CLEAN INFRASTRUCTURE: EFFICIENCY INVESTMENTS FOR JOBS, CLIMATE, AND CONSUMERS

Lowell Ungar, Steven Nadel, and James Barrett

September 2021

An ACEEE White Paper

ACEEE

American Council for an Energy-Efficient Economy

Contents

About ACEEE

The **American Council for an Energy-Efficient Economy** (ACEEE), a nonprofit research organization, develops policies to reduce energy waste and combat climate change. Its independent analysis advances investments, programs, and behaviors that use energy more effectively and help build an equitable clean energy future.

About the Authors

Lowell Ungar is the director of federal policy at ACEEE. He develops and promotes legislation and administrative actions in all economic sectors and leads cross-cutting policy research. Prior to joining ACEEE, Lowell was director of policy at the Alliance to Save Energy and a legislative aide in both the U.S. Senate and the House of Representatives. Lowell earned a PhD in physical chemistry from the University of Chicago and a BS in chemistry from Stanford University.

Steven Nadel is ACEEE's executive director, a position he has held since 2001. Prior to that he served as deputy director and led ACEEE's utility and buildings programs. He has worked in the energy efficiency field for 41 years, including with a utility, an environmental organization, and a community housing organization. He has more than 200 publications. Steve earned an MS in energy management from the New York Institute of Technology, an MA in environmental studies, and a BA in government from Wesleyan University.

James Barrett is a visiting fellow at ACEEE. He concentrates on the nexus of climate change, energy efficiency, and economics. Prior to joining ACEEE, James was executive director of Redefining Progress and an economist at the Economic Policy Institute, the Joint Economic Committee, and the Institute for Biological Energy Alternatives. James earned an MA and PhD in economics from the University of Connecticut and a BA in economics from Bucknell University.

Acknowledgments

The authors gratefully acknowledge the external reviewers, internal reviewers, colleagues, and sponsors who supported this report. This report was made possible through the generous support of the Heising-Simons Foundation and the Tilia Fund.

Jennifer Amann, Ed Rightor, Neal Elliott, and Peter Huether assisted in the analysis. Reviewers included: Jeff Genzer (NASEO), Nora Esram (ACEEE), and Lauren Ross (ACEEE). External review and support do not imply affiliation or endorsement. Last, the authors would like to thank Mariel Wolfson for developmental editing, Mary Robert Carter for managing the editorial process, Phoebe Spanier for copy editing, Roxanna Usher for proofreading, and Ben Somberg, Kate Doughty, and Wendy Koch for their help in launching this paper.

Suggested Citation

Ungar, L., S. Nadel, and J. Barrett. 2021. *Clean Infrastructure: Efficiency Investments for Jobs, Climate, and Consumers*. Washington, DC: American Council for an Energy-Efficient Economy. aceee.org/white-paper/2021/09/clean-infrastructure-efficiency-investments-jobs-climate-and-consumers.

Executive Summary

KEY TAKEAWAYS

The energy efficiency investments proposed in this report could achieve

- 3.2 million added jobs over the lifetime of the investments and savings
- 4.5 billion tons of reduced carbon dioxide emissions
- $282 billion in net energy bill and other consumer savings (e.g., manufacturing cost, health, and comfort benefits)

Energy efficiency investments can create jobs now and reduce greenhouse gas (GHG) emissions for years to come while also saving money for consumers and businesses and improving public health. This is especially true for low-income families and communities of color, who have been disproportionately affected by the pandemic and economic recession. Efficiency investments can put people back to work throughout the economy, including the hundreds of thousands of efficiency workers who lost their jobs in the pandemic. The investments are also a down payment on deploying efficiency to cut U.S. GHG emissions in half by 2050.

We estimated the energy saved, carbon emissions avoided, and jobs added due to proposed energy efficiency investments in homes and commercial buildings, manufacturing plants, electric vehicles, transportation infrastructure, states, and cities. These investments yield both economic and environmental benefits, and they promote social equity through increased investment in affordable housing. They can be implemented quickly, often using existing federal programs. They generally employ local construction workers and use equipment and components manufactured domestically. And because of their energy savings and other benefits, federal investments can leverage private funds to increase their impacts.

OVERALL RESULTS

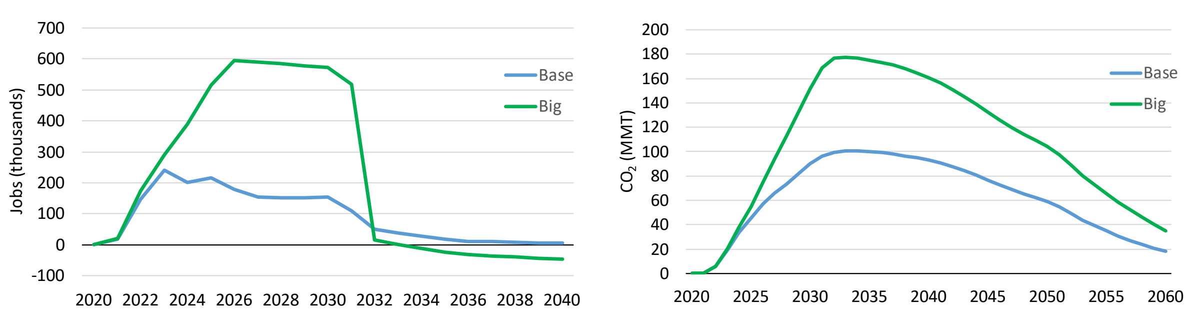

Figure ES1. Net added jobs and CO_2 emissions reductions by year for the two packages of investments

We looked at a "base" package of proposals and a "big" package with larger investments. We estimate that the base investments would result in 1.6 million more people working for a year (*job-years*), and the big investments in 3.2 million job-years, over the lifetime of the investments and savings. As shown in figure ES1, during the largest investments, the proposed packages would add about 200,000 and 600,000 jobs each year, respectively, with further job impacts after 2031 due to saving energy and repaying the cost of the investments.

Over time, the investments would result in 2.6 billion (base) or 4.5 billion (big) metric tons of reduced carbon dioxide emissions, roughly the total emissions for all U.S. cars, SUVs, and minivans for five years; they would produce more than $250 billion (base) or $280 billion (big) in lower energy bills and other net benefits for consumers (present value). The investments would also help develop long-term markets for advanced clean technologies and practices, and bring further economic and environmental benefits we mostly did not quantify, including cleaner air, better health, and improved international competitiveness.

RESULTS BY INVESTMENT

Table ES1 shows the impacts by proposed investment. The largest investments create the most jobs; completing millions of home energy upgrades alone could add 1.3 million job-years. Size of investment also matters for reducing GHG emissions, but some of the greatest reductions are from industrial programs, for which we expect rapid payback and large savings per dollar invested. The greatest leverage of private capital is for some industrial programs, commercial building improvements, and electric trucks.

The most-transformational long-term market impacts would be from deploying heat pumps and heat pump water heaters, commercializing new low-carbon industrial technologies, and building new zero-energy homes and commercial buildings.

Home improvements for low- and moderate-income households, including in affordable rental housing, bring health and housing quality benefits as well as energy bill savings to households most in need. Industrial measures yield benefits—from waste reduction and improved products—that can exceed their energy savings.

More generally, pumping money into the economy in job-intensive sectors such as construction creates jobs, regardless of the kind of investment. Energy efficiency investments do that and more. They also create long-term jobs and economic growth through energy savings that typically pay back more than the initial investment. The energy savings reduce GHG emissions and air pollution, help consumers and businesses financially, and can benefit the health and finances of overburdened households. Efficiency investments are effective as stimulus, as the foundation for a clean economy, and as assistance for American consumers and businesses.

Table ES1. Net cumulative impacts from the proposed investments

	Base package				Big package			
	Federal investment (PV $billion)	Total jobs created (thousand job-years)	CO_2 emissions avoided (MMT)	Net savings (PV $billion)	Federal investment (PV $billion)	Total jobs created (thousand job-years)	CO_2 emissions avoided (MMT)	Net savings (PV $billion)
Buildings								
LI weatherization	2.7	11	9	0.1	9.6	40	34	0.3
Apartment retrofits	Included under home retrofits				47.8	331	198	–0.7
Home retrofits	7.0	83	48	0.9	66.1	901	593	48.4
Equipment rebates	9.9	58	98	–2.1	114.6	256	1,064	–31.9
Bldg. tax incentives	28.7	488	323	13.7	31.9	692	444	22.0
Industry								
Energy management	3.1	170	505	95.2	3.1	170	505	95.2
Industrial innovation	8.8	367	1,294	136.0	8.8	367	1,294	136.0
Transportation								
EV tax credits	52.9	239	226	8.4	52.9	239	226	8.4
Transport CO_2 progs.	6.6	102	54	1.2	6.6	102	54	1.2
Cross-cutting								
State and local progs.	6.5	99	65	3.3	6.5	99	65	3.3
Total	126.3	1,617	2,622	256.8	348.0	3,198	4,475	282.2

PV is discounted present value; MMT is million metric tons; LI is low-income; EV is electric vehicle. The programs are described below. In addition to the savings listed here under state and local programs, state energy programs also are critical to implementing home retrofits, one of the industry energy management programs, and other measures. While there would be some overlap between the home energy retrofit programs and the home improvements tax credit, we believe the reduction in savings would be small and do not include it here.

Introduction

As businesses attempt to return to full operation despite resurgent COVID-19 outbreaks, unemployment remains a problem, especially among low-income communities and communities of color. We need to create jobs in a way that benefits all. At the same time, we are facing a looming climate crisis and a need to cut greenhouse gas (GHG) emissions as much as possible.

Energy efficiency can create jobs now while making a down payment on future carbon abatement. At the end of 2020, an estimated 2.1 million people worked at least in part on energy efficiency, down from a 2019 high of 2.4 million due to pandemic-related job losses (DOE 2021). A previous ACEEE report found that energy efficiency could cut U.S. GHG emissions in half by 2050 (Nadel and Ungar 2019). Achieving that goal would require a large and sustained increase in energy efficiency investments—and in the number of trained workers to implement them. It would also result in long-term energy savings and job creation throughout the economy as families and businesses spend the funds they will be saving on their energy bills.

The energy efficiency investment proposals we analyze here are designed for both short-term economic and long-term environmental benefits; they also promote social equity by ramping up investments in affordable housing. These proposals can be implemented quickly, often using existing federal programs and relationships, but will be most effective with long-term commitments. They involve local construction workers as well as equipment and components manufactured domestically. Further, because of the energy savings and other benefits these proposals provide, federal funding can often leverage private funds to increase the impacts.

The proposals will not only produce direct energy savings but also speed the development of technologies and practices needed for transformation to a greener economy. Electric vehicles (EVs), deep energy retrofits of homes and commercial buildings, electric heat pumps, and new industrial processes all are critical pathways to a low-carbon economy.

Some of the proposals are designed specifically to help communities hit hardest by the pandemic and resulting economic recession, especially households and businesses overburdened by energy bills. Improving the homes of low-income families both lowers their energy bills and provides a healthier, more comfortable place to live. Moreover, many jobs created by the proposals would provide income to the same communities.

We previously analyzed 13 efficiency investments across all economic sectors to estimate net jobs creation, carbon emissions reductions, and energy savings (Ungar et al. 2020). In this update to our 2020 paper, we use a similar methodology to look at several new proposals, some redesigned proposals, and a couple with only updated numbers and baseline assumptions. Most of them are longer-term investments, often over 10 years, and a couple are at much larger scale than any we analyzed before. Thus, we also look at the collective impacts from a "base" package and "big" package of measures. This analysis includes

BUILDINGS

- *Home retrofits.* Programs to cut energy waste in existing homes, including an increase in the low-income *Weatherization Assistance Program* (WAP), a new *Green, Resilient, Efficient, and Affordable Homes for Tenants* (GREAHT) program for multifamily apartment buildings, and a new *HOPE for HOMES* rebate and job training program
- *Building tax incentives.* Improvements to existing tax incentives for home improvements (25C), new homes (45L), and both new and upgraded commercial buildings (179D)
- *Heat pump and appliance incentives.* New proposals to spur use of heat pumps and heat pump water heaters, as well as induction stoves, heat pump dryers, and super-efficient refrigerators and washing machines, through consumer rebates or through a manufacturer tax incentive

INDUSTRY

- *Industrial energy management.* Energy assessments, technical assistance, and grants for small manufacturers through the existing *Industrial Assessment Centers*, for medium manufacturers through a new *FlexTech* state program, and for large firms through a new *Save Energy and Carbon Now* program; also, matching funds to hire new energy managers and support for strategic energy management
- *Industrial innovation.* A new *First Three* program to provide support for initial commercial-scale applications of innovative carbon-saving technologies, and new support for innovations in industrial clusters

TRANSPORTATION

- *Electric vehicle tax credits.* Expansion of tax credits for electric passenger vehicles (30C) and electric chargers (30D) and a new credit for electric trucks
- *Transportation carbon reduction programs.* Proposed transportation bill programs to fund investments to reduce fuel use and emissions

CROSS-CUTTING

- *State and local programs.* New funding for the *State Energy Program* and for *Energy Efficiency Conservation Block Grants* to implement energy efficiency and renewable energy measures

In the following sections, we briefly describe the analysis methodology, then each program and its estimated impacts, and finally the combined results. Appendix A offers detailed results.

