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Energy Efficiency and the Rebound Effect

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Updated November 19, 2001

Abstract. Several measures in the 107th Congress seek to increase energy efficiency as a means to decrease dependence on foreign oil, cut electricity demand and to curb both air pollution and greenhouse gas emissions. However some claim that these measures may not be as effective as projected because of the rebound effect. The rebound effect is defined as the difference between the projected and the actual savings due to increased efficiency.

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Summary

Several measures in the 107th Congress seek to increase energy efficiency as a means to decrease dependance on foreign oil, cut electricity demand and to curb both air pollution and greenhouse gas emissions. However some claim that these measures may not be as effective as projected because of the rebound effect.

By definition, increasing a device's energy efficiency decreases its consumption of energy. However, a simple projection may overestimate the energy savings unless it accounts for the consumer's response to lower costs. For example, a company that doubles the efficiency of an electric home heating system projects that the cost of operating this device should be cut in half. But now that it is cheaper to heat his house, the consumer may choose to increase the setting on his thermostat. Instead of saving the money and reducing the demand for electricity which the increased efficiency would allow, the consumer may choose to spend some of the money saved to live at a more comfortable temperature. This is an example of the rebound effect.

The rebound effect is defined as the difference between the projected and the actual savings due to increased efficiency. It is a combination of three components: direct effects, indirect effects, and market or dynamic effects. The home heating example cited above is an example of the direct effect. An example of the indirect effect is the consumer choosing to spend the savings from a more efficient home heater to purchase another electric device such as a new hair dryer. The market or dynamic effect occurs when a decrease in aggregate demand causes the energy price to fall. This, in turn, makes new uses economically viable or increases the market penetration of existing devices, driving up demand. An example of this is the introduction of a more efficient coal burning engine used in the extraction of coal in the mid-1880s. The new engine was predicted to reduce overall consumption; however, its use greatly lowered the price of coal. Thus more people could afford to use coal heat in their homes, which greatly increased demand.

The size of a rebound depends on many factors, including the type of device being improved, energy prices, consumer income, and the overall state of the economy. For typical consumer end-uses, the rebound usually ranges between 0% and 40%. That is, the actual energy savings ranges from 60% to 100% of the projected amount.

Policymakers may be able to more accurately gauge the realistic benefits of proposed efficiency programs by accounting for the rebound effect. For instance, some may consider it desirable compensate for the rebound effect by increasing appliance efficiency or fuel economy standards even further than previously suggested. Alternately, others may feel that a lower energy savings estimate means reduced program cost effectiveness. A third choice would be to slightly lower expectations of the proposed program.

How the rebound effect changes projected reductions in greenhouse gas emissions is controversial, although it is generally agreed that increases in efficiency will reduce emissions per unit of Gross Domestic Product.

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Introduction

Interest and Role of Congress

Increasing efficiency offers the benefits of decreasing energy consumption, reducing greenhouse gas emissions, and preserving the limited resources used for producing energy while lowering energy bills for the consumer. Because of this observation, some have suggested that increasing energy efficiency could reduce the need for increased domestic production while lowering dependence on foreign oil.[1] Several bills under consideration in the 107th Congress focus on increasing energy efficiency as part of a comprehensive national energy policy, including H.R. 4, the Securing America's Future Energy Act; S. 389, the National Energy Security Act of 2001; S. 596, the Energy Security and Tax Incentive Policy Act of 2001; and S. 597, the Comprehensive and Balanced Energy Policy Act of 2001. Parts of these bills encourage greater energy efficiency through a variety of means, including tax incentives, grants, efficiency standard mandates, and increased money for energy efficiency research.

