



POLICY BRIEF

Costs of Residential Energy Efficiency Investments are Twice their Benefits: Implications for Policy

Evaluation by Meredith Fowlie, Michael Greenstone and Catherine Wolfram

SUMMARY

- » Energy efficiency improvements are central components of several major energy policy initiatives globally and a core pillar of most long-term carbon abatement strategies. However, there is a gap between the uptake of efficiency measures and their perceived attractiveness based on projected costs and benefits.
- » To explore these issues, a research team from the University of Chicago and the University of California, Berkeley, conducted a first-of-its kind field test of one energy efficiency program: the Federal Weatherization Assistance Program. The analysis was based on a randomized controlled trial conducted with a sample of more than 30,000 households in the state of Michigan. Such experiments are considered the gold standard for evidence.
- » The study found that the costs of the energy efficiency investments were about double households' energy savings. Further, the energy savings projected in advance by engineering calculations are roughly 2.5 times the savings found by the study, underscoring that these models' results must be validated in the field.
- » Past studies have claimed that energy efficiency investments don't deliver the expected energy savings because of a 'rebound effect': households adjust their behaviors and consume more energy services than they had before the investments were made. However, the study found no evidence that households turned up their thermostats in the winter indicating no evidence of this 'rebound effect.'
- » Even when accounting for the broader societal benefits of energy efficiency investments, the costs still substantially outweigh the benefits. The average annual rate of return is -9.5 percent when judged from society's perspective. This finding of low, indeed negative, returns may help explain why energy efficiency investments have low take-up rates. The weatherization upgrades were also found to be expensive ways to cut carbon. The cost per ton of CO₂ avoided in the sample amounted to \$329, significantly larger than the \$38 per ton that the federal government estimates as the social cost of carbon.

INTRODUCTION

Improvements in energy efficiency are often touted as win-win investments for consumers, businesses, and society at large. Energy users save money without sacrificing comfort or productivity (win number one) and society as a whole benefits from reduced exposure to pollutants, lower levels of greenhouse gas emissions, and even enhanced energy security and reliability (win number two).

As the International Energy Agency (IEA) put it in one recent analysis, "energy efficiency is widely recognized as the most cost-effective and readily available means to address numerous energy-related issues, including energy security, the social and economic impacts of high energy prices and concerns about climate change."¹

Global data on energy efficiency investments suggests that significant progress has been made over the past several decades. IEA estimates that the global market for investments in energy efficiency was as large as \$360 billion in 2011, and that total final energy consumption in IEA member countries is today 60 percent lower than would have been the case without the investments in efficiency

that were made over the past four decades—a savings of 1.7 billion tons of oil equivalent.²

For this reason, energy efficiency investments are often placed at the heart of efforts to reduce CO₂ emissions to confront climate change. At a global level, energy efficiency improvements account for 49 percent of greenhouse gas emissions reductions in 2020 at no cost to economic growth, according to the scenario used by the IEA to limit global warming to the 2°C target recommended by climate scientists.

Despite the projected benefits and cost-savings, energy consumers in a range of settings—from automotive markets to home heating and commercial building

efficiency—aren't taking advantage of these seemingly cost-effective investments. This has led researchers to ask: Why not?

In response to this question, policy analysts and academics have put forth a wide range of theories. Perhaps consumers undervalue efficiency because they are incapable of weeding through all of the information and long-term calculations required to make the rational choice. Or perhaps the transaction costs of opting for a series of residential system upgrades are simply too onerous for most homeowners. If the projected energy savings from efficiency investments are lower than expected, perhaps it's because consumers end up using more energy services (such

as increased demand for heating in the winter), eating into their savings—the well-known 'rebound effect.' Advocates of these and other explanations have, in turn, proposed policy mechanisms to address them and close the 'energy efficiency gap.'

But what if there is a different, more fundamental, and even simpler explanation? Nearly all proposed solutions for closing the energy efficiency gap have taken what the models project as efficiency gains for granted. To date, there have been very few efforts to analyze real-life performance of efficiency upgrades in order to ask a basic question: Are these investments performing as advertised?

