Curr Sustainable Renewable Energy Rep (2016) 3:35–41
DOI 10.1007/s40518-016-0044-2

The Potential for Additional Energy Efficiency Savings Including How the Rebound Effect Could Affect This Potential

Steven Nadel[1]

Published online: 22 July 2016

Abstract Since the 1970s, efforts to improve energy efficiency and save energy have been undertaken by many countries, businesses, and individuals. Since 1980, energy efficiency has reduced US energy use by about 1.2 % per year, with savings even higher in some countries and a bit lower in other countries. Given this past history, this paper reviews a variety of studies that estimate how much energy efficiency potential remains, looking at studies that estimate efficiency potential out to at least 2030 and, in multiple cases, out to 2050. Based on these studies as well as past accomplishments, we find that compound energy efficiency savings of 1.0–1.4 % per year appear to be feasible, and savings of 2.0–2.6 % per year might be possible but have been infrequently demonstrated in practice. These estimates of potential future savings by and large do not include rebound effects, although estimates of past efficiency improvements do generally include rebound effects. We summarize studies that look at direct and indirect rebound effects. We find that direct and indirect rebound effects are generally each in the range of 10–20 % and therefore total rebound typically is in the 20–30 % range. We then reduce the estimates of future energy efficiency potential to account for this rebound and find that at a minimum it appears that recent rates of energy efficiency improvement can be sustained for many years. Some studies estimate that even higher rates of energy efficiency improvement can be achieved, but to do so would be entering largely uncharted territory.

This article is part of the Topical Collection on *End-Use Efficiency*

✉ Steven Nadel
SNadel@aceee.org

[1] American Council for an Energy-Efficient Economy, Washington, DC, USA

Keywords Energy efficiency · Energy efficiency potential · Rebound effect · Energy intensity

Introduction and Context

Since the 1970s, efforts to improve energy efficiency and save energy have been undertaken by many countries, businesses, and individuals. As the International Energy Agency (IEA—an organization of 29 developed countries) recently noted: "Energy efficiency has been the primary factor in driving down energy consumption in IEA countries over the last decade." In 2014 alone, IEA estimates that energy efficiency reduced IEA countries' total primary energy supply by 760 Mega-tonnes of oil equivalent (Mtoe) (32 EJ) as a result of energy efficiency investments since 1990 [1]. To put these savings in perspective, in 2013 (the most recent year with data), the entire world used 13,559 Mtoe [2•], of which IEA countries used about 43 % [3]. Thus, the 760 Mtoe of IEA annual energy savings represents about 13 % of IEA energy demand.

Some countries have saved even more. For example, Nadel et al. examined energy use and energy savings in the USA since 1980 and estimated that energy efficiency efforts since 1980 reduced US primary energy use in 2014 by about 58 quadrillion Btus of energy (61 EJ); without energy efficiency, 2014 energy consumption would have been about 59 % higher (primary energy use is total energy use and includes energy lost in electric generation as well as transmission and distribution of electricity and fuels). On a compound basis, they estimate energy efficiency has reduced US energy consumption by 1.2 % per year. Energy intensity (energy use per dollar of GDP) has declined by about 2.0 % per year over this period, but they estimate that about 60 % of this change is due to energy efficiency and the other 40 % due to structural change in the US economy (e.g., less heavy manufacturing and more services) [4•]. Likewise, Schlomann and Eichhammer estimate that between 1990 and 2011, German absolute primary energy use fell by 12 % (a compound average of 0.6 % per year), while primary energy intensity fell by an average of 2.0 % per year [5] (the same as the USA). Data compiled by the US Energy Information Administration (EIA) shows that five large energy-consuming countries (India, Poland, Russia, Ukraine, and the UK) reduced their energy intensity per dollar of GDP over the 2000–2011 period (the last year with full data) by more than 20 %, and an additional five large energy consumers (Canada, Germany, South Africa, Taiwan, and the USA reduced their energy intensity by 15–20 % [3]. Improvements of 15 and 20 % work out to compound annual improvements of 1.5 and 2.0 %, respectively. More recently, China has had aggressive energy efficiency targets as part of recent five-year plans. For the 2011–2015 plan, they report that energy intensity has improved 18.2 % over the 5-year period [6]. This is a 4.0 % annual compound rate of improvement—an impressive achievement. However, as noted above for the USA, some of the improvement in China, India, Poland, etc., are probably due to structural changes in their economies—not all of the improvement is due to energy efficiency.

