent lower if the houses were better insulated and sealed and if they had all Energy Star appliances, compact fluorescent lightbulbs (CFLs), tankless water heaters, and highly efficient heating, ventilation, and air conditioning (HVAC) equipment.³
- The Intergovernmental Panel on Climate Change (IPCC) concluded that wider adoption of “mature technologies”—only when the environmental benefits outweigh the technical costs—could yield energy savings of around 30 percent.⁴ The IPCC considered the same kinds of technologies that the NREL study considers, plus reflective building materials and low-emissivity windows.
- A much-cited study by McKinsey & Co. concluded that residential and commercial energy consumption could be cut by around 20 percent worldwide in little more than a decade using many of the technologies discussed above, and by reducing standby energy consumption.⁵

Although many analysts believe that estimates of technically feasible savings substantially overstate the energy-efficiency gap, such estimates are helpful for identifying where energy can be saved. However, to the extent that they do not illuminate why a technology is not more widely

³ National Renewable Energy Laboratory, *Maximizing Residential Energy Savings: Net Zero Energy Home Technology Pathways*, NREL/TP-550-44547 (2008). Energy Star is a designation (by the Environmental Protection Agency and the Department of Energy) for certain types of appliances and other electronic equipment. Energy Star products typically use 10 percent to 25 percent less energy than the applicable minimum-efficiency standard. See “How a Product Earns the Energy Star Label,” www.energystar.gov/index.cfm?c=products.pr_how_earn.

⁴ Mark Levine and others, “Residential and Commercial Buildings,” in *Climate Change 2007: Mitigation*, Fourth Assessment Report (Intergovernmental Panel on Climate Change, 2007).

⁵ McKinsey Global Institute, *The Carbon Productivity Challenge: Curbing Climate Change and Sustaining Economic Growth* (June 2008). McKinsey estimates that energy savings in the residential and commercial sectors could reduce worldwide energy consumption by 8 percent. Because those sectors are responsible for 40 percent of total consumption in the United States, the implied energy savings in those sectors is 20 percent (see the notes to Table 1).

adopted, estimates of technically feasible savings offer little guidance for energy-efficiency policy.

In addition to the market imperfections that are the subject of this paper, the slow adoption rates that underlie the difference between *economically feasible* and *realistically achievable* savings also depend on consumers' legitimate preferences for product attributes other than energy efficiency. Performance and quality also matter to consumers. For example, although early compact fluorescent lightbulbs used less energy and had lower lifetime costs than conventional lightbulbs, many consumers rejected them because they did not turn on instantly and the quality of light was cold, flickering, and ashen. As quality has improved (and prices have come down), unit sales of CFLs have increased substantially: In 2007, CFLs accounted for more than 20 percent of all screw-in lightbulbs sold.⁶ Thus, their slow initial rate of adoption may have had little to do with an energy-efficiency gap.

In any case, policies to address imperfections in energy-efficiency markets will have greater net benefits to the extent that they take consumer preferences into account—even though that usually will mean the resulting energy savings will be substantially less than the maximum possible energy savings.

To express the energy-efficiency gap in terms of a primary social cost of energy consumption in buildings, suppose environmental damages from carbon dioxide emissions were between 3 percent and 23 percent of the delivered retail price of electricity (reflecting a range of estimates).⁷ Then, if policies succeeded in raising energy efficiency by enough to cut building

⁶ National Research Council (2010), *op. cit.*.

⁷ For natural gas, CO₂ damages are estimated to range from 2 percent to 19 percent of the retail price. Ranges are based on an estimated social cost of carbon dioxide between about \$5 and \$40 per metric ton of carbon dioxide (in 2012 dollars); emissions of 1,384 pounds (0.63 metric tons) of CO₂ per megawatt of electricity, on average, from all sources of generation; and 5.45 kilograms (0.005 mt) of CO₂ per therm of natural gas. (Social costs of carbon dioxide: Interagency Working Group on Social Cost of Carbon, "Technical Support Document: Social

energy consumption by 5 percent, narrowing that energy-efficiency gap by perhaps half, those damages would fall by the equivalent of 0.15 percent to 1.15 percent of total energy expenditures in buildings. That implies that the annual value of the avoided environmental damages would have been between about \$600 million and \$4.6 billion (in 2012 dollars), or about \$5 to \$40 per U.S. household per year.⁸

Reasons for the Gap

This paper focuses on three market imperfections associated with the adoption of energy-efficient technologies:⁹

- Energy prices are misperceived and may differ from the incremental cost of service;
- Consumers' responses to price signals are hampered by imperfect information; and
- Consumers' assessments of potential energy savings tend to be too low because of biased reasoning.

Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866" (February 2010). Emissions: Environmental Protection Agency, "Calculations and References," www.epa.gov/cleanenergy/energy-resources/refs.html.) Those estimates imply likely CO₂ damages from electricity generation between about 0.35 cents per kilowatt hour and 2.75¢/kWh, and from natural gas between \$0.02/therm and \$0.20/therm (author's calculations). Average retail prices are around 11¢/KWh for electricity (ranging from 7.99¢ in Idaho to 19.25¢ in Connecticut, and 28.10¢ in Hawai'i) and \$1.00/therm for natural gas (ranging from \$0.78 in North Dakota to \$1.73 in Florida, and \$4.30 in Hawai'i). (See Energy Information Administration, "Average Retail Price for Bundled and Unbundled Consumers, by Sector, Census Division, and State, 2010," www.eia.gov/electricity/sales_revenue_price/pdf/table4.pdf, and "Natural Gas Prices," www.eia.gov/dnav/ng/ng_pri_sum_a_EPG0_PRS_DMcf_a.htm.)

⁸ Author's calculation based on total sales of electricity of about \$315 billion in 2010 in the residential and commercial sectors, and about \$88 billion for natural gas (values in \$2012). See Energy Information Administration, "Electric Power Annual 2010," www.eia.gov/electricity/annual/pdf/table7.3.pdf, and "Natural Gas Summary," www.eia.gov/dnav/ng/ng_sum_lsum_dcu_nus_a.htm. For the number of U.S. households (114.8 million in 2010), see Bureau of the Census, "Projections of the Number of Households and Families in the United States: 1995 to 2010 - P25-1129," Figure 1, p. 6, www.census.gov/prod/1/pop/p25-1129.pdf. Damages would not change appreciably if calculations included expenditures for fuel oil, heating oil, and kerosene.

⁹ For a more detailed discussion, see Kenneth Gillingham, Richard Newell, and Karen Palmer, *Energy Efficiency Economics and Policy*, Working Paper 15031 (National Bureau of Economic Research, June 2009).