Methodology

For each proposal, we estimated likely national electricity, natural gas, and oil savings; monetary and emissions savings; and costs. These are projections for what we believe is a likely scenario for implementation—not an idealized scenario with maximum potential impacts—and they represent the net change compared to a baseline scenario in which the proposals are not enacted.

For appropriated funds, we typically started from the amount of federal funding, then estimated the amount of private or state match (if any) and the administrative costs. We then estimated the annual energy savings over time from the combined investment. For tax incentives, we estimated the market uptake based either on experience with similar incentives or on a baseline market and price and an estimated price demand elasticity. We assumed that the measures would be enacted in the early fall, and that most investments would start in 2022 and continue through 2031, although in a few cases they would spur private investments through 2050. Finally, we assumed that the savings and the financing costs would continue as late as 2080, depending on measure lifetimes and loan terms. Appendix B presents details on the methodology and our assumptions for each proposal.

We estimated energy cost savings and carbon dioxide (CO_2) emissions reductions for each proposal by year using projected average retail prices by sector. We based the average emissions intensities for electricity and each fuel on the U.S. Energy Information Administration's *Annual Energy Outlook 2021* (EIA 2021) reference case. In a few cases, we also included other financial ("non-energy") benefits from the measures—mostly health savings from improved low-income housing, increased comfort from other home retrofits, and process cost savings in manufacturing plants—but we made no attempt to be comprehensive, and we did not include other benefits such as the value of carbon abatement. All dollar amounts are in 2020 dollars, and we discounted cumulative financial impacts using a 5% real discount rate.

We estimated each proposal's net macroeconomic impacts using a version of our DEEPER input-output model (described in Appendix C). We estimated how many jobs would be created and lost due to the investment of government and consumer funds in the efficiency measures (and the loss of other uses of those funds) as well as due to the consequent energy bill savings for consumers and reduced payments to utilities and fuel providers. We did not include the investments' non-energy benefits, but those jobs impacts would not be large. Because the investments are intended as economic stimulus, we assumed that the federal funding would be financed using Treasury bonds over 30 years. All investments and savings are paid for, so the net jobs impact can be negative in some years. Jobs are shown as the net increase or decrease in the number of full-time equivalent jobs by year, aggregated as "job-years."

These estimates have a high level of uncertainty. For some proposals, little existing data indicate a provision's impact; we therefore had to base the assumptions on our judgment, which was reviewed by outside experts.

Proposed Investments: Descriptions and Impacts

We now describe each of the proposals and the key results of our analyses. We report the investments, energy cost savings, and non-energy benefits separately as cumulative discounted present values (except for appropriated investment amounts in the text, which are generally in nominal dollars, consistent with how they appear in legislation, and hence differ from the present values in the tables). CO_2 emissions reductions are cumulative (but not discounted). Jobs numbers are in cumulative net added job-years—that is, the additional full-time-equivalent employment for a year—considering both investments and savings. Appendix A offers more detailed results.

HOME RETROFIT PROGRAMS

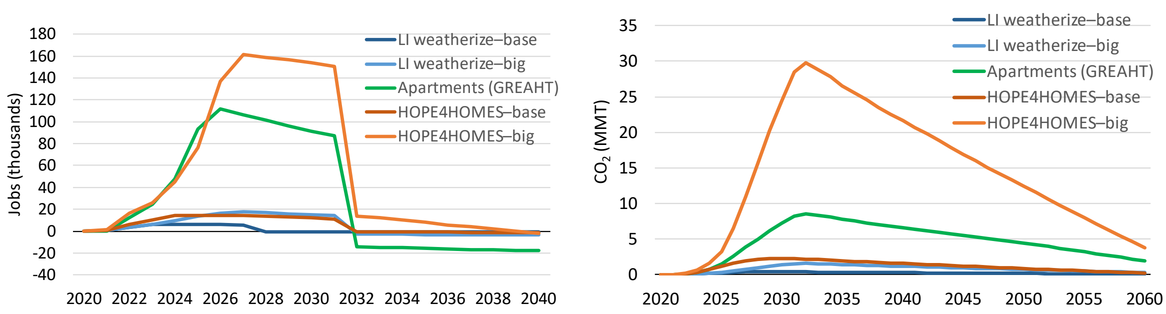

Figure 1. Net jobs created and carbon reduced from refreshing three home retrofit programs—WAP, HOPE for HOMES and GREAHT

Description

Existing homes are one of the hardest sectors to reach with GHG reduction measures, but improving housing is essential for decarbonization—most of today's homes will still be here in 2050—for equity, and to create local jobs. We examined three retrofit programs for different kinds of residences: the low-income Weatherization Assistance Program (WAP), a proposed HOPE for HOMES (H4H) rebate program, and a proposed affordable multifamily program named Green, Resilient, Efficient, and Affordable Homes for Tenants (GREAHT).

WAP. WAP provides funds to states for energy efficiency upgrades for low-income households. Weatherization reduces energy costs, improves health and safety, and supports energy efficiency jobs across the country. Since its launch in 1976, WAP has served more than 7 million homes with cost-effective efficiency measures including air sealing and insulation, as well as upgraded heating and cooling systems, water heaters, lighting, and appliances. A well-established network of states, Community Action Agencies, other nonprofits, local government agencies, and private contractors use Department of Energy (DOE) and other funds to deliver weatherization services to approximately 85,000 low-income families each year (NASCSP 2020). Recovery Act funding helped support weatherization of 1 million homes from 2010–2012, demonstrating the program's capacity to ramp up services quickly. We modeled a $3.5 billion base program in accordance with the Senate Infrastructure Investment and Jobs Act (117th Congress 2021e) and a larger $15 billion program that would serve 1.8 million homes.

HOPE for HOMES. This proposed program would provide online training for workers on home weatherization and rebates to homeowners for weatherization work. It is targeted at households above the qualifying levels for WAP. The program provides for rebates via state energy offices for achieving 15–35% or higher savings with comprehensive whole-home retrofits. The proposal has now added performance rebates for multifamily homes. Because lower income families may not be able to afford retrofits even with the base rebates, the amounts are doubled for low- and moderate-income families. We modeled two versions of the program—extending the currently proposed legislation (117th Congress 2021c) to last 10 years, and enhancing the current proposal for single-family homes with higher incentives and more funding. Note we have not included the proposal's prescriptive rebates administered by DOE because of overlap with rebates discussed below.

GREAHT. This proposed Department of Housing and Urban Development (HUD) program targets multifamily buildings, with a particular focus on affordable housing. A large portion of low- and moderate-income families rent subsidized or "naturally occurring affordable" apartments, often in older buildings that need work. Under the program, state housing finance agencies would provide grants and loans to building owners for energy efficiency, solar, electrification, repairs to improve health and safety, and resilience measures with caps on the grant for each category. Energy efficiency measures would be part of all retrofits, but owners could choose from among the other components. A brief version is included in the House Financial Services Committee draft of the Housing Is Infrastructure Act (117th Congress 2021d). We analyzed a program that serves 8.7 million units over 10 years.

Impacts

These high-budget programs include $15 billion for WAP, $106 billion for HOPE for HOMES, and $75 billion for GREAHT in the big package (all in nominal dollars). We estimate that together these programs should result in saving about $112 billion in energy (present value) and 824 million tons of reduced CO_2 emissions (equivalent to the emissions of 178 million cars and light trucks for a year); see table 1. The enhanced HOPE for HOMES and GREAHT programs have among the highest emissions reductions of the options we examined for this study as well as the highest costs. Non-energy benefits for these programs are substantial, especially for low-income homeowners and renters—based on prior evaluation studies, we estimate these additional benefits (e.g., reduced medical and tenant turnover costs) to be $80 billion.

These programs would result in the creation of about 380,000 net job-years over the first 5 years, and about 1.3 million total lifecycle job-years, including additional jobs created due to the long-term energy savings. Figure 1 shows the net added jobs by year through 2040 and the CO_2 emissions reductions through 2060.

Table 1. Cumulative impacts from home retrofit programs

	Federal investment (PV $billion)	Other investment (PV $billion)	Jobs created (thousand job-years)	CO_2 emissions avoided (MMT)	Energy cost savings (PV $billion)	Non-energy benefits (PV $billion)
LI weatherize–base	2.7	-	11	9	1.2	1.6
LI weatherize–big	9.6	-	40	34	4.3	5.6
Apartments (GREAHT)	47.8	9.3	331	198	23.8	32.6
HOPE for HOMES–base	7.0	3.3	83	48	7.4	3.7
HOPE for HOMES–big	66.1	11.7	901	593	84.1	42.1
Home retrofits–big	123.5	20.9	1,272	824	112.2	80.3

Investment in the table is shown in present value, but in the text it is in cumulative nominal dollars

BUILDING EFFICIENCY TAX INCENTIVES

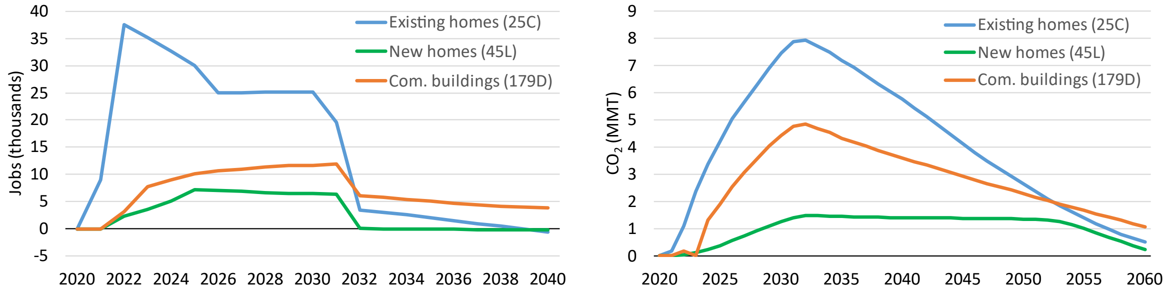

Figure 2. Net jobs created and carbon reduced from refreshing three federal tax incentives—45L, 179D, and 25C

Description

Tax incentives have been an important way of helping homeowners and building owners improve efficiency. Three federal energy efficiency tax incentives—for efficient new homes (section 45L of the tax code), existing home retrofits (section 25C), and new and improved commercial buildings (179D) —are overdue for a "refresh" to target incentives to the highest levels of efficiency and to make them available for more projects. We analyzed the Senate Finance Committee's Clean Energy for America Act (117th Congress 2021a), which revises and increases all the incentives.

Key improvements include making 179D more usable for retrofits and increasing the incentive for deep retrofits and for highly efficient new buildings; increasing the 25C incentive to 30% of the cost of eligible measures, with higher efficiency criteria and an increased cap of $1,500 each year; and making 45L a two-tier program, one based on Energy Star and the other on DOE's Zero Energy Ready Homes program. With these revisions, the incentives would spur key measures for decarbonization—zero-energy homes and buildings and deep retrofits of commercial buildings. The bill would also extend the incentives; our analysis assumes they last until 2031. However, many individuals (especially lower-income families) and some companies would still be unable to use tax incentives; such homeowners would need to rely on the home retrofit programs described in the previous section.

Impacts

Across the three incentives, we estimate total federal revenue loss over 10 years of about $40 billion (nominal dollars). These estimates are based on past use of these provisions, estimates on future use by other analysts, and ACEEE judgment on the impact of changes instituted in the Senate Finance Committee bill. We estimate that these tax credits should result in saving about $46 billion in energy (present value) and 323 million tons of reduced

CO_2 emissions (equivalent to the emissions of 70 million cars and light trucks for a year) over time; see table 2. We did not attempt to estimate non-energy benefits. The commercial building tax deduction has the highest leverage (consumer investment per unit of federal cost) and the most CO_2 savings per federal dollar. The home improvement credit has the largest savings but also the largest cost (in part paying for investments that would have been made without the credit). These estimates reflect reductions in use of multifamily and commercial incentives due to the requirement to pay prevailing wages. Estimates for the "big" package in the combined results do not include that reduction.

These tax incentives would result in the creation of about 190,000 net job-years over the first 5 years, and 490,000 total lifecycle job-years, including additional jobs created due to the long-term energy savings. Figure 2 shows the net added jobs by year through 2040 and the CO_2 emissions reductions through 2060.

