Synapse
Energy Economics, Inc.

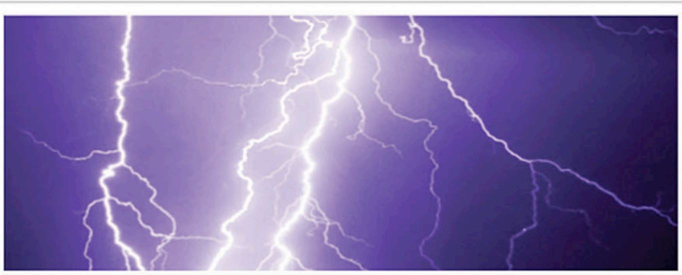
The Jevons Paradox and Energy Efficiency

A Brief Overview of Its Origins and Relevance to Utility Energy Efficiency Programs

February 2, 2011

AUTHORS

William Steinhurst, Vladlena Sabodash



22 Pearl Street
Cambridge, MA 02139

www.synapse-energy.com
617.661.3248

Table of Contents

1. Introduction to the Rebound Effect

During the last decades various energy efficiency policies have been implemented in order to reduce dependence on electric energy and conventional fossil fuels, reduce consumption of energy, and cut resulting environmental effects. However, improved energy efficiency allows a given quantity of energy services (heating, lighting, motor drive) to be obtained with a smaller cost for purchased energy than would otherwise be needed. As a consequence,

1. an energy customer may need to spend less to purchase the same amount of energy service and, so, may have more disposable income which may lead to demand for more goods and services, possibly including more of the same energy service that was made more efficient;
2. the unit cost of an energy service may be smaller because less purchased energy is needed to deliver the same amount of energy service which, in turn, may cause an increase in demand for that energy service; and
3. reduced demand for energy in the market as a whole may lead to a lower unit cost of energy (through either a lower clearing price in competitive markets or a lower marginal dispatch cost in price-regulated markets) which, in turn may lead to an offsetting increase in the demand for energy.

These three effects may be thought of as the income effect, the price effect and DRIPE effect (demand reduction induced price effect), respectively. Each is implied by classical microeconomics where demand is determined by the crossing of the relevant supply curve and demand curve. Another way to think about these effects is that they are all implicit in the usual econometric equations for demand as a function of price and income. Taken together, they are usually referred to as the rebound effect.[1]

Rebound from energy efficiency can also be classified into direct and indirect rebound. Direct rebound results from an increase in use of a device that becomes more efficient and is a combination of the price and income effects. An indirect rebound results from an increased consumption of other goods and services and increased energy use associated with production of those goods and services as consumer's disposable income increases.

In general, the rebound effect may affect net energy savings in three different ways:[2]

1. negative rebound, where actual energy savings are higher than expected due to changes in consumers' behavior towards more aggressive savings;
2. typical rebound, where actual energy savings are less than expected;
3. back-fire, where actual energy savings are negative (known as "Jevons paradox").

---

[1] During the 1980s, the first one or two of these effects were sometimes the subject of controversy in energy efficiency policy debates and were referred to, collectively, as either "snapback" or the "Khazoom effect," after Daniel Khazoom, the author of an influential paper on the subject. See Khazzoom (1987).
[2] Ehrhardt-Martinez and Laitner (2010)

The idea of the rebound effect was first stated in the 19th century by William Stanley Jevons in his book *The Coal Question*, where he concluded that "it is wholly a confusion of ideas to suppose that the economical use of fuel is equivalent to a diminishing consumption. The very contrary is the truth." In other words, Jevons and his advocates claim that energy efficiency induces more demand for energy, which makes benefits from energy efficiency policies and investment obsolete.[3]

2. Relevance to Current Energy Efficiency Programs

Applicability of Jevons paradox is limited today. Although the existence of the rebound effect is not denied, the size of it is trivial at the overall economy level, as shown in the literature analyzing the issue. This is the case because energy cost is only a small component in the overall costs of most processes and products. Overall energy spending accounts for only 6-8 percent of GDP in the U.S. For example, a household savings of $100 on energy bill through energy efficiency measures would increase the household's disposable income that can be spend on more goods and services, but only $6-8 would be spent on more energy and overall consumption of energy would be reduced by $92-94. The rebound effect is not large enough to offset total benefits from energy efficiency.[4]

Recent proponents of the Jevons paradox as an argument against the benefits of energy efficiency provide numerous examples of increased penetration of air conditioning, increased number and size of refrigerators and more miles driven observed over time as air conditioners, refrigerators and cars become more efficient. However, they don't take into account income growth that took place in parallel with that increase in efficiency. Penetration, size and utilization rates for these items of equipment increased as people had more money to spend and the devices became cheaper.[5] It is not disputed that demand for energy can grow due to price and income effects and those effects are included and modeled in reputable energy demand forecasts and assessments of energy efficiency policy.