Misperceived Prices. A building's energy efficiency is typically determined by choices made by a builder or landlord on behalf of future tenants or owners who will pay the energy bills and accrue any energy savings. In principle, builders and landlords (and homeowners) can recoup investments in energy efficiency by charging more in rent or by seeking a higher sales price. But in practice, it is difficult to document the value of energy-efficient investments in order to command those higher prices: Evidence of the investment is often concealed behind walls, or reported on window or appliance stickers that are removed or inaccessible after installation. In such circumstances, builders' and owners' decisions about energy efficiency may be little influenced by energy prices. That market imperfection, arising whenever a builder or owner makes an adoption decision on behalf of current (or future) occupants, is often called the "tenant/landlord" or "split incentive" problem.

Evidence about the practical impact of the tenant/landlord problem comes from a variety of sources. For instance, a survey by the California Energy Commission shows that rented houses in California are 20 percent less likely to have insulation in attics and ceilings and 13 percent less likely to have it in outside walls.¹⁰ In California's relatively mild climate, the energy lost to those differences is perhaps 2 percent (or less) per affected household, according to analysts' preliminary estimates.¹¹ In hotter or colder locations, the losses would be greater.

A more pervasive example of split incentives pertains to the familiar cable-television set-top box. As of 2007 there were nearly 150 million of the devices in U.S. homes. In nearly all cases, the cable box is selected by the cable service provider, not by the customer who pays for the electricity the box consumes. A typical cable box draws 25 watts of power or more at all times, even when switched "off" or placed in standby mode. By one estimate, the devices

¹⁰ Kenneth Gillingham, Matthew Harding, and David Rapson, *Split Incentives in Residential Energy Consumption*, unpublished manuscript (2011).

¹¹ Ibid.

consume a combined 20 terawatt-hours of electricity per year in the United States, the equivalent of about 57 million 40-watt lightbulbs kept on year-round. That is around 1.5 percent of total energy consumed in the U.S. residential sector.¹²

According to the International Energy Agency, the energy consumption of cable boxes could be cut by around 75 percent just by using existing, cost-effective technologies.¹³ But because a typical device only costs about \$25 per year to operate (at 11.5 cents per kilowatt hour, assuming a cable box draws 25 watts of power), it is not very costly for people to ignore the issue. With little demand from households for a more energy-efficient cable box, and with service providers not paying for the energy the devices consume, manufacturers face little demand for energy efficiency from the cable-television providers who purchase the devices.

Another market imperfection relating to energy price signals concerns the electricity meters that all buildings have. Most of those meters can only support a single electricity price rate, because they only record total consumption, not time-of-day usage. However, at peak periods of demand, the cost of providing electricity can exceed that price; conventional meters cannot deliver that signal of higher costs to consumers. “Smart” meters that keep track of energy usage by time of day can support multiple prices, including higher prices at peak periods, and can report those prices to consumers. That gives consumers a greater incentive to conserve energy and to shift some usage to off-peak periods. As smart meters become more widely installed, the market imperfection of misperceived energy prices will decline in importance.

Imperfect Information. Private incentives to supply information about product energy efficiency are weak, in part because much of the value of that information is social: Information can simultaneously benefit an unlimited number of people, and once it has been supplied, anyone

¹² International Energy Agency, *Mind the Gap: Quantifying Principal-Agent Problems in Energy Efficiency* (Organization for Economic Cooperation and Development, 2007), pp. 137–149.

¹³ *Ibid.*, p. 147.

can freely disseminate it to whomever they wish. The manufacturers and early adopters who generate it may realize little private benefit.

In practice, that implies that markets, by themselves, tend to supply too little information about energy efficiency. In addition, potential adopters' interests are best served if that information is expressed in terms that bear directly on the adoption decision (for instance, if it emphasizes a product's operating costs rather than the amount of energy it consumes), and if it is placed in context (for instance, if one product's energy performance is compared against others'). By themselves, markets may supply imperfect information about energy efficiency because there may be little private return to the effort to figure out how to express that information in a way that would be most useful to consumers.

Biased Reasoning. Research suggests that individuals' assessments of potential energy savings are systematically biased.¹⁴ Such departures from optimal decisionmaking would not persist if people could learn about and adjust for their biases through accumulated experience. But long-lived technologies give them few opportunities to do that. In particular, people have difficulty assessing their energy savings because few building technologies or appliances provide feedback about the amount of energy they are actually consuming.

Research has shown that for relatively small devices like CFLs, personal computers, and stereos, people make reasonably accurate estimates of the amount of energy they use. But for larger or more energy-intensive appliances like air conditioners, dishwashers, space heaters, and electric clothes dryers, their estimates are way off: Those appliances use more than three times as

¹⁴ See, for example, David Greene, "Uncertainty, Loss Aversion, and Markets for Energy Efficiency," *Energy Economics*, vol. 33, no. 4 (July 2011), pp. 608–616; and Stefano DellaVigna, "Psychology and Economics: Evidence from the Field," *Journal of Economic Literature*, vol. 47, no. 2 (2009), pp. 315–372.

much energy as people think they do.¹⁵ Researchers made that discovery by asking survey respondents to compare an appliance’s energy consumption to that of a standard 100-watt lightbulb. The researchers chose that comparison in order to simulate the “anchoring-and-adjustment” heuristic that people are known to use to estimate energy consumption: They implicitly adopt a salient reference point, like the energy used by a lightbulb, as a metric for assessing the energy consumption of smaller devices. For larger appliances, people tend to make larger estimates as multiples of their implicit metric. Thus, people tend to underestimate energy consumption because those adjustments for larger appliances tend to be too small.

Policy Approaches to Reducing the Energy-Efficiency Gap

A variety of federal policies—including financial incentives for energy efficiency, minimum-efficiency standards, and energy labeling programs—have helped limit energy consumption in buildings. The budgetary costs of those policies are distributed across several programs. Annual outlays in the “energy conservation” category of the federal budget reached \$1.4 billion in 2009 and have exceeded \$0.5 billion for all but one of the past 20 years. A one-time boost from the American Recovery and Reinvestment Act of 2009 (ARRA) provided substantial additional funding, much of it for home weatherization and other state-level energy programs (ARRA provided a combined \$8.1 billion in budget authority); “green” retrofits of federal buildings (\$4.5 billion in budget authority); low-income Energy Star housing and other local and regional initiatives (\$3.2 billion for “energy efficiency and conservation” block grants); and research and development (\$2.9 billion, including \$400 million for ARPA-E, the Advanced Research Projects Agency—Energy, a Department of Energy (DOE) agency created in 2007 to

¹⁵ Shahzeen Attari and others, “Public Perceptions of Energy Consumption and Savings,” Proceedings of the National Academy of Sciences, *PNAS Early Edition* (August 16, 2010), pp. 1–6.

research new energy technologies).¹⁶ ARRA also included several billion dollars in tax credits for energy-saving home improvements.¹⁷ As a result of that additional budget authority, outlays in the “energy conservation” category rose to \$5 billion in 2010, \$6.7 billion in 2011, and an estimated \$9.4 billion in 2012.¹⁸ Those amounts have not yet completely exhausted the additional budget authority provided in ARRA.