Table 2. Cumulative impacts from building efficiency tax incentives

	Federal investment (PV $billion)	Other investment (PV $billion)	Jobs created (thousand job-years)	CO_2 emissions avoided (MMT)	Energy cost savings (PV $billion)
Existing homes (25C)	19.7	1.7	243	168	25.7
New homes (45L)	7.0	–2.7	51	42	5.7
Com. buildings (179D)	2.0	4.8	195	113	14.9
Building tax incentives	28.7	3.8	488	323	46.2

Investment in the table is shown in present value, but in the text it is in cumulative nominal dollars. Other investment is negative when federal spending displaces private investment, usually because it partly pays for measures that would have been taken anyway.

HEAT PUMP, HEAT PUMP WATER HEATER, AND APPLIANCE REBATES AND TAX CREDITS

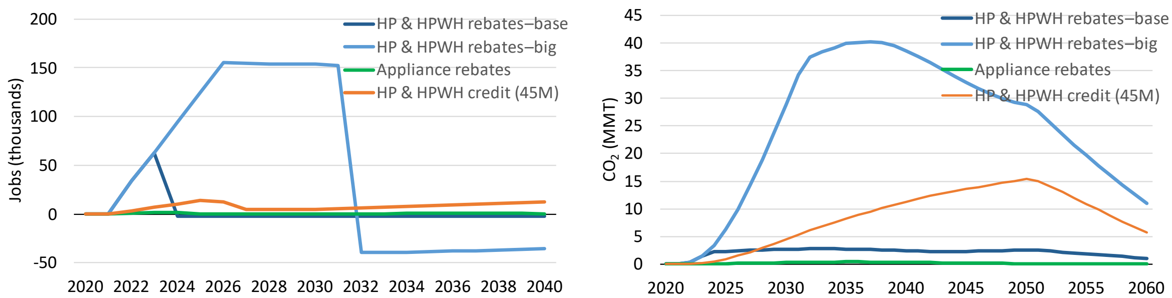

Figure 3. Net jobs created and carbon reduced from heat pump/heat pump water heater credits and from appliance rebates

Description

Most studies on strategies for decarbonizing U.S. buildings conclude that efficient electric heat pumps (HP) and heat pump water heaters (HPWH) will need to provide the majority of space and water heating, rather than conventional furnaces, boilers, and water heaters that burn fossil fuels on-site (see for example Mai et al. 2018, Larson et al. 2020, and IEA 2021).[1] As a result, a variety of proposals for federal investments have focused on increasing use of heat pumps and heat pump water heaters.

In this section we analyze three proposals: (1) the Zero Emissions Home Act (ZEHA) proposed by Senator Heinrich (D-NM) and others (117th Congress 2021h), (2) reviving a manufacturer tax credit for efficient appliances (section 45M of the tax code) to focus on heat pumps and heat pump water heaters, and (3) reviving a program from the American Recovery and Reinvestment Act of 2009 that provided rebates for high-efficiency appliances via state energy offices.

ZEHA. ZEHA provides specified consumer rebates for high-efficiency heat pumps, heat pump water heaters, induction ranges, heat pump clothes dryers, and electric panel upgrades to accommodate the power draw of these electric appliances. There are basic incentives and then higher incentives for low- and moderate-income households as well as tribal households. ZEHA also allows DOE to provide incentives for solar, electric vehicle charging,

---

[1] Heat pumps essentially work like air conditioners to cool a home but reverse the direction to heat it—they extract heat from the colder outdoors and expel the heat into the home. That is much more efficient than heating directly with electricity and avoids the direct emissions from fuel combustion.

and other electric system improvements, but we did not include these optional provisions in our cost or savings estimates.

Tax credit. For 45M, we looked at a 10-year credit (up to a per-manufacturer cap) that provides incentives to manufacturers for incremental increases in annual sales relative to a base period. Residential, commercial, and industrial equipment would be covered. After an initial phase-in, the credit would include only domestic production. Incentives to manufacturers can shift entire markets at reduced costs.

Rebate programs. For appliance rebates, we included the highest efficiency refrigerators and washing machines as well as induction ranges and heat pump clothes dryers (the latter two products are also covered by ZEHA, but we analyze them here). These rebates would go directly to customers.

Impacts

We modeled two versions of ZEHA; one with a budget of about $10 billion and one for the legislation as introduced, without any funding limitation. We also modeled the 45M tax credit for a federal PV cost close to $5 billion (nominal cost is $7 billion). An additional $0.4 billion is provided for appliance rebates.

Based on data from appliance manufacturers, DOE analyses, and other sources, we estimate that the ZEHA program with a $10 billion budget could result in saving $6 billion in energy and 91 million tons of reduced CO_2 emissions (equivalent to the emissions of 20 million cars and light trucks for a year); see table 3.

We estimate the tax credit could result in saving $17 billion in energy and 254 million tons of reduced CO_2 emissions (equivalent to the emissions of 55 million cars and light trucks for a year). Based on experience with "upstream" incentives for manufacturers, we estimate the 45M credit would have a greater impact on product sales and especially on long-term market transformation per federal dollar, even as it only pays incentives for incremental increases in product production.

The ZEHA incentives and the resulting energy savings would create 90,000 net job-years over the first 5 years, and 46,000 total lifecycle job-years, with job losses due to paying back the initial investments. In contrast, while the tax credit would result in only a fraction of the initial jobs, it would create more total jobs per federal dollar due to the continued increase in sales and the long-term energy savings. Figure 3 shows the net added jobs by year through 2040 and the CO_2 emissions reductions through 2060.

Table 3. Cumulative impacts from heat pump, heat pump water heater, and appliance credits and rebates

	Federal investment (PV $billion)	Other investment (PV $billion)	Jobs created (thousand job-years)	CO_2 emissions avoided (MMT)	Energy cost savings (PV $billion)
HP & HPWH rebates–base	9.5	–0.9	46	91	6.0
HP & HPWH rebates–big	114.2	–27.0	244	1,057	54.6
Appliance rebates	0.4	0.4	12	7	1.3
HP & HPWH credit (45M)	6.7	8.8	153	254	16.8

In the table, investment is shown in present value, but in the text it is in cumulative nominal dollars. There is overlap in impacts between ZEHA and 45M, so in subsequent totals we use ZEHA and not 45M so as to avoid double-counting.

INDUSTRIAL ENERGY MANAGEMENT PROGRAMS

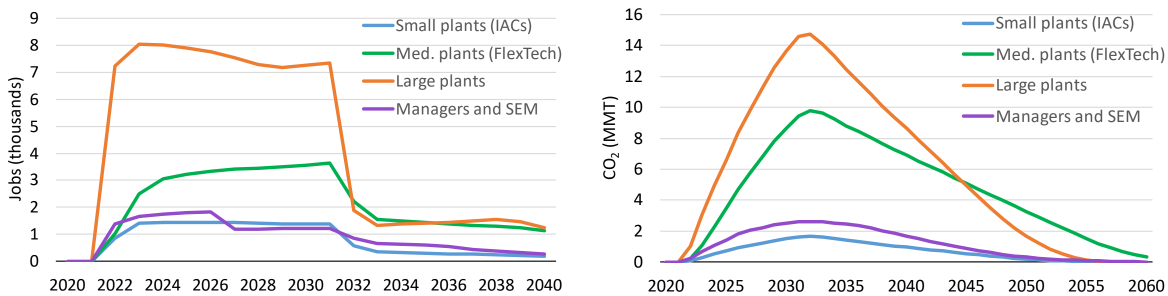

Figure 4. Net jobs created and carbon reduced from industrial energy management programs

Description

Many large industrial facilities have operated energy management programs for decades, with leading companies using these programs to reduce energy use dramatically and usually gain even larger process cost savings (Ungar and Whitlock 2019; Draves 2020; 3M 2021). Energy management typically includes a range of measures to reduce energy waste through energy assessments, real-time monitoring, improved maintenance and operations, and capital improvements. Many small and medium-sized firms have limited energy management efforts, and even most large firms can do more. Energy management is a critical foundation for even deeper cuts in industrial GHG emissions. A variety of investment proposals would bolster these efforts:

Industrial assessment centers (IACs). IACs are university-based centers that provide energy assessments to small industrial firms and in the process help train engineering students in energy management. Senators Jeanne Shaheen and Rob Portman have proposed to expand the program, with the latest proposal included in the Senate Energy and Natural Resources Committee's Energy Infrastructure Act (117th Congress 2021e). This proposal includes expanding to community colleges and training centers, establishing centers of excellence, and providing grants to manufacturing plants to increase uptake of energy audit recommendations.

FlexTech. The New York State Energy Research and Development Authority (NYSERDA) has operated a FlexTech program for many years to co-fund engineering studies on specific promising energy efficiency measures, and then offer low-cost financing for measure implementation. While all plants are eligible, the particular focus has been on medium-sized plants. Representative Paul Tonko (a former head of NYSERDA) has proposed a national program (State Industrial Competitiveness Act of 2021, 117th Congress 2021g) to implement FlexTech in each state via state energy offices.

Save Energy and Carbon Now. For very large plants, from 2005 to 2008 DOE ran the Save Energy Now program in response to natural gas price spikes. The program targeted the largest gas-consuming manufacturing facilities with assessments, technical assistance, and staff training. Ultimately, the program performed 680 assessments with a reduction of 50 trillion Btus in natural gas consumption at these facilities over the first 2 years, and achieved savings of about $500 million. We examined a similar program targeting the 3,000 largest U.S. manufacturing plants with a focus on reducing both energy use and GHG emissions.

Energy managers and strategic energy management. Many large plants have energy managers on staff whose job is to identify and implement strategies to reduce energy use. Some plants have implemented *strategic energy management* (SEM) programs that use a Plan-Do-Check-Act process of continual improvement, a process that gained acceptance with the ISO 9001 quality standard many years ago (Therkelsen et al. 2021) and more recently has been applied to energy management in ISO 50001 and DOE's 50001 Ready program. We examined a program that would co-fund the salaries of new energy manager positions for up to three years and would assist companies to establish SEM programs.

Impacts

The four provisions together would have a total federal cost of $4.4 billion over 10 years (nominal dollars). Across these programs, industrial customers would match the federal spending more than two to one. Based on evaluations of past experience with these and similar programs, we estimate that this funding should result in saving about $34 billion in energy (present value) and about 500 million tons of reduced CO_2 emissions (equivalent to the emissions of more than 100 million cars and light trucks for a year); see table 4. Save

Energy and Carbon Now has the highest energy, emissions, and financial savings, but FlexTech has the most savings per federal dollar.

The four programs would create about 50,000 net job-years over the first 5 years, and about 170,000 total lifecycle job-years, including additional jobs created due to the long-term energy savings. Figure 4 shows the net added jobs by year through 2040 and the CO_2 emissions reductions through 2060.

Table 4. Cumulative impacts from industrial energy management programs

	Federal investment (PV $billion)	Other investment (PV $billion)	Jobs created (thousand job-years)	CO_2 emissions avoided (MMT)	Energy cost savings (PV $billion)	Non-energy benefits (PV $billion)
Small plants (IACs)	0.4	0.6	15	27	2.7	5.6
Med. plants (FlexTech)	0.6	1.5	50	190	11.2	23.6
Large plants	1.6	5.4	87	241	16.8	35.3
Managers and SEM	0.5	1.0	18	47	3.8	7.9
Industrial energy manage.	3.1	8.5	170	505	34.4	72.4

Investment in the table is shown in present value, but in the text it is in cumulative nominal dollars.

INDUSTRIAL INNOVATION PROGRAMS

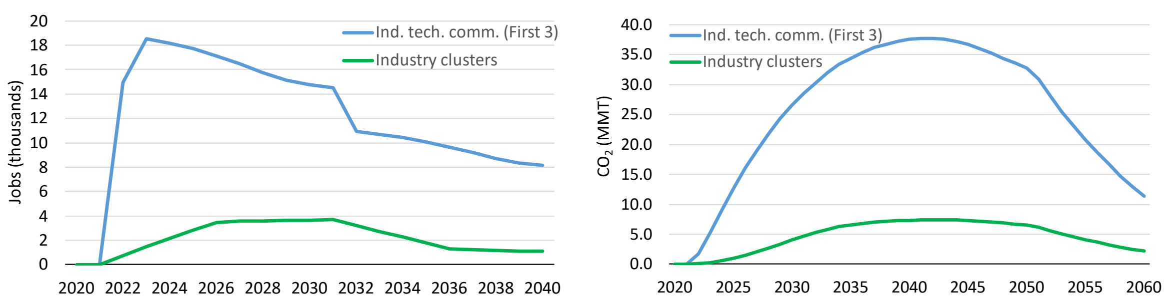

Figure 5. Net jobs created and carbon reduced from “first three” and industrial clusters programs

Description

Decarbonizing the industrial sector will require implementation of many new technologies to transform the way products are produced, in addition to better energy management. These technologies include new, lower-emission approaches to producing carbon-intensive materials such as steel, aluminum, chemicals, glass, and cement; new, lower-embodied-carbon products that can replace higher-carbon products in some applications; low-carbon fuels; and carbon capture and sequestration or use. DOE has been funding research and sometimes demonstrations for innovative industrial technologies for many years, but the first commercial-scale applications can cost hundreds of millions or even billions of dollars. To address this need, we examined a program to be run by the Advanced Manufacturing Office (AMO) at DOE that would co-fund the first three commercial-scale installations of transformative technologies with large energy and GHG savings. Projects would be selected through an annual solicitation process (Nadel, Elliott, and Rightor 2021).