1 International Energy Agency (IEA), "Energy Efficiency Indicators: Essentials for Policy Making," (2014)

2 IEA, "Energy Efficiency Market Report," (2014)

Research Design

In an effort to answer this question, Meredith Fowlie (UC-Berkeley), Michael Greenstone (UChicago), and Catherine Wolfram (UC-Berkeley), as part of The E2e Project, conducted the first large-scale evidence on returns to residential energy efficiency investments from a randomized controlled trial. The goal: to evaluate the validity of projected energy efficiency gains, as well as the various theories used to explain the energy efficiency gap.

The authors focused on the Federal Weatherization Assistance Program (WAP), the United States' largest residential energy efficiency program meant to reduce the energy burden of low-income Americans by installing energy efficiency upgrades in their homes. Since its inception in 1976, more than 7 million low-income households have received weatherization assistance through the program.

The authors conducted their analysis during the period following the enactment of the American Recovery and Reinvestment Act of 2009, which significantly increased WAP spending from roughly \$450 million in 2009 to nearly \$5 billion for the 2011-2012 program years. On average, households in the study received about \$5,000 worth of upgrades to their home designed to reduce their monthly electricity and heating bills. In addition to an energy audit, the most frequent measures included furnace replacement, attic and wall insulation, and weather stripping. These upgrades were made at no out-of-pocket cost to the participating households.

The analysis focused on a sample of more than 30,000 WAP-eligible households in the state of Michigan, which is one of the largest recipients of WAP funding nationally. One quarter of the randomly selected households (treatment group) were encouraged to apply for the program through almost 7,000 home

visits and more than 32,000 phone calls. Once households signaled interest, the staff scheduled 2,700 follow-up appointments to assist the households with the application materials. This included extensive paperwork documenting their eligibility (utility bills, earnings documentation, social security numbers and deeds to the home). The remaining households (control group) were able to apply for the program if they chose, but were not actively encouraged to apply, nor did they receive any assistance completing their application.

The research approach was designed to allow the authors to answer two critical questions with regard to energy efficiency: (1) How do energy efficiency investments perform in the real world compared to model predictions?; and (2) Do residential energy consumers change their behavior in response to energy efficiency improvements (i.e., is there a rebound effect)?

Findings

1. The energy efficiency measures undertaken by households in the study reduced household energy consumption by between 10 and 20 percent on average. These are economically significant savings. However, energy savings realized at the average participating household were less than half of the average savings predicted by engineering models. (Figure 1)

2. The costs of the energy efficiency investments were roughly double the benefits. Specifically, the average household received approximately \$5,000 of energy efficiency investments, but the estimated benefits of the investments were only about \$2,400.

3. There is no evidence of a significant rebound effect. Some speculate that energy efficiency investments don't deliver on their promised energy savings because households adjust their behaviors and consume more energy services than they had before the investments were made. This is known as the rebound effect. Through field surveys, the study found that indoor temperatures were not statistically different in weatherized and unweatherized households. (Figure 2)

Findings continued

4. Residential energy efficiency appears to be a poor investment on average. A common metric to judge the desirability of investments is the annual rate of return. For example, an investment that has an upfront cost of \$1,000 and returns \$100 in one year would have an annual rate of return of 10 percent. The engineering model projections of the annual rate of return to the energy efficiency investments conducted as part of this study are 11.8 percent. This would be a very attractive investment as it greatly exceeds historical returns on stocks (5.9 percent), corporate bonds (1.87 percent), and real estate (.85 percent).

However, this paper's results suggest that the returns to residential energy efficiency

investments fall well below these alternatives when judged from a homeowner's (-2.2 percent) or society's (-9.5 percent) perspective. (Figure 3)

5. The weatherization upgrades were found to be very expensive ways to cut carbon. While some may argue that broader societal benefits—in the form of reduced greenhouse gas emissions—justify the energy efficiency investments, the findings do not support this claim. The analysis of the cost per ton of CO₂ saved in the sample amounted to \$329 per ton, far more than the federal government's estimate for the social cost of carbon of \$38 per ton.