However, existing federal policies do not fully address imperfections in energy-efficiency markets. In some cases the potential exists to do more, via adjustments in policy scope, stringency, or design. But the benefits—increased energy savings and reduced greenhouse-gas emissions—would have to be weighed against the policy costs. Other potential federal policies could also help reduce the remaining market imperfections in a cost-beneficial way.

Because policy costs can rise rapidly with increases in policy stringency, it is unlikely that the gap can be eliminated entirely at an acceptable cost. But the four policy approaches I describe here can narrow it, creating meaningful environmental and energy-savings benefits in excess of costs. (As a general rule, some analysts have concluded, the number of independent policy instruments deployed in a particular market should not exceed the number of meaningful imperfections in that market.)¹⁹

- **Social-cost pricing of energy use.** This policy would raise energy prices to account for environmental damages. But it would only partially address

¹⁶ Congressional Budget Office, *Federal Climate Change Programs: Funding History and Policy Issues* (March 2010), Table 4, p. 9.

¹⁷ Joint Committee on Taxation, *Estimated Budget Effects of the Revenue Provisions Contained in the Conference Agreement for H.R. 1, the “American Recovery and Reinvestment Tax Act of 2009,”* JCX-19-09 (provisions 7 and 8, p. 3), www.jct.gov/x-19-09.pdf.

¹⁸ Office of Management and Budget, Historical Tables, “Table 3.2—Outlays by Function and Subfunction: 1962-2017,” www.whitehouse.gov/omb/budget/Historicals.

¹⁹ Jan Tinbergen, *On the Theory of Economic Policy* (Amsterdam: North Holland, 1952). For a concise discussion of policy implications, see Robert Mundell, “The Nature of Policy Choices,” *International Economics* (New York: Macmillan, 1968), pp. 201–203. For a contemporary policy application, see Nils Axel Braathen, “Instrument Mixes for Environmental Policy: How Many Stones Should be Used to Kill a Bird?” *International Review of Environmental and Resource Economics*, vol. 1, no. 2 (2007), pp. 185–235.

imperfections in markets for energy-efficiency products because several of those imperfections dampen the effects of energy prices on the demand for energy efficiency.

- **Financial incentives.** These policies—comprising a variety of grants, tax credits, and rebates—would reduce the energy-efficiency gap to the extent that the technologies favored by those incentives were affected by market imperfections and to the extent that the incentives caused people to adopt technologies they otherwise would not have.
- **Energy-efficiency standards.** These policies, which include energy codes for buildings, would reduce the gap to the extent that they were well-targeted. The budgetary costs of more-stringent standards and codes would be minimal, but those policies probably would have greater costs to the economy than would the other two types of policies, for a given level of energy savings. They would offer greater certainty in the energy savings they would achieve, however.
- **Information.** Providing more and better information about energy efficiency would allow consumers to make more well-informed trade-offs between energy efficiency and other product attributes. Improvements in the type of information and in how it is presented would tend to reduce the energy-efficiency gap whenever the information led consumers to actions they would not have taken otherwise.

In addition, any policies that encouraged demand for energy efficiency would also, in turn, induce greater private-sector investment in research and development (R&D) to improve upon and expand the number of cost-effective, energy-saving technologies.

Social-Cost Pricing of Energy Use

As long as energy prices do not reflect the costs of environmental damages and capacity costs from the production and consumption of energy, individuals have too little incentive to adopt energy-efficient technologies or to limit their energy consumption. Taxing or imposing a cap on CO₂ emissions would provide stronger incentives to do both. Because individuals would decide for themselves how best to respond to the higher energy prices that a tax or an emissions cap would produce, the resulting energy savings would be achieved at the lowest possible cost (providing that the imperfections in energy-efficiency markets were adequately addressed).

Because the potential benefits of energy conservation are greater in peak periods than at other times of the day, pricing electricity according to the time of day would have effects analogous to putting a price on carbon dioxide emissions. To meet peak demand, utilities bring additional generation capacity on-line. Fixed-rate electricity pricing does not reflect the higher costs of using those auxiliary generating units, and thus does not provide the additional incentive for energy conservation during peak periods that time-of-day pricing would provide.

Pricing Carbon Dioxide Emissions. Research on how energy consumption responds to energy prices suggests that adding the social cost of CO₂ to those prices, via either a tax or a cap on emissions, could eventually narrow the energy-efficiency gap by around one-fourth (based on current estimates). But it would take many years. Adding the social cost of carbon dioxide emissions to energy prices would cause electricity consumption to decline in the short run by 0.4 percent to 3 percent (and natural gas consumption to decline by 0.3 percent to 2.5 percent) based on estimates of the responsiveness of energy demand to changes in energy prices. That short-run response would be led by behavioral responses like adjusting thermostat settings and being more

diligent about shutting off lights in empty rooms. Increased energy efficiency would follow, but with a lag.²⁰

Providing that the price increases were sustained, the long-run decrease in energy consumption would probably be in a range of 1 percent to 7 percent for electricity (0.8 percent to 6 percent for natural gas), reflecting a gradual increase in energy-efficient technology as adoption opportunities arose.²¹ However, those long-run effects would take a decade or more to achieve, as durable goods gradually wore out and as people made other energy-efficiency improvements to homes and commercial buildings. The difference between the long-run and short-run estimates—long-run energy consumption would decline by somewhere between 0.6 percentage points and 4 percentage points more—is the estimated effect of adopting energy-efficient technologies in response to higher energy prices. The center point of that range suggests that pricing CO₂ emissions would narrow the energy-efficiency gap by about one-fourth, assuming the gap was about 10 percent.