As a complement to this effort, we also examined an AMO program proposal that would foster research, development, and demonstration of innovative technologies by focusing on regional industrial clusters. Industrial companies in several sectors (e.g., chemicals, steel, and refining) are concentrated geographically in clusters, where a network of facilities, suppliers, service providers, specialized infrastructure, trained workers, and academic collaborators develop mutually beneficial resources, transportation, and workforce. Based on successful programs in Europe (e.g., see Safety4Sea 2019), this new competitive grant program would encourage clusters to work together to spur innovation.

Impacts

We estimate that First Three would have a federal cost of $10 billion over 10 years and clusters would cost $3 billion (both in nominal dollars). Across these two programs, industrial customers would match federal spending more than two to one, in part because we assume these programs would be transformative and result in further investments to the end of our analysis (2050). Based on typical energy savings for industrial programs per dollar of spending, we estimate that this funding should result in saving $46 billion in energy (present value), nearly $100 billion in other benefits to the companies, and more than 1 billion tons of reduced CO_2 emissions (more than the total emissions of all U.S. cars and light trucks for a year); see table 5. First Three has particularly large impacts, with the largest carbon and energy Btu savings of any of the programs examined in this paper.

These two programs would create about 77,000 net job-years over the first 5 years, and about 370,000 total lifecycle job-years, including additional jobs created due to the long-term energy savings. Figure 5 shows the net added jobs by year through 2040 and the CO_2 emissions reductions through 2060.

Table 5. Cumulative impacts from industrial innovation incentives

	Federal investment (PV $billion)	Other investment (PV $billion)	Jobs created (thousand job-years)	CO_2 emissions avoided (MMT)	Energy cost savings (PV $billion)	Non-energy benefits (PV $billion)
Ind. tech. comm. (First 3).	7.0	17.0	317	1,092	46.0	96.9
Industry clusters	1.8	2.6	50	201	6.9	14.6
Industrial innovation	8.8	19.6	367	1,294	52.9	111.4

Investment in the table is shown in present value, but in the text it is in cumulative nominal dollars

TAX CREDITS FOR ELECTRIC CARS, TRUCKS, AND EV CHARGING EQUIPMENT

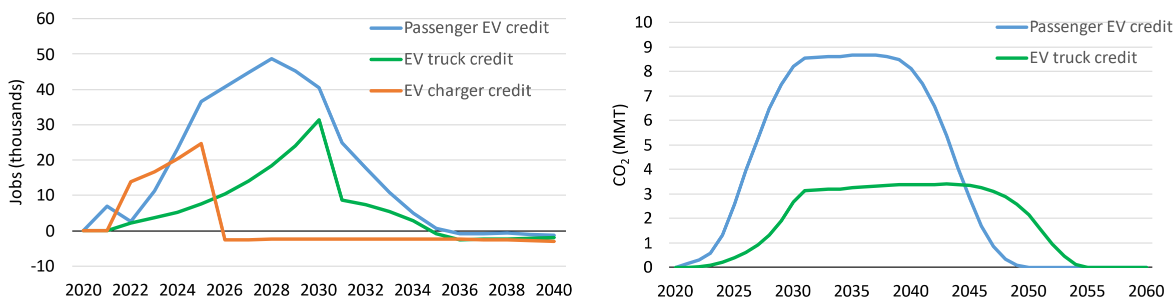

Figure 6. Net jobs created and carbon reduced from vehicle tax credits

DESCRIPTION

Electric vehicles (EVs) are essential to slash greenhouse gas emissions from road transportation. EVs also offer numerous other benefits, such as reducing or eliminating local pollution, saving fuel, and reducing vehicle operating costs. While not modeled in this analysis, EVs can also provide storage services to the grid and complement the deployment of renewable energy.

The automotive industry is a vital component of U.S. manufacturing, with vehicle sales accounting for roughly 3.5% of U.S. gross domestic product. Plug-in vehicles are more likely to be manufactured domestically than other vehicles, and 250,000 U.S. auto workers already work with alternative-fuel vehicles (Piotrowski 2018). Supporting the EV market can help create high-quality jobs and aid the stimulus effort. Investing in EV supply equipment (EVSE) such as chargers is crucial to supporting the uptake of EVs and can create badly needed local manufacturing and installation jobs.

EV tax credits support both domestic EV manufacturing and growth of the country's nascent EV market. Under the 30D tax credit, buyers of some light-duty plug-in EVs currently qualify for a federal tax credit to offset part of the upfront cost. The credit ranges from $2,500 to $7,500 but is phased out after the first 200,000 plug-ins sold by a given automaker, a cap already reached by Tesla and General Motors. We modeled a proposal in the GREEN Act of 2021 (117th Congress 2021b) to expand the per-automaker limit to 600,000, but with a lower maximum credit of $7,000.

Currently, there are no federal tax credits for medium- and heavy-duty electric trucks. We modeled a proposal based on the Clean Energy for America Act (117th Congress 2021a) that includes a 30% tax credit on battery electric and fuel cell vehicles, modified to end in 2030. We also modeled the impacts of extending the current 30C tax credit for EV charging infrastructure (that is, EVSE) through the end of 2025, based on the Green Act of 2021. In this proposal, new charging infrastructure would continue to qualify for a tax credit of up to 30% of the overall cost, with an additional 20% credit available for fleet-related installations and public stations.

Impacts

We estimate that these extended tax provisions would increase new light-duty EV sales by 2 million vehicles between 2021 and 2030, and medium- and heavy-duty EVs by 0.5 million. For the light-duty tax credit, our analysis projects that the cost to the federal government over the next 10 years would total $31 billion (present value). For the medium- and heavy-duty tax credit and the EVSE tax credit, the costs to the federal government would be $15 billion and $7 billion, respectively. The light-duty tax credit would reduce CO_2 emissions by 151 million tons, while the medium- and heavy-duty tax credit would reduce emissions by 75 million tons, after accounting for the emissions caused by increased electricity use.

The added light-duty EVs would be very cost effective, even though most of the tax credits would go to people who would buy EVs anyway, and in later years the credit would exceed the added cost. As table 6 shows, the result would be consumer fuel savings (minus added electricity use) of $21 billion. Given that the added cost of the vehicles (after financing) is $6.5 billion, the net fuel savings over vehicle cost is almost $14 billion (present value).

We assume that our analysis of the vehicle credits captures the emissions savings resulting from greater EVSE investment. There would likely also be some switching from EV charging at home to charging at public stations, which may not result in additional net energy or emissions savings beyond what we credit to the EV tax credits.

These results do not include the very important impact that these credits would have on the EV market after they expire. Increasing EV sales should result in further price reductions from economies of scale and technological advancement, which would further increase sales and energy benefits beyond the life of these credits.

Combined, the credits would result in 175,000 additional job-years in the first 5 years and almost 240,000 total lifecycle job-years as use of the credits grows with the EV markets. Figure 6 shows the net added jobs by year through 2040 and emissions reductions by year through 2060. The job impacts shown below for the EVSE credit appear small because the energy savings are included under the other credits.

Table 6. Cumulative impacts from EV tax incentives

	Federal investment (PV $billion)	Other investment (PV $billion)	Jobs created (thousand job-years)	CO_2 emissions avoided (MMT)	Energy cost savings (PV $billion)
Passenger EV credit	31.4	–23.9	176	151	21.2
EV truck credit	14.7	–6.9	62	75	7.3
EV charger credit	6.8	–2.0	0 *	- *	- *
Elec. vehicle tax credits	52.9	–32.9	239	226	28.4

***The energy savings and impacts from the charger credit are included under the other credits. Other investment is negative when federal spending displaces private investment, usually because it partly pays for measures that would have been taken anyway.**

TRANSPORTATION CARBON POLLUTION REDUCTION PROGRAM

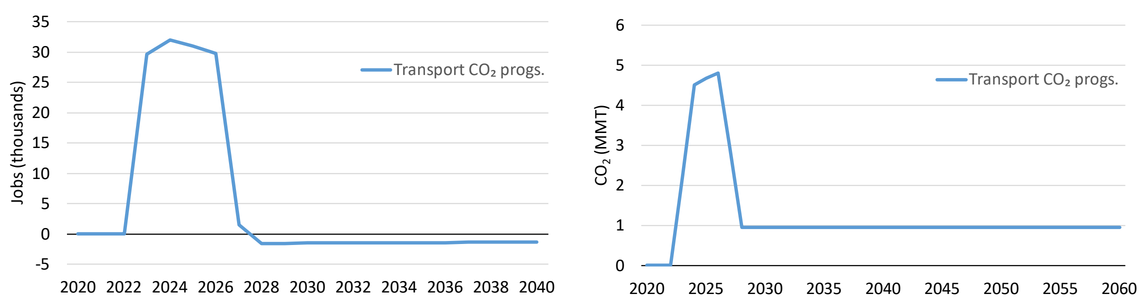

Figure 7. Net jobs created and carbon reduced from transportation CO_2 programs

Description

Transportation is now the biggest source of carbon emissions in the United States, and more than half of those emissions come from passenger vehicles (EPA 2021). The proposed Carbon Pollution Reduction Program would provide states with $8.35 billion over a four-year period (2023–2026) to spend on transportation programs that are expected to reduce GHG emissions. These programs go beyond vehicle efficiency to improve mobility with less driving and traffic. The carbon reduction program is included in the House INVEST in America Act (117th Congress 2021f); a similar but smaller and looser program is in the Senate's Surface Transportation Reauthorization Act of 2021 (part of 117th Congress 2021e). In the House version, states have significant autonomy over the types of projects they can fund, with the restriction that the money cannot be spent to increase capacity for single-occupancy vehicles. The federal Department of Transportation would be required to monitor states' progress and report on their emissions reductions.

The Carbon Pollution Reduction Program would allow states to test different approaches to increasing energy efficiency in personal transportation. Eligible projects vary but may include improving public transit, bike lanes, and pedestrian infrastructure, as well as increasing freight and traffic efficiency. In addition to helping consumers save on fuel costs, expected state investments can further the COVID-19 recovery effort by creating good construction jobs over the next decade.

Impacts

We estimate that this program would save almost $8 billion on energy bills for consumers and businesses and avoid 54 million tons of CO_2 (equivalent to the emissions of 12 million cars and light trucks for a year); see table 7. The program would result in more than 90,000 additional job-years in 2022–2026 and 100,000 total lifecycle job-years, including additional jobs created due to the long-term fuel savings. Figure 7 shows the net added jobs by year through 2040 and emissions reductions by year through 2060.

We assume that one-third of the money would go toward public transit, thus decreasing vehicle miles traveled (VMT) in personal vehicles and overall emissions. Large amounts would also go toward systems operations efficiency and freight intermodality (19% each), with smaller amounts going toward travel demand management (13%), land use and smart growth initiatives (9%), and pedestrian and biking infrastructure (9%). All aim to increase the efficiency of and reduce emissions from transportation.

Table 7. Cumulative impacts from the transportation carbon reduction program

	Federal investment (PV $billion)	Jobs created (thousand job-years)	CO_2 emissions avoided (MMT)	Energy cost savings (PV $billion)
Transport CO_2 progs.	6.6	102	54	7.8

Investment in the table is shown in present value, but in the text it is in cumulative nominal dollars. We do not include any local funding; while it is difficult to know for a new program, we expect investment by others would be relatively small.