Some recent studies have shown the non-trivial benefits from energy efficiency programs and the subtlety of rebound effects.

> a) Tsao, et al., (2010)[6] found significant potential for growth in consumption of energy as new technologies and more efficient appliances become available. This increased consumption of energy can potentially increase both human productivity and consumption of energy associated with this increased productivity. However, they also showed that, even if a large rebound occurs, there are still significant savings from energy efficiency measures when GDP growth is taken into account.

---

[3] Owen (2010).
[4] See Levi (2010) for more discussion and examples on rebound effect.
[5] Levi (2010).
[6] Tsao, et al., (2010).

b) A 2011 ACEEE report showed that energy efficiency policies will increase energy savings, lower energy prices and increase household income after accounting for rebound effects.[7] In the scenario analyzed in that study, reduced energy expenses and increased income did stimulate consumption of more goods and services that will take back 25% of the saved energy, but that 75% of the energy efficiency gains still went into an overall reduction in energy consumption. The study also suggested that growing income and declining energy expenses are the drivers of growth in saturation for many energy intensive appliances, while improved energy efficiency contributes only marginally to growing usage. Increased use of some of these appliances may slow down soon or even stop as markets approach saturation for these devices, reducing potential for further rebound. Overall, energy efficiency moderated growth in energy use, which has resulted in energy in the U.S. growing slower than GDP since 1973.

c) A 2010 summary of meta-studies on rebound effects of energy efficiency showed the value of the direct rebound effect is significantly lower than total savings from energy efficiency.[8] Table 1 shows selected results. Even if the rebound effect is large, energy efficiency contributes to increased activity, comfort, lower energy costs, and overall improvement in welfare.

Table 1. Empirical Evidence of the Rebound Effect in the United States

Sector	End Use	Size of Rebound Effect
Residential	Space Heating	10-30%
Residential	Space Cooling	0-50%
Residential	Water Heating	<10-40%
Residential	Lighting	5-12%
Residential	Appliances	0%
Residential	Automobiles	10-30%
Business	Lighting	0-2%
Business	Process Uses	0-20%

Source: Greening, Greene and Difiglio (2000) and IEA (1998) as presented in Ehrhardt-Martinez and Laitner (2010)

7 Nadel (2011).
8 Ehrhardt-Martinez and Laitner (2010).

d) According to one response to a recent *New Yorker* article on rebound (Goldstein, 2010, responding to Owen, 2010), U.S. demand for refrigeration has been growing at a rate that would have resulted in electricity demand of about 175GW today. Instead, refrigerator energy use today is less than 15GW as a result of all the energy efficiency policies adopted. That extra 160GW of capacity would have required 400 large coal plants that we do not need today.

If Jevons argument were valid today, the economy would not be able to cut its overall energy use through reliance on energy efficiency. To refute this proposition, Goldstein provided showed that California, which implemented a wide range of reforms to encourage energy efficiency and promote renewable energy in the state, has seen projected savings from electric energy efficiency of 15% overall, as shown in Figure 1. Compared to the rest of the country, California reduced its per capita energy usage by 40%, as shown in Figure 2.