Some articles in the popular press have suggested, however, that efforts to conserve energy by increasing efficiency will produce less than the expected results because of the rebound effect.[2] This effect (also referred to as the "take-back" or "snap-back") was first described in 1865 when Stanley Jevons observed that the introduction of the new efficient steam engine initially decreased coal consumption which led to a drop in the price of coal. This meant not only that more people could afford to heat their homes with coal, but also that coal was now economically viable for new uses, which ultimately greatly increased coal consumption.[3] More recently, analysts have focused on the rebound effect in the electricity and gasoline markets. Analysts disagree on the presence and magnitude of this phenomenon and ongoing

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[1] For a thorough discussion of these topics, see CRS Reports RL30414, *Global Climate Change: The Role for Energy Efficiency*, RS31033, *Energy Efficiency and Renewable Energy Fuel Equivalents to Potential Oil Production from the Arctic National Wildlife Refuge (ANWR)* and CRS Issue Brief IB10020 *Energy Efficiency: Budget, Climate Change, and Electricity Conservation Issues* by Fred Sissine.

[2] See K. Strassel. *Conservation wastes money*. Wall Street Journal. May 17, 2001. Eastern Edition. p. A26; F. Pearce. *Consuming myth*. New Scientist. September 5, 1998. p. 18-19; and J. Glassman, *The conservation myth as the latest (sub)urban legend*, [http://www.TechCentralStation.com/NewsDesk.asp?FormMode=MainTerminalArticles&ID=68]

[3] W.S. Jevons. *The coal question: can Britain survive?* First published 1865, Republished Macmillan, London 1906.

research continues to shape this debate. If a large rebound effect exists in these markets, it might weaken arguments for increased efficiency requirements and strengthen arguments to scale back government-supported efforts. This paper describes the rebound effect, outlines the current thinking of experts in this field, and discusses the possible energy policy ramifications of this effect.

What is Energy Efficiency?

Energy efficiency is the property of a device which describes how much energy it requires to produce its product. For example, a typical incandescent lightbulb may require 1 kilowatt-hour of electricity to stay lit for 10 hours. If a technological change allows a new lightbulb to produce the same level of light for the same length of time using only one-half kilowatt-hour, the new device is said to be twice as energy efficient as the original device. The user of the new lightbulb would be expected to use half the amount of electricity and to pay half the amount to operate the bulb compared to the less efficient bulb. Although it is still using energy, because the new bulb uses less, it is said to conserve energy. The consumer could also achieve the same savings by leaving the less efficient bulb on for half as long. The reduction of output to realize savings, as in this case, is an example of curtailment.[4]

Overall energy use in the United States, driven by economic and population growth, has generally steadily increased throughout the nation's history. However, at least over the last several decades, total energy use has not risen as much as might have been projected by the growth in Gross Domestic Product (GDP, see "projected" in **Figure 1**). If energy had continued to be consumed at the same rate per dollar of GDP as in 1949, the energy demand in 1999 would have been approximately 183 quadrillion British Thermal Units (Quad BTU) as opposed to the actual use of approximately 97 Quad BTU. The amount of energy required to produce a dollar of GDP has steadily decreased over this period (**Figure 2**). In 1949, the production of the equivalent of a single 1996 dollar required nearly 21,000 BTU. By 1999, this number had dropped to about 11,000 BTU. This is due to both structural changes in the U.S. economy and great improvements in technology including energy efficiency.[5] In spite of these changes, overall energy use has increased due to both increases in population and energy use per person.[6]

