Efficient energy use

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Efficient energy use, sometimes simply called **energy efficiency**, is the goal to reduce the amount of energy required to provide products and services. For example, insulating a home allows a building to use less heating and cooling energy to achieve and maintain a comfortable temperature. Installing fluorescent lights or natural skylights reduces the amount of energy required to attain the same level of illumination compared with using traditional incandescent light bulbs. Compact fluorescent lights use one-third the energy of incandescent lights and may last 6 to 10 times longer. Improvements in energy efficiency are generally achieved by adopting a more efficient technology or production processes [2] or by application of commonly accepted methods to reduce energy losses.

A spiral-type integrated compact fluorescent lamp, which has been in popular use among North American consumers since its introduction in the mid-1990s.[1]

There are many motivations to improve energy efficiency. Reducing energy use reduces energy costs and may result in a financial cost saving to consumers if the energy savings offset any additional costs of implementing an energy efficient technology. Reducing energy use is also seen as a solution to the problem of reducing carbon dioxide emissions. According to the International Energy Agency, improved energy efficiency in buildings, industrial processes and transportation could reduce the world's energy needs in 2050 by one third, and help control global emissions of greenhouse gases.[3]

Energy efficiency and renewable energy are said to be the *twin pillars* of sustainable energy policy[4] and are high priorities in the sustainable energy hierarchy. In many countries energy efficiency is also seen to have a national security benefit because it can be used to reduce the level of energy imports from foreign countries and may slow down the rate at which domestic energy resources are depleted.

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Overview

Energy efficiency has proved to be a cost-effective strategy for building economies without necessarily increasing energy consumption. For example, the state of California began implementing energy-efficiency measures in the mid-1970s, including building code and appliance standards with strict efficiency requirements. During the following years, California's energy consumption has remained approximately flat on a per capita basis while national U.S. consumption doubled.[5] As part of its strategy, California implemented a "loading order" for new energy resources that puts energy efficiency first, renewable electricity supplies second, and new fossil-fired power plants last.[6]

Lovins' Rocky Mountain Institute points out that in industrial settings, "there are abundant opportunities to save 70% to 90% of the energy and cost for lighting, fan, and pump systems; 50% for electric motors; and 60% in areas such as heating, cooling, office equipment, and appliances." In general, up to 75% of the electricity used in the U.S. today could be saved with efficiency measures that cost less than the electricity itself. The same holds true for home-owners, leaky ducts have remained an invisible energy culprit for years. In fact, researchers at the US Department of Energy and their consortium, Residential Energy Efficient Distribution Systems (REEDS) have found that duct efficiency may be as low as 50-70%. The US Department of Energy has stated that there is potential for energy saving in the magnitude of 90 Billion kWh by increasing home energy efficiency.[7]

Other studies have emphasized this. A report published in 2006 by the McKinsey Global Institute, asserted that "there are sufficient economically viable opportunities for energy-productivity improvements that could keep global energy-demand growth at less than 1 percent per annum"—less than half of the 2.2 percent average growth anticipated through 2020 in a business-as-usual scenario.[8] Energy productivity, which measures the output and quality of goods and services per unit of energy input, can come from either reducing the amount of energy required to produce something, or from increasing the quantity or quality of goods and services from the same amount of energy.

The Vienna Climate Change Talks 2007 Report, under the auspices of the United Nations Framework Convention on Climate Change (UNFCCC), clearly shows "that energy efficiency can achieve real emission reductions at low cost."[9]

Appliances

Modern appliances, such as, freezers, ovens, stoves, dishwashers, and clothes washers and dryers, use significantly less energy than older appliances. Installing a clothesline will significantly reduce your energy consumption as your dryer will be used less. Current energy efficient refrigerators, for example, use 40 percent less energy than conventional models did in 2001. Following this, if all households in Europe changed their more than ten-year-old appliances into new ones, 20 billion kWh of electricity would be saved annually, hence reducing CO_2 emissions by almost 18 billion kg.[10] In the US, the corresponding figures would be 17 billion kWh of electricity and 27,000,000,000 lb (1.2×10^{10} kg) CO_2.[11] According to a 2009 study from McKinsey & Company the replacement of old appliances is one of the most efficient global measures to reduce emissions of greenhouse gases.[12] Modern power management systems also reduce energy usage by idle appliances by turning them off or putting them into a low-energy mode after a certain time. Many countries identify energy-efficient appliances using energy input labeling.[13]

The impact of energy efficiency on peak demand depends on when the appliance is used.[14] For example, an air conditioner uses more energy during the afternoon when it is hot. Therefore, an energy efficient air conditioner will have a larger impact on peak demand than off-peak demand. An energy efficient dishwasher, on the other hand, uses more energy during the late evening when people do their dishes. This appliance may have little to no impact on peak demand.