STATE AND LOCAL PROGRAMS

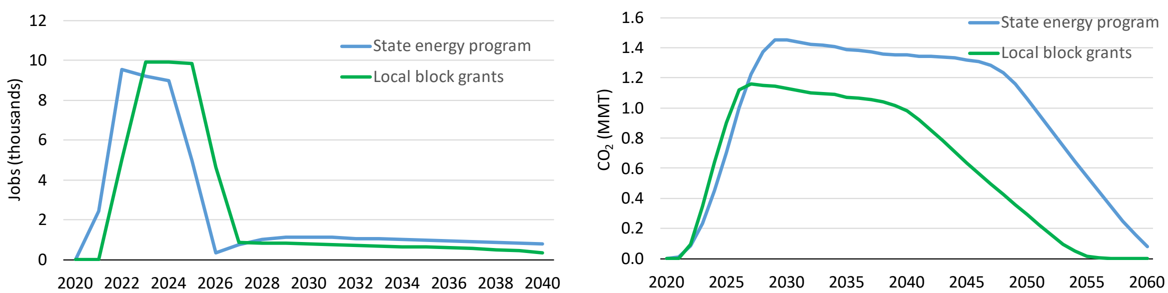

Figure 8. Net jobs created and carbon reduced from SEP and EECBG

Description

State and local governments play an essential role in delivering energy efficiency around the country, both in implementing voluntary efficiency programs and in setting policies, including building energy codes, building performance standards, vehicle emissions standards, and local zoning.

The *State Energy Program* (SEP) helps states advance energy efficiency, renewable energy, and energy security. As an existing DOE grant program that has helped build programs, policies, and energy plans in every state, SEP is well suited to invest money quickly while giving states flexibility in how they make investments. It proved effective in the Great Recession, especially for work on building energy codes, building retrofit programs and loans, and renewable energy markets (not included here). The broad funding proposed here is in addition to the state energy offices' role in HOMES and other targeted programs.

The *Energy Efficiency and Conservation Block Grants* (EECBG) program would provide grants and technical assistance to local and state governments for energy efficiency and renewable energy projects. EECBG funding, first offered as a one-time program through the 2009 Recovery Act stimulus, helped build local capacity in energy efficiency. A revived EECBG program would create jobs in areas such as energy efficiency retrofits, street and traffic lighting upgrades, providing financial incentives, building design, renewable and distributed energy projects, and related program and policy development.

Impacts

We modeled $3.8 billion in funding for SEP and $3.9 billion for EECBG over about four years. We did not include any added state or private funds because they were not included in the ARRA evaluations; previous evaluations of SEP, however, have found large leverage. Based on experience under ARRA, we estimate that this funding should result in saving about $10 billion in energy and 65 million tons of reduced CO_2 emissions (equivalent to the emissions of 14 million cars and light trucks for a year); see table 8. However, the savings vary by orders of magnitude for different fund uses and thus would depend on how states choose to use the money. The SEP evaluation found that the greatest savings per dollar by far was for work on building energy codes; building performance standards should also yield large savings.

Furthermore, the impacts of these programs are only in part shown by their direct savings. State energy offices, as well as local offices, are important implementers for many of the programs discussed in this paper, such as the HOPE for HOMES residential retrofit program, the FlexTech industrial program, and the appliance rebate program. Flexible funding under SEP and EECBG will help the state and local offices build the capacity to effectively implement the other programs.

The grants and the resulting energy savings would create 70,000 net job-years over the first 5 years, and almost 100,000 total lifecycle job-years, including additional jobs created due to the long-term energy savings. Figure 8 shows the net added jobs by year through 2040 and the CO_2 emissions reductions through 2060.

Table 8. Cumulative impacts from state and local program investments

	Federal investment (PV $billion)	Jobs created (thousand job-years)	CO_2 emissions avoided (MMT)	Energy cost savings (PV $billion)
State Energy Program	3.3	58	40	5.4
Local block grants	3.2	41	25	4.4
State and local progs.	6.5	99	65	9.9

Investment in the table is shown in present value, but in the text it is in cumulative nominal dollars. Although we do not include non-federal leveraged funds here, these programs do leverage significant funding.

Combined Results

The investments we describe here create jobs, help consumers, and reduce GHG emissions. Tables 9 and 10 show the results for all the proposals; Appendix A offers more detailed results. The proposals that are only in the "base" package are in blue; the proposals that are only in the "big" package are in green; the proposals in black are in both packages. The total federal investment is shown on the left in table 9, along with the added leveraged investment from private sources or from state or utility programs. In a few cases, the federal investment displaces other investment, as when tax incentives help pay for investments that would have been made anyway. Key long-term impacts are shown on the right, including the cumulative reduction in CO_2 emissions, the total energy cost savings, and selected financial non-energy benefits such as reduced manufacturing and healthcare costs.

Table 9. Cumulative impacts from the proposed investments

	Federal investment (PV $billion)	Other investment (PV $billion)	CO_2 emissions avoided (MMT)	Energy cost savings (PV $billion)	Non-energy benefits (PV $billion)
Buildings					
Home retrofits–base	9.7	3.3	57	8.7	5.3
Home retrofits–big	123.5	20.9	824	112.2	80.3
Equipment rebates–base	9.9	–0.5	98	7.3	-
Equipment rebates–big	114.6	–26.7	1,064	55.9	-
Building tax incent.–base	28.7	3.8	323	46.2	-
Building tax incent.–big	31.9	8.2	444	62.1	-
Industry					
Industrial energy manage.	3.1	8.5	505	34.4	72.4
Industrial innovation	8.8	19.6	1,294	52.9	111.4
Transportation					
Elec. vehicle tax credits	52.9	–32.9	226	28.4	-
Transport CO_2 progs.	6.6	-	54	7.8	-
Cross-cutting					
State and local progs.	6.5	-	65	9.9	-
Base Total	126.3	1.8	2,622	195.6	189.2
Big Total	348.0	–2.4	4,475	363.7	264.1

We analyzed only selected non-energy benefits for some of the investments.

Table 10. Estimated net job creation (thousand full-time-equivalent job-years)

	2022–2025	2026–2030	2031–	Total
Buildings				
Home retrofits–base	68	76	–51	93
Home retrofits–big	377	1,358	–464	1,272
Equipment rebates–base	97	–11	–28	58
Equipment rebates–big	320	772	–836	256
Building tax incent.–base	192	215	81	488
Building tax incent.–big	225	277	189	692
Industry				
Industrial energy manage.	53	68	50	170
Industrial innovation	77	97	193	367
Transportation				
Elec. vehicle tax credits	175	306	–242	239
Transport CO_2 progs.	93	27	–17	102
Cross-cutting				
State and local progs.	70	12	17	99
Base Total	824	791	2	1,617
Big Total	1,390	2,918	–1,110	3,198

The largest estimated carbon impacts in the big package, as shown in figure 9, are from industrial innovation measures, due to spurring further long-term private investments, and from a large package of home retrofit programs, which assume unprecedented federal efficiency investments. The largest jobs impacts, as well as largest energy cost savings, are from the large home retrofit package and the building tax incentives (if usage is not deterred by prevailing wage rules; in general, it is hard to predict the market effects of tax incentives). The energy cost savings for industrial programs are a little lower because industrial energy prices are lower; however, they could yield very large non-energy benefits (which are not incorporated in the jobs estimates).

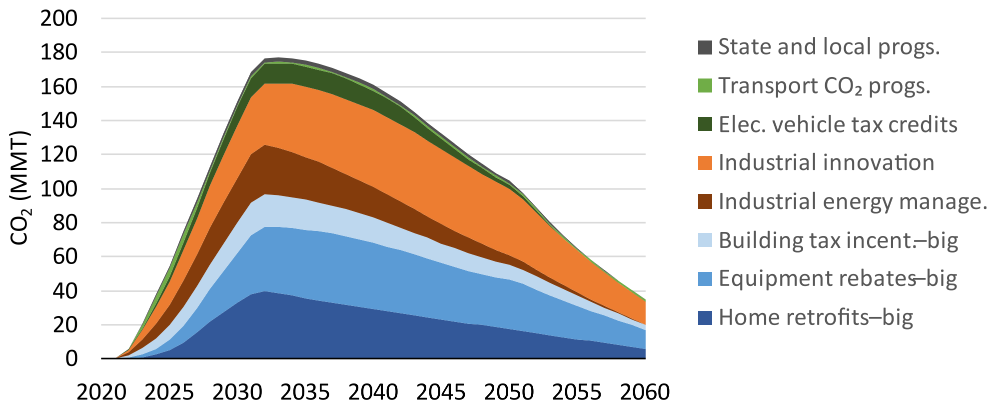

Figure 9. CO_2 emissions reductions by year for each kind of investment in the big package

By far the largest carbon impacts per federal dollar are for the industrial energy management and innovation programs, which are very cost effective (the equipment tax credit, especially the heat pump water heater portion, would also have large leverage, but the rebate proposal is more expensive). The largest jobs impacts per federal dollar are for the commercial buildings tax deduction and industrial energy management (and again the equipment tax credit). On the other hand, some proposed spending helps pay for important investments that would have happened to some extent anyway, such as the expansion of the EV tax credit and support for windows and insulation in the 25C home improvements tax credit.

Although the energy and carbon savings are expensive, expanding WAP and supporting retrofits for affordable apartments is particularly helpful for low-income families and communities of color, which have been most affected by the pandemic and economic recession. Improving their homes not only reduces their monthly expenses but also provides important health benefits.

Combined, these investments would have large impacts. In the base package, we estimate that $126 billion in investments yields 2.6 billion tons of CO_2 emissions reductions. We also estimate cumulative energy savings of 53 quadrillion Btus, worth $195 billion (present value) and a similar amount in financial benefits other than energy savings. The big package would be nearly three times as large, with significantly higher impacts: 4.5 billion tons of CO_2 emissions reductions (about 11 months of total U.S. energy-related emissions), and energy savings of 88 quads, worth $364 billion. But we did not try to count all non-energy benefits or all long-term benefits in advancing technologies and practices, reducing costs, and developing markets for key decarbonization tools. The emissions reductions in 2030 from the big package would already be about 8% of the reduction from projected emissions needed to meet the new U.S. commitment under the Paris Agreement.

Figure 10 shows the creation of jobs for the base package over a longer time period than the previous figures, along with the total added investment and energy cost savings. Table 10 shows the jobs by investment. The investments themselves create jobs in the first few years due to the construction and manufacturing needed to implement the measures. In later years, multiple competing effects arise. The energy savings result in net added jobs as economic activity shifts from the energy sector, which requires relatively few workers, to more job-intensive sectors in which the energy savings are spent. We simultaneously assume that the debt that financed the government investment and part of the leveraged investment is paid back, resulting in fewer jobs.

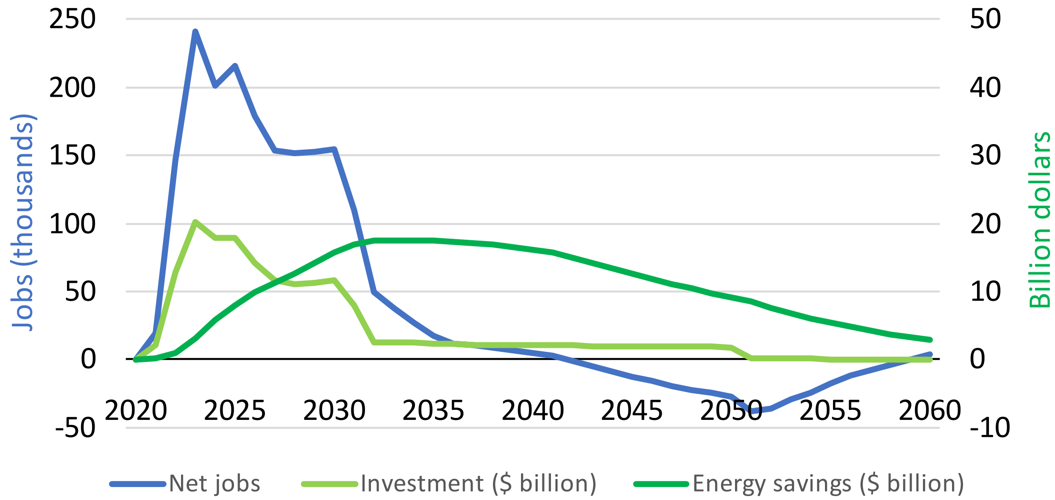

Figure 10. Net added jobs by year, compared to total investment and energy bill savings. Net jobs are negative when the jobs lost due to paying for earlier financed federal and other spending exceed the jobs gained from continuing energy savings.

Conclusions

Energy efficiency investments can create jobs now and spur long-term decarbonization through deep energy retrofits, zero-energy buildings, heat pumps, electric vehicles, industrial process innovation, and more. These investments not only directly create domestic jobs in construction and manufacturing but also spur additional long-term jobs and economic growth as consumers spend energy savings that typically more than pay back the initial investment. The energy savings not only cut GHG emissions but also reduce air pollution, help consumers and businesses financially, and strengthen the electric grid, enabling more electrification. And the large proposed home energy programs will benefit the health and finances of low-income families.

