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Focusing and improving traditional energy efficiency strategies

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ABSTRACT

Energy efficiency can get us about half of the way to long-term climate goals. Traditional energy efficiency strategies — vehicle and appliance efficiency standards, building energy codes, utility energy efficiency programs and Energy Star — can provide about half the achievable efficiency savings (i.e., savings of about one-quarter of projected 2050 energy use). However, these strategies can benefit from a variety of improvements, and other programs and policies addressing buildings, transportation and industry can achieve substantial additional savings. These efficiency policies can be combined with strategies involving no- and low-carbon energy sources to put the United States on a trajectory toward meeting long-term energy and climate targets.

1. Introduction

The United States is now more than twice as efficient as it was in 1973, as measured in energy use per dollar of gross national product (e.g., 5.45 thousand Btu per dollar in 2018, relative to 12.1 in 1973 [EIA, 2019]). A substantial share of these savings is due to several key energy efficiency policies: vehicle and appliance efficiency standards, building energy codes, utility energy efficiency programs and Energy Star. These energy savings have many benefits, including reducing consumer and business energy bills, providing jobs, and in some cases improving comfort and health (Nadel et al., 2015). Savings in 2017 from these leading policies, summarized in Table 1, total more than 20% of 2017 U.S. energy use, even after allowing for some overlap in savings among the policies.

Analysis by the American Council for an Energy-Efficient Economy (Nadel, 2018), the Rocky Mountain Institute (Lovins, 2014) and others has found that energy efficiency can approximately cut U.S. energy use and carbon emissions in half by 2050 relative to business-as-usual estimates for 2050, making probably the largest contribution toward helping the U.S. reach long-term targets of reducing greenhouse gas (GHG) emissions by 80% or more. Some of the available efficiency opportunities for the U.S. through 2040 are illustrated in Fig. 1.

As can be seen in Fig. 1, the energy uses covered by the traditional energy efficiency policy approaches still provide significant savings opportunities, and thus these traditional approaches will likely remain part of energy and emissions reduction efforts in the future. However, the electric grid and efficiency opportunities are now in a period of substantial change and, as a result, these traditional approaches will need to be honed and refreshed. In addition, other approaches will need to be added.

In this paper, we discuss the five approaches charted in Fig. 1 — what they have accomplished, and how they can be better focused to meet climate goals. We discuss them in the order of greatest past energy savings, as summarized in Table 1. In addition, we briefly discuss a few complementary approaches and their potential role.

2. Vehicle fuel economy standards

Corporate Average Fuel Economy (CAFE) standards were established by Congress in 1975, in the wake of the OPEC oil embargo. With electric vehicles (EVs) becoming more common (some analysts predict that EVs will account for the majority of car and light-truck sales in the 2030s [Risman, 2017]), vehicle efficiency will become an important factor in the contribution of EVs to electricity demand.

CAFE standards have been applied since 1978 for cars, 1982 for light trucks, and 2014 for medium and heavy trucks. The car and light-truck standards changed very little in the 1990s and early 2000s, but since 2010 have been revised more substantially, as illustrated in Fig. 2. Future standards for cars and light trucks are subject to great debate. The Obama administration set targets through 2025, with targets increasing about 5% per year from model year 2020 onward based on an analysis of cost-effective fuel economy improvements. The Trump Administration has proposed a rule to hold the standards flat beyond 2020, but this decision will likely be challenged by multiple states and other organizations in court. In addition, California and more than a dozen other states are planning to continue to enforce GHG emissions standards equivalent to the Obama standards; the Trump administration has also formally proposed to terminate their ability to do so. It will probably be more than a year before the courts resolve these interrelated issues.

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Table 1
Energy Savings in 2017 from Leading Energy Efficiency Policies.
Source: Nadel, 2019.

	Savings in Quads*
Corporate Average Fuel Economy (CAFE) standards on vehicles	9.0
Appliance and equipment efficiency standards	6.0
Energy Star	4.2
Utility sector energy efficiency programs	2.7
Building energy codes	1.5

* A “quad” is a quadrillion Btu; the U.S. uses about 100 quads per year. Savings are relative to what energy use would have been in 2017 without each of the policies.

In addition to vehicle GHG standards, California and nine other states also have zero emission vehicle (ZEV) standards that require that a specified portion of vehicle sales be ZEVs.[1] For example, California is requiring about 2.5% of vehicles to be ZEVs in 2018, rising to about 8% in 2025; the actual regulations are more complicated, hence the “about” qualifier. (UCS, 2019).

