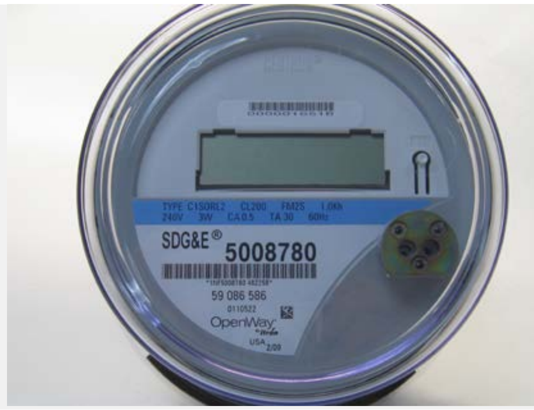
# A MICROECONOMIC FRAMEWORK FOR EVALUATING ENERGY EFFICIENCY REBOUND AND SOME IMPLICATIONS




## Capturing the effects resulting from an energy efficiency improvement

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## Context

**In policy discussions, the most cost-effective response to climate change is often said to be energy efficiency:** improving appliances to provide the same services using less energy, and thus causing fewer greenhouse gas emissions (GHGs). The impact of such policies on total energy use is controversial, however, because the improvement can lead to greater use of the appliance and increased spending on other goods that were previously not affordable, a phenomenon known as "**rebound.**"

Because rebound is seen as a rational response by consumers to a decrease in price and an increase in income, in standard economic analysis it is viewed as a positive consequence of the energy efficiency investment. Nonetheless, in measuring the energy savings from an efficiency upgrade, rebound is an offset to the direct measurement of energy saved from a more efficient appliance. When the goal is to reduce total energy consumption, rebound can be viewed as a negative consequence. **The extent of rebound is the subject of hot debate and has led to a wide variety of views on the role that energy efficiency can play in addressing climate change.**

**This study focuses on measuring the size of "rebound" and the net energy saved after an energy efficiency upgrade. This is not an analysis of the societal benefits of an energy efficiency upgrade, which is itself an important topic, but distinct from the quantity measurement issue.**

## Main Lessons

1. It is important to understand **how energy efficiency will change societies' consumption of energy**, which requires measuring the size of the rebound. If ignored, rebound leads to significant overstatement of energy savings.
2. **Dissecting the rebound into substitution and income effects** allows its precise estimation.
3. **Prices don't always reflect incremental costs, especially in electricity**. For energy efficiency rebound, this is important because it means that only some of the savings from reducing energy use creates new income, while the rest is a transfer of income from other consumers or companies.

## Original Citation

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## Understanding the Problem: a Basic Model

### Defining the problem and dissecting the different effects

**Suppose a consumer replaces her old air conditioner (AC) with a more efficient AC unit. What happens to her energy consumption after the new unit is installed?** The goal of this study is to describe the change in energy consumption after an energy efficiency upgrade, dissecting rebound into several different effects:

***Direct Energy Savings***: To begin with, we know that a more efficient AC uses less energy to provide the same level of cooling, hence it costs less to operate than the old unit. If the consumer operates the new AC in the same way that she operated the old one, she will save money.

***Income Effect:*** If these savings are greater than the cost of buying the new AC, they can create additional income for the consumer. Wealthier, she now needs to decide how to spend this additional income. She may crank up the AC or buy something else that also uses energy. The net impact on energy consumption from the income effect will be positive.

***Substitution Effect:*** Even if there is no additional income from the new AC, the price of an hour of cooling is now relatively lower than it was before. If she spends more on AC, then she will have to spend less on some other good. The net impact on energy usage depends on the relative energy intensity of what she no longer purchases relative to using more AC.

**The final effect on energy usage will be the sum of all these components:**

**Direct Energy Savings**

- Decrease in energy cost per unit of cooling
- ▼ **Saves money** while operating the AC for the same number of hours as before
- ▼ **Consumes less energy**

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**Income Effect**

- If savings are larger than the cost of the new AC: additional income (if savings smaller than cost of new AC, then negative income effect)
- ▼ Might purchase more cooling or might purchase something else that also uses energy
- ▼ **Consumes more energy**

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**Substitution Effect**

- The price of an hour of AC is now lower relative to everything else
- ▼ Uses more AC
- ▼ Uses less of something else
- ▼ **Might consume more energy** depending on the goods she substitutes away from

### History of energy efficiency Analyses: three major fields

**Engineering Literature**

- Focuses on measuring the direct energy savings resulting from a given investment.

**Magnitude of Rebound**

- Concerned with measuring the magnitude of rebound effects
- This study is intended to contribute to this strand.

**Societal Impacts**

- Estimates the societal impacts of the quantitative changes found in the other two lines of research.

## Some Considerations

### Prices don't always reflect incremental costs

**Economists often assume that prices reflect incremental cost, but that is not always the case**, especially in the areas of utility-delivered energy. **Utilities' retail electricity and natural gas prices are generally set well above incremental cost.** This is important because pricing above incremental cost means that only some of the savings from reducing energy use creates new income, while the rest is a transfer of income from the ratepayers (or shareholders) who must cover the utility's lost revenues due to the reduced energy consumption.

For example, suppose a customer pays $10 per MMBTU for natural gas, when the actual cost to provide it is $6. In this case, the customer investing in a more efficient furnace or other appliance that uses natural gas saves $10 by reducing gas use, but only $6 of it is net savings, or income creation, for the economy as a whole. The other $4 was going towards covering the utility's fixed costs or to utility profits. The energy efficiency investment means that either someone else must cover the $4 of fixed costs or that utility profits are lower by that amount. Either way, $4 of the income gain to the customer is offset by an equal income loss either to other ratepayers (who may have had to make up the lost revenue) or to shareholders. The $6 is expected to generate income-effect rebound, but the $4 income transfer is not.