6. Increasing participation in energy efficiency programs is difficult. Using a firm with extensive experience in managing outreach campaigns, the research team conducted almost 7,000 home visits, more than 32,000 phone calls, and 2,700 follow-up appointments. Yet despite this aggressive outreach and personal assistance, only 6 percent of households in the treatment group participated in the program, compared to 1 percent in the control group. In total, it costs more than \$1,000 for each additional household encouraged to undertake these free energy efficiency investments, suggesting that significant hassles are preventing households from participating. (Figure 4)

Figure 1: Average Projected Household Energy Savings

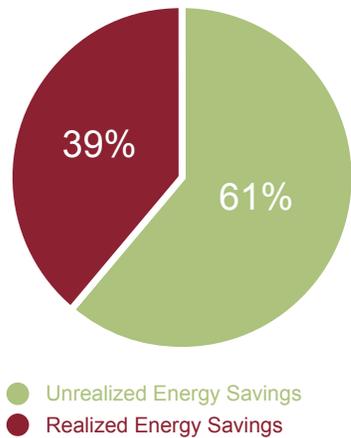


Figure 2: Average Indoor Temperature Across Weatherized Versus Unweatherized Households

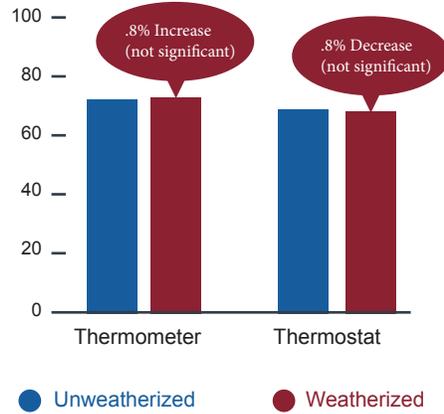


Figure 4: Success Rate Across Groups

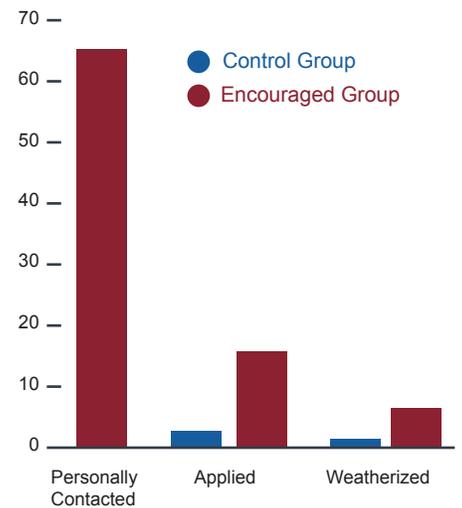
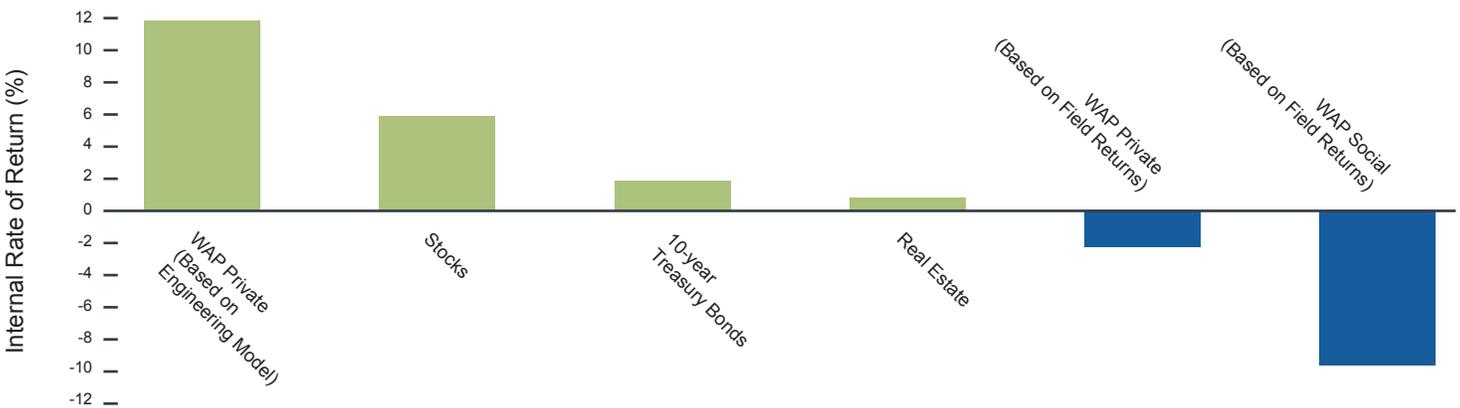