Building design

A building's location and surroundings play a key role in regulating its temperature and illumination. For example, trees, landscaping, and hills can provide shade and block wind. In cooler climates, designing northern hemisphere buildings with south facing windows and southern hemisphere buildings with north facing windows increases the amount of sun (ultimately heat energy) entering the building, minimizing energy use, by maximizing passive solar heating. Tight building design, including energy-efficient windows, well-sealed doors, and additional thermal insulation of walls, basement slabs, and foundations can reduce heat loss by 25 to 50 percent.[13]


Receiving a Gold rating for energy and environmental design in September 2011, the Empire State Building is the tallest and largest LEED certified building in the United States and Western Hemisphere.[15]

Dark roofs may become up to 39 C° (70 F°) hotter than the most reflective white surfaces. They transmit some of this additional heat inside the building. US Studies have shown that lightly colored roofs use 40 percent less energy for cooling than buildings with darker roofs. White roof systems save more energy in sunnier climates. Advanced electronic heating and cooling systems can moderate energy consumption and improve the comfort of people in the building.[13]

Proper placement of windows and skylights as well as the use of architectural features that reflect light into a building can reduce the need for artificial lighting. Increased use of natural and task lighting has been shown by one study to increase productivity in schools and offices.[13] Compact fluorescent lights use two-thirds less energy and may last 6 to 10 times longer than incandescent light bulbs. Newer fluorescent lights produce a natural light, and in most applications they are cost effective, despite their higher initial cost, with payback periods as low as a few months.[16]

Effective energy-efficient building design can include the use of low cost Passive Infra Reds (PIRs) to switch-off lighting when areas are unoccupied such as toilets, corridors or even office areas out-of-hours. In addition, lux levels can be monitored using daylight sensors linked to the building's lighting scheme to switch on/off or dim the lighting to pre-defined levels to take into account the natural light and thus reduce consumption. Building Management Systems (BMS) link all of this together in one centralised computer to control the whole building's lighting and power requirements.[17]

The choice of which space heating or cooling technology to use in buildings can have a significant impact on energy use and efficiency. For example, replacing an older 50% efficient natural gas furnace with a new 95% efficient one will dramatically reduce energy use, carbon emissions, and winter natural gas bills. Ground source heat pumps can be even more energy efficient and cost effective. These systems use pumps and compressors to move refrigerant fluid around a thermodynamic cycle in order to "pump" heat against its natural flow from hot to cold, for the purpose of transferring heat into a building from the large thermal reservoir contained within the nearby ground. The end result is that heat pumps typically use four times less electrical energy to deliver an equivalent amount of heat than a direct electrical heater does. Another advantage of a ground source heat pump is that it can be reversed in summertime and operate to cool the air by transferring heat from the building to the ground. The disadvantage of ground source heat pumps is their high initial capital cost, but this is typically recouped within five to ten years as a result of lower energy use.

Smart meters are slowly being adopted by the commercial sector to highlight to staff and for internal monitoring purposes the building's energy usage in a dynamic presentable format. The use of Power Quality Analysers can be introduced into an existing building to assess usage, harmonic distortion, peaks, swells and interruptions amongst others to ultimately make the building more energy-efficient. Often such meters communicate by using wireless sensor networks.[18]

Green Building XML (gbXML) is an emerging schema, a subset of the Building Information Modeling efforts, focused on green building design and operation. gbXML is used as input in several energy simulation engines. But with the development of modern computer technology, a large number of building energy simulation tools are available on the market. When choosing which simulation tool to use in a project, the user must consider the tool's accuracy and reliability, considering the building information they have at hand, which will serve as input for the tool. Yezioro, Dong and Leite[19] developed an artificial intelligence approach towards assessing building performance simulation results and found that more detailed simulation tools have the best simulation performance in terms of heating and cooling electricity consumption within 3% of mean absolute error.