Neither a tax nor a cap on emissions would eliminate the gap, because adding the social cost of carbon dioxide to energy prices would not directly address the market imperfections that underlie that gap. Neither approach would unite the split incentives of landlords and tenants (or builders and buyers), provide consumers with more or better information about energy

²⁰ Estimates of short-run price elasticities center around -0.15 (for both electricity and natural gas) in the residential and commercial sectors. The estimated effect on demand is the product of the price elasticity and the price increase. See Carol Dahl and Carlos Roman, “Energy Demand Elasticities: Fact or Fiction? A Survey Update,” in *Energy, Environment and Economics in a New Era* (Washington, D.C.: 24th Annual North American Conference of the United States and International Association for Energy Economics, 2004); and Anthony Paul, Erica Myers, and Karen Palmer, “A Partial Adjustment Model of U.S. Electricity Demand by Region, Season, and Sector,” *Discussion Paper 08-50* (Washington, D.C.: Resources for the Future, 2009).

²¹ Estimates of long-run price elasticities center around -0.35 or -0.4 for both electricity and natural gas. Netting out the short-run response of -0.15, the effect of increased energy efficiency may be around -0.2 or -0.25 (or slightly more, because consumers will readjust their behavioral responses once they have invested in energy efficiency. That is known as the rebound effect). For electricity price elasticity, see Paul, Myers, and Palmer, “A Partial Adjustment Model of U.S. Electricity Demand by Region, Season, and Sector”. For natural gas price elasticity, see National Renewable Energy Laboratory, *Regional Differences in the Price Elasticity of Demand for Energy*, NREL/SR-620-39512 (February 2006).

efficiency, or cause individuals to be less prone to biased reasoning about energy efficiency. However, because both approaches would increase the value of saving energy, they would partially close that gap.

A tax would be less effective in reducing the energy-efficiency gap than an emissions cap to the extent that it failed to induce all economically rational investments in energy efficiency because of those market imperfections. Although a cap on carbon dioxide emissions would, by contrast, guarantee that any emissions target would be met (assuming effective monitoring and enforcement), imperfections in energy-efficiency product markets would mean the cap would not be met at the lowest possible cost (via reduced utilization and increased energy efficiency). Instead, like a tax, the cap would induce too small an increase in energy efficiency and too great a reduction in economic output. To see why, note that an emissions cap would transmit financial incentives to consumers via higher energy prices (reflecting the price of an emissions permit). The weaker an effect a cap had on energy efficiency, the greater the costs would be from reducing output to meet the cap—and thus the higher the price would be of an emissions permit. If the cap was set commensurate with carbon damages, insufficient investment in energy efficiency would drive the permit price above the cost of those damages, reducing the net gains from the policy.

Time-of-Day Pricing. Time-of-day pricing using “smart” electricity meters can provide an incentive to adopt energy-efficient technologies that operate at peak periods of energy demand. Air conditioner systems are a prime example of such a technology. Initial experience with the meters shows that they encourage consumers to slightly reduce their peak-period energy consumption, when variable-rate electricity prices are higher. Analysis of a sample of households that voluntarily adopted the meters found that a 10 percent increase in the peak-period price

would induce about a 1 percent decrease in a household's electricity consumption.²² The response was slightly greater among households that were also given a “pricelight” that glows red to alert residents to higher electricity prices. The analysis found no compensating increase in off-peak consumption.

Those findings largely reflect short-term responses. In the longer term, the effect of time-of-day pricing would be somewhat greater because that pricing would also induce households to replace older, less-efficient air conditioners. Manufacturers would also find demand for technologies (like programmable appliances and devices that allowed appliances to receive price information from the electric meter) that would make it easier for consumers to respond to changes in electricity prices.

More widespread adoption of smart meters and time-of-day pricing largely depends on how many more states decouple electric utilities' regulated rates of return from their revenues. If the meters caused consumption to fall by enough during peak periods, a utility's total revenue could decline. Decoupling would allow utilities to maintain the same overall return if they suffered a drop in revenue after offering time-of-day pricing. Thirteen U.S. states have decoupled rates or otherwise removed disincentives for utilities to adopt time-of-day pricing. Another eight states have initiated pilot decoupling programs.²³

Federal policy options to encourage the adoption of smart meters include regulatory approvals, adoption incentives, and management of consumer privacy concerns.²⁴ Better information about smart meters' role in energy conservation—and about the purpose of peak

²² Hunt Allcott, “Rethinking Real-Time Electricity Pricing,” *Resource and Energy Economics*, vol. 33, no. 4 (November 2011), pp. 820–842. Because the results are based on a self-selected sample of households that voluntarily adopted smart meters, they may overstate the average effect of smart meters given current technology.

²³ Energy Information Administration, “Decoupling treatment of electric and gas utilities can differ within a state,” *Today in Energy* (May 5, 2011), www.eia.gov/todayinenergy/detail.cfm?id=1250.

²⁴ See “New Electricity Meters Stir Fears,” *The New York Times* (January 30, 2011); and “PG&E Offers Opt-Out for Smart Meters at a Cost,” *CNET* (March 25, 2011), news.cnet.com/8301-11128_3-20047091-54.html.

pricing to alter consumption patterns—could increase consumers’ acceptance of, and their behavioral responses to, those meters. Some adopters may not fully understand that time-of-day pricing means higher utility bills for customers who consume a significant fraction of their electricity during peak periods and who fail to adjust when prices are high. Regulators could ease consumers’ “sticker shock” (increases in utility bills that the customer did not expect) by phasing in those prices gradually. During the transition to full time-of-day pricing, customers might continue to face fixed-rate prices, while their utility bills reported a second total: what the customer would owe under time-of-day pricing.

Financial Incentives

Financial incentives—grants or tax credits, rebates, and discounts—can address the problems of imperfect information and biased reasoning. Those incentives are a direct cost to the federal budget.

Grants. Since 1976, DOE’s Weatherization Assistance Program (WAP) has provided grants—currently averaging \$6,500 per participating household—to retrofit nearly 6.5 million houses for low-income families. The WAP is not solely an environmental program: The monthly savings on utility bills is a form of financial assistance. Access to credit is often problematic for low-income households, and many of them would be unable to finance their home’s weatherization. For housing that is particularly energy-inefficient, WAP retrofits can be a cost-effective way to achieve CO₂ emissions reductions.