EVs are likely to play an increasingly important role in reducing energy use and lowering carbon emissions, since EVs generally need less energy per mile traveled (see Box 1). Continued steady increases in CAFE standards are needed to encourage both EVs and more efficient conventional vehicles. The current CAFE standard formula includes a bonus for non-petroleum fueled vehicles that inflates the value of these vehicles. Future vehicle standards should better reflect the energy and GHG emissions impacts of EVs relative to those of vehicles powered by internal combustion engines. These impacts should probably be based on a projected future generation mix over the life of the vehicle.

In addition, if a major societal goal is to increase EV market share due to their energy savings and GHG reduction benefits, a national ZEV target should be considered. General Motors has proposed a weak such target (Gatelu, 2018); stronger targets should be considered. China has adopted ZEV targets (Cui, 2018). Several other countries are moving in this direction, with nine countries announcing plans to ban sales of gasoline or diesel vehicles, typically by 2030 or 2040. However, none of these proposals has been adopted into law yet (Coren, 2018).

While this discussion has focused on personal vehicles, the U.S. also has CAFE standards for commercial vehicles, ranging from large pickup trucks to 18-wheelers. The current standards are set through 2027 but significantly higher fuel economy is possible, including use of electric trucks (Department of Energy, 2019).

There have even been suggestions of CAFE or GHG emissions standards for airplanes, a growing source of energy consumption and GHG emissions (CRS, 2017).

3. Appliance and equipment efficiency standards

California established the first appliance efficiency standards in the 1970s and the policy spread to several other states before the U.S. Congress established national standards for 13 products in 1987. Since then, Congress enacted new laws adding standards for additional product categories in 1992, 2005 and 2007, and the Department of Energy (DOE) added a few under its regulatory authority in 2015 and 2016. The national standards program now covers about 60 product categories. DOE has also periodically reviewed and revised standards since 1987, based on technical feasibility and economic justification. Standards for some products, such as refrigerators, have been revised several times, but others, such as those for furnaces[2] and showerheads, are essentially unchanged from the levels enacted by Congress.

The Appliance Standards Awareness Project (ASAP) periodically estimates the cost-effective savings that are achievable from revising existing standards and establishing a few new standards. Their most recent assessment, published in 2016, found that updated federal standards which could be adopted by the mid-2020s could reduce U.S. energy use by 2.6 “quads” per year by 2035, and 4.0 quads per year by 2050 (deLaski et al., 2016). The impact of past and future standards on total U.S. energy use is illustrated in Fig. 4.

Of the potential new savings, about 70% would come from standards for just a dozen products including five products that have had several rounds of improved standards already (water heaters, central air conditioners and heat pumps, electric motors, refrigerators and freezers, and commercial rooftop air conditioners). Others that have had fewer rounds of improved standards to date are particularly ripe for new standards (showerheads, clothes dryers, industrial fans, residential faucets, distribution transformers and industrial air compressors). Some of the largest savings opportunities involve a step change in technology – heat pump water heaters, variable speed air conditioners and heat pumps, amorphous core distribution transformers and condensing furnaces. Others involve water-using products (showerheads and faucets) and industrial motor-driven equipment (fans and air compressors). But standards that yield smaller savings are also important; they add up to nearly a third of the total estimated potential. Some regulated product categories probably offer little additional savings potential after multiple rounds of standards (e.g., dishwashers) and/or market shifts to substitute technologies (e.g., fluorescent tubes).

The ASAP study was not exhaustive since the research lacked data to assess one-fourth of the products covered by federal standards, and generally did not consider products outside of the scope of current federal regulation. For example, standards for a few new products should be considered, such as EV chargers, perhaps building on a new Energy Star specification.[3] The study also did not attempt to assess the potential for subsequent rounds of improvements: technological change likely will open the door to further savings potential in 2030 and beyond. To meet long-term carbon goals at least cost, we will ultimately need to adopt all or most of the standards included in the ASAP study and will need to update these standards again in the 2030s and 2040s.