A deep energy retrofit is a whole-building analysis and construction process that uses to achieve much larger energy savings than conventional energy retrofits. Deep energy retrofits can be applied to both residential and non-residential ("commercial") buildings. A deep energy retrofit typically results in energy savings of 30 percent or more, perhaps spread over several years, and may significantly improve the building value.[20] The Empire State Building has undergone a deep energy retrofit process that was completed in 2013. The project team, consisting of representatives from Johnson Controls, Rocky Mountain Institute, Clinton Climate Initiative, and Jones Lang LaSalle will have achieved an annual energy use reduction of 38% and $4.4 million.[21] For example, the 6,500 windows were remanufactured onsite into superwindows which block heat but pass light. Air conditioning operating costs on hot days were reduced and this saved $17 million of the project's capital cost immediately, partly funding other retrofitting.[22] Receiving a gold Leadership in Energy and Environmental Design (LEED) rating in September 2011, the Empire State

Building is the tallest LEED certified building in the United States.[15] The Indianapolis City-County Building recently underwent a deep energy retrofit process, which has achieved an annual energy reduction of 46% and $750,000 annual energy saving.

Energy retrofits, including deep, and other types undertaken in residential, commercial or industrial locations are generally supported through various forms of financing or incentives. Incentives include pre-packaged rebates where the buyer/user may not even be aware that the item being used has been rebated or "bought down". "Upstream" or "Midstream" buy downs are common for efficient lighting products. Other rebates are more explicit and transparent to the end user through the use of formal applications. In addition to rebates, which may be offered through government or utility programs, governments sometimes offer tax incentives for energy efficiency projects. Some entities offer rebate and payment guidance and facilitation services that enable energy end use customers tap into rebate and incentive programs.[23]

Industry

Industry uses a large amount of energy to power a diverse range of manufacturing and resource extraction processes. Many industrial processes require large amounts of heat and mechanical power, most of which is delivered as natural gas, petroleum fuels and as electricity. In addition some industries generate fuel from waste products that can be used to provide additional energy.

Because industrial processes are so diverse it is impossible to describe the multitude of possible opportunities for energy efficiency in industry. Many depend on the specific technologies and processes in use at each industrial facility. There are, however, a number of processes and energy services that are widely used in many industries.

Various industries generate steam and electricity for subsequent use within their facilities. When electricity is generated, the heat that is produced as a by-product can be captured and used for process steam, heating or other industrial purposes. Conventional electricity generation is about 30% efficient, whereas combined heat and power (also called co-generation) converts up to 90 percent of the fuel into usable energy.[24]

Advanced boilers and furnaces can operate at higher temperatures while burning less fuel. These technologies are more efficient and produce fewer pollutants.[24]

Over 45 percent of the fuel used by US manufacturers is burnt to make steam. The typical industrial facility can reduce this energy usage 20 percent (according to the US Department of Energy) by insulating steam and condensate return lines, stopping steam leakage, and maintaining steam traps.[24]

Electric motors usually run at a constant speed, but a variable speed drive allows the motor’s energy output to match the required load. This achieves energy savings ranging from 3 to 60 percent, depending on how the motor is used. Motor coils made of superconducting materials can also reduce energy losses.[24] Motors may also benefit from voltage optimisation.

Industry uses a large number of pumps and compressors of all shapes and sizes and in a wide variety of applications. The efficiency of pumps and compressors depends on many factors but often improvements can be made by implementing better process control and better maintenance practices. Compressors are commonly used to provide compressed air which is used for sand blasting, painting, and other power tools.

According to the US Department of Energy, optimizing compressed air systems by installing variable speed drives, along with preventive maintenance to detect and fix air leaks, can improve energy efficiency 20 to 50 percent.[24]

Vehicles

Toyota Prius used by NYPD Traffic Enforcement

The estimated energy efficiency for an automobile is 280 Passenger-Mile/10^6 Btu.[25] There are several ways to enhance a vehicle's energy efficiency. Using improved aerodynamics to minimize drag can increase vehicle fuel efficiency. Reducing vehicle weight can also improve fuel economy, which is why composite materials are widely used in car bodies.