Given this past history, an important question is how much energy efficiency potential remains in developed countries? Another important question is what is the energy efficiency potential in developing countries that are seeking to grow their economies and improve standards of living? In this paper, we review some of the major studies on energy efficiency potential, covering studies from the USA, Europe, and Japan and also touching on other countries including several less-developed countries. Our focus is on estimates of potential out to 2040–2050, but we also review some studies that look at shorter-terms.

One factor that affects energy efficiency potential is the rebound effect—when consumers and businesses improve energy efficiency, they sometimes channel some of the efficiency gains into increased comfort (e.g., increasing the thermostat set point in winter) or amenity (e.g., driving their more efficient car more kilometers). Also, if consumers and businesses save energy, they generally reduce their energy bills, and some of these financial savings may be invested in ways that increase energy use such as a factory investing in a new production line. If rebound is substantial, it can reduce the energy savings achieved. We review key studies that estimate the size of rebound effects in different market segments, summarize results across different markets, and then comment on how these results may affect the size of the long-term energy efficiency opportunity. One important point to note is that all of the data on the previous page are based on actual energy use and therefore incorporate rebound effects. The question is how to allow for rebound in projections of potential future energy savings.

Energy Efficiency Potential

There are many studies that estimate energy efficiency potential. In this section, we focus on some of the major ones, emphasizing long-term studies. But first, a brief typology of energy efficiency potential studies is in order. Energy efficiency potential studies look at a variety of potentials, but the most common are technical potential, economic potential, and achievable potential. Technical potential is what is possible without considering cost-effectiveness. Economic potential only includes cost-effective measures but implicitly assumes 100 % adoption. Achievable potential is an estimate of what can be achieved given specific policies and programs. In the discussion below, we concentrate on economic and achievable potential estimates, as many studies estimate one or the other and only some do both. Potential studies can be bottom-up or top-down. Bottom-up studies look at the savings from specific energy efficiency policies and measures, building up the potential as a series of building blocks. Underlying these studies are specific assumptions about which policies and measures and how much they will save. Top-down studies look at overall rates of efficiency improvement, often based on past experience, such as some of the estimates of past experience discussed in the section above. Potential studies can look at *primary energy use* (defined previously) and/or *final energy* which does not include upstream losses in power and energy systems (sometimes called site energy or delivered energy). Unless otherwise noted, the figures we discuss below are for primary energy since primary energy is a more complete measure of total energy use.

Dozens of studies have been published in recent years that estimate the potential for energy efficiency improvements in the next few decades including major studies by the IEA [2•], European Union [7, 8•], Deep Decarbonization Pathways Project [9•, 10], Rocky Mountain Institute (RMI) [11], the American Council for an Energy-Efficient Economy (ACEEE) [12, 13••], and the Electric Power Research Institute (EPRI) [14]. There are also several recent journal articles [15–17]. Table 1 summarizes these major studies. These are not the only studies, but they do give a flavor for recent work.

A few comments on some of the studies:

- The deep decarbonization studies were on 15 individual countries. All of the countries found substantial opportunities for energy efficiency and other energy intensity improvements as shown in Fig. 1. In most developed countries, these efficiency improvements were accompanied by absolute reductions in final energy consumption in 2050 relative to 2010 consumption. In developing countries, absolute final energy consumption increased over the 2010–2050 period, with the increases ranging from 36–41 % in Mexico to 225–338 % in India [18].