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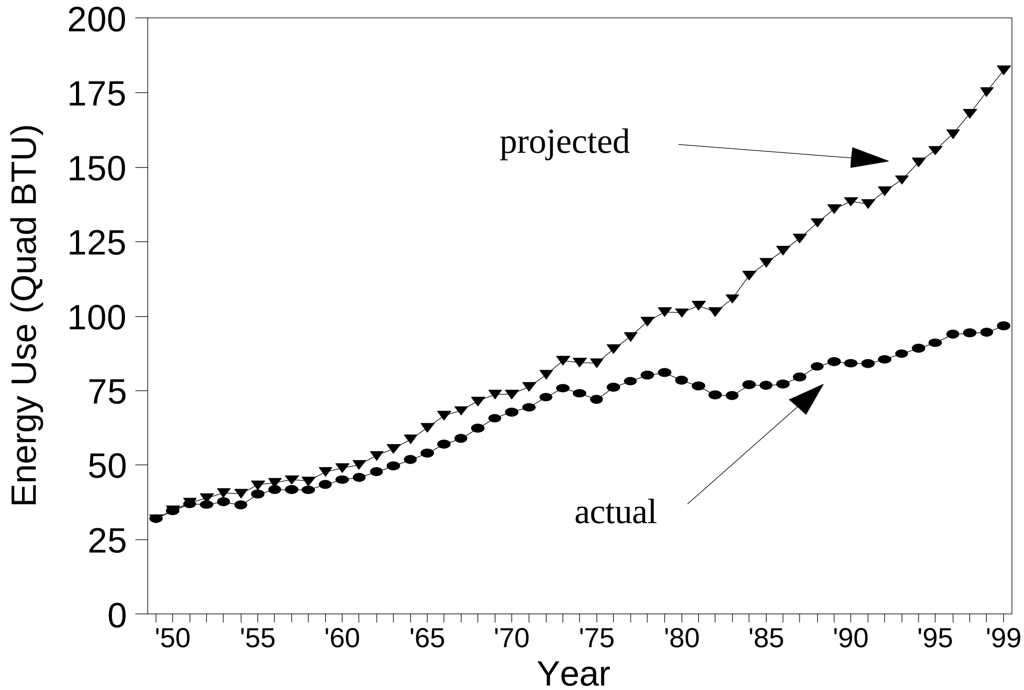
[4] For a more detailed discussion of energy efficiency, conservation and curtailment see CRS Issue Brief IB10020, *Energy Efficiency: Budget, Climate Change, and Electricity Conservation Issues* by Fred Sissine.

[5] U.S. Dept. of Energy. *Energy Efficiency in the U.S. Economy Energy Conservation Trends Understanding the Factors Affecting Energy Conservation Gains and Their Implications for Policy Development*. DOE/PO-0034. Washington D.C., April 1995.

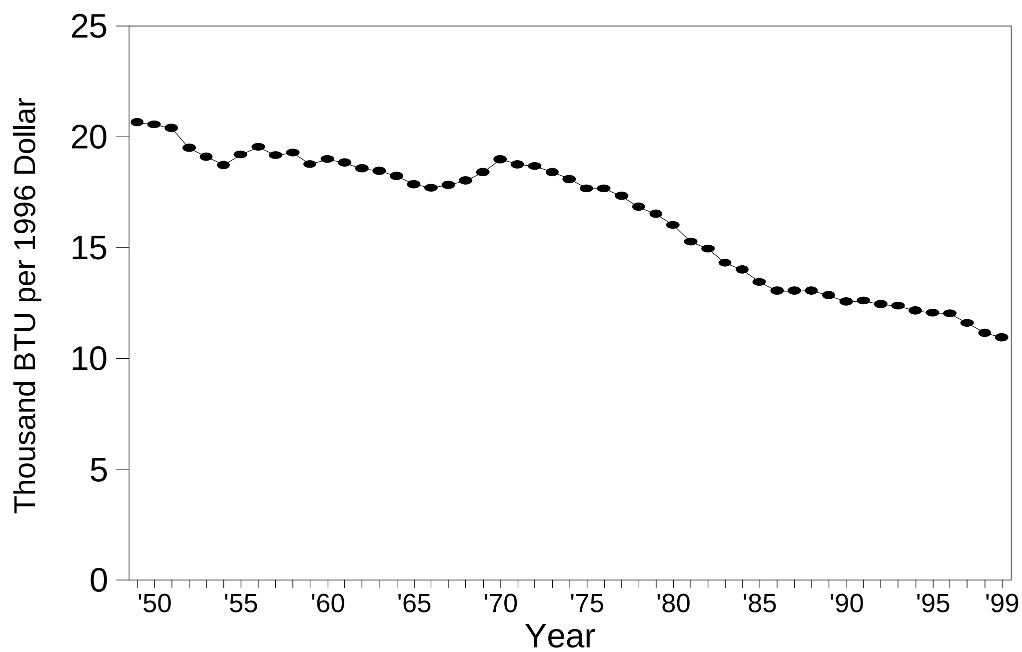
[6] U.S. Dept. of Energy. *Annual Energy Review 2000*. DOE/EIA-0384.Washington D.C., 2000. p. 38.