More advanced tires, with decreased tire to road friction and rolling resistance, can save gasoline. Fuel economy can be improved by up to 3.3% by keeping tires inflated to the correct pressure.[26] Replacing a clogged air filter can improve a cars fuel consumption by as much as 10 percent on older vehicles. [27] On newer vehicles (1980s and up) with fuel-injected, computer-controlled engines, a clogged air filter has no effect on mpg but replacing it may improve acceleration by 6-11 percent.[28]

Typical Brazilian filling station with four alternative fuels for sale: biodiesel (B3), gasohol (E25), neat ethanol (E100), and compressed natural gas (CNG). Piracicaba, Brazil.

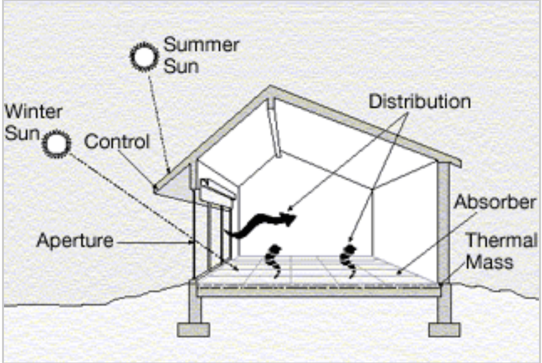
Energy-efficient vehicles may reach twice the fuel efficiency of the average automobile. Cutting-edge designs, such as the diesel Mercedes-Benz Bionic concept vehicle have achieved a fuel efficiency as high as 84 miles per US gallon (2.8 L/100 km; 101 $\text{mpg}_{\text{-imp}}$), four times the current conventional automotive average.[29]

The mainstream trend in automotive efficiency is the rise of electric vehicles (all@electric or hybrid electric). Hybrids, like the Toyota Prius, use regenerative braking to recapture energy that would dissipate in normal cars; the effect is especially pronounced in city driving.[30] Plug-in hybrids also have increased battery capacity, which makes it possible to drive for limited distances without burning any gasoline; in this case, energy efficiency is dictated by whatever process (such as coal-burning, hydroelectric, or renewable source) created the power. Plug-ins can typically drive for around 40 miles (64 km) purely on electricity without recharging; if the battery runs low, a gas engine kicks in allowing for extended range. Finally, all-electric cars are also growing in popularity; the Tesla Roadster sports car is the only high-performance all-electric car currently on the market, and others are in preproduction.[31]

Alternative fuels

Alternative fuels, known as non-conventional or advanced fuels, are any materials or substances that can be used as fuels, other than conventional fuels. Some well known alternative fuels include biodiesel, bioalcohol (methanol, ethanol, butanol), chemically stored electricity (batteries and fuel cells), hydrogen, non-fossil methane, non-fossil natural gas, vegetable oil, and other biomass sources.

Energy conservation



Elements of passive solar energy design, shown in a direct gain application

Energy conservation is broader than energy efficiency in including active efforts to decrease energy consumption, for example through behavioural change, in addition to using energy more efficiently. Examples of conservation without efficiency improvements are heating a room less in winter, using the car less, air-drying your clothes instead of using the dryer, or enabling energy saving modes on a computer. As with other definitions, the boundary between efficient energy use and energy conservation can be fuzzy, but both are important in environmental and economic terms.[32] This is especially the case when actions are directed at the saving of fossil fuels.[33] Energy conservation is a challenge requiring policy programmes, technological development and behavioral change to go hand in hand. Many energy intermediary organisations, for example governmental or non-governmental organisations on local, regional, or national level, are working on often publicly funded programmes or projects to meet this challenge.[34]

The National Renewable Energy Laboratory maintains a comprehensive list of apps useful for energy efficiency.[35]

Commercial property managers that plan and manage energy efficiency projects generally use a software platform to perform energy audits and to collaborate with contractors to understand their full range of options. The Department of Energy (DOE) Software Directory (http://apps1.eere.energy.gov/buildings/tools_directory/software.cfm/ID=622/pagename=alpha_list_sub) describes EnergyActio software, a cloud based platform designed for this purpose.