Table 1 Summary of key energy efficiency potential studies

Study	Region	Potential energy savings	End year	Compound annual savings rate	Notes	Reference number
World Energy Outlook	World	29 %	2040	1.2 %	Bottom-up analysis. New policies scenario + additional cost-effective measures + author estimate that EE in basecase is similar to New Policies.	[2•]
Deep Decarbonization Pathways Project	15 large countries	Avg. 64 % reduction in E/GDP	2050	2.2 % (1.2 % if 60 % due to EE)	Summary of studies on 15 individual countries. Looked at major efficiency measures that were generally thought to be cost-effective.	[9•]
Reinventing Fire	USA	39–56 %	2050	1.0–1.4 %	Bottom-up study with some consideration of economics and achievability. Low-end is for technologies and more productive use of energy; high-end adds integrative design.	[11]
ACEEE Long-Term EE Potential	USA	42–59 %	2050	1.1–1.6 %	Bottom-up study with some consideration of economics and achievability. Low-end is for advanced technologies; high-end includes new denser development.	[12]
Neubauer	40+ studies on regions in USA	Median of 1.3 %/ year for elec. and 0.9 %/ year for natural gas	Various	1.4 % for elec and 1.0 % for natural gas	Compilation of many different studies. Compound rate based on an estimated 15-year average study period.	[13••]
Electric Power Research Institute	USA	10.8–17.5 %	2035	0.6–1.0 %	Bottom-up study. High end of range is economic potential, low-end is the lower of two achievable potential estimates.	[14]
Sugiyama et al.	World	1.3–2.9 %/year	2030	Median of 2.3 % (1.4 % if 60 % due to EE)	Global economic models examined scenarios consistent with two degrees warming. These are changes in E/GDP.	[15]
Sreedharan	USA	~10–25 % for elec. and ~20 % for natural gas	2020	1.0–2.6 % for elec and 2.0 % for natural gas	Compilation of multiple studies. For economic potential.	[16]
Wang and Brown	USA	10.2 %	2035	0.4 %	Estimated achievable electricity savings potential from 11 specific policies.	[17]
European Commission	EU	10 %	2030	1.0 %	For savings 2020–2030 in their preferred scenario. Top-down study; used a 17.5 % discount rate.	[7]
DG ENER	EU	23 % for primary energy	2030	2.6 %	For savings 2020–2030. Bottom-up study, used 2–15 % discount rate, varying by sector.	[8•]
Pathways to Deep Decarbonization in Japan	Japan	53 % for primary energy	2050	1.9 %	For the mixed scenario. Looked at major efficiency measures that were generally thought to be cost-effective.	[10]

- In addition to providing numbers, the ACEEE study by Neubauer [13••] also examines the many assumptions some of these reports make, finding that inputs have a significant impact on results. Key assumptions include participation rates in energy efficiency programs, estimates of the impacts of building codes and equipment efficiency standards, the extent to which emerging technologies are included in the estimates, and the assumptions about avoided costs (the higher the avoided cost, the more efficiency that is cost-effective).
- Reviewing the detailed assumptions in the EPRI study [14] relative to the other studies, the EPRI study included few new technologies (e.g., LED lighting was not included), little in the way of whole-system improvements (what RMI calls integrative design), tended to use relatively high measure costs and used a relatively restrictive cost-effectiveness test that includes all costs but only the benefits to the utility.
- The Wang and Brown study [17] looked at savings from 11 specific policies, capturing some but not all of the available efficiency potential. Savings are greater in the first 10 years (0.6 %/year) than the next 15 years (0.35 %/year). In order to sustain savings, policies will need to be periodically updated.