Figure 1. Domestic Energy Use 1949-1999 and Projected Use at 1949 Use Rates



Source: Adapted from *Annual Energy Review 2000*, DOE/EIA-0384(2000) p. 38

Figure 2. Energy Use per Dollar Gross Domestic Product



Source: Adapted from *Annual Energy Review 2000*, DOE/EIA-0384 p. 38

Definition of the Rebound Effect

The rebound effect is most simply defined as the difference between the projected and the actual energy consumption following an increase in energy efficiency. The projections can be made by simply calculating the difference in energy required by the new device and the less efficient one to meet a fixed level of service (e.g. amount of heat supplied). However, the actual amount of energy used also depends on possible consumer or market responses to the lower costs. To account for these changes, analysts use empirical studies and complex economic models. The rebound effect consists of direct, indirect, and market or dynamic components that can happen following the installation of more energy efficient equipment.

Direct Effects

Following the installation of a more energy efficient device, a consumer might choose to use more of the service instead of realizing all of the potential cost savings. In the previously introduced lightbulb example, the owner of a more efficient bulb might choose to leave the light on longer if that adds to his utility since it is cheaper to operate than the old one.

A more commonly cited hypothetical example of the direct rebound effect is that of a person living in a cool climate who takes advantage of a tax incentive to purchase a more efficient home heating system. Since the new system costs less to operate, the user might choose to keep his energy bill constant but live in a warmer house by setting the thermostat higher. In this case, the rebound effect completely erases the energy savings expected from the increase in efficiency. The savings were converted into an increase in comfort rather than a decrease in energy consumption.

Another oft-cited hypothetical example is that the owner of a highly fuel efficient car may be more likely to drive further than owners of less efficient vehicles. Instead of realizing the cost savings at the gasoline pump, the owner may realize the savings as increased pleasure driving or by choosing to live in a community that requires a longer commute. In this case, the direct rebound effect is unlikely to completely erase the energy savings, since driving consumes time as well as fuel. For example, consider a person who trades-in a sports utility vehicle for a hybrid gasoline-electric car. This person is unlikely to choose to live four or five times further away from work because of time constraints. A similar argument can be made for the consumer's pleasure driving.

In general, direct rebound effects are limited since a person will only leave a light on for so long, increase the thermostat setting so high, or drive so far. Factors other than cost often dictate energy use by individuals.

Indirect Effects

A consumer who saved money as a result of increased energy efficiency of one device may choose to buy other consumer goods which use the same energy resource. For example, a person with a more efficient air conditioner could spend the money saved on a hair dryer or some electronic equipment.

As is the case with direct effects, indirect effects could theoretically erase all the projected energy savings but are unlikely to cause an overshoot; i.e. an increase in efficiency is unlikely to cause an increase in energy demand through direct or indirect rebounds. For example, a person who was sufficiently constrained by his energy budget to limit the use of the less efficient device is likely to use the new devices only up to the same budget constraints.

Market or Dynamic Effects

Direct and indirect effects result from a change in behavior of the consumer. In contrast, market or dynamic effects arise from a change in the behavior of the market. For example, an improvement in the energy efficiency of a device could be large enough to significantly decrease the demand for a resource, leading to a lower market price, making new uses for that resource economically viable.

An example of this type of effect was the first example of rebound observed by Jevons in the British coal trade 1800s.[7] The introduction of a more efficient coal-fired water pumping engine made coal mining much more productive. Coal mines were now burning much less coal themselves to produce coal. This greatly decreased the price of coal, which allowed more people to use coal to heat their homes, which in turn greatly increased the demand for coal. In many ways this may be parallel to the recent large increase in the efficiency of combustion turbines that some believe has been a principal reason for the growth in demand for natural gas for electricity generation.

Theory Versus Practice

Under certain circumstances, the rebound effect could actually turn an increase in efficiency into an increase in consumption. However, this has only happened in very special cases such as in some developing countries or in new markets such as the coal market of the mid-1800s. In mature markets, it is generally accepted that although real, the rebound effect is limited.[8] One recent survey of seventy-five empirical studies found the size of the rebound effect for typical electric end-use equipment to be between 0% and 40%.[9] That is, the actual decrease in energy use can range from 60% to 100% of the projected amount (see **Table 1**).