For many of these products, voluntary programs to recognize high efficiency products and provide incentives for the highest efficiency products would be useful to help increase end-user and contractor familiarity and comfort with high efficiency technologies. In the future, we will need to increase the focus on step-changes for key products (e.g., heat pump water heaters, variable speed air conditioners and amorphous core transformers) and will need to focus more on how standards can drive savings in systems such as those that use fans, pumps and compressors. Closer integration between standards and voluntary programs would also enhance the savings potential for both strategies.

4. Energy star

Energy Star has been a powerhouse, combining product specifications, system specifications (e.g., Energy Star New Homes), service specifications (e.g., Home Performance with Energy Star), and benchmarking efforts (e.g., Energy Star Buildings). Energy Star was started by the U.S. Environmental Protection Agency (EPA) in 1992 and has since expanded to include the Department of Energy.

Product specifications now cover more than 50 products. Specifications are typically set to recognize the most efficient quartile of products. To help differentiate the very best products, in 2011, EPA added Energy Star Most Efficient recognition for a subset of products. In order to meet long-term GHG reduction goals, using Energy Star Most Efficient to set ambitious targets will be increasingly important, with

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[1] In California, the ZEV definition includes electric, fuel cell and hybrid vehicles.

[2] There was one small inconsequential revision.

[3] See www.energystar.gov/products/other/evse

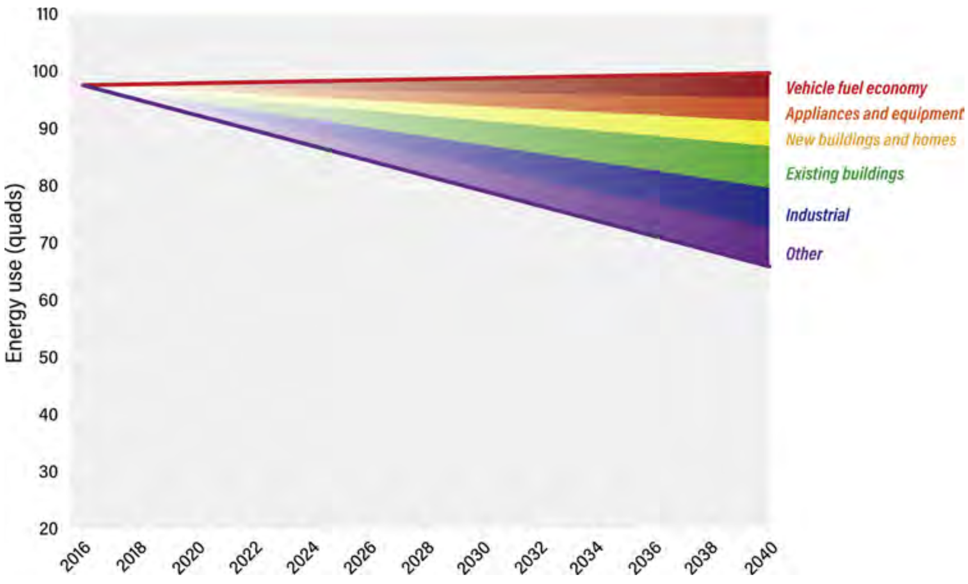

Fig. 1. Opportunities for energy efficiency savings 2018-2040. The top line is projected energy consumption in the absence of new savings from these policies, with the colored wedges showing savings from each policy set. Continuing the trend from 2040 to 2050 results in approximately 50% savings by 2050. "Other" includes power sector and transportation beyond vehicle efficiency. Source: Based on data in Nadel, 2018.