Energy Efficiency Potential Discussion

A substantial majority of the studies discussed above are finding potential future energy efficiency improvements of about 1.0–1.4 % per year. These are mostly achievable potential estimates, but some are economic potentials. These rates of

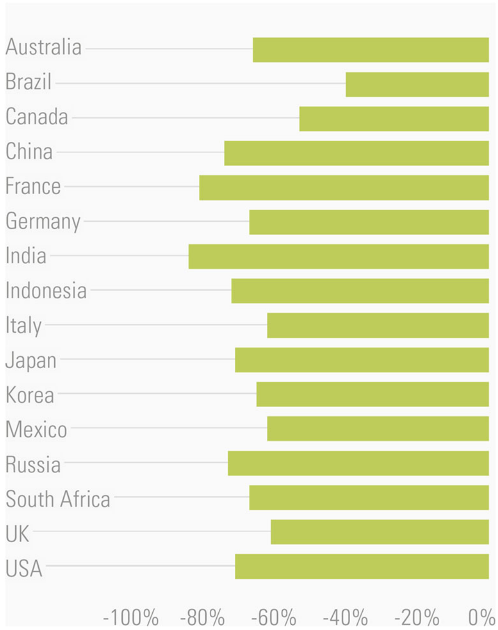

Fig. 1 Estimated available reduction in energy use per dollar of GDP from 2010–2050 by country [9•]

efficiency improvement are in line with efficiency improvements since 1990 in several major countries as discussed in the "Introduction and Context" section of this paper. While achieving these potentials is not easy, as discussed by Alcott and Greenstone [19], past experience as well as a critique of this work [20] leads us to conclude that achieving future savings of this magnitude should be possible.

A few of the studies find higher efficiency potentials of about 2.0–2.6 % per year including the more aggressive scenarios in the RMI and ACEEE studies of the USA; some of the deep decarbonization scenarios if all of the improvement is due to efficiency and none to structural change, and the study on the European Union prepared for the DG ENER. As discussed in the "Introduction and Context" section, this level of efficiency improvement has not been achieved in high-income countries in the recent past and therefore for these potentials to be achievable will require more aggressive interventions that have generally been employed in the past. Such efficiency improvements have been achieved in isolated cases in the high-income countries in the past (e.g., several American utilities have achieved electricity efficiency savings of more than 2 % per year [21], and California achieved a reduction over 6 % in 1 year from a combination of efficiency improvements and conservation behavior during a major energy crisis [22]) and have also been achieved in some developing countries such as China during their last five-year plan [6]. Overall, it is unclear if these levels of savings can be achieved across entire economies for multiple decades.

The Rebound Effect

Different authors have suggested different types of rebound effects, but these boil down to two general types—direct and indirect. Direct rebound is the impact of a purchase of an efficient product on the purchaser's use of that product. For example, a car buyer may drive an efficient car more often than an inefficient one or a homeowner who weatherizes his/her house may use a portion of the savings to increase the temperature in the house in the winter in order to increase comfort. Indirect rebound, on the other hand, reflects other upstream impacts including the following: (1) the impact of respending the money that consumers and businesses save from improved energy efficiency (sometimes called an income effect) and (2) the fact that as factories and other parts of the economy get more efficient, production costs may be lower and as a result prices decline and demand for these products can increase (sometimes called a substitution effect). An example of the first is a household that cuts its heating bill and takes back a little of the savings on higher thermostat settings but then spends the money saved on eating out or buying a new television. An example of the second is that efficiency improvements in aluminum smelting can reduce the price of aluminum, thereby fostering increased aluminum sales that require additional energy to produce this aluminum.

Over the years, many studies have examined the rebound effect for specific programs and policies on specific countries, and there have been multiple meta-compilations of these studies [23–25]. There have also been several more recent reviews and compilations including the ones by Economic Consulting Associates (ECA) [26••], Gillingham et al. [27••], and Nadel [28].

Direct Effects

In Table 2, findings on direct rebound effects are summarized, drawing primarily from these more recent studies but also drawing in some key studies referenced in these recent studies. Direct effects have been most extensively studied for passenger vehicles and for space heating in developed countries, but there are also some data for developing countries, other residential energy uses, and for some commercial and industrial applications.