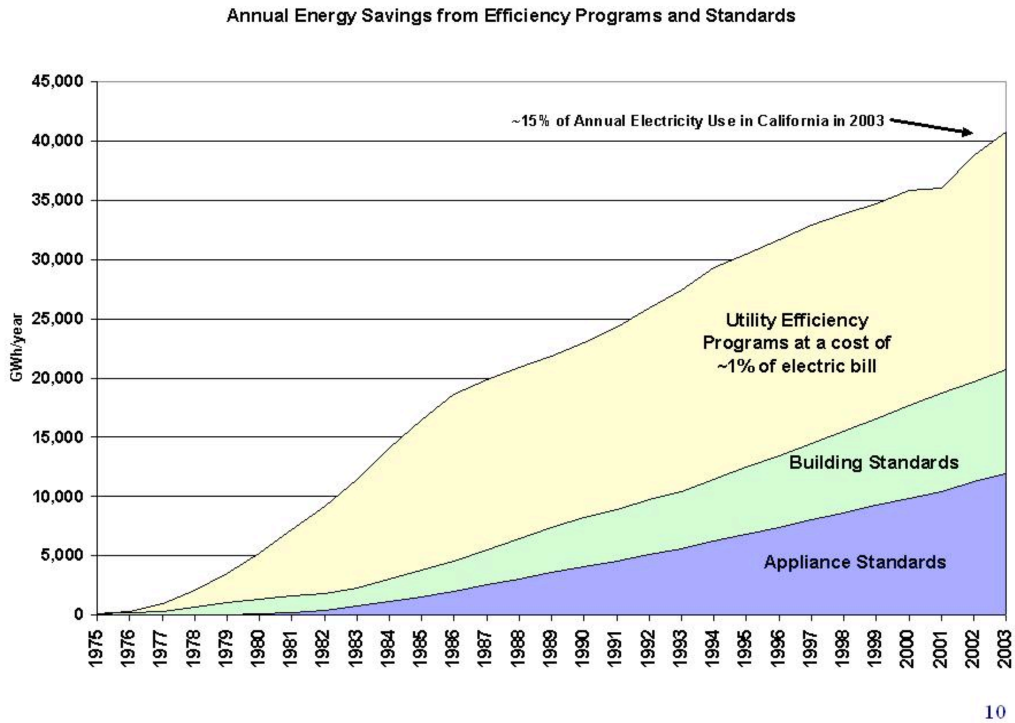
In summary, the relevant research shows that benefits from energy efficiency policies and programs significantly outweigh any increased energy consumption from rebound effects. Energy efficiency rebound effects have contributed only marginally to energy consumption, while the primary drivers of increased saturation or utilization of energy consuming appliances are growth in income and reduced prices, especially for the energy consuming equipment, itself. Even in the presence of the rebound effect, energy efficiency policies remain strikingly successful in moderating growth in energy use, increasing productivity, providing more comfort, lowering energy costs, and improving overall social welfare.

Three Types of Rebound Effects

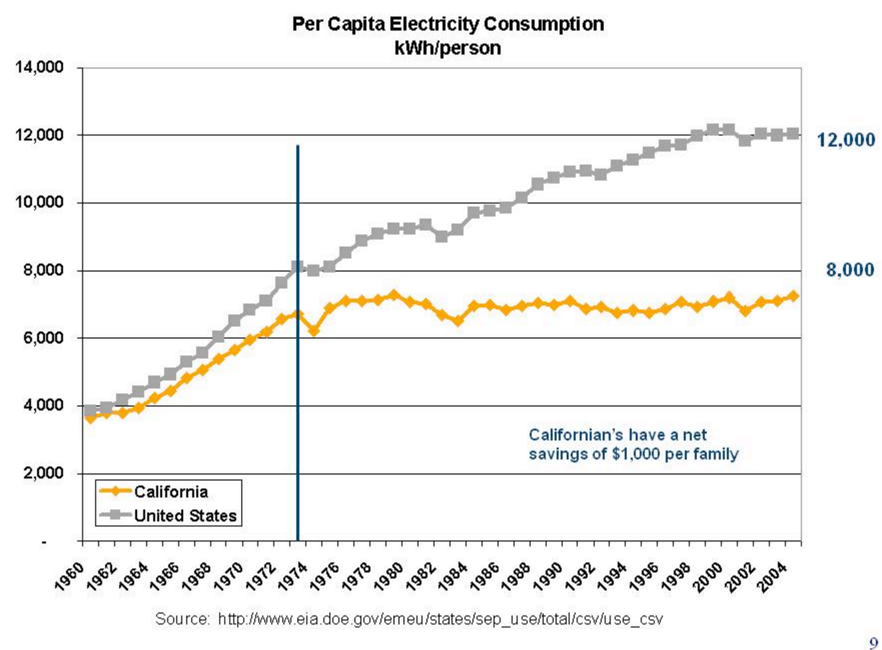
Price Effect Example: Suppose a residential customer requires 10 Btu per day to heat water for domestic consumption and that the cost of the energy to do so is $1 per Btu. The customer's bill for energy to produce hot water is then $10 per day. Now, suppose the water heater is replaced with a more efficient model that only requires 5 Btu per day to produce the same amount of hot water at the same temperature. The customer's energy bill for hot water is now $5 per day (assuming that the unit price has not changed). However, the customer may now consume an additional Btu's worth of hot water for an additional $0.50 instead of an additional $1. For most goods and services, a certain percentage decrease in unit cost leads, on average, to a certain percentage increase is demand for that good or service; the ratio of those percentages is that product's own-price elasticity. If the own-price elasticity for hot water is -0.20, then microeconomics suggests the customer would choose to consume (-50% price change) x (-20% price elasticity) or an additional 1 Btu per day worth of hot water.