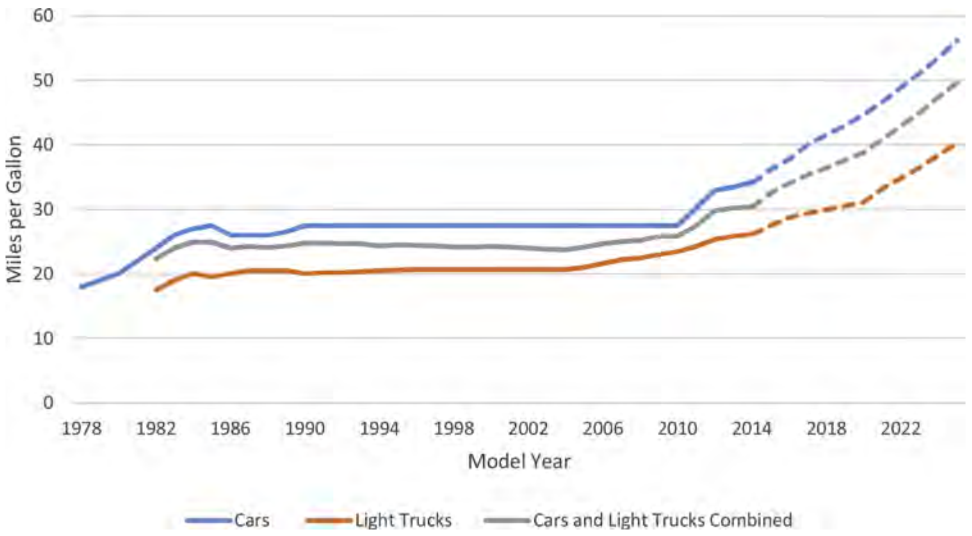

Fig. 2. Fuel economy standards for cars and light trucks. This graph does not show the impact of possible rollbacks, as discussed in the text. *Source:* ACEEE, based on data from NHSTA and EPA.

these levels becoming the foundation for future Energy Star and minimum standards as market share grows. It will also be very important to keep Energy Star specifications up-to-date, revising specifications when the market share for Energy Star in a specific category approaches 50%. As new products become more common, specifications can be developed, as happened recently for EV chargers.

ENERGY STAR Buildings is also very important. The program encourages building owners to benchmark their buildings on a 1–100 scale; buildings with a score of 75 and above earn the ENERGY STAR designation; those with lower scores are encouraged to pursue a multistep upgrade strategy. In 2018, more than 270,000 properties used EPA's ENERGY STAR Portfolio Manager® tool to measure and track their energy use, water use, and/or waste and materials. Over the past five years, the number of buildings actively using Portfolio Manager to benchmark their energy performance increased by more than 30% and the commercial building square footage actively benchmarked grew by over 40% (EPA, 2019). EPA conducted a study looking at buildings that were benchmarked annually over the 2008–2012 period, finding that, on average, these buildings had reduced their weather-normalized energy use by 7% over this four-year period (EPA, 2012). More than 8100 buildings earned the ENERGY STAR label in 2018, bringing the total to more than 34,000. EPA estimates that, on average, ENERGY STAR-certified buildings use 35% less energy than typical buildings nationwide (EPA, 2019).

Recently, EPA updated its benchmarking models to use the latest available building performance data, an important step for keeping the program up-to-date. Going forward, increasing the availability of data for additional space types would be useful, so EPA could provide more ENERGY STAR 1–100 scales for additional types of buildings.

Likewise, DOE operates the Home Performance with Energy Star program to encourage home energy retrofits. As of the end of 2018, there were 41 active state and local programs and 775,000 homes had been retrofit since the start of the program in 2002. Project energy savings have averaged about 25% of total household energy consumption, but vary by region. The average project costs about $5700 (Dunn, 2019). In order to encourage more homeowners to participate and complete retrofits, strategies to reduce costs and simplify participation should be pursued. In addition, local programs probably need to

Box 1
Fuel Economy Comparison Between EVs, Hybrid and Conventional Vehicles

EVs have much higher consumer label fuel economy than gasoline powered vehicles, although power system losses are not included in label fuel economy. When we include both power system and fuel refining losses on a national average basis, EVs still do much better than conventional gasoline vehicles and somewhat better than hybrid vehicles. Looking at full-cycle GHG emissions, EVs do a little better still. These data are illustrated in Fig. 3

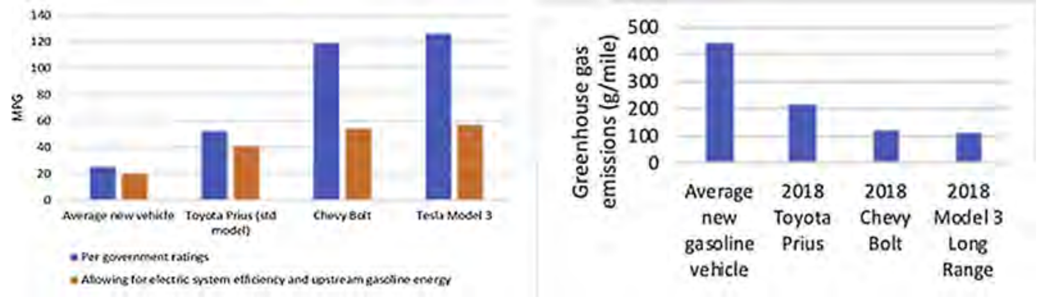

Fig. 3. Comparison of two EVs, a hybrid car and the average new vehicle on fuel economy and emissions per mile. Based on U.S. government fuel economy and emissions labels for 2018 vehicles. The adjustments for upstream system losses are by ACEEE and are based on a 45% efficient power plant and 28% upstream energy losses for gasoline (the latter derived from Argonne National Laboratory's GREET 2018 model). GHG emissions derived by ACEEE from GREET 2018 using the current national average generation mix..