Indirect Effects

ECA [26••] summarizes a variety of studies that look at indirect rebound effects in particular markets. They report median indirect effects of 6–31 % for high-income countries, varying

Table 2 Estimates of direct rebound effects from recent studies

Market segment	Study	Region	Estimated rebound	Notes	Reference number
Passenger vehicles	ECA	Developed countries	9–30 %, median of 20 %		[26••]
	ECA	Developing countries	28–43 %, median of 35 %		[26••]
	Gillingham et al.	Developed countries	4.5–46 %, median of 15.5 %	These are based on elasticities and they caution that "recent evidence suggests that consumers may respond comparatively less to changes in energy efficiency than to changes in fuel price."	[27••]
	Gillingham et al.	Developing countries	7.5–62 %, median of 21 %		[27••]
	Hughes et al.	USA	21–34 % over 1975–1980, 4.2 % over 2000–2009		[29]
	Small and Van Dender	USA	22.6 % over 1966–2001; 10.7 % over the 1997–2001		[30]
	Small and Hymel	USA	4.2 % over 2000–2009	For their preferred asymmetric model	[31]
Residential space	ECA	High-income countries	12–56 %, median of 30 %		[26••]
	Greening et al.	Same as above	10–30 %		[24]
	Sorrell	Same as above	10–30 %		[25]
	Nadel	USA	1–12 %	Raises questions about studies claiming higher rebound in the USA	[28]
Other residential	Davis	USA	6 %	For clothes washers	[32]
	Davis et al.	Mexico	Savings from high-effic. refrigerators less than expected and high-effic. air conditioners increased energy use		[33]
	Nadel	USA	5–12 % for lighting, 5 % for clothes washers, 1–13 % for air conditioning and little evidence of rebound for water heating		[28]
Commercial and industrial	ECA	High-income countries	0–19 %, median of 4 %		[26••]
	Gillingham et al.	3 US states	9–12 %, median of 10 %	These are elasticities for electricity and include residential as well as C&I	[27••]
	Gillingham et al.	Developing countries	2–40 %, median of 13 %	These are elasticities for electricity and include residential as well as C&I	[27••]

by the energy use being examined. Based on their review of these studies, their most likely estimate of indirect effects is 10–20 % for high-income countries and 20 % for middle-/low-income countries. Gillingham et al. [27••] discuss a variety of indirect effects. First, they note work by others that found an indirect rebound effect of 5–15 %; for example, Thomas and Azevedo [34] found a 5–15 % indirect rebound effect in US households using an input-output model and a detailed consumer expenditure survey to estimate income elasticities. Second, they explore a macroeconomic price effect, such as the impact of oil price changes on economic growth, concluding that in the case of the oil market, this effect is likely to be on the order of 20–30 %. And third, they discuss use of calibrated simulation models of a country's economy. For example, studies on the UK and world economies estimated total rebound (direct plus indirect) of 11 % [35] and 21 % [36], respectively.

Rebound Effect Discussion

Most of the results summarized in Table 2 indicate direct rebound effects on the order of 10 % plus indirect effects on the order of 10–20 % for a total rebound of about 20–30 %. The International Risk Governance Council (IRGC) reaches a similar conclusion, finding that: "The evidence to date from econometric studies that generally use price elasticity, income elasticity and elasticity of substitution suggests that direct and indirect rebound effects in developed economies are moderate and that investments in energy efficiency can save between 70 and 85 per cent of the anticipated energy reduction, while allowing households to enjoy the benefits of higher consumption" [37]. However, the data in Table 2 indicate that there are some important exceptions where direct rebound can be higher including with passenger vehicles and space heating outside of the USA (the latter for countries with cold climates where spaces are currently not heated to comfortable temperatures) and appliances and air conditioning in developing countries. In these other cases, direct rebound might generally be on the order of 20 %, except they could well be higher for appliances and air conditioning in developing countries. Furthermore, economies are particularly sensitive to oil prices, with macroeconomic rebound associated with oil savings in the range of 20–30 %. Estimates of indirect rebound effects are often imprecise. As the IRGC notes "indirect rebound effect is likely to depend on the economy under study and most of these drivers have not been thoroughly investigated across a broad number of economies. In addition, prior work has been largely parametric; [more] empirical research on the magnitude of… indirect rebound effects is needed" [37].