After receiving an average of about \$260 million in funding per year (in 2012 dollars) for the 10 years from 1999 to 2008, WAP received \$5 billion of one-time funding under ARRA in

2009 that was originally to be spent by 2011.²⁵ (The Congress has extended the deadline beyond March 2012 because it proved impractical for the state agencies to increase their spending rate enough to exhaust their ARRA funding by the original deadline.)²⁶

A study by Oak Ridge National Laboratory (ORNL) concluded, on the basis of a 2005 review of WAP projects in 18 states and the District of Columbia, that the average dollar spent on WAP retrofits had returned at least \$1.30 in natural-gas savings benefits (some projects also saved electricity), or at least \$2.20 including health, safety, and environmental benefits.²⁷ WAP retrofits from 1993 to 2002 are estimated to have reduced participating households' energy consumption by an average of 31 percent.²⁸ DOE claims that the energy savings for 2010, from all past WAP retrofits, totaled \$2.1 billion.²⁹

For fiscal year 2012, the Congress appropriated \$65 million for WAP, to supplement what lawmakers anticipated would be about \$1.5 billion in remaining ARRA funds.³⁰ For fiscal 2013, the President's budget requested \$139 million in WAP funding.³¹

²⁵ Congressional Research Service, *DOE Weatherization Program: A Review of Funding, Performance, and Cost-Effectiveness Studies* (January 11, 2012); the gross domestic product deflator is from the Bureau of Economic Analysis; and author's calculations.

²⁶ For a discussion of challenges in spending WAP's ARRA funding, see Congressional Budget Office, *Federal Climate Change Programs: Funding History and Policy Issues* (March 2010), pp. 20–21.

²⁷ Martin Schweitzer, *Estimating the National Effects of the U.S. Department of Energy's Weatherization Assistance Program with State-Level Data: A Metaevaluation Using Studies from 1993 to 2005*, ORNL/CON-493 (Oak Ridge, Tenn.: Oak Ridge National Laboratory, September 2005), <http://weatherization.ornl.gov/pdf/CON-493FINAL10-10-05.pdf>. See also Congressional Budget Office, *Federal Climate Change Programs: Funding History and Policy Issues* (March 2010), <http://www.cbo.gov/ftpdocs/112xx/doc11224/03-26-ClimateChange.pdf>.

²⁸ Linda Berry and Martin Schweitzer, *Metaevaluation of National Weatherization Assistance Program Based on State Studies, 1993-2002*, ORNL/CON-488 (Oak Ridge, Tenn.: Oak Ridge National Laboratory, 2003).

²⁹ Department of Energy, "Weatherization Assistance Program" (fact sheet, June 2010), http://www1.eere.energy.gov/library/pdfs/48098_weatherization_assisprog_fsr4.pdf.

³⁰ U.S. House of Representatives, 112th Congress, House Report 112-118, "Energy and Water Development Appropriations Bill, 2012: Federal Energy Assistance Programs," www.gpo.gov/fdsys/pkg/CRPT-112hrpt118/pdf/CRPT-112hrpt118.pdf.

³¹ Department of Energy, "FY 2013 Congressional Budget Request: Budget Highlights" (February 2012), www.cfo.doe.gov/budget/13budget/Content/Highlights.pdf.

One policy approach to reducing CO₂ emissions via home weatherization would be to maintain or increase WAP funding in future years, to keep it at or above historic levels. Studies like the ORNL analysis cited above have found that returns to WAP spending have been significantly more than a dollar for each dollar spent. One counterargument is that there may be higher social returns to other types of federal energy-efficiency spending, such as on basic research and development. Another counterargument is that, although WAP retrofits are provided at no cost to the recipients, homeowners bear nonfinancial costs, such as transactions costs. WAP retrofits involve at least two site visits—an initial audit, followed by installation—and residents must be present. Such costs appear to discourage some households from participating. One study found that fewer than 25 percent of Michigan households that were offered free WAP retrofits accepted them.³²

Tax Credits, Rebates, and Discounts. Federal income tax credits for making energy-efficient improvements to buildings were first offered from 1978 to 1985. About 30 million tax filers claimed the credits, which ultimately cost the Treasury about \$10 billion. Individual credits were relatively small, however, and subsequent studies found little evidence that they encouraged very many people to make improvements they would not have made anyway.³³

Currently, builders can qualify for federal “Energy Efficient Home” tax credits of \$1,000 or \$2,000 per house if the house exceeds a reference standard for energy efficiency by, respectively, 30 percent or 50 percent. Through 2015, homeowners may claim a “Residential Energy Efficient Property” tax credit covering 30 percent of the cost of a geothermal heat pump, a wind turbine, solar panels, or a fuel-cell generator. A 10 percent “Residential Energy Property”

³² Meredith Fowlie, Michael Greenstone, and Catherine Wolfram, “An Experimental Evaluation of the Weatherization Assistance Program” (unpublished working paper, 2011). The paper also finds that households that declined to participate gave up several hundred dollars per year in potential energy savings.

³³ National Research Council, *Real Prospects for Energy Efficiency in the United States* (2010).

credit had been available through 2011 for added insulation, energy-efficient windows, and energy-efficient heating and air conditioning systems. One policy approach to reducing carbon dioxide emissions would be to restore, increase, or extend such tax preferences.

Another policy approach relates to home financing. In some cases, home buyers can receive a small federally financed discount on their mortgage if they are buying a qualifying energy-efficient house. For instance, the Environmental Protection Agency has a small pilot program to provide mortgages on Energy Star houses at slightly reduced rates. For homeowners and home buyers, DOE and the Department of Housing and Urban Development have a joint “PowerSaver” program that provides up to \$25,000 in low-cost home-equity financing, backed by the Federal Housing Administration, for investments in a home’s energy efficiency. And the Federal Housing Administration offers an “energy-efficient mortgage insurance” program that provides lower-cost financing by allowing homeowners to add the cost of energy-efficiency improvements onto their mortgages.

Those programs all implicitly recognize that borrowers’ loan-repayment risks are slightly reduced by the monthly energy savings they receive from their investments in their home’s energy efficiency. But it is not clear that private lenders’ failure to account for such energy savings constitutes a significant market imperfection. In any case, the scope of such programs remains quite small.

Where new technologies are concerned, tax credits that encourage early adoption can create valuable information—about the existence of a new technology, where to buy it, where to find an installation contractor, how well it performs, and perhaps how much energy it saves—for other potential adopters. The market imperfection that justifies tax credits for early adoption is that early adopters are not otherwise rewarded for creating and disseminating that information.

Without a financial incentive for early adopters, that information would disseminate more slowly, possibly too slowly from the standpoint of overall social well-being.

The risk that adoption tax credits will simply reward actions that people would have taken anyway can be limited by providing incentives only until a new technology becomes sufficiently established in the marketplace. Then the tax credits will reward *early* adopters—whether or not they would have adopted early anyway—but not later adopters, who instead can benefit from the risks taken by early adopters. Although the tax credits will inevitably reward *some* people for actions they would have taken anyway, offering the credits only for a certain time limits that risk while increasing the number of early adoptions and hastening the spread of information. As a new technology becomes established, the incremental value of further dissemination declines, eliminating the policy rationale for continuing to reward adoption.