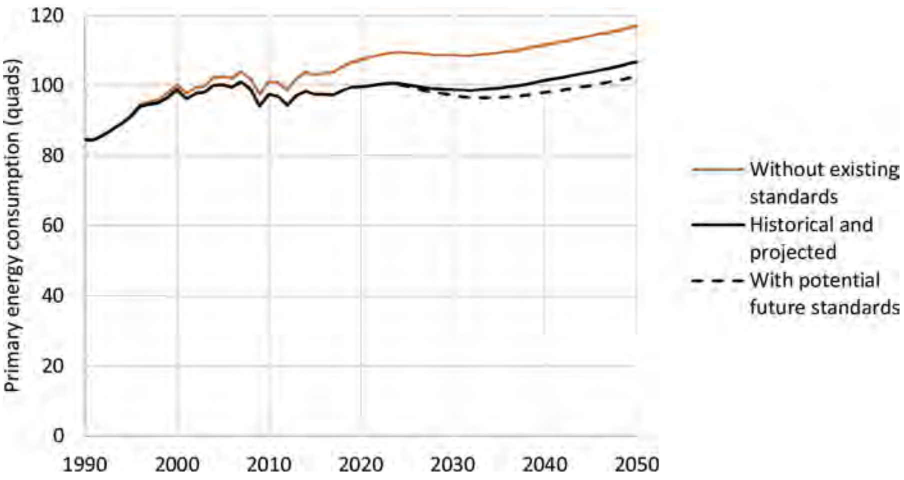

Fig. 4. U.S. energy use 1990–2050, showing impact of appliance and equipment efficiency standards. The solid black line is actual and projected energy use, including the impact of standards that have already been set. The orange line estimates energy consumption if the U.S. had no standards. The dotted black line shows the potential impact of new standards that might be set by the mid-2020s. Source: ASAP analysis.

increase financial incentives, develop their local workforce through training and certification programs, and educate households about home energy use by adopting disclosure policies and providing information on promising home energy efficiency improvements.

5. Utility sector energy efficiency programs

Utility-funded energy efficiency programs include programs operated by utilities as well as programs operated by other program administrators using ratepayer funds (e.g., Efficiency Vermont and the Energy Trust of Oregon). These programs began in the 1970s, spurred originally by the need to save power immediately after the accident at the Three Mile Island power plant. Since then, these programs have steadily ramped up in spending and first-year savings, although that growth has slowed in recent years. Many states and utilities have maintained current spending and savings rates, only some utilities are expanding programs, and in a few cases programs are being throttled back. These programs continue to be, on average, the cheapest resource at about 3.1 cents per kilowatt-hour nationally (Molina and Relf, 2018; Hoffman et al., 2018). On the other hand, total annual savings, including savings from measures installed in earlier years, continues to grow, as incremental annual savings are generally much greater than savings from measures installed about a decade ago that are now wearing out. These trends are shown in Figs. 5 and 6.

In late 2018, Lawrence Berkeley National Laboratory (LBL) published estimates of future electric utility spending and savings (not natural gas), based on detailed review of laws, regulations and filings by state, as well as discussions with many experts. In their medium case, they project spending to increase to $8.6 billion in 2030, about a 45% increase relative to their estimate of 2016 spending. The majority of this increase is due to expected inflation; they estimate a 2.7% annual increase in nominal terms, but only 0.7% per year in real (inflation-adjusted) terms. LBL estimates that in 2016, efficiency programs funded by utility customers saved 27.5 billion kWh (incremental savings), equal to 0.74% of retail sales. Efficiency programs funded by utilities offset at least 1% of investor-owned utility load in 23 states, with four states exceeding savings of 2% of sales. In their medium case, LBL projects incremental annual electricity savings to increase very modestly to 28 billion kWh in 2030 (Goldman et al., 2018).