Figure 3: WAP Rates of Return Compared to Other Investments



Note and Sources:
 The WAP Projected Private bar reflects the private internal rate of return over 16 years using the projected energy savings from the National Energy Audit Tool (NEAT). The WAP Experimental Private bar reflects the internal rate of return over 16 years using experimental estimates of cost savings from Fowle, et. al (2015). The WAP Social bar adds the additional benefit of carbon emissions reductions to these estimates and removes the fixed distribution costs of electricity and natural gas utilities. Internal rates of return for investments other than WAP represent the compound annual growth rate from 1928-2014. Data for returns for Stocks, 10-year treasury bonds, and 3-month T bills come from the website of Aswath Damodaran, Professor of Finance at NYU. His calculations use historical data on the S & P 500, T-bill rates, and Treasury bond rates and dividends from the Federal Reserve Database in St. Louis (FRED). Data for housing returns comes from Robert Shiller, Professor of Economics at Yale University. Housing returns in the graph show the geometric mean of the percentage change of the Case-Shiller real home price index.

Policy Recommendations

In sum, this research finds that the efficiency measures studied are saving significantly less energy than expected and, therefore, that the return on investment is far lower than projected. It appears likely that the majority of the gap between modeled and observed efficiency can be attributed to a systematic overestimation of efficiency gains by the engineering models and audit tools. This finding should be validated in other settings, but it already has significant implications for policy, which has largely been based on the presumption that the models are accurate.

While this specific energy efficiency investment did not deliver all it promised, there are likely to be beneficial energy efficiency investments out there. However, as this analysis illustrates, potential energy efficiency investments need to be rigorously tested in real-world conditions over extended periods of time to ensure they are delivering as intended. Engineering models are needed to understand the full potential of new technologies under ideal usage, but they do not suffice in ensuring that these investments deliver the greatest bang for the buck. State-of-the-art field testing would not only allow for the development of more impactful energy efficiency investments, but would provide clear evidence of why these investments are economically and socially beneficial, ensuring the success of energy efficiency policies now and in the future.

The results of this analysis suggest that there is an opportunity for policymakers to 1) focus more heavily on other policies that reduce greenhouse gas emissions at a lower cost, 2) ensure that energy efficiency investments are delivering by dedicating resources to state-of-the-art evaluation techniques, and 3) require improvements in engineering models. These recommendations are further elaborated on below.

1. Rely on the most efficient approaches to reducing greenhouse gas emissions. There is a great need to address the urgent problem of climate change, while keeping the costs to a minimum. Many existing and planned policies, including residential energy efficiency policies, rely on projected energy savings to guide investment. This study finds that realized energy savings can fall far short of these projections. As policymakers design

their climate policies, there is an opportunity to choose market-based approaches, like cap-and-trade programs and carbon taxes, rather than policies that are justified by projected energy savings. These types of carbon pricing policies have proved to be efficient time and again.

2. Work to ensure energy efficiency investments deliver promised savings by relying on field studies that use state-of-the-art evaluation approaches. The Department of Energy and states already devote considerable resources to evaluation, measurement and verification of energy efficiency programs, but almost none of the resulting evidence is based on field studies that use state-of-the-art evaluation techniques, like randomized controlled trials. The Department of Energy and state Public Utility Commissions have an opportunity to improve energy efficiency policy by raising the bar on what qualifies as evidence. The creation of research teams that would be responsible for overseeing the design and implementation of evaluations and data collection efforts could facilitate this transition. A good parallel can be drawn to the World Bank's Development Impact Evaluation Initiative (DIME), created in 2005, that systematically evaluates its own projects. DIME started with 28 interventions. In 2011, it oversaw over 300.

3. Evaluate and work to improve the engineering models. This analysis documents a systematic overestimation of efficiency gains by the engineering models used to inform an important residential energy efficiency program. If the existing models continue to be used, there is a high risk that efficiency policy will continue to deliver poor results. It is critically important that the models be adjusted to match the field evidence so that they deliver the true impacts, not the potential ones.



The E2e Project unites top researchers in economics, engineering, and other fields to close the energy efficiency gap using transparent and state-of-the-art analytical techniques. E2e is a joint initiative of University of California – Berkeley, the Massachusetts Institute of Technology, and the University of Chicago: three recognized leaders in energy research.

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