Currently, some states and utility companies offer tax credits and rebates for high-efficiency lighting (and for other innovative energy-saving technologies).³⁴ For example, a single 60-watt-equivalent LED lightbulb might last as long as 25 traditional incandescent lightbulbs and over its lifetime could save \$58 (in purchase and operating costs) compared with the cost of all of those incandescent bulbs.³⁵ But at around \$30, an LED lightbulb may be 20 times as expensive as an individual incandescent lightbulb. To purchase such a bulb is to place a costly bet that it will not burn out or break prematurely, that it will be used often enough to generate the anticipated energy savings, and that the light it produces will be of satisfactory quality. By reducing the expected payback period, those incentives encourage adoption by increasing the

³⁴ See, for example, Edison Foundation, *Compilation of U.S. Energy Efficiency Program Profiles* (2009), pp. 87–100, www.edisonfoundation.net/iee/reports/IEE_EEProgSummariesPUBLIC_0609.pdf.

³⁵ Author's calculation based on incandescent bulbs with 1,000-hour lifetimes versus a 12-watt LED bulb rated for 25,000 hours; an electricity price of \$0.11/kWh; and a 5 percent annual discount rate. Manufacturer claims of \$130 in energy savings are misleading because that figure does not discount future savings. Most of the savings would not be realized for 10 to 20 years.

likelihood that such a bet will pay off. (By 2014, new federal energy-efficiency standards for lighting will probably lead to greater production and sales of such products, which will help reduce both their upfront cost and uncertainty about their performance.)

Energy-Efficiency Standards

Energy-efficiency standards (for appliances and for buildings) are designed to eliminate inefficient technologies and practices. As a policy tool, standards are a blunt instrument. Unlike incentives that encourage energy efficiency but let people make their own choices, standards take away (some) choices. As such, they impose costs on consumers and producers—and for some people those costs will exceed the benefits. But to the extent that standards induce manufacturers to develop more-efficient technologies, in the long run standards can also lead to new choices.

Standards can be justified, in some cases, on the basis of split incentives, where building technologies are chosen by individuals who will not be using them or paying their energy costs. They may also be justified as a response to biased reasoning, where potential adopters underestimate the value of energy savings.³⁶ In the first case, standards can eliminate appliances that may appeal to landlords and builders because they are relatively inexpensive but that informed consumers would not choose for themselves because they consume a lot of energy. Standards can perform the same function where biased reasoning would lead consumers to choose such appliances—although a less-costly solution in that case would be to provide information about the (full lifetime) value of energy savings. Standards prevent adopters from making energy-inefficient choices.

³⁶ However, some analysts assert that regulators are as prone to error in determining how stringent a standard should be as adopters are in trying to make optimal choices. See V. Kerry Smith, “Reflections on the Literature,” *Review of Environmental Economics and Policy* (Winter 2007).

No regulation can produce benefits without imposing some costs. Aside from restricting choice, standards impose costs by causing manufacturers to devote more innovative effort to energy efficiency, drawing resources away from other profitable uses. The justification for imposing efficiency standards hinges, therefore, on the value of the environmental and energy savings benefits versus their costs. Those costs can also include higher prices and manufacturer costs, performance trade-offs, and other indirect consumer costs.

Standards may also make some people worse off, even if the aggregate benefits outweigh the costs (and thus other people are made better off). For example, because the energy savings from insulation and energy-efficient HVAC equipment are lower in milder climates, the benefits of stringent standards for those technologies are lower in those regions and could be less than the costs in some cases. One type of standard, the building energy code, is set by state and local governments, so those codes can differ in ways that take regional climate into account. Appliance standards are set at the federal level, however, and do not consider regional climate differences. But manufacturers have indicated that they prefer uniform national standards for appliances, compared to the patchwork of state standards they faced before 1987.

Appliance Standards. Federal appliance standards were first implemented in 1987.³⁷ From 1987 through 2007, related federal spending totaled between \$200 million and \$250 million, or around \$12 million per year (in 2012 dollars).³⁸ The costs to consumers have been greater by several orders of magnitude: In 2000, appliance standards added an estimated

³⁷ The standards were implemented pursuant to the Energy Policy and Conservation Act (EPCA) of 1975 (Public Law 94-163) and subsequent public laws. Revisions to appliance-standard legislation were made in 1987, in The National Appliance Energy Conservation Act (Public Law 100-357); the Energy Policy Act of 1992 (Public Law 102-486); and the Energy Policy Act of 2005 (Public Law 109-58).

³⁸ Stephen Meyers, James McMahon, and Barbara Atkinson, *Realized and Projected Impacts of U.S. Energy Efficiency Standards for Residential and Commercial Appliances*, Environmental Energy Technologies Division, Lawrence Berkeley National Laboratory (March 2008); and author's calculations.

\$2.5 billion to consumers' appliance-purchase costs.³⁹ However, the value of their energy savings, an estimated \$4.8 billion in 2000 and around \$64 billion cumulatively through 2005 in the residential sector, are greater still.⁴⁰

The most notable gains in energy efficiency over that time were in refrigerators. Although they are larger now than they were in 1980, refrigerators today use about 70 percent less energy. That change is primarily a result of a DOE-funded innovation in compressor technology.⁴¹ Energy-efficiency standards for refrigerators became more stringent after that advance, and manufacturers' adoption of the technology followed.⁴²

That example illustrates how appliance standards can influence product attributes as well as the mix of products that are offered for sale. Standards change the context in which potential adopters frame and evaluate their options. As such, standards can shift social norms about energy efficiency. Because individuals' preferences are influenced by external reference points—the size of houses in their neighborhood, the array of refrigerator choices offered by their local retailer, and the energy-efficient features they find in new houses—standards can affect individuals' decisions by influencing their views about how energy efficient their homes are relative to others, as well as their expectations about what their monthly energy costs should be.

Thus, one policy approach toward future appliance standards would be to continue to make them gradually more stringent. The justification depends on the costs of the underlying technologies and how increases in energy efficiency would affect product performance. It also

³⁹ Kenneth Gillingham, Richard Newell, and Karen Palmer, "Energy Efficiency Policies: A Retrospective Examination," *Annual Review of Environment and Resources*, vol. 31 (November 2006), pp. 193–237, citing Meyers and others (op. cit.)

⁴⁰ Cumulative savings: Meyers and others (op. cit.); annual savings: Gillingham and others (op. cit.).

⁴¹ National Research Council, *Energy Research at DOE: Was It Worth It? Energy Efficiency and Fossil Energy Research 1978 to 2000* (Washington, D.C.: National Academies Press, 2001).