In recent years, often about half of the savings from utility-funded programs have been from lighting. As LED lighting becomes common, opportunities for additional lighting energy savings will decline,

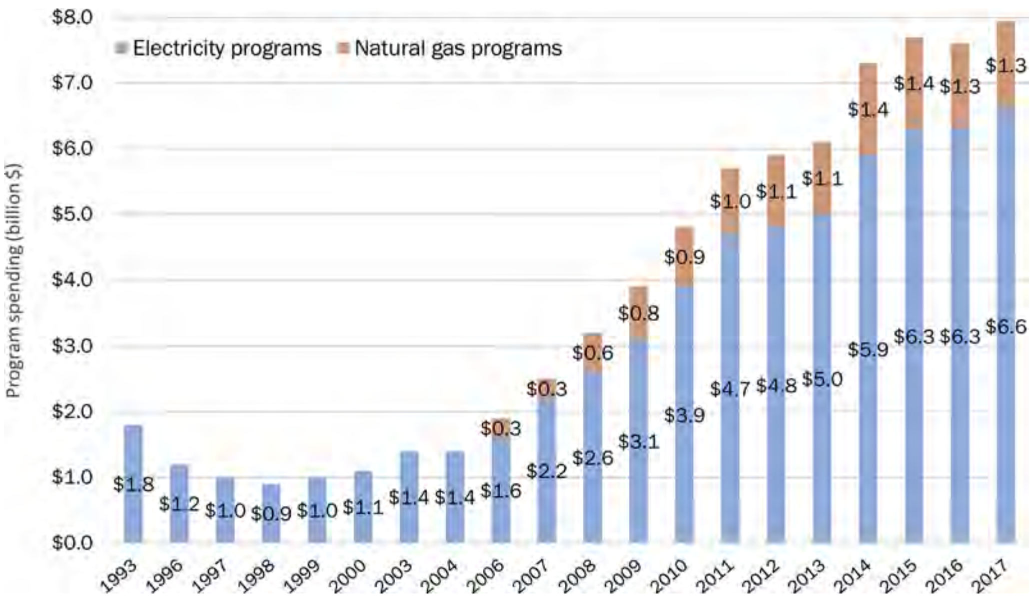

Fig. 5. Spending on utility-funded energy efficiency programs, 1993-2017. These figures are in nominal dollars and include inflation. Source: Berg et al., 2018.

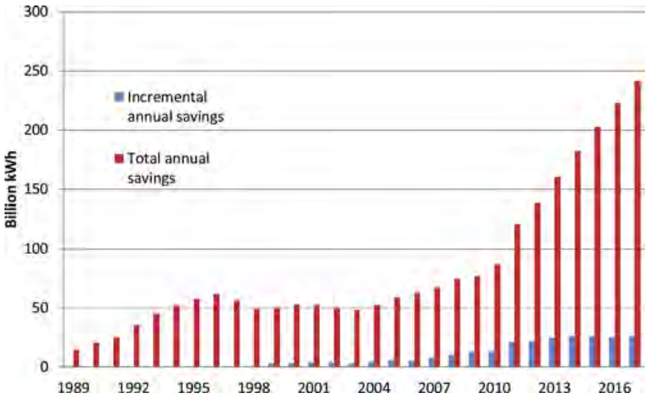

Fig. 6. Incremental and total annual savings from utility energy efficiency programs, 1989-2017. Source: Berg et al., 2018.

although there will still be substantial savings available from improved lighting fixtures, layouts and controls (Mellinger, 2018). Utility-funded program opportunities for appliances have also declined due to the impact of minimum efficiency standards. Still, ample savings are available; but instead of a few silver bullets, there are lots of silver BBs. For example, York et al. (2015) examined efficiency program opportunities out to 2030, finding opportunities to reduce electricity use by 21.5% in their medium scenario. Key efficiency measures were:

- Improving the efficiency of plug loads such as computers, televisions and set-top boxes.
- Very high efficiency air conditioners and heat pumps.
- Reducing excess voltage on distribution circuits (often labeled conservation voltage reduction).
- New construction and building retrofit programs.
- Smart manufacturing, smart buildings and smart thermostats.
- Combined heat and power systems.
- Advanced lighting design and controls.
- Heat pump water heaters.
- Real-time energy use feedback and behavioral response.
- Strategic energy management initiatives for large customers.
- High efficiency industrial and commercial fans, pumps and compressed air systems.