There have also been a few claims of "backfire," such as in reports by the Breakthrough Institute and its contributors [38]. "Backfire" means that rebound is larger than the efficiency savings and therefore energy use increases rather than decreases as a result of efficiency programs, policies, and investments. Most other analysts reject these claims. For example, Gillingham et al. state "the existing literature does not provide support for claims that energy efficiency gains will be reversed by the rebound effect" [27••]. ECA estimates that total economy-wide rebound effects (direct plus indirect) likely range from 10–60 % depending on the sector, end-use, and income of the country—well short of the 100 % needed for backfire [26••]. And Cullenward and Koomey specifically question the data on high rebound effects in the industrial sector [39].

Energy Efficiency Potential Considering the Rebound Effect

In our section on energy efficiency potential, we found that compound energy efficiency savings of 1.0–1.4 % per year appear to be feasible, and savings of 2.0–2.6 % per year might be possible but have been infrequently demonstrated in practice. These estimates of potential future savings by and large do not include rebound effects, although the historic estimates of 0.6–2.0 % per year discussed in the "Introduction and Content" section do include rebound. If we incorporate a range of 20–30 % rebound into these future savings estimates, then the net energy savings potential after rebound becomes 0.7–1.1 % per year that is likely feasible and 1.4–2.1 % per year that is potentially possible. Considering actual accomplishments in recent years, the upper ends of these ranges might be higher—perhaps 0.7–1.5 % per year likely feasible and 1.4–2.5 % per year potentially possible. These are broad ranges but these ranges indicate the wide variety of applications and countries as well as the imprecision of many of the estimates.

Conclusions

Countries around the world have made substantial energy efficiency progress but much more cost-effective energy efficiency potential remains. At a minimum, it appears that recent rates of energy efficiency improvement can be sustained for many years. Some studies estimate that even higher rates of energy efficiency improvement can be achieved but to do so would be entering largely uncharted territory.

Acknowledgments Helpful comments on a draft of this paper were provided by Drs. Ken Gillingham, Yu Wang, and Jim Barrett.

Compliance with Ethical Standards

Conflict of Interest Steven Nadel declares that he has no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by the author.

References

Papers of particular interest, published recently, have been highlighted as:
• Of importance
•• Of major importance

1. International Energy Agency (IEA). Energy efficiency market report 2015, market trends and medium-term prospects. https://www.iea.org/publications/freepublications/publication/energy-efficiency-market-report-2015-.html.
2.• International Energy Agency (IEA). World energy outlook 2015. Paris: International Energy Agency; 2015. **This is an in-depth analysis that looks at potential savings from energy efficiency policies and additional cost-effective energy efficiency measures in countries accounting for nearly half of global energy demand**.
3. Energy Information Administration. International Energy Statistics. https://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=44&pid=44&aid=2. This percentage is for 2012, the last year for which data are available.
4.• Nadel S, Elliott N and Langer T. Energy efficiency in the United States: 35 years and counting. American Council for an Energy-Efficient Economy, Washington, DC. 2015. http://aceee.org/research-report/e1502. **Examines many energy efficiency trends in the USA from 1980 to 2014**.
5. Schlomann B and Eichhammer W. Energy efficiency policies and measures in Germany. Fraunhofer Institute for Systems and Innovation Research ISI, Karlsruhe, Germany. 2012 http://www.isi.fraunhofer.de/isi-wAssets/docs/x/de/publikationen/National-Report_Germany_November-2012.pdf.
6. National Bureau of Statistics. "Statistical Communique" (in Chinese). Beijing. 2016 http://www.stats.gov.cn/tjsj/zxfb/201602/t20160229_1323991.html.
7. European Commission. "Commission staff working document and impact assessment accompanying the document, communication from the commission to the European Parliament and the Council, Energy Efficiency and its Contribution to Energy Security and the 2030 Framework for Climate and Energy Policy." Brussels. 2014 https://ec.europa.eu/energy/sites/ener/files/documents/2014_eec_ia_adopted_part1_0.pdf.
8.• Braungardt S, Eichhammer W, Elsland R, Fleiter T, Klobasa M, Krail M, Pfluger B, Reuter M, Schlomann B, Sensfuss F, Tariq S, Kranzl L, Dovidio S, and Gentili P. 2014 (revised). Study evaluating the current energy efficiency policy framework in the EU and providing orientation on policy options for realizing the cost-effective energy-efficiency/saving potential until 2020 and beyond. Karlsruhe, Vienna and Rome. Franhofer Institute for Systems and Innovation Research ISI and Technische Universitat Wien and Price Waterhouse Cooper PwC. https://ec.europa.eu/energy/sites/ener/files/documents/2014_