Most studies generally are not designed to include the market or dynamic effects because they are very difficult to measure. There have been few attempts to measure these market effects, leaving their magnitude open for debate among analysts. For example, Leonard Brookes argues that this type of rebound is very large and has

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[7] See Jevons, 1905 or for a summary using modern economic language see L. Brookes *Energy efficiency fallacies revisited.* Energy Policy. June 2000. Vol 28. No. 6-7. p. 359.

[8] L. Schipper. *On the rebound: the interaction of energy efficiency, energy use and economic activity. An introduction.* Energy Policy. June 2000. Vol 28. No. 6-7. pp. 351-353.

[9] Ibid. p. 353 and L. Greening D. Greene and C. Difiglio, *Energy efficiency and consumption – the rebound effect – a survey*. Energy Policy. June 2000. Vol 28. No. 6-7. p. 398.

permitted the population growth and ever-increasing energy demands that have occurred since the early 19th century.[10] Others strongly disagree, suggesting exactly the opposite, that the increasing population and higher living standards drive the increase in energy demand. Furthermore, they argue, without the past efficiency improvements, demand would much greater (see "projected" in **Figure 1**).[11]

Table 1. Measured Rebound Effects of Various Devices

End-Use Device Category	Size of Rebound [a]
Space Heating	10 - 30%
Space Cooling	0 - 50%
Water Heating	10 - 40%
Residential Lighting	5 - 12%
Home Appliances	0%
Automobiles	10 - 30%

Source: Adapted from L. Greening et al., *Energy efficiency and consumption – the rebound effect – a survey*. Energy Policy. June 2000. Vol 28. No. 6-7. p. 398.

[a] These studies generally excluded market rebound effects.

The few attempts to project market effects suggest that in the domestic marketplace even large increases in the efficiency of the entire economy would produce only a small to moderate rebound.[12] For example, one of the higher estimates was found by the U. S. Department of Energy (DOE). The DOE model predicted that a 6.7% increase in the overall energy efficiency of the U.S. domestic economy between 1995 and 2015 would produce a 5.5% decrease in demand; i.e. a market rebound about 18%.[13] It is interesting to note that in this model, the increase in efficiency would also produce an increase in GDP of about one-half percent by 2015.

Factors Affecting Amount of Rebound

[10] L. Brookes, p. 359

[11] L. Schipper and M. Grubb, *On the rebound? Feedback between energy intensities and energy uses in IEA countries.* Energy Policy. June 2000. Vol 28. No. 6-7. pp. 367-399.

[12] L. Greening et al., p. 398.

[13] A. Kydes, *Sensitivity of energy intensity in U.S. energy markets to technological change and adoption.* Issues in Midterm Analysis and Forecasting. DOE/EIA 060797. U.S. Dept of Energy, Washington DC. pp. 1-42.

As evident from **Table 1**, not only does the size or presence of a rebound depend on the broad end-use category but there can be a large variation within categories as well. This reflects the large number of factors that can contribute to the presence and size of a rebound.[14]

The principal factor in determining the presence and size of a direct rebound is the existence of unmet demand. The larger the degree of unmet demand, the more likely there is to be direct rebound effect. For example, there is more likely to be a rebound effect when increasing furnace efficiency in poorly insulated homes in cold climates than in well insulated homes in mild climates.[15] In the absence of unmet demand, the direct rebound effect may be zero, although indirect and dynamic rebounds may exist.

Cost of operation of the device may play an important role in determining if there is unmet demand. If the energy cost of operating a particular device plays a negligible role in determining the consumer's utility bill, there may be little or no rebound effect. For example, if a new toaster uses half the energy of the old one, the consumer might be unlikely to make more toast than previously, since it is unlikely that the cost of operating the toaster was restraining its use. In contrast, in climates in which the heating bill contributes a large portion of a consumer's energy budget, cost may be restricting use. In this case, a large increase in efficiency may result in the consumer using some of the savings to increase comfort.

A related factor is the contribution of energy costs to the total cost of operation of the device. For example, the cost of operating a furnace is largely determined by the cost of energy, whereas, in the toaster example, the cost of operation also relies to a large degree on the cost of bread. Therefore, even if there was an unmet demand for toast, the rebound may be smaller for a more efficient toaster than for a similarly improved furnace.