The investments we discuss here make sense as stimulus, with the potential to add more than three million job-years over the next four years. They make sense as investments in a green economy, with the potential to avoid 4.5 billion tons of CO_2 emissions. And they make sense for American consumers and businesses, for whom they could save nearly $300 billion.

References

117th Congress. 2021a. *Clean Energy for America Act, S. 1298* (as passed by the Senate Finance Committee). www.congress.gov/bill/117th-congress/senate-bill/1298/.

117th Congress. 2021b. *GREEN Act of 2021, H.R. 848* (as introduced). www.congress.gov/bill/117th-congress/house-bill/848.

117th Congress. 2021c. *HOPE for HOMES Act of* 2021, S. 1768 and HR 3456 (as introduced). www.congress.gov/bill/117th-congress/senate-bill/1768.

117th Congress. 2021d. *Housing Is Infrastructure Act of 2021* (draft released by the House Financial Services Committee). financialservices.house.gov/uploadedfiles/hiinfr_003_xml.pdf.

117th Congress. 2021e. *Infrastructure Investment and Jobs Act, H.R. 3684* (as passed by the Senate). www.congress.gov/bill/117th-congress/house-bill/3684.

117th Congress. 2021f. *INVEST in America Act, H.R. 3684* (as passed by the House). www.congress.gov/bill/117th-congress/house-bill/3684.

117th Congress. 2021g. *State Industrial Competitiveness Act of 2021, HR 4676* (as introduced). www.congress.gov/bill/117th-congress/house-bill/4676.

117th Congress. 2021h. *Zero-Emission Homes Act of 2021, S. 2370/HR 4872* (as introduced). www.congress.gov/bill/117th-congress/senate-bill/2370.

3M. 2021. *Improving Every Life: 2021 Sustainability Report*. St. Paul, Minnesota: 3M. multimedia.3m.com/mws/media/2006066O/2021-sustainability-report.pdf.

DOE (Department of Energy). 2021. *2021 United States Energy & Employment Report*. Washington, DC: DOE. www.energy.gov/us-energy-employment-jobs-report-useer.

Draves, M. 2020. "Continuous Improvements on Saving Energy and Waste Powered by #TeamDow Employees." corporate.dow.com/en-us/seek-together/dow-recognized-for-sustainability-efforts.html.

EIA (Energy Information Administration). 2021. *Annual Energy Outlook 2021*. Washington, DC: EIA. www.eia.gov/outlooks/aeo/.

EPA (Environmental Protection Agency). 2021. "Fast Facts on Transportation Greenhouse Gas Emissions." www.epa.gov/greenvehicles/fast-facts-transportation-greenhouse-gas-emissions.

IEA (International Energy Agency). 2021. *Net Zero by 2050; A Roadmap for the Global Energy Sector*. Paris: IEA. www.iea.org/reports/net-zero-by-2050 .

IMPLAN Group LLC. 2021. *IMPLAN 2019 Dataset*. Huntersville, NC: IMPLAN Group LLC. www.IMPLAN.com.

Larson, E., C. Greig, J. Jenkins, E. Mayfield, A. Pascale, C. Zhang, J. Drossman, R. Williams, S. Pacala, R. Socolow, E. Baik, R. Birdsey, R. Duke, R. Jones, B. Haley, E. Leslie, K. Paustian, and A. Swan. 2020. *Net-Zero America: Potential Pathways, Infrastructure, and Impacts (Interim Report)*. Princeton, NJ: Princeton University. netzeroamerica.princeton.edu/img/Princeton_NZA_Interim_Report_15_Dec_2020_FINAL.pdf.

Mai, T., P. Jadun, J. Logan, C. McMillan, M. Muratori, D. Steinberg, L. Vimmerstedt, R. Jones, B. Haley, and B. Nelson. 2018. *Electrification Futures Study: Scenarios of Electric Technology Adoption and Power Consumption for the United States*. Prepared by NREL (National Renewable Energy Laboratory). Washington, DC: DOE. www.nrel.gov/docs/fy18osti/71500.pdf.

Nadel, S., and L. Ungar. 2019. *Halfway There: Energy Efficiency Can Cut Energy Use and Greenhouse Gas Emissions in Half by 2050*. Washington, DC: ACEEE. aceee.org/research-report/u1907.

Nadel, S., N. Elliott, and E. Rightor. 2021. *"First Three": Providing Critical Support to New Low-Carbon Industrial Process Technologies*. Washington, DC: ACEEE. aceee.org/policy-brief/2021/09/first-three-providing-critical-support-new-low-carbon-industrial-process.

NASCSP (National Association of State Community Service Programs). 2020. *Weatherization Assistance Program Funding Report, PY 2019*. Washington, DC: NASCSP. nascsp.org/wp-content/uploads/2021/01/NASCSP-2019-WAP-Funding-Survey_Final.pdf.

Piotrowski, M. 2018. "Electric Vehicles Support U.S. Manufacturing, Jobs." *The Fuse,* May 8. www.energyfuse.org/electric-vehicles-support-u-s-manufacturing-jobs/.

Safety4Sea. 2019. "Port of Rotterdam Successfully Adopts Innovation, Report Says." *Safety4Sea*, April 23. safety4sea.com/port-of-rotterdam-successfully-adopts-innovation-report-says/.

Therkelsen, P., H. Fuchs, W. Miller, A. Whitlock, and E. Rightor. 2021. *Strategic Energy Management Program Persistence and Cost Effectiveness*. Prepared by Berkeley Lab and ACEEE. Washington, DC: NASEMC (North American Strategic Energy Management Collaborative). www.aceee.org/research-report/ie2101.

Ungar, L. 2018. *The Impact of Federal Energy Efficiency Programs*. Washington, DC: ACEEE. www.aceee.org/fact-sheet/federal-ee-programs.

Ungar, L., and A. Whitlock. 2019. *Energy Efficiency and Corporate Sustainability: Saving Money While Meeting Climate Goals*. Washington, DC: ACEEE. aceee.org/sites/default/files/pdfs/eecs-smmcg_0.pdf.

Ungar, L., J. Barrrett, S. Nadel, R. Elliott, E. Rightor, J. Amann, P. Huether, and M. Specian. 2020. *Growing a Greener Economy: Job and Climate Impacts from Energy Efficiency Investments*. Washington, DC: ACEEE. aceee.org/white-paper/2020/09/growing-greener-economy-job-and-climate-impacts-energy-efficiency-investments.

Young, R., S. Hayes, S. Nadel, G. Herndon, and J. Barrett. 2013. *Economic Impacts of the Energy Efficiency Provisions in the Energy Savings & Industrial Competitiveness Act of 2013 and Select Amendments*. Washington, DC: ACEEE. aceee.org/sites/default/files/pdf/white-paper/shaheen-portman-2013.pdf.

Appendix A. Detailed Results

The results here are presented at the level at which we analyzed the measures, and for which we made the assumptions in Appendix B. In some cases the results in the paper are aggregated (e.g., Home retrofits – base includes HOMES – Multifamily and HOMES – Whole retrofit).

Table A1. Estimated cumulative energy savings and carbon abatement from the proposed investments

	Electricity (TWh)	Natural gas (TBtu)	Oil (mbd)	Total energy (quads)	CO_2 emissions (MMT)
LI weatherize–base	11.5	83	0.00	0.20	9
LI weatherize–big	45.6	323	0.00	0.79	34
Apartments (GREAHT)	322.6	1,490	0.04	4.76	198
HOMES – Multifamily	41.8	87	0.00	0.48	18
HOMES – Whole retrofit	55.8	220	0.00	0.76	31
HOMES – Whole–big	1,107.0	4,269	0.05	14.85	593
Heat pump rebate	–113.8	1,650	0.03	0.98	77
HP water heater rebate	33.2	89	0.00	0.39	14
Electrical panel rebate	-	-	-	-	-
Appliance rebates	21.5	11	-	0.20	7
Heat pump rebate–big	–1,619.6	21,587	0.33	11.71	972
HP water heater rebate–big	193.0	536	0.00	2.29	85
Electrical panel rebate–big	-	-	-	-	-
Heat pump credit	-192.6	3,503	0.05	2.52	177
HP water heater credit	98.9	271	0.00	1.17	43
Home imp. credit–shell	185.0	778	-	2.50	100
Home imp. credit–equip	126.7	533	-	1.71	68
New home credit	91.4	281	-	1.11	42
Comm. bldg. deduction	203.1	315	-	2.14	76
Comm. bldg. retrofit deduct.	101.6	158	-	1.07	38
Large plant audits	99.6	797	-	1.77	76

	Electricity (TWh)	Natural gas (TBtu)	Oil (mbd)	Total energy (quads)	CO_2 emissions (MMT)
Large plant grants	215.2	1,722	-	3.82	165
Med. plants (FlexTech)	217.8	2,178	-	4.33	190
Small plant audits	46.2	72	-	0.49	18
Small plant grants	23.1	36	-	0.25	9
Plant energy managers	41.9	335	-	0.74	32
Strategic energy mgmt.	39.0	55	-	0.41	15
Ind. tech. comm. (First 3)	1,193.2	9,944	-	21.39	1,092
Industry clusters	91.0	3,035	-	4.12	201
Passenger EV credit	–137.8	-	0.41	1.61	151
EV truck credit	–212.2	-	0.29	0.13	75
EV charger credit	-	-	-	-	-
Transport CO_2 progs.	–1.4	-	0.12	0.80	54
State energy program	91.9	187	0.01	1.06	40
Local block grants	65.9	91	0.00	0.69	25

Table A2. Estimated cumulative present value investments and savings ($billion)

	Federal investment	Consumer investment	Energy bill savings	Non-energy benefits	Net savings
LI weatherize–base	2.7	-	1.2	1.6	0.1
LI weatherize–big	9.6	-	4.3	5.6	0.3
Apartments (GREAHT)	47.8	9.3	23.8	32.6	-0.7
HOMES – Multifamily	1.8	0.7	2.5	1.3	1.2
HOMES – Whole retrofit	5.2	2.5	4.9	2.5	-0.3
HOMES – Whole–big	66.1	11.7	84.1	42.1	48.4
Heat pump rebate	8.9	-0.9	4.4	-	-3.5
HP water heater rebate	0.4	-0.1	1.5	-	1.2
Electrical panel rebate	0.1	0.2	-	-	-0.3

	Federal investment	Consumer investment	Energy bill savings	Non-energy benefits	Net savings
Appliance rebates	0.4	0.4	1.3	-	0.6
Heat pump rebate–big	107.7	-27.6	44.9	-	-35.2
HP water heater rebate–big	4.8	-0.8	9.8	-	5.8
Electrical panel rebate–big	1.8	1.3	-	-	-3.1
Heat pump credit	5.3	7.0	10.0	-	-2.3
HP water heater credit	0.5	0.7	4.7	-	3.5
Home imp. credit–shell	16.0	-0.4	15.3	-	-0.3
Home imp. credit–equip	3.8	2.1	10.4	-	4.5
New home credit	7.0	-2.7	5.7	-	1.4
Comm. bldg. deduction	1.3	3.4	9.9	-	5.2
Comm. bldg. retrofit deduct.	0.7	1.7	5.0	-	2.6
Large plant audits	0.7	1.5	5.2	11.0	14.1
Large plant grants	0.9	3.9	11.5	24.3	31.0
Med. plants (FlexTech)	0.6	1.5	11.2	23.6	32.7
Small plant audits	0.1	0.6	1.8	3.7	4.8
Small plant grants	0.3	0.1	0.9	1.9	2.4
Plant energy managers	0.3	0.6	2.2	4.5	5.8
Strategic energy mgmt.	0.2	0.4	1.6	3.4	4.5
Ind. tech. comm. (First 3)	7.0	17.0	46.0	96.9	118.9
Industry clusters	1.8	2.6	6.9	14.6	17.1
Passenger EV credit	31.4	-23.9	21.2	-	13.7
EV truck credit	14.7	-6.9	7.3	-	-0.6
EV charger credit	6.8	-2.0	-	-	-4.8
Transport CO_2 progs.	6.6	-	7.8	-	1.2
State energy program	3.3	-	5.4	-	2.1
Local block grants	3.2	-	4.4	-	1.2

Table A3. Estimated net job creation (thousand full-time-equivalent job-years)