Sustainable energy

Energy efficiency and renewable energy are said to be the “twin pillars” of a sustainable energy policy. Both strategies must be developed concurrently in order to stabilize and reduce carbon dioxide emissions. Efficient energy use is essential to slowing the energy demand growth so that rising clean energy supplies can make deep cuts in fossil fuel use. If energy use grows too rapidly, renewable energy development will chase a receding target. Likewise, unless clean energy supplies come online rapidly, slowing demand growth will only begin to reduce total carbon emissions; a reduction in the carbon content of energy sources is also needed. A sustainable energy economy thus requires major commitments to both efficiency and renewables.[36]

Rebound effect

If the demand for energy services remains constant, improving energy efficiency will reduce energy consumption and carbon emissions. However, many efficiency improvements do not reduce energy consumption by the amount predicted by simple engineering models. This is because they make energy services cheaper, and so consumption of those services increases. For example, since fuel efficient vehicles make travel cheaper, consumers may choose to drive farther, thereby offsetting some of the potential energy savings. Similarly, an extensive historical analysis of technological efficiency improvements has conclusively shown that energy efficiency improvements were almost always outpaced by economic growth, resulting in a net increase in resource use and associated pollution.[37] These are examples of the direct rebound effect.[38]

Estimates of the size of the rebound effect range from roughly 5% to 40%.[39][40][41] The rebound effect is likely to be less than 30% at the household level and may be closer to 10% for transport.[38] A rebound effect of 30% implies that improvements in energy efficiency should achieve 70% of the reduction in energy consumption projected using engineering models. The rebound effect may be particularly large for lighting, because in contrast to tasks like transport there is effectively no upper limit on how much light could be considered useful.[42] In fact, it appears that lighting has accounted for about 0.7% of GDP across many societies and hundreds of years, implying a rebound effect of 100%.[43]

Organisations and programs

International

- 80 Plus
- 2000-watt society
- IEA Solar Heating & Cooling Implementing Agreement Task 13
- International Institute for Energy Conservation
- International Energy Agency (e.g. One Watt initiative)
- International Electrotechnical Commission
- International Partnership for Energy Efficiency Cooperation
- World Sustainable Energy Days

Australia

- Department of Climate Change and Energy Efficiency
- Department of the Environment, Water, Heritage and the Arts
- Sustainable House Day

European Union

- Building energy rating
- Eco-Design of Energy-Using Products Directive
- Energy efficiency in Europe

- Orgalime, the European engineering industries association

Iceland

- Marorka
- Africa

India

- 88888 Lights Out
- Bureau of Energy Efficiency
- Energy Efficiency Services Limited

Japan

- Cool Biz campaign

Lebanon

- The Lebanese Center for Energy Conservation

United Kingdom

- The Carbon Trust
- Energy Saving Trust
- National Energy Action
- National Energy Foundation
- Creative Energy Homes
- Energy Managers Association (http://www.theema.org.uk/)

United States

- Alliance to Save Energy
- American Council for an Energy-Efficient Economy (ACEEE)
- Building Codes Assistance Project
- Building Energy Codes Program
- Consortium for Energy Efficiency
- Energy Star, from United States Environmental Protection Agency
- Enervee
- Industrial Assessment Center
- National Electrical Manufacturers Association
- Rocky Mountain Institute

- Indian energy strategies

See also

- Cogeneration
- Data center infrastructure efficiency
- Electrical energy efficiency on United States farms
- Electric vehicle#Efficiency
- Energy audit
- Energy Efficiency Implementation
- Energy recovery
- Energy resilience
- Performance per watt
- List of energy storage projects
- List of least carbon efficient power stations
- Negawatt power
- Passenger miles per gallon
- Renewable heat
- Standby power
- U.S. Department of Energy Solar Decathlon
- The Green Deal
- World Energy Engineering Congress
- Energy Reduction Assets
- John A. "Skip" Laitner

References

1. ^ "Philips Tornado Asian Compact Fluorescent" (http://www.lamptech.co.uk/Spec%20Sheets/Philips%20CFL%20Tornado.htm). Philips. Retrieved 2007-12-24.
2. ^ Diesendorf, Mark (2007). *Greenhouse Solutions with Sustainable Energy*, UNSW Press, p. 86.
3. ^ Sophie Hebden (2006-06-22). "Invest in clean technology says IEA report" (http://www.scidev.net/News/index.cfm?fuseaction=readNews&itemid=2929&language=1). Scidev.net. Retrieved 2010-07-16.
4. ^ "The Twin Pillars of Sustainable Energy: Synergies between Energy Efficiency and Renewable Energy Technology and Policy" (http://web.archive.org/web/20080505041521/http://aceee.org/store/proddetail.cfm?CFID=2957330&CFTOKEN=50269931&ItemID=432&CategoryID=7). Aceee.org. Archived from the original (http://aceee.org/store/proddetail.cfm?CFID=2957330&CFTOKEN=50269931&ItemID=432&CategoryID=7) on 2008-05-05. Retrieved 2010-07-16.