report_2020-2030_eu_policy_framework.pdf. **A comprehensive bottom-up analysis estimating a high level of available energy efficiency savings in the EU**.
9.• Institute for Sustainable Development and International Relations (IDDRI) and Sustainable Development Solutions Network (SDSN). Pathways to deep decarbonization, 2015 Report. http://deepdecarbonization.org/wp-content/uploads/2016/03/DDPP_2015_REPORT.pdf. **Summary of studies looking at energy efficiency and decarbonization potential in 15 of the world's major economies on all inhabited continents**.
10. Kinuma M, et al. Pathways to deep decarbonization in Japan. 2015. Institute for Sustainable Development and International Relations (IDDRI) and Sustainable Development Solutions Network (SDSN). http://deepdecarbonization.org/wp-content/uploads/2015/09/DDPP_JPN.pdf.
11. Lovins A, Rocky Mountain Institute. Reinventing fire: bold business solutions for the new energy era. White River Junction: Chelsea Green Publishing; 2011.
12. Laitner J, Nadel S, Elliott RN, Sachs H, and Khan S. The long-term energy efficiency potential: what the evidence suggests. 2012. Washington, DC: ACEEE. http://aceee.org/research-report/e121.
13.•• Neubauer M. Cracking the TEAPOT: economic and achievable energy efficiency potential studies. 2014. American Council for an Energy-Efficient Economy, Washington, DC. http://aceee.org/research-report/u1407. **Summarizes more than 40 efficiency potential studies on the USA, good discussion of the influence of key assumptions in estimating energy efficiency potential**.
14. Electric Power Research Institute. 2014. U.S. energy efficiency potential through 2035. Palo Alto, CA, EPRI. http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001025477.
15. Sugiyama M, Akashi O, Wada K, Kanudia A, Li J, Weyant J. Energy efficiency potentials for global climate change mitigation. Clim Chang. 2014;123(3):397–411.
16. Sreedharan P. Recent estimates of energy efficiency potential in the USA. Energy Effic. 2013;6(3):433–45.
17. Yu W, Brown M. Policy drivers for improving electricity end-use efficiency in the U.S.: an economic-engineering analysis. Energy Effic. 2014;7:517–46.
18. These data come from the 15 individual country studies, available at: http://deepdecarbonization.org/countries/.
19. Allcott, Hunt, and Michael Greenstone. 2012. "Is there an energy efficiency gap?" http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1987250.
20. Nadel S and Langer T. 2012. "Comments on the July 2012 revision of 'is there an energy efficiency gap?'" American Council for an Energy-Efficient Economy, Washington, DC. http://aceee.org/white-paper/comments-on-revision-efficiency-gap.
21. Baatz B and Gilleo A. Big savers: experiences and recent history of program administrators achieving high levels of energy savings. 2016. American Council for an Energy-Efficient Economy, Washington, DC. http://aceee.org/research-report/u1601.
22. California State and Consumer Services Agency. The summer 2001 conservation report. Prepared by the California Energy Commission, Sacramento, CA. http://www.energy.ca.gov/reports/CEC-400-2002-001/CEC-100-2002-001.PDF.
23. Nadel S. The takeback effect: fact or fiction? 1993. American Council for an Energy-Efficient Economy, Washington, DC. http://www.aceee.org/research-report/u933.
24. Greening L, Greene D, Difiglio C. Energy efficiency and consumption—the rebound effect—a survey. Energy Policy. 2000;28:389–401.