In a slightly different manner than with direct rebounds, unmet demand also plays a role in determining the presence and size of indirect and market rebounds. For example, a consumer may not have any unmet demand for furnace use, but the reduction of the consumer's energy budget allows the use of other energy-using devices to meet an unmet demand elsewhere in their energy budget. This would produce an indirect rebound effect. A market effect could be produced if the consumer used the savings to purchase other devices to satisfy previously unrecognized demands. For example, the savings on energy may allow a family to purchase a VCR or computer which had not been considered under their previous budget constraints. On the other hand, it may allow a family to replace another old energy consuming product with a more efficient one.

Because of the importance of unmet demand in determining the presence and size of a rebound, large rebounds are more likely to occur under conditions where

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[14] L. Greening et al., pp. 389-401.

[15] G. Milne and B. Boardman, *Making cold homes warmer: the effect of energy efficiency improvements in low-income homes*. Energy Policy. June 2000. Vol 28. No. 6-7. pp.411-424.

large degrees of unmet demand exists, such as in low-income countries and among low-income consumers in wealthy countries.[16] To use the example of home heating in a cold climate, energy costs are more likely to restrain heater use by low-income families than by more wealthy families. This would likely lead to a larger rebound in the low-income family since they have a larger unmet demand than the wealthy family.

Other factors that can play a role in the presence or size of a rebound include the state of the economy and state of the energy market. Market or dynamic effects are more likely to occur in developing economies since they will tend to have high levels of unmet demand. As seen in the coal market in the 1800s, in emerging energy markets, small efficiency increases in either production or distribution can lead to decreases in price that may lead to large increases in market penetration and demand.

Examples of Rebound

Space heating. Because the majority of residential energy used is for space heating (51% in the U.S. in 1997)[17], many studies have looked for the rebound effect in this sector. These studies vary in which device was examined (e.g. better insulation or more efficient heaters) as well as geographic location. The studies generally found that the amount of the rebound effect depended on the unmet demand for heating before the improvements were made. This section describes the findings of two representative peer-reviewed studies that found evidence of a rebound.

In Great Britain, a study examining the results of sixteen energy conservation programs between 1971 and 1992 found that the amount of the rebound was directly related to the average temperature inside the home before the improvements.[18] These improvements typically doubled the heating efficiency of the house through various means such as draft proofing and adding attic or wall insulation. The authors found that in homes with an initial average temperature of 57º F, not uncommon in low-income families, there was a rebound effect as high as 50%. On the other hand in higher income homes with initial temperature of 68º F there was no rebound effect. They found that although some low-income consumers increased the setting on the thermostat, many did not change the thermostat but chose to heat additional rooms of their houses.

In a much broader analysis of the space heating sectors in many different countries, another study showed that although home heating efficiency greatly improved between the early 1970s and the mid 1990s, energy demand for home

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[16] L. Schipper, *On the rebound: the interaction of energy efficiency, energy use and economic activity. An introduction.* Energy Policy. June 2000. Vol 28. No. 6-7. p. 353.

[17] Energy Information Administration, *A look at residential energy consumption in 1997*. DOE/EIA-0632. U.S. Dept. of Energy, Washington DC, p. 9.

[18] G. Milne and B. Boardman, *Making cold homes warmer: the effect of energy efficiency improvements in low-income homes.* Energy Policy. June 2000. Vol 28. No. 6-7. pp. 411-424.

heating outpaced GDP growth in Great Britain and Japan.[19] In contrast, in most other countries examined, including the United States, the demand for home heating energy decreased in relation to GDP growth, suggesting little or no sector-wide rebound. The authors attribute the differences to the very high degree of unmet heating demand in both Great Britain and Japan in the early 1970s.

Many other studies find similar results, with some noting other factors in the presence and size of rebound including household income, geographic location, type of improvement (e.g. better insulation or better heaters), and the presence of elderly or children in the home.