5. ^ Zehner, Ozzie (2012). *Green Illusions* (http://greenillusions.org). London: UNP. pp. 180–181.
6. ^ "Loading Order White Paper" (http://www.energy.ca.gov/2005publications/CEC-400-2005-043/CEC-400-2005-043.PDF) (PDF). Retrieved 2010-07-16.
7. ^ "Weatherization in Austin, Texas" (http://www.greencollaroperations.com/weatherization-austin-tx.html). Green Collar Operations. Retrieved 2010-07-16.
8. ^ STEVE LOHR (November 29, 2006). "Energy Use Can Be Cut by Efficiency, Survey Says" (http://www.nytimes.com/2006/11/29/business/29energy.html). *the newyork times*. Retrieved November 29, 2006.
9. ^ http://unfccc.int/files/press/news_room/press_releases_and_advisories/application/pdf/20070831_vienna_closing_pre
10. ^ "Ecosavings" (http://ecosavings.electrolux.com/#int_en). Electrolux.com. Retrieved 2010-07-16.
11. ^ "Ecosavings (Tm) Calculator" (http://www.electrolux.com/ecosavings_us). Electrolux.com. Retrieved 2010-07-16.
12. ^ McKinsey & Company (2009). *Pathway to a Low-Carbon Economy : Version 3 of the Global Greenhouse Gas Abatement Cost Curve*, p. 7.
13. ^ ***a b c d*** Environmental and Energy Study Institute. "Energy-Efficient Buildings: Using whole building design to reduce energy consumption in homes and offices" (http://www.eesi.org/buildings_efficiency_0506). Eesi.org. Retrieved 2010-07-16.
14. ^ "The impact of energy efficiency on peak demand" (http://www.energydsm.org/energy-efficiency). Energydsm.com. Retrieved 2010-07-16.
15. ^ ***a b*** "Empire State Building Achieves LEED Gold Certification | Inhabitat New York City" (http://inhabitat.com/nyc/empire-state-building-achieves-leed-gold-certification/). Inhabitat.com. Retrieved October 12, 2011.
16. ^ "CFL savings calculator" (http://www.green-energy-efficient-homes.com/cfl-savings-calculator.html). Green-energy-efficient-homes.com. 2013-08-06. Retrieved 2013-08-21.
17. ^ Creating Energy Efficient Offices - Electrical Contractor Fit-out Article
18. ^ "Wireless smart meter by ecowizard" (http://www.ecowizard.net/). Ecowizard.net. Retrieved 2010-07-16.
19. ^ Yezioro, A; Dong, B; Leite, F (2008). "An applied artificial intelligence approach towards assessing building performance simulation tools". *Energy and Buildings* **40** (4): 612. doi:10.1016/j.enbuild.2007.04.014 (http://dx.doi.org/10.1016%2Fj.enbuild.2007.04.014).
20. ^ http://jeancarassus.zumablog.com/images/2128_uploads/Fuerst_New_paper.pdf
21. ^ "Visit > Sustainability & Energy Efficiency | Empire State Building" (http://esbnyc.com/sustainability_energy_efficiency.asp). Esbnyc.com. 2011-06-16. Retrieved 2013-08-21.
22. ^ Amory Lovins (March–April 2012). "A Farewell to Fossil Fuels" (http://www.foreignaffairs.com/articles/137246/amory-b-lovins/a-farewell-to-fossil-fuels). *Foreign Affairs*.
23. ^ http://www.efficco.com/about-us.php
24. ^ ***a b c d e*** Environmental and Energy Study Institute. "Industrial Energy Efficiency: Using new technologies to reduce energy use in industry and manufacturing" (http://archives.eesi.org/publications/Fact%20Sheets/EC_Fact_Sheets/EE_Industry.pdf). Eesi.org. Retrieved 2010-07-16.
25. ^ Richard C. Dorf, *The Energy Factbook*, McGraw-Hill, 1981
26. ^ "Tips to improve your Gas Mileage" (http://www.fueleconomy.gov/feg/maintain.shtml). Fueleconomy.gov. Retrieved 2010-07-16.