25. Sorrell S, Dimitropoulos J, Somerville M. Empirical estimates of the direct rebound effect: a review. Energy Policy. 2009;37:1356–71.
26.•• Economic Consulting Associates. 2014. Phase 1 final report: the rebound effect for developing countries. http://www.evidenceondemand.info/phase-1-final-report-the-rebound-effect-for-developing-countries.**Examines the results of many different studies on rebound effects in both high- and low/middle-income countries**.
27.•• Gillingham, Kenneth, David Rapson, and Gernot Wagner. "The rebound effect and energy efficiency policy." Review of environmental economics and policy 10(1):68-88. http://reep.oxfordjournals.org/content/10/1/68.full. **Reviews many different studies on the rebound effect—particularly strong on indirect effects, both micro- and macroeconomic**.
28. Nadel S. "The rebound effect: large or small? 2012. American Council for an Energy-Efficient Economy, Washington, DC. http://aceee.org/white-paper/rebound-effect-large-or-small.
29. Hughes J, Knittel C, Sperling D. Evidence of a shift in the short-run price elasticity of gasoline demand. Energy J. 2008;29(1):93–114.
30. Small K and Van Dender K. "Fuel efficiency and motor vehicle travel: the declining rebound effect." 2007. Irine, CA, University of California. http://www.economics.uci.edu/files/docs/workingpapers/2005-06/Small-03.pdf. A slightly earlier version was published in Energy Journal (28)1: 25–51.
31. Small K and Hymel Kent. "The rebound effect from fuel efficiency standards: measurement and projection to 2035." Prepared for U.S. EPA, Washington, DC. 2011. https://www3.epa.gov/otaq/climate/documents/mte/420r15012.pdf.
32. Davis L. Durable goods and residential demand for energy and water: evidence from a field trial. RAND J Econ. 2008;39(2):530–46.
33. Davis L, Fuchs A, Gertler P. Cash for coolers: evaluating a large-scale appliance replacement program in Mexico. Am Econ J Econ Pol. 2015;6(4):207–38. http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2014/12/05/000442464_20141205134555/Rendered/PDF/929360JRN0240A00Box385297B00PUBLIC0.pdf.
34. Thomas B and Azevedo I. "Estimating direct and indirect rebound effects for U.S. households with input-output analysis. Ecological Economics 86(2013): 1188-210. https://www.andrew.cmu.edu/user/ilimade/Ines_Azevedo/papers/thomas_2013a.pdf and http://www.contrib.andrew.cmu.edu/~ilimade/Ines_Azevedo/papers/thomas_2013b.pdf.
35. Barker T, Ekins P, Foxon T. The macro-economic rebound effect and the UK economy. Energy Policy. 2007;35(10):4935–46.
36. Barker T, Dagoumas A, Rubin J. The macroeconomic rebound effect and the World Economy. Energy Effic. 2009;2(4):411–27.
37. International Risk Governance Council. The rebound effect: implications of consumer behavior for robust energy policies. 2013. https://www.andrew.cmu.edu/user/ilimade/Ines_Azevedo/papers/IRGC_ReboundEffect-FINAL.pdf.
38. Luke, Max, Amy Meyer, Harry Saunders, Ted Nordhaus, Michael Shellenberger and Alex Trembath. 2014. Lighting, electricity, steel: energy efficiency backfire in emerging economies. Oakland, CA, Breakthrough Institute. http://thebreakthrough.org/images/pdfs/Lighting_Electricity_Steel.pdf.
39. Cullenward D, Koomey J. A critique of Saunders' 'historical evidence for energy efficiency rebound in 30 US sectors'. Technol Forecast Soc Chang. 2016;103:203–13.