Automobile fuel efficiency. In recent years there has been much debate concerning calls to increase the Corporate Average Fuel Economy (CAFE) standards for motor vehicles.[20] Most of the economic studies have found that a 10% to 30% rebound followed a 10% increase in fuel efficiency.[21] In other words, instead of fuel consumption dropping 10% following a 10% improvement in fuel efficiency, consumption only dropped by 7% to 9% because of the rebound effect. One of the most thorough studies recently made use of the massive amount of information on domestic car use compiled by the U.S. Department of Energy and the U.S. Energy Information Administration.[22] The study found that the long-term direct rebound associated with increasing domestic fuel efficiency is likely 20%. This figure, based on the assumption that the improvements came at a cost to the consumer, could rise to 30% if there was no added cost.

Lighting in rural India – an example of overshoot. As discussed above, in theory it is possible for an increase in efficiency to produce an increase in the demand for an energy resource. However, in practice this has been very rare.

One example is found in a recent examination of a pilot program in non-electrified rural Indian villages that provided solar powered lanterns to homes to use instead of their kerosene lamps.[23] One of the main aims of the program was to reduce the use of kerosene to near zero except during the seasons when there was insufficient sunshine to charge the solar lanterns.

The researchers found that because of the much brighter light generated by the new lamps, the families increased the number of hours lighting was used by two to

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[19] L. Schipper and M. Grubb, p. 371.

[20] For review of this issue please see CRS Issue Brief IB90122: *Automobile and Light Truck Fuel Economy: Is CAFE Up to Standards?* by Robert Bamburger.

[21] L. Greening et al., p. 398.

[22] D. Greene, J. Kahn and R. Gibson, *An econometric analysis of the elasticity of vehicle travel with respect to fuel cost per mile using RTEC survey data.* Oak Ridge National Lab ORNL-6950. March 1999. U.S. Dept of Energy. Washington DC. This complex economic model included independent variables for fuel efficiency (milage) and fuel cost, so that it could distinguish the effect changes to either had on vehicle miles traveled.

[23] J. Roy, *The rebound effect: some empirical evidence from India.* Energy Policy. June 2000. Vol 28. No. 6-7. pp. 433-438.

three times. The families became accustomed to brighter light for longer periods of time, which caused an increase in demand for kerosene during the seasons when the solar lanterns could not fully meet the new lighting demand. Furthermore, the reduction of the cost of lighting allowed many families to switch from traditional, labor intensive cooking fuels (e.g. firewood and animal dung) to kerosene. These changes in lifestyle eventually produced, in some villages, a doubling of the demand for kerosene.

This example emphasizes the role of unmet demand in determining a rebound as well as the special circumstances required for an increase in efficiency to produce an increase in demand.

Effects on Policy

Energy Efficiency as a Means of Reducing Demand

As noted above, there has been much debate on the role that government-supported increases in energy efficiency – through incentives and/or mandates – should play in the development of national energy policy. Although some analysts have argued that rebounds will erase most or all of the decreases in demand created by such increases in efficiency, as seen above, the best empirical information now available suggests that in the domestic electricity and gasoline markets, increases in efficiency will decrease demand.

Because many factors determine whether there is a significant rebound, it may be impossible to predict its presence or size, *a priori*. However, previous studies suggest that some consumer end-uses are more likely to have a rebound and provide some indication of its potential size. For example, as seen in **Table 1**, increasing the energy efficiency of home appliances ("white goods") is likely to have a smaller rebound than increasing the efficiency of space heating.

In objectively evaluating the impact of a proposed increase in energy efficiency, it may be helpful for policymakers to know if the proponents of efficiency programs have included potential rebound effects in their projections. Similarly, policymakers may find it helpful to evaluate the claims of large rebounds predicted by opponents of programs to increase efficiency.

If previous studies have suggested that a significant rebound is likely to occur under a particular program, policymakers may find it desirable to account for its presence. For instance, some may consider it desirable to increase appliance efficiency or fuel economy standards even further than originally suggested to compensate for the predicted rebound effect. On the other hand, some policymakers may feel that the likely energy savings have been reduced to a point that makes the proposed program no longer cost effective. Another choice could be to keep the same program but slightly lower expectations of the projected energy savings.