In general, going forward, there is a need for more focus on system opportunities – new construction, HVAC, strategic energy management, industrial processes and whole building retrofits. Likewise, Neme and Grevatt (2016) discuss a number of the same measures and also discuss several program approaches that merit more attention such as upstream product rebates and deep dives into locally important markets (e.g., snowmaking in Vermont),

While not covered by York et al., beneficial electrification can also provide additional energy savings on a total Btu basis, typically saving gasoline and other fossil fuels while using more electricity, as discussed by Coakley and Hewitt elsewhere in this special issue of *Electricity Journal.* In addition to pursuing a broader array of measures, utility-funded programs will also need to pursue a variety of other “upgrades” such as better integrating efficiency programs with demand response programs and distributed energy resource efforts. To aid these combined efforts, energy savings targets will need to look at not only kWh savings, but will also need to consider the Btu, GHG, and/or peak demand savings opportunities from energy efficiency. Gold et al. (2019) discuss these issues at length.

6. Building energy codes

Building energy codes were first developed in the U.S. following the 1973 OPEC oil embargo. Organizations such as the American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) and the International Code Council have led efforts to develop national model codes, which states and cities then adopt, sometimes with modifications. A few states, such as California, have developed their own codes. Building energy codes recognize that it is much easier and less expensive to design efficiency into new construction than it is to try to retrofit efficiency into buildings after they are constructed.

The original model codes (published in 1975 and 1980) have been regularly revised as new energy-saving technologies and techniques become available. Code revisions are generally set based on levels of efficiency that result in economic cost savings over a period of 7–18 years, varying with the code. Due to these code upgrades, a typical commercial building built to the 2010 code uses about half the energy of a 1980 building, while for new homes, energy use has been reduced by about 40%. These trends are illustrated in Fig. 7.

Going forward, multiple organizations, including the American Society of Heating, Refrigerating and Air-conditioning Engineers, the state of California and the Canadian government, are targeting zero net

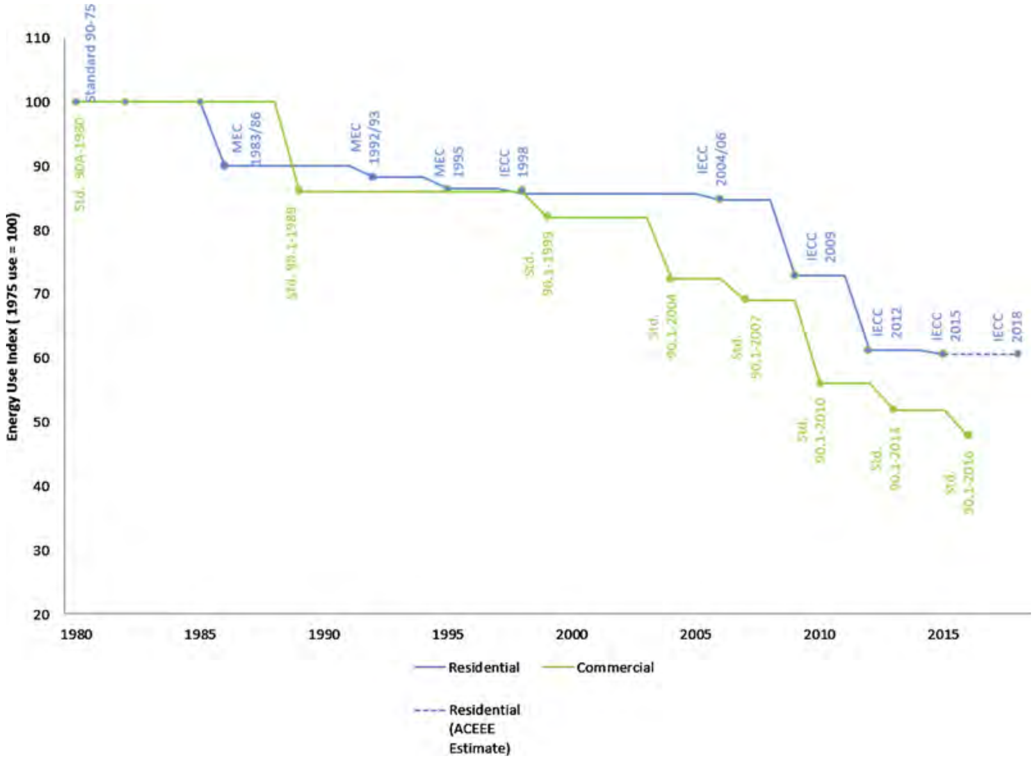

Fig. 7. Energy savings from progressive revisions of national model energy codes. A building built to the 1975 (residential) and 1980 (commercial) model codes is set to an energy index of 100, with subsequent codes normalized to this index. Source: ACEEE analysis using data from U.S. DOE Building Codes Program.