### Tension: rebound and the EE Gap

The policy focus on energy efficiency is due to the **widespread view that there is an energy efficiency gap**, which is generally defined as neglected opportunities for individuals (or companies) to save money by improving energy efficiency. To the extent that agency or information barriers prevent these investments, it seems likely that they would also reduce or eliminate rebound. For example, if people fail to purchase LED lights because they are unaware of the impact of lighting costs on their electricity bill, then they are less likely to respond to lower incremental lighting costs by leaving the lights on more.

**Recognizing this issue points out a possible bias in forecasts of rebound. If consumers don't pay attention to their energy costs and, as a result fail to make cost-saving energy efficiency investments, then estimates of rebound may overstate the response of consumers and lead to over-estimates of rebound.**

### Technological Change

***Correlation is not causation…***

Energy efficiency improvements are also likely correlated with improvements in other attributes of a good. A technological change makes the good more attractive and increases its consumption. This also means that consumers will appear more responsive to energy prices than they actually are. For instance, as PCs have become more energy efficient, many other attributes have also changed so that demand for PCs has strongly increased. The vast majority of this has nothing to do with energy efficiency and should not be attributed to rebound.

***… And failed R&Ds should also be accounted for.***

Claims of large rebound effects often appeal to an idea that is true of innovation in general: specific breakthroughs can have enormous income effects, because the innovation has low cost of replication. This is true of successful R&D and does suggest that the income effect rebound may be significant. However, it does not recognize that some of the costly R&D that is done – including in EE - fails to discover improvements and ends up reducing income. The full effect of innovation must include both impacts. Still, the net effect seems likely to be strongly positive.

# ILLUSTRATIVE CALCULATIONS

## AUTO FUEL ECONOMY

Fuel economy is a central area of disagreement about rebound. For this calculation, **consider a new mid-sized sedan that is upgraded to meet fuel economy standards so that rather than getting 25 MPG, it gets 50 MPG. The upgrade isn't costless; assume it adds manufacturing costs of $3000 to the sedan.**

An illustrative, but realistic, calculation of rebound from doubling the fuel economy would be a direct reduction of 513 MMBTU in gasoline consumption, offset by a 56 MMBTU increase from the income-effect rebound and a 66 MMBTU increase from the substitution-effect for a net effect of a decrease of gasoline consumption by 391 MMBTU or 24%. Thus, doubling fuel efficiency has a direct energy savings effect of cutting fuel use by 50%, but nearly one-quarter of that will be offset by rebound, so the net decline in fuel use would be 38%.

**Doubling the fuel efficiency of a Ford Fusion**

| | MMBTU |
|---|---|
| Direct energy savings | - 513 |
| Income and substitution net rebound | +122 |
| **Net effect (reduction)** | **- 391** |

## LIGHTING

**Another interesting exercise is to compare the rebound for incandescent lighting with LED lights.**

**Savings from LEDs are substantial.** Results suggest that income-effect rebound is quite small in the case of lighting, around 6% for energy for both types of bulbs and 3%-4% for greenhouse gas emissions. **Substitution-effect rebound, however, is substantially larger and very sensitive to consumers' responsiveness to prices.**

Still, even in the case of a conservative scenario, where people strongly respond to the upgrade, the total rebound is about 43% for energy with an LED, and 30% for GHGs[1].

# FINAL THOUGHTS

This study presents a framework that is helpful in organizing the measurement of energy efficiency rebound from end-user efficiency upgrades. Dissecting rebound into **its** different components allows one to more directly map the impact of an energy efficiency upgrade to changes in energy usage and greenhouse gas emissions. The results of this approach applied to auto fuel economy and lighting suggest that rebound in these cases is a substantial factor which, if ignored, would lead to significant overstatement of energy savings. In these two cases, however, it also appears that "backfire" – rebound in excess of 100% of the direct energy savings – is unlikely.

While the research focuses entirely on quantification of rebound, it is important to remember the societal implications. When rebound does occur, it reflects the creation of economic value as consumers are able to re-optimize in response to a change in relative prices. In that normative sense, rebound should be celebrated, not bemoaned. Still, for policy purposes, it is important to understand how energy efficiency will change societies' consumption of energy, which requires quantification of rebound.

[1] These calculations do not include economy-wide rebound. For more details please refer to the original study.

## Related Reading


- ✓ KHAZZOUM, Daniel. 1980. "*Implications of Mandated Efficiency in Standards for Household Appliances,*" **Energy Journal**, 1(4), October, pp. 21-40.
- ✓ BINSWANGER, Mathias. 2001. "*Technological progress and sustainable development: what about the rebound effect?*" **Ecological Economics** 36, pp. 119132.
- ✓ BERKHOUT, Peter; Jos MUSKENS, and Jan VELTHUIJSEN. 2000. "*Defining the rebound effect,*" **Energy Policy**, 28, pp. 425-432.
- ✓ GILLINGHAM, Kenneth; Matthew KOTCHEN; David RAPSON, and Gernot WAGNER. 2013 "*The Rebound Effect is Overplayed,*" **Nature** 493, pp. 475-476.
- ✓ THOMAS, Brinda and Ines AZEVEDO. 2013. "*Estimating direct and indirect rebound effects for U.S. households with input-output analysis Part 1: Theoretical framework*" **Ecological Economics**.


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