	2022–2025	2026–2030	2031–	Total
LI weatherize–base	23	9	–21	11
LI weatherize–big	33	83	–76	40
Apartments (GREAHT)	178	508	–355	331
HOMES – Multifamily	12	19	0	32
HOMES –Whole retrofit	33	48	–30	51
HOMES – Whole–big	166	768	–33	901
Heat pump rebate	86	–12	–50	24
HP water heater rebate	5	0	17	22
Electrical panel rebate	2	–0	–1	0
Appliance rebates	5	1	7	12
Heat pump rebate–big	298	717	–894	120
HP water heater rebate–big	12	41	70	123
Electrical panel rebate–big	6	14	–19	1
Heat pump credit	52	14	23	89
HP water heater credit	5	3	56	64
Home imp. credit–shell	113	90	–63	141
Home imp. credit–equip	31	35	36	102
New home credit	18	34	–1	51
Comm. bldg. deduction	20	37	72	130
Comm. bldg. retrofit deduct.	10	19	36	65
Large plant audits	10	12	4	27
Large plant grants	21	25	15	61
Med. plants (FlexTech)	10	17	23	50
Small plant audits	3	4	4	11
Small plant grants	2	3	-1	4
Plant energy managers	4	3	3	9
Strategic energy mgmt.	3	4	2	9
Ind. tech. comm. (First 3)	69	79	168	317

	2022–2025	2026–2030	2031–	Total
Industry clusters	7	18	25	50
Passenger EV credit	81	220	–125	176
EV truck credit	19	98	–55	62
EV charger credit	76	–12	–63	0
Transport CO_2 progs.	93	27	–17	102
State energy program	35	4	19	58
Local block grants	35	8	–1	41

Table A4. Estimated cumulative carbon abatement (MMT/$billion PV) and net job creation (job-years/$million PV) per federal investment and per total investment present value

	CO_2/federal	CO_2/total	Jobs/federal	Jobs/total
LI weatherize–base	3	3	4	4
LI weatherize–big	4	4	4	4
Apartments (GREAHT)	4	3	7	6
HOMES – Multifamily	10	7	18	13
HOMES – Whole retrofit	6	4	10	7
HOMES – Whole–big	9	8	14	12
Heat pump rebate	9	10	3	3
HP water heater rebate	35	45	53	68
Electrical panel rebate	0	0	2	1
Appliance rebates	18	9	31	16
Heat pump rebate–big	9	12	1	2
HP water heater rebate–big	18	21	26	31
Electrical panel rebate–big	0	0	0	0
Heat pump credit	33	14	17	7
HP water heater credit	87	38	129	56
Home imp. credit–shell	6	6	9	9
Home imp. credit–equip	18	12	27	17

	CO_2/federal	CO_2/total	Jobs/federal	Jobs/total
New home credit	6	10	7	12
Comm. bldg. deduction	57	16	98	28
Comm. bldg. retrofit deduct.	57	16	98	28
Large plant audits	109	35	38	12
Large plant grants	189	35	70	13
Med. plants (FlexTech)	292	89	76	23
Small plant audits	129	26	77	15
Small plant grants	31	25	15	12
Plant energy managers	104	34	30	10
Strategic energy mgmt.	87	27	52	17
Ind. tech. comm. (First 3)	157	46	45	13
Industry clusters	111	46	28	11
Passenger EV credit	5	20	6	24
EV truck credit	5	10	4	8
EV charger credit	0	0	0	0
Transport CO_2 progs.	8	8	15	15
State energy program	12	12	18	18
Local block grants	8	8	13	13

Appendix B. Detailed Assumptions and Methodology

In this appendix, we briefly describe the methodology and key assumptions used in our impact estimates. We discuss the cost and savings estimates for individual measures below; because there is little overlap, we assume the estimates are additive in the packages.

We estimate the most likely impact of implementing the proposals compared to a baseline if the proposals are not enacted. Thus, the relevant federal and consumer investment is only the increase compared to what each would have spent in the baseline case. We calculate impacts for measures by year, and we assume the implementation would start in late 2021 or early 2022; the cumulative and cost-benefit numbers include savings through the lifetimes of those measures and financing as late as 2080 (though the savings and costs are mostly small after 2050). We generally assume only half a year's savings on average in the year a measure is implemented, as the measures are spread over the year.

We include a rebound effect of 10% for most residential and light-duty vehicle savings, 8% for heavy-duty vehicle savings, and 5% for heat pump and commercial and industrial savings (except for the transportation CO_2 programs, for which we assume that any rebound is already included in the savings estimates); for the shift to electric vehicles (EVs), we base the rebound on the fuel cost savings (Nadel and Ungar 2019).

We use the Annual Energy Outlook (AEO) 2021 reference case (EIA 2021) for energy prices by fuel, sector, and year; the carbon intensity by fuel and in some cases by year; and some baseline projections. We calculate present values using a real discount rate of 5%. The costs in some cases are financed (see details below). All monetary impacts are in constant 2020 dollars.

Although there is some overlap between investments, notably the home retrofits, 25C tax credit, and heat pump incentives, all are important ways of supporting home energy upgrades; we believe that overlap is small and did not account for it here. We generally did not include multiple proposals that would achieve the same goals in one package.

For several of the proposals, we had very limited data on which to base our assumptions. We therefore had to rely on our own expert judgment, along with that of other ACEEE staff and the reviewers. We previously analyzed a handful of the programs (Ungar 2018); although the overall methodology is similar, we assumed different funding amounts and completely revised the analyses.

We discuss the assumptions for specific provisions below; in some cases, further details can be found in Appendix B of our earlier report (Ungar et al. 2020). The methodology for estimating macroeconomic impacts is in Appendix C.

Home retrofits								
				HOPE4HOMES–base		HOPE4HOMES–big		
	LI weatherize–base	LI weatherize–big	Apartments (GREAHT)	HOMES - Multifamily	HOMES - Whole retrofit	HOMES - Whole - big		Notes (see below for details on GREAHT and on HOMES)
Federal funding ($ billion nominal)	3.50	15.00	75.00	2.67	7.67	106.16		
Administrative costs (% federal)	0%	0%	10%	11%	22%	14%		Whole HOMES and BIG HOMES include HOPE training; WAP administrative cost included in measure cost.
Leveraged funding (per federal $)	0%	0%	28%	50%	68%	22%		Based on difference between cost and rebate amount
Number of homes (millions)	0.45	1.82	8.73	1.38	1.80	20.00		Based on federal funding and cost
Average federal cost /added unit ($ real)	7,196	7,196	6,752	1,530	2,936	3,939		Based on utility and DOE program experience; see below for details on GREAHT and HOMES
Avg. measure cost /added unit ($ real)	6,250	6,250	8,498	2,301	4,926	4,802		
Baseline energy use	Based on AEO	Based on AEO	Based on AEO	Based on AEO	Based on AEO	Based on AEO		AEO numbers adjusted for single family and multifamily using the Residential Energy Consumption Survey (RECS)
Avg. electricity savings (%)	12%	12%	34%	25%	25%	25%		Based on utility and DOE program experience
Avg. natural gas savings (%)	24%	24%	50%	25%	25%	25%		
Avg. savings lifetime (years)	20	20	20	20	18.6	18.6		
Decay of savings	Straight lir	Straight lin	Straight lin	Straight lin	Straight lin	Straight line		
Rebound (%)	10%	10%	10%	10%	10%	10%		
Non-energy benefits (% energy)	128%	130%	137%	50%	50%	50%		HOMES is onservative estimate for market-rate programs.
% of cost financed	0%	0%	50%	50%	25%	25%		
Loan type			Commercia	Commercia	Mortgage	Mortgage		
Invest. Sector %--Construction	32%	32%	60%	60%	42%	42%		
Invest. Sector %--Manufacturing	47%	47%	25%	25%	50%	50%		
Invest. Sector %--Services	21%	21%	15%	15%	8%	8%		

Building tax incentives	Comm. bldg. deduction	Comm. bldg. retrofit deduct.	Home imp. credit - equip	Home imp. credit - shell	New home credit		Notes
Federal funding ($ billion nominal)	1.94	0.97	5.20	21.99	10.26		Commercial retrofit assumed to be 1/2 of new commercial, but otherwise identical.
Administrative costs (% federal)	1%	1%	1%	1%	1%		
Leveraged funding (per federal real $)	290%	290%	71%	-2%	-64%		For new homes, credit more than covers costs
Baseline units w/ incentive (millions)					1.20		
Added units w/ incentive (millions)					2.40		
Avg. incentive per unit ($)					3,325		
Avg. federal cost /added unit ($ real)					3,757		
Avg. measure cost /added unit ($ real)					1,797		
Baseline energy use					PNNL		
Avg. annual electricity savings (kWh)					1,822		
Avg. annual natural gas savings (kBtu)					5,773		
Simple payback--electric (years)	5	5	6	10			
Simple payback--gas (years)	10	10	6	10			
Electric share (investment or savings)	82%	82%	74%	74%			
Gas share	18%	18%	26%	26%			
Savings--electricity (kWh/$)	33.33	33.33	17.82	10.69			
Savings--natural gas (kBtu/$)	51.75	51.75	74.94	44.96			
Avg. savings lifetime (years)	22	22	18	18	30		
Decay of savings	Straight lir	Straight lin	Weibull	Straight lin	Step function		
Rebound (%)	5%	5%	10%	10%	10%		
Non-energy benefits (% energy)	0%	0%	0%	0%	0%		
% of cost financed	40%	40%	10%	10%	90%		
Loan type	Commercia	Commercia	Mortgage	Mortgage	Mortgage		
Invest. Sector %--Construction	60%	60%	45%	45%	60%		
Invest. Sector %--Manufacturing	20%	20%	45%	45%	20%		
Invest. Sector %--Services	20%	20%	10%	10%	20%		

Heat pump, HPWH, and electrical panel incentives										
	HP & HPWH rebates–base			HP & HPWH rebates–big			HP & HPWH credit (45M)			
	Heat pump rebate	HP water heater rebate	Electrical panel rebate	Heat pump rebate - big	HP water heater rebate - big	Electrical panel rebate - big	Heat pump credit	HP water heater credit		Notes. Heat pump numbers include both whole-home and minisplit HP; HP replacing existing HP do not qualify for the rebate but do for the credit
Federal funding ($ billion nominal)	9.97	0.46	0.17	169.44	7.75	2.77	6.50	0.61		All HP & HPWH credit numbers in the report add 15% to account for commercial and industrial equipment.
Administrative costs (% federal)	0%	0%	0%	0%	0%	0%	0%	0%		
Leveraged funding (per federal real $)	22%	42%	237%	-11%	16%	137%	285%	285%		Increase in net consumer cost compared to federal funding
Base case units - w/ incentive (millions)	0.23	0.24	0.03	2.04	2.23	0.47	3.53	0.57		Units that get the rebate or credit but would have been sold anyway. All residential.
Base case units - no incentive (millions)	10.97	24.02		10.97	22.03		113.61	23.69		Qualifying units not due to the rebate or credit sold after rebate or credit ends.
Added units - w/ incentive (millions)	2.55	0.09	0.07	39.73	2.67	1.21	5.07	0.41		Units sold due to the rebate or credit that get the incentive--estimated direct impact.
Added units - after incentive (millions)	3.81	1.77	0.19	37.37	8.22	1.31	17.22	5.19		Unit sales increase due to the rebate or credit after the incentive ends for a manufacturer.
Avg. incentive per unit ($)	3,466	1,358	1,636	3,526	1,358	1,436	809	667		Rebates are increased for low- and moderate-income (LMI) customers
Avg. federal cost /added unit ($ real)	1,518	238	630	1,910	611	956	276	103		After 5 years, credits only pay for increase in sales over a baseline
Avg. measure cost /added unit ($ real)	1,783	331	1,995	1,707	702	2,140	989	374		Upstream credits reduce markups and increase scale; also more of sales are late in period with lower prices.
Baseline energy use	RECS	RECS	RECS	RECS	RECS	RECS	RECS	RECS		
electricity savings (kWh)	-1,255	1,441		-1,474	1,434		-607	1,431		Based on estimated shares of heating equipment replaced
Avg. annual fuel savings (kBtu)	19,902	3,974		21,430	4,101		12,005	4,041		
Avg. savings lifetime (years)	15	13		15	13		15	13		
Decay of savings	Weibull	Weibull		Weibull	Weibull		Weibull	Weibull		
Rebound (%)	5%	5%		5%	5%		5%	5%		
Non-energy benefits (% energy)	0%	0%		0%	0%		0%	0%		
% of cost financed	30%	30%	30%	30%	30%	30%	30%	30%		
Loan type	Mortgage	Appliance	Mortgage	Mortgage	Appliance	Mortgage	Mortgage	Appliance		
Invest. Sector %-- Construction	50%	50%	50%	50%	50%	50%	50%	50%		
Invest. Sector %-- Manufacturing	50%	50%	50%	50%	50%	50%	50%	50%		
Invest. Sector %-- Services	0%	0%	0%	0%	0%	0%	0%	0%		