27. ^ http://www.eesi.org/files/auto_efficiency_0506.pdf
28. ^ http://www.fueleconomy.gov/feg/pdfs/Air_Filter_Effects_02_26_2009.pdf
29. ^ http://www.eesi.org/files/auto_efficiency_0506.pd
30. ^ Nom * (2013-06-28). "La Prius de Toyota, une référence des voitures hybrides | L'énergie en questions" (https://www.lenergieenquestions.fr/prius-toyota-modele-reference-voitures-hybrides/). Lenergieenquestions.fr. Retrieved 2013-08-21.
31. ^ "2008 Tesla Roadster - Car News" (http://www.caranddriver.com/reviews/hot_lists/car_shopping/green_machines/2008_tesla_roadster_car_news). Car and Driver. Retrieved 2010-07-16.
32. ^ Dietz, T. et al. (2009).Household actions can provide a behavioral wedge to rapidly reduce U.S. carbon emissions (http://www.pnas.org/content/106/44/18452.full). PNAS. 106(44).
33. ^ Diesendorf, Mark (2007). *Greenhouse Solutions with Sustainable Energy*, UNSW Press, p. 87.
34. ^ Breukers, Heiskanen, et al. (2009). Interaction schemes for successful demand-side management. Deliverable 5 of the CHANGING BEHAVIOUR (http://www.energychange.info/index.php) project. Funded by the EC (#213217).
35. ^ "National Renewable Energy Laboratory. (2012)" (http://en.openei.org/apps/). En.openei.org. Retrieved 2013-08-21.
36. ^ [1] (http://www.paenergyfuture.psu.edu/pubs/aceee_reports/aceee2007sustainable.pdf)(American Council for an Energy-Efficient Economy)
37. ^ Huesemann, Michael H., and Joyce A. Huesemann (2011). *Technofix: Why Technology Won't Save Us or the Environment* (http://www.newtechnologyandsociety.org), Chapter 5, "In Search of Solutions II: Efficiency Improvements", New Society Publishers, Gabriola Island, Canada.
38. ^ ***a b*** The Rebound Effect: an assessment of the evidence for economy-wide energy savings from improved energy efficiency (http://www.ukerc.ac.uk/Downloads/PDF/07/0710ReboundEffect/0710ReboundEffectReport.pdf) pp. v-vi.
39. ^ Greening, Lorna A.; David L. Greene; Carmen Difiglio (2000). "Energy efficiency and consumption—the rebound effect—a survey". *Energy Policy* **28** (6–7): 389–401. doi:10.1016/S0301-4215(00)00021-5 (http://dx.doi.org/10.1016%2FS0301-4215%2800%2900021-5).
40. ^ Kenneth A. Small and Kurt Van Dender (September 21, 2005). "The Effect of Improved Fuel Economy on Vehicle Miles Traveled: Estimating the Rebound Effect Using U.S. State Data, 1966-2001" (http://repositories.cdlib.org/ucei/policy/EPE-014). University of California Energy Institute: Policy & Economics. Retrieved 2007-11-23.
41. ^ "Energy Efficiency and the Rebound Effect: Does Increasing Efficiency Decrease Demand?" (http://www.policyarchive.org/handle/10207/bitstreams/3492.pdf). Retrieved 2011-10-01.
42. ^ Kyba, C. C. M.; Hänel, A.; Hölker, F. "Redefining efficiency for outdoor lighting". *Energy & Environmental Science*. doi:10.1039/C4EE00566J (http://dx.doi.org/10.1039%2FC4EE00566J).
43. ^ Tsao, J Y; Saunders, H D; Creighton, J R; Coltrin, M E; Simmons, J A (8 September 2010). "Solid-state lighting: an energy-economics perspective". *Journal of Physics D: Applied Physics* **43** (35): 354001. doi:10.1088/0022-3727/43/35/354001 (http://dx.doi.org/10.1088%2F0022-3727%2F43%2F35%2F354001).