energy and carbon codes by 2030 as an important part of decarbonization policy. (Zero net energy means that a building generates as much energy as it uses over the course of a year.) These buildings typically use energy efficiency to cut loads by 60% or more relative to current codes, and then use onsite or community renewable energy systems to serve the remaining load.

Achieving such a goal will require parallel efforts to improve codes each code cycle, with voluntary programs to exceed codes and building experience and support for future code changes, just as the voluntary Energy Star program helps to lay a foundation for future equipment efficiency standards. Moving toward zero net energy codes will require expanding code coverage to include more energy end-uses (e.g., refrigeration and plug loads), and moving more toward performance approaches, ultimately involving whole buildings rather than relying on prescriptive measures (e.g., required insulation levels and equipment efficiencies). These strategies are discussed in more detail by Amann (2014) and Perry (2018).

In addition to developing and adopting improved codes, code implementation and compliance efforts will also be very important, as will efforts to reach states and localities not presently covered by recent codes.

7. Complementing these traditional approaches with additional policies

The five traditional policies discussed above can achieve substantial savings – about 25% savings as shown in the red, orange and yellow wedges in Fig. 1, plus a portion of the green wedge. However, as Fig. 1 also shows, about double this level of savings are possible. To achieve these additional savings will require additional policy approaches:

7.1. Building benchmarking and retrofit policies

Thirty U.S. states, cities and counties have adopted policies requiring that large commercial buildings (and sometimes multifamily buildings) be benchmarked every year, typically using the Energy Star benchmarking tool (IMT, 2019). Evaluations of these policies have found energy savings ranging from 2 to 14% (Mims et al., 2017). Some cities and states, such as the District of Columbia, New York City and Washington State, are going a step further and mandating energy efficiency retrofits; e.g., New York City is requiring 26% average energy savings by 2030 (Urban Green, 2019). In addition, some cities, such as Berkeley, California, and Portland, Oregon, are requiring home energy ratings for home sales, encouraging buyers to purchase efficient homes and new homebuyers to upgrade their homes (ACEEE, 2018)

7.2. Smart buildings and manufacturing, strategic energy management

A new generation of controls and sensors, combined with sophisticated data mining practices, can help identify hidden energy waste and optimize buildings and industrial processes, achieving energy savings of 15% or more. A complementary measure is strategic energy management, which offers a long-term approach to energy efficiency that includes setting goals, tracking progress and reporting results with an eye toward continuously improving systems and reducing energy use — and achieves savings of about 4–5% per year. These approaches are discussed by York et al. (2015). These practices can be incorporated into utility programs, but there is much that large energy users can and should do on their own or through performance contracting.

7.3. Improving the efficiency of planes and freight movement, and reducing vehicle miles traveled

There are substantial opportunities to reduce transportation energy use beyond vehicle efficiency standards. For example, airplane energy use can be reduced by as much as 40%, passenger vehicle miles traveled reduced by as much as 20%, and similar savings can be achieved from improved freight management strategies — such as enabling seamless transitions among highway, rail, water, and air modes to allow a dynamic, multimodal assignment of goods to the network, assigning loads to the least energy-intensive mode that meets each load's needs. Nadel (2018) discusses these opportunities.

8. Conclusion

Energy efficiency can be about half of the solution for reaching long-term climate goals. In addition, energy efficiency can reduce consumer and business energy bills, provide jobs, and in some cases improve comfort and health. Continuing and refreshing traditional energy efficiency strategies — vehicle and appliance efficiency standards, building energy codes, utility energy efficiency programs and Energy Star – can provide about half the achievable efficiency savings (i.e., savings of about one-quarter of projected 2050 energy use). Other programs and policies addressing buildings, transportation and industry can achieve substantial additional savings. These efficiency policies can be combined with strategies involving no- and low-carbon energy sources to put the U.S. on a trajectory toward meeting long-term energy and climate targets.

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