⁴² Meyers and others (op. cit.).

depends on whether other policies are in place: A tax or a cap on carbon dioxide emissions, for instance, would weaken (if not necessarily eliminate) the justification for efficiency standards.

Building Energy Codes. Building energy codes require that specified energy-saving technologies be included in new and renovated structures. Federal energy codes exist for mobile homes and federal buildings. Otherwise, however, the federal government is only indirectly involved with energy codes: Through its Building Energy Codes Program, DOE collaborates in the development of the model codes that many states and municipalities adopt, performs technical analyses to support code revisions, and provides financial incentives and technical assistance to help states enforce and update their codes.

With the Energy Policy Act of 1992 (Public Law 102-486), the federal government mandated that states adopt commercial building energy codes that would meet or exceed an applicable model energy code, and that they update their codes whenever new model codes are introduced that would improve energy efficiency.⁴³ That law also required states to consider adopting the model energy code for residential structures, but that is not a mandate.⁴⁴ Most states have adopted the IECC (International Energy Conservation Code) model code, some with modification; as of 2009, though, eight states had no mandatory residential energy code, and four others had not updated their energy codes in at least eight years.⁴⁵ Four states—California, Oregon, Washington, and Florida—have developed their own, more-stringent energy codes.

⁴³ The model code for residences is the International Energy Conservation Code, maintained by the U.S.-based International Code Council; for commercial buildings and multifamily high-rise dwellings, the model code is ASHRAE 90.1, maintained by the American Society of Heating, Refrigeration, and Air Conditioning Engineers. As of 2008, 19 states had adopted the IECC and 27 states had adopted ASHRAE 90.1 (or more-stringent codes).

⁴⁴ The Congress has recently considered legislation that would have created a national building code (S. 1733) or would have required states to adopt stringent building energy codes of their own (H.R. 2454).

⁴⁵ Online Code Environment & Advocacy Network, “Code Status: Residential,” <http://bcap-ocean.org/code-status-residential> and “Code Status: Commercial,” bcap-ocean.org/code-status-commercial.

Energy codes can prevent builders from using clearly inefficient practices. In California, per capita energy consumption has remained roughly constant for the past 30 years, while it increased 50 percent nationally.⁴⁶ Florida’s new building codes are estimated to have cut electricity consumption by around 4 percent and natural gas consumption by 6 percent in new houses.⁴⁷ A large-scale study of residential building codes and electricity consumption, using data from 1970 through 2006, credits the adoption of such codes with a 3 percent to 5 percent reduction in residential electricity consumption per capita in 2006 in housing built subject to those codes.⁴⁸ DOE asserts that its Building Energy Codes Program saves around \$2.5 billion per year in energy expenditures and that the program has saved more than \$14 billion since 1992.⁴⁹

Energy codes impose compliance costs on builders, who share those costs with buyers and, by extension, building occupants. The codes also impose nonfinancial costs on occupants to the extent that they affect a building’s performance—its lighting, ventilation, window operability, and other functions. According to the National Research Council, the direct compliance costs for energy codes are “usually paid back through energy savings in seven or fewer years.”⁵⁰

⁴⁶ Dora L. Costa and Matthew E. Kahn, *Why Has California’s Residential Electricity Consumption Been so Flat Since the 1980s? A Microeconomic Approach*, PWP-CCPR-2010-041 (California Center for Population Research, December 2010), papers.cpr.ucla.edu/papers/PWP-CCPR-2010-041/PWP-CCPR-2010-041.pdf.

⁴⁷ Grant D. Jacobsen and Matthew J. Kotchen, *Are Building Codes Effective at Saving Energy? Evidence from Residential Billing Data in Florida*, Working Paper 16194 (Cambridge, Mass.: National Bureau of Economic Research, July 2010), www.nber.org/papers/w16194.

⁴⁸ Anin Aroonruengsawat, Maximilian Auffhammer, and Alan H. Sanstad, “The Impacts of State Level Building Codes on Residential Electricity Consumption” (forthcoming, *Energy Journal*).

⁴⁹ \$2.5 billion is about 0.7 percent of current energy expenditures (on electricity and natural gas) in the residential and commercial sectors. (See Energy Information Administration, *2009 Summary Tables – Expenditures: Total End-Use Expenditures*, www.eia.gov/state/seds/seds-data-complete.cfm#expend.) Savings estimates: Department of Energy, *Multi-Year Program Plan: Building Regulatory Programs*, Energy Efficiency and Renewable Energy Program (October 2010), apps1.eere.energy.gov/buildings/publications/pdfs/corporate/regulatory_programs_mypp.pdf. See also Department of Energy, “Building Codes Energy Program,” www.energycodes.gov/why_codes/.

⁵⁰ National Research Council, *Real Prospects for Energy Efficiency in the United States* (2010), citing Western Governors’ Association, *Clean and Diversified Energy Initiative*, Energy Efficiency Task Force Report (January 2006), www.westgov.org/wga/initiatives/cdeac/Energy%20Efficiency-full.pdf.

Ensuring that energy codes achieve their intended level of energy savings requires that adequate resources be devoted to enforcement. So, one policy approach to gaining increased energy savings from building codes would be to provide states with resources to increase their enforcement and compliance efforts. Currently, there is much variation in enforcement effort and results across states. In recent legislation, the Congress has sought to address that issue. In particular, ARRA established a goal for DOE's building-code efforts: that each state achieve 90 percent compliance with its own energy codes. Some states' legislative priorities include increased support for building inspections, greater priority for energy efficiency in enforcement efforts, and additional funding for implementation and enforcement of building codes.⁵¹

Although states are responsible for their own building codes, another policy approach would be to provide increased technical support and additional financial rewards to states that adopted more-stringent codes.

Information

Information policies can help mitigate the market's underprovision of certain kinds of information. Federal programs relating to energy information for buildings and appliances involve collecting and certifying information relating to energy consumption and energy efficiency, which the market undersupplies, and by presenting that information in unified formats designed to draw an observer's attention and aid comprehension. Those efforts are focused on three federal programs: EnergyGuide (to certify and rate the energy consumption of appliances), Energy Star (to identify energy-efficient appliances, office equipment, and buildings), and EnergySmart (to certify and rate buildings' energy consumption). The latter program

⁵¹ Western Governors' Association, *Building an Energy-Efficient Future: Policy Recommendations for Energy Efficient Buildings* (January 2008), www.westgov.org/wga/publicat/EnergyEfficiency07.pdf.

complements the private-sector Leadership in Energy and Environmental Design (LEED) rating system for buildings.⁵²

Energy-performance labeling programs, which can be applied to buildings as well as to appliances, can help address split incentives by giving builders and landlords a way to credibly certify the likely energy savings from technologies they have installed, and thus to recoup those investments through higher rents or buildings' sales prices. The labels also partially mitigate the effects of biased reasoning to the extent that they alter a potential adopter's beliefs about the likely value of energy savings.