Appliances incentives						
	Appliance rebates					
	Induction ranges	HP clothes dryers	Refrigerators	Clothes washers		Notes
Federal funding ($ billion nominal)	0.45					
Administrative costs (% federal)	0%					
Leveraged funding (per federal real $)	165%					Increase in net consumer cost compared to federal funding
Base case units - w/ incentive (millions)	0.47	0.01	0.22	0.63		Units that get the rebate or credit but would have been sold anyway. All residential.
Base case units - no incentive (millions)	9.60	1.69	18.89	53.30		Qualifying units not due to the rebate or credit sold after rebate or credit ends.
Added units - w/ incentive (millions)	0.24	0.01	0.22	0.63		Units sold due to the rebate or credit that get the incentive--estimated direct impact.
Added units - after incentive (millions)	1.24	0.16	2.36	3.66		Unit sales increase due to the rebate or credit after the incentive ends for a manufacturer.
Avg. incentive per unit ($)	250	250	100	100		
Avg. federal cost /added unit ($ real)	40	19	9	15		
Avg. measure cost /added unit ($ real)	250	250	100	100		Upstream credits reduce markups and increase scale; also more of sales are late in period with lower prices.
Baseline energy use						
Avg. annual electricity savings (kWh)	93	428	162	247		Mostly based on Energy Star data
Avg. annual natural gas savings (kBtu)	580	244	-	-		
Avg. savings lifetime (years)	13.375					
Decay of savings	Weibull					
Rebound (%)	5%					
Non-energy benefits (% energy)	0%					
% of cost financed	25%					
Loan type	Appliance					
Invest. Sector %--Construction	10%					
Invest. Sector %--Manufacturing	50%					
Invest. Sector %--Services	40%					

Industrial programs										
	Large plant audits	Large plant grants	Med. plants (FlexTech)	Small plant audits	Small plant grants	Plant energy managers	Strategic energy mgmt.	Ind. tech. comm. (First 3)	Industry clusters	Notes
Federal funding ($ billion nominal)	1.00	1.25	0.95	0.20	0.42	0.38	0.25	10.00	3.00	
Administrative costs (% federal)	7%	7%	2%	7%	7%	7%	7%	7%	7%	For medium plants, states administer
Leveraged funding (per federal real $)	257%	520%	257%	475%	28%	268%	257%	441%	259%	
Levelized cost of saved energy--electric ($/kWh)	0.02	0.02	0.01			0.02	0.02	0.03	0.03	Med. Plants (FlexTech) savings from New York program experience
LCOE--gas ($/MMBtu)	2.50	2.50	1.00			2.50	2.50	3.00	3.00	Levelized cost of saved energy (LCOE)
Electric share (investment or savings)	50%	50%	50%			50%	85%	50%	20%	
Gas share	50%	50%	50%			50%	15%	50%	80%	
Savings--electricity (kWh/$)	36.34	36.34	79.75	4.04	4.04	36.34	56.92	29.07	11.63	Small plant (IAC) savings from recent assessments in IAC database
Savings--natural gas (kBtu/$)	290.73	290.73	797.51	6.29	6.29	290.73	80.77	242.28	387.64	
Avg. savings lifetime (years)	13	13	16.5	13	13	13	10	13	13	
Decay of savings	Straight lir	Straight lin	Straight lin	Straight lin	Straight lin	Straight lin	Straight lin	Straight lin	Straight line	
Rebound (%)	5%	5%	5%	5%	5%	5%	5%	5%	5%	
Non-energy benefits (% energy)	211%	211%	211%	211%	211%	211%	211%	211%	211%	
% of cost financed	50%	50%	50%	50%	50%	0%	50%	50%	50%	
Loan type	Industrial	Industrial	Industrial	Industrial	Industrial		Industrial	Industrial	Industrial	
Invest. Sector %--Construction	33%	33%	33%	33%	33%	0%	33%	33%	50%	
Invest. Sector %--Manufacturing	33%	33%	33%	33%	33%	50%	33%	33%	30%	
Invest. Sector %--Services	33%	33%	33%	33%	33%	50%	33%	33%	20%	

Transportation incentives						
	Passenger EV credit	EV truck credit	EV charger credit	Transport CO_2 progs.		Notes (see Ungar et al. 2020 for more details)
Federal funding ($ billion nominal)	44.71	23.54	8.19	8.35		
Administrative costs (% federal)	0%	0%	0%	5%		
Leveraged funding (per federal real $)	-84%	-51%	-34%	0%		Based on credits (including for base case Evs and chargers that have no added cost) and measure costs. Passenger credits are more than the added cost.
Baseline units - w/ incentive (millions)	3.88	0.54	1.10			
Baseline units - after incentive (millions)	13.72	0.00	3.85			
Added units - w/ incentive (millions)	2.05	0.53	0.53			Based on a price elasticity
Added units - after incentive (millions)	0.00	0.00	0.00			
Average incentive per unit ($)	6,773	19,065	4,758			
Average federal cost /added unit ($ real)	19,570	38,430	14,672			
Avg. measure cost /added unit ($ real)	3,863	19,784	9,844			
Avg. annual electricity savings (kWh)	-3,331	-16,996				
Avg. annual diesel savings (gallons)	-	320				
Avg. annual gasoline savings (gallons)	550	804				
Savings 1--electricity (kWh/$)				-0.18		From program experience. Estimated long-term and short-term savings are separated.
Savings 1--diesel (gal/$)				0.10		
Savings 1--gasoline (gal/$)				0.41		
Avg. savings lifetime (years)	17.5	22.5		40		
Decay of savings	Custom	Custom		Step function		
Savings 2--gasoline (gal/$)				0.22		
Avg. savings lifetime (years)				1		
Decay of savings				Step function		
Rebound (%)	10%	8%		0%		
Non-energy benefits (% energy)	0%	0%		0%		
% of cost financed	70%	70%	40%	0%		
Loan type	Auto	Auto	Commercia			
Invest. Sector %--Construction	0%	0%	50%	88%		
Invest. Sector %--Manufacturing	100%	100%	30%	0%		
Invest. Sector %--Services	0%	0%	20%	13%		

State and local funding				Notes
	State energy program	Local block grants		
Federal funding ($ billion nominal)	3.81	3.93		
Administrative costs (% federal)	0%	0%		Administrative costs included in measure costs below
Leveraged funding (per federal real $)	0%	0%		Evaluation did not include leveraged funding; previous eval
Savings--electricity (kWh/$)	25.19	17.70		
Savings--natural gas (kBtu/$)	50.13	24.36		
Savings--propane (kBtu/$)	1.06	0.00		
Savings--oil (gallon/$)	0.06	0.00		
Avg. savings lifetime (years)	29	23		
Decay of savings	Custom	Custom		
Rebound (%)	0%	0%		Included in savings?
Non-energy benefits (% energy)	0%	0%		
% of cost financed	0%	0%		
Loan type				
Invest. Sector %--Construction	37%	38%		
Invest. Sector %--Manufacturing	62%	60%		
Invest. Sector %--Services	2%	2%		

HOMES Assumptions					Base HOMES		Big HOMES			
Single-family homes	% of rebate funds	% of rebates	Average whole-home energy savings per project (%)	Avg. project cost	Avg. non-LMI rebate	Avg. LMI rebate	Avg. non-LMI rebate	Avg. LMI rebate		Notes: Rebates are doubled for low- and moderate-income (LMI) households
Performance rebates (based on modeled or measured savings)										
20+% savings	33%	29%	20%	$4,000	$2,000	$3,200	$3,000	$3,800		
35+% savings	33%	15%	35%	$8,500	$4,000	$6,800	$6,375	$8,075		
% of funding and rebates with LMI add	50%	33%								
Multifamily homes - performance rebates										
20+% savings	50%	67%	20%	$2,500	$1,250	$2,000				Cost and rebate amounts are averages over both 20% and 35% rebates.
35+% savings	50%	33%	35%	$2,500	$1,250	$2,000				
% of funding and rebates with LMI add	67%	50%								
Partial rebates not analyzed because they overlap with ZEHA rebates, but would be:										
Insulation + air sealing	17%	37%	10%	$2,150	$645	$1,290				
Insulation + air sealing and HVAC	17%	20%	20%	$5,850	$1,500	$3,000				HVAC is efficient heat pump, air conditioner or furnace
Contractor incentives										
Data incentive (% of partial rebates)		67%			$250	$250				
LI community incentive (% of performance rebates)		33%				$200		$200		

GREAHT assumptions	% of units	Avg. annual energy savings per unit				Other benefits	Avg. incentive			Notes
Measure		Electricity (kWh)	Natural Gas (MMBtu)	Propane (MMBtu)	Fuel Oil (gal)	(% of bill savings or invest.)				
Efficiency	100%	1,637	3.33	0.08	2.0	71%	$3,000			Savings are 25% of average multifamily unit consumption
Electrification	25%	-1,464	13.15	0.69	20.4	71%	$5,250			Fuel savings based on heating and cooling use of respective fuels, but with oil and propane heated units twice as likely to be electrified. Added electricity use 30% of fuel savings (on site energy basis). Assume once electrified, owner replaces equipment at end of life through 2050 with electrified equipment at 60% of initial cost (and with continued savings).
Solar	33%	2,940				71%	$5,250			Savings assume average solar cost at $3/W and average annual savings of 1.4 kWh/W.
Health and safety	80%					150%	$1,200			
Climate resilience	25%					150%	$3,000			
Owner assumed to pay 20% of incentive amount (hence total cost is 120% of total										

Appendix C. Methodology of the Macroeconomic Model

To evaluate the macroeconomic impacts of energy efficiency policies, we use the proprietary Dynamic Energy Efficiency Policy Evaluation Routine model. The model, recently renamed DEEPER, has a 20-year history of use and development.

The DEEPER Modeling System is a quasi-dynamic input-output (I/O) model of the U.S. economy. I/O models use economic data to study the relationships among producers, suppliers, and consumers. They are often used to show how interactions among all three impact the macroeconomy. DEEPER draws on trade information from the IMPLAN Group LLC (IMPLAN 2021), energy use data from the AEO, and employment and labor data from the Bureau of Labor Statistics. Figure C1 shows a flow diagram of the model.

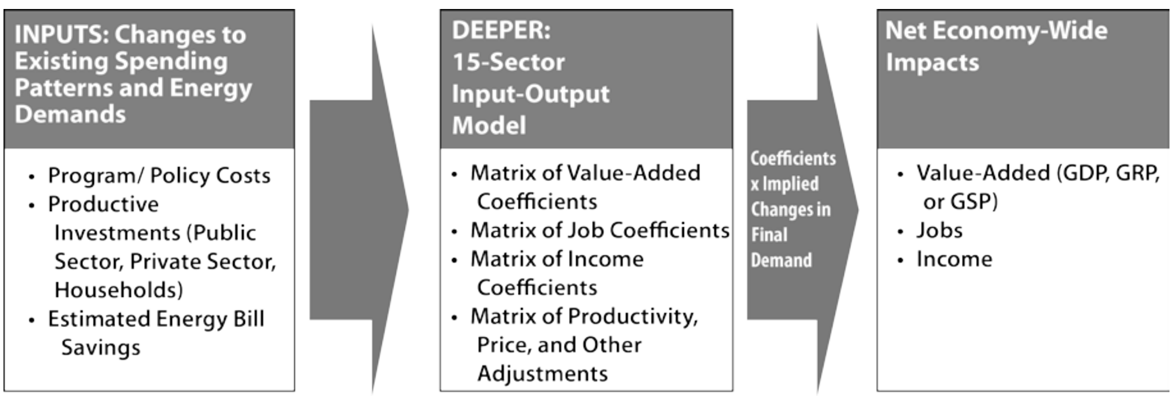

Figure C1. The DEEPER model

DEEPER results are driven by changes in demand for energy and other goods and services, as well as alternate investment patterns resulting from projected changes in policies and prices between baseline and policy scenarios. The inputs are changes in spending on efficiency measures and energy bills of residential, commercial, and industrial consumers, and of government; changes in program spending, revenue, and production of utilities; changes in investments in manufacturing, services, and multiple construction sectors; and changes in financial services. The end result is a net change between the reference and policy scenarios in jobs, income, and value added (the market value of all final goods and services), which is measured as gross domestic product (GDP).

Like all economic models, DEEPER has strengths and weaknesses. It is robust in comparison with some I/O models because it can account for price and quantity changes over time and is sensitive to shifts in investment flows. It also reflects sector-specific labor intensities across the U.S. economy. However, it is important to remember when interpreting DEEPER model results that they rely heavily on the assumptions for individual policies, and like any prediction of the future, they are subject to uncertainty. More details on the DEEPER model are available in previous papers (Young et al. 2013).

Besides the energy analysis results, a key input to DEEPER is the economic sectors in which the investments are made. The basic sectors are shown for each investment in Appendix B. Within those large sectors, we chose an appropriate subsector in each case, such as residential construction, light-duty vehicle manufacturing, and architecture and engineering.