If a rebound is projected, this may complicate interpretation of legislation written with specific savings goals. For example, the language of H. R. 4 instructs the Secretary of Transportation to establish

> "... average fuel economy standards for automobiles (except passenger automobiles) manufactured in model years 2004 through 2010 that are calculated to ensure that the aggregate amount of gasoline projected to be used in those model years by automobiles to which the standards apply is at least 5 billion gallons less than the aggregate amount of gasoline that would be used in those model years by such automobiles [under the 2002 standards]...."

Because previous studies strongly suggest that there will be a rebound between 10% and 30%, some policymakers might find it useful to explicitly instruct the Secretary of Transportation to take the likely rebound effect into account when calculating the average fuel economy required to save the five billion gallons of gasoline.

It is important to remember that losses in energy savings due to the rebound effect are generally associated with gains in quality of life of the consumer. That is, the owner of a more efficient heater can choose to live in a warmer house or spend the energy cost savings on some other consumer good. This observation leads some to argue that the ultimate goal should be increasing overall economic efficiency rather than just focusing on increasing energy efficiency.[24]

Energy Efficiency as a Means of Reducing Greenhouse Gas Emissions

The rebound effect can increase the difficulty of projecting the reduction in greenhouse emissions from an improvement in energy efficiency. For example, a consumer who saves money on his heating bill may spend it on another carbon-intensive activity. Alternatively, the money could be spent on a less carbon-intensive activity.

Both the believers in very large rebounds and their critics agree that increases in efficiency are unlikely to be enough to meet calls for large reductions in greenhouse gas production, but for different reasons. Believers in large rebounds predict that since increases in efficiency will increase consumption, they will also lead to increases in greenhouse gas emissions.[25] Those who believe in small rebounds agree with the majority of studies that suggest that increases in energy efficiency have a large potential to reduce greenhouse gas emissions,[26] but in the absence of additional

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[24]L. Brookes, p. 362.

[25]L. Brookes, pp. 359-365.

[26]For a thorough discussion of the role for energy efficiency in reducing greenhouse gas emissions see *CRS Issue Brief IB10020, Energy Efficiency: Budget, Oil Conservation, and Electricity Conservation Issues* and *CRS Report RL30414, Global Climate Change: the Role for Energy Efficiency* by Fred Sissine.

measures efficiency improvements may be insufficient to reach Kyoto Protocol goals, especially in the face of relatively cheap energy and economic growth.[27]

Both groups agree that increases in efficiency will decrease greenhouse gas emissions per unit of GDP. However, there is disagreement over whether the government should support efficiency programs as a major strategy for reducing emissions.[28] Believers in large rebounds argue that since increases in efficiency are likely to increase the output of greenhouse gases, government efforts in this area are misdirected.[29] On the other hand, believers in small rebounds argue that since governments tend to support the growth in GDP, it is only reasonable that they also support efforts to minimize the concomitant increase in greenhouse gas emissions.[30] They also point to the many studies that credit government-supported efficiency programs with decreases in energy demand. For example, at least 25% of the energy saved by more efficient appliances is attributed to increased government-mandated standards.[31] Similarly, the Green Lights program, an EPA sponsored voluntary participation program, is credited with forestalling the production of 5 billion pounds of carbon dioxide emissions and 17 million pounds of nitrogen oxide emissions between 1991 and 1996.[32]

[27] L. Schipper, p. 351, L. Greening et al., p. 399, C. Sanne, *Dealing with environmental savings in a dynamical economy – how to stop chasing your tail in the pursuit of sustainability*. Energy Policy. June 2000. Vol 28. No. 6-7. pp. 487-495.

[28] L. Schipper, p. 351, L. Brookes, p. 359, C. Sanne, pp. 487-495.

[29] L. Brookes, p. 359.

[30] L. Schipper, p. 351, C. Sanne, 487-495.

[31] L. Schipper et al., *Energy Efficiency and Human Activity: Past Trends, Future Prospects*. Cambridge University Press. Cambridge, England. 1992. p. 214.

[32] R. Howarth et al., *The economics of energy efficiency: insights from voluntary participation programs*. Energy Policy. June 2000. Vol 28. No. 6-7. p. 479.

For Additional Reading

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