Designing energy labels so that consumers can easily take in the information addresses a related imperfection: People may be inattentive to energy costs because those costs are not as salient as the upfront purchase price of a technology. When people purchase an appliance, most of its energy costs are in the future and they are estimates. In principle, inattention could as easily lead people to overvalue potential energy savings as to undervalue them. And for appliances, adopters may be rationally inattentive to energy efficiency, because the value of energy savings from one model to another may be smaller than the difference in price.⁵³ But in view of the evidence, cited previously, that consumers' rules of thumb systematically underestimate appliances' energy consumption, the provision of information should increase their willingness to pay for energy efficiency.

Information policies can be relatively inexpensive to maintain, in the sense that once information has been created, it can be reproduced at very little cost. That type of policy also imposes few costs on consumers, aside from attracting their attention. In particular, information programs do not constrain choice. There are also some indirect costs and benefits associated with

⁵² LEED is the U.S. Green Building Council's building-performance rating system. It is based on buildings' resource efficiency and indoor environmental quality.

⁵³ James M. Sallee, "Rational Inattention and Energy Efficiency" (draft, June 3, 2011).

those programs. Individuals' ability to process information about energy efficiency is limited, however: It can take time and effort to determine whether an adoption would be worthwhile. Labeling programs can reduce those costs by providing adopters with information they need to make an informed decision. (According to one credible estimate, the Energy Star program may have achieved \$50 billion in energy savings from its 1992 inception until 2006.)⁵⁴ One disadvantage is that the labels may draw potential adopters' attention away from other dimensions of their adoption decision.

Voluntary Standards for Energy Use in Buildings. The LEED certification program is an indication of consumers' willingness to pay for energy efficiency in buildings. DOE has developed a voluntary "EnergySmart" program that gives builders a way to receive energy-efficiency ratings for the new houses they build and to display the rating on a label placed near the entryway or electric panel.⁵⁵ The scope of the EPA's Energy Star program has been expanded to include energy-efficient houses and commercial buildings.⁵⁶ Both types of voluntary standards combine the pure provision of information on prospective energy use with an emphasis on reaching particular thresholds of performance (such as ranking in the top 25 percent of energy-efficient buildings to earn the Energy Star designation).

Because such programs are voluntary, there may still be considerable scope for expansion. If policymakers wished to increase the scale of such programs, one approach would be to facilitate or subsidize certification. Another, more costly, approach would be to mandate that buildings display labels reporting their energy performance (which would have to be certified).

⁵⁴ Gregory K. Homan and others, *Savings Estimates for the United States Environmental Protection Agency's Energy Star Voluntary Product Labeling Program* (Lawrence Berkeley National Laboratory, 2008, ACEEE Summer Study on Energy Efficiency in Buildings).

⁵⁵ Department of Energy "DOE Challenge Home," <http://www1.eere.energy.gov/buildings/challenge/energysmart.html>.

⁵⁶ Of the houses built in the United States in 2006, 11.4 percent were Energy Star compliant; in 10 states, the share was above 25 percent.

Building labels are now required in Great Britain, Australia, and within the European Union. There, an energy performance certificate must be prominently displayed on all public buildings over 1,000 square meters and be “made available to the owner [of a building] in case of new construction, or to the prospective buyer or tenant in case of rent or sale.”⁵⁷

Appliance Labeling. The familiar yellow EnergyGuide appliance labels are the product of a federal energy-efficiency policy of long standing. In addition to aiding consumer choice, the program is thought to have stimulated private R&D investment and innovation that increased energy efficiency.⁵⁸ A 2007 redesign sought to make the labels more effective by emphasizing annual operating costs over energy consumption. For most consumers, energy consumed—reported in units of kilowatt-hours or therms—is less salient than costs and must be translated into dollars in order to compare appliances in terms of cost of ownership. The 2007 redesign still leaves it to consumers to calculate expected *lifetime* energy costs, in present-value terms—information they would need to correctly calculate the cost of ownership. Few consumers are likely to do a present-value calculation and, because it involves slightly advanced mathematical techniques, fewer have the training for it. But present value comes from a standard formula and could be provided on the label alongside annual operating costs.

Thus, one policy approach to achieving further reductions in CO₂ emissions from the EnergyGuide program would be to enhance the labels so that they show present-value lifetime costs. Another approach would be to consider how the labels present information comparing different models. Each EnergyGuide label reports a range of operating costs for other “similar” models. When the comparisons are narrowly defined, such as “refrigerator/freezers with in-door

⁵⁷ European Commission, *Directive on the Energy Performance of Buildings* (2002/91/EC), europa.eu/legislation_summaries/energy/energy_efficiency/l27042_en.htm.

⁵⁸ Richard Newell, Adam Jaffe, and Robert Stavins, “The Induced Innovation Hypothesis and Energy-Saving Technological Change,” *The Quarterly Journal of Economics*, vol. 114, no. 3 (August 1999), pp. 941–975.

ice dispensers,” consumers can more easily compare models that have features they want. But narrow comparisons make it difficult to assess how much energy those defining features use. Adding a second comparison to the EnergyGuide labels, showing the range of energy used by all models (for instance, all refrigerator/freezers), would address that issue. Another policy option would be to express an appliance’s energy consumption in familiar terms, like the number of lightbulb equivalents, as a salient reference point to help consumers assess the value of energy savings from one model to the next. That might be particularly useful for appliances that consume relatively large amounts of energy, where the potential value of energy savings is greater.

Labeling can also affect the way consumers operate their appliances. For instance, many washing machine manufacturers used to make the “warm-water wash” setting the default operating mode, by adding a mark to that setting on the dial. Researchers found that if that mark was removed, consumers would treat “cold-water wash” as the implicit default. That reduced the washing machines’ energy consumption by an average of 24 percent.⁵⁹

Therefore, another policy option is to engage a federal laboratory that studies appliances’ energy consumption to evaluate the potential for saving energy via other such innovations in appliance labeling as it pertains to default settings.

⁵⁹ Charlie Wilson and Hadi Dowlatabadi, “Models of Decision Making and Residential Energy Use,” *Annual Review of Environment and Resources*, vol. 32 (2007), p. 176.