Income Effect Example: Continuing with the above example, the customer still has a savings of $4 on her energy bill. The customer will typically save some percentage of this disposable income or use it to pay down debt. The balance may be spent on purchase of some additional goods or services, which will have some quantity of energy consumed during their production. Depending on the savings rate and what additional goods or services are demanded, some additional amount of energy may be consumed. In particular, for some but not all goods and services, a certain percentage increase in disposable income leads, on average, to a certain percentage increase is demand for that good or service; the ratio of those percentages is that product's income elasticity. If hot water had a positive income elasticity, reducing the amount of energy purchased to produce a Btu of hot water would lead to a certain percentage increase in its use.

DRIPE Effect Example: If the energy source for heating the customer's water is electricity, and if the electricity is ultimately purchased from a wholesale clearing market, there may be a DRIPE effect. Suppose enough customers implement the above energy efficiency measure so that the aggregate demand for electricity in the wholesale market falls by 1%. In that case, the most expensive 1% of bids that would have cleared in that market will be rejected instead, dropping the clearing price. In some markets this has been seen to result in roughly a 1% drop in the market clearing price. To the extent that retail customers realize that drop as a savings in their retail price (typically about one-half of retail electric prices are for purchased power and not all customers would see any price reduction due to their rate designs), there would be some savings to *all* retail customers, not just those who implemented the energy efficiency measures. This savings could lead to some additional price and income rebound.



Source: Goldstein (2010).



Source: Goldstein (2010).

3. References:

Ehrhardt-Martinez, K., and J. Laitner, "Rebound, Technology and People: Mitigating the Rebound Effect with Energy-Resource Management and People-Centered Initiatives," *ACEEE Summer Study on Energy Efficiency in Buildings*, 2010.

Holladay, M., "Musings of an Energy Nerd: The Jevons Paradox: How Efficiency Improvements May be Undermining Sustainability." Available at: http://www.greenbuildingadvisor.com/blogs/dept/musings/jevons-paradox

Goldstein, D., "Some Dilemma: Efficient Appliances Use Less Energy, Produce the Same Level of Service with Less Pollution and Provide Consumers with Greater Savings. What's Not to Like?" blog posting, December 2010. Available at: http://switchboard.nrdc.org/blogs/dgoldstein/some_dilemma_efficient_applian_1.html

Greening, L., D. Green, and C. Difiglio, 2000. "Energy efficiency and Consumption – the Rebound Effect – a Survey," *Energy Policy* 28 (6-7): 389-401.

[IEA] International Energy Agency, 2010. "Energy service Demands and Low-Carbon Technologies: Understanding the Human Dimensions," in *Energy Technology Perspectives*. Paris, France: IEA. (forthcoming)

Khazzoom, D., 1987. "Energy Saving Resulting from the Adoption of More Efficient Appliances." *The Energy Journal* 8(4): 85-89.

Levi, M., "Mangling Energy Efficiency Economics," Council on Foreign Relations, December 2010. Available at: http://blogs.cfr.org/levi/2010/12/14/mangling-energy-efficiency-economics/

Madlener, R., and B. Alcott, "Energy Rebound and Economic Growth: a Review of the Main Issues and Research Needs," *Proceedings of the 5th International Biennial Workshop Advances in Energy Studies—Perspectives into Energy Future,*" September 2006, Porto Venere, Italy.

Nadel, S., *Our Perspective on the "Rebound Effect"—Is It True That the More Efficient a Product Becomes, the More Its Owner Will Use It?*", ACEEE, January 2011. Available at: http://www.aceee.org/node/7121

Owen, D., "The Efficiency Dilemma," *The New Yorker*, December 2010.

Troast, P., "The Jevons Paradox: Time to Send It the Way of the Dodo?" Available at: http://www.energycircle.com/blog/2010/06/21/jevons-paradox-time-send-it-way-of-dodo

Tsao, J., H. Saunders, J. Creighton, M. Coltrin and L. Simmons, "Solid-State Lighting: an Energy-Economics Perspective," *Journal of Physics D: Applied Physics*, 43 (2010).