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An overview of the energy efficiency potential

John A. "Skip" Laitner*

Economic and Human Dimensions Research Associates, 5751 North Kolb Road, Suite 40108, Tucson, AZ 85750-3773, United States

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ABSTRACT

The global economy is not particularly energy-efficient. At current levels of consumption the U.S. economy, for example, is an anemic 14% efficient – which means that the United States wastes about 86% of the energy now burned to maintain its economy. Most recently, Laitner et al. (2012) documented an array of untapped cost-effective energy efficiency resources roughly equivalent to 250 billion barrels of oil. That is a sufficient scale that would enable the U.S. to cut total energy needs in half compared to business-as-usual projections for the year 2050, and still maintain a robust economy.

1. Introduction

All interactions of matter involve flows of energy. This is true whether they have to do with earthquakes, the movement of the planets, or the various biological and industrial processes at work almost anywhere in the world. Within the context of a regional or national economy, the assumption is that energy should be used as efficiently as possible. An industrial plant working two shifts a day 6 days a week for 50 weeks per year, for example, may require more than one million dollars per year in purchased energy if it is to maintain operation. An average American household may spend $2000 or more per year for electricity and natural gas to heat, cool, and light the home as well as to power all of the appliances and gadgets within the house. And an over-the-road trucker may spend $60,000 or more per year on fuel to haul freight an average of 100,000 miles. Regardless of either the scale or the kind of activity, a more energy-efficient operation can lower overall costs for the manufacturing

* Tel.: +1 571 332 9434.
E-mail address: econskip@gmail.com

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plant, for the household, and for the trucker. The question is whether the annual energy bill savings are worth either the cost or the effort that might be necessary to become more energy-efficient?[1]

In one sense of the word, the global economy is not especially energy-efficient. At current levels of consumption the U.S. economy, for example, is only 14% energy-efficient – which means that the United States wastes about 86% of the energy now burned to maintain its economy (Laitner, 2013) building on (Ayres and Warr, 2009). Because of that very significant level of inefficiency, many in the business and the policy community increasingly look to energy efficiency improvements as cost-effective investments to reduce waste and cut costs. One current example of this win–win opportunity is the advent of energy service companies (ESCo's) that save energy for clients at no cost to them, while making a profit for themselves.

The current system of generating and delivering electricity to homes and businesses in the United States is just 32% efficient. That is, for every three lumps of coal or other fuel used to generate power, only one lump in the form of electricity is actually delivered to homes and businesses. What America wastes in the generation of electricity is more than Japan needs to power its entire economy. The technologies that power the fossil–fuel economy, for example the internal combustion engine and steam turbines, are no more efficient today than they were in 1960, when President Eisenhower was in office. Laitner (2013) suggests that this level of inefficiency may actually constrain the greater productivity of the economy. And yet, any number of technologies can greatly improve energy performance. Combined heat and power (CHP) systems, for example, can deliver efficiencies of 65–80% or more in generating power and usable heat or steam, at a substantial economic savings (Chittum and Sullivan, 2012). And an incredible array of waste-to-energy and recycled energy technologies can further increase overall efficiency and save money (Worrell et al., 2003).

2. Historical impact of energy efficiency

As one of the richest and more technologically advanced regions of the world, the United States has expanded its economic output by more than 3-fold since 1970. Per capita incomes are also twice as large today compared to incomes in 1970. Notably, however, the demand for energy and power resources grew by only 40% during the same period.[2] This decoupling of economic growth and energy consumption is a function of increased energy productivity: in effect, the ability to generate greater economic output (that is, to produce more goods and services), but to do so with less energy. Having achieved these past gains with an often ad hoc approach to energy efficiency improvements, there is compelling evidence to suggest that even greater energy productivity benefits can be achieved. Indeed, the evidence suggests that since 1970, energy efficiency, in its many different forms has met three-fourths of the new U.S. demands for energy services to maintain the production of goods and services. And this has happened, despite the lack of efficiency gains in the electric power sector, as pointed out by Casten (this volume).

Energy efficiency has been an invisible resource. Unlike a new power plant or a new oil well, we do not see energy efficiency at work. A new car that gets 20 miles per gallon, for example, may not seem all that much different than a car that gets 40 miles or more per gallon. And yet, the first car may consume 500 gallons of gasoline to go 10,000 miles in a single year while the second car my need to only 250 gallons per year. In effect, energy efficiency in this example is the energy we do not use to travel 10,000 miles per year. More broadly, energy efficiency may be thought of as the cost-effective investments in the energy we do not use either to produce a certain amount of goods and services within the economy.

3. The cost-effective potential for exploiting the energy efficiency resource

Can the substantial investments that might be required in the more energy-efficient technologies save money for businesses and consumers? Lazard Asset Management (2012) provides a detailed

[1] The mentioned energy expenditures are derived from several calculations by the author.

[2] These and other economic and energy-related data cited are the author's calculations based on data drawn from various resources available from the Energy Information Administration (EIA annual-a, 2012; annual-b for 2013).

review of the various costs associated with electricity generation. They note, for instance, that meeting new energy demand by building new coal and nuclear power plants might cost an average of 8–14 cents per kilowatt-hour (kWh) of electricity generated. The costs for various renewable energy resources such as wind energy or photovoltaic energy systems (i.e. solar cells that convert sunlight directly into electricity) might range from 6 to 20 cents per kWh. In comparison, both Lazard and the American Council for an Energy-Efficient Economy (ACEEE) estimate a range of energy efficiency measures that might cost the equivalent of 3–5 cents per kWh of electricity service (Lazard Asset Management, 2012; Elliott et al., 2011). McKinsey and Company (2007) identified vast opportunities for investments in energy efficiency that would generate at least a 10% return on investment. When spread out over an annual $170 billion energy efficiency market potential, McKinsey suggested an average 17% return might be expected across that spread of annual investments. A subsequent study (McKinsey and Company, 2009) suggests that through the year 2020 there is sufficient cost-effective opportunity to reduce our nation's energy use by more than 20% – if we choose to invest in the more efficient use of our energy resources.

Such investments can deliver dramatic reductions in pollution. The Union of Concerned Scientists (Cleetus et al., 2009) recently published a detailed portfolio of technology and program options that would lower U.S. heat-trapping greenhouse gas emissions 56% below 2005 levels in 2030. Their analysis indicated an annual $414 billion savings for U.S. households, vehicle owners, businesses, and industries by 2030. After subtracting out the annual $160 billion costs (constant 2006 dollars) of the various policy and technology options, the net savings are on the order of $255 billion per year. Over the entire 2010 through 2030 study period, the net cumulative savings to consumers and businesses were calculated to be on the order of $1.7 trillion under their recommended scenario.

Most recently, Laitner et al. (2012) documented an array of untapped cost-effective energy efficiency resources roughly equivalent to 250 billion barrels of oil. That is a sufficient scale that would enable the United States to cut total energy needs in half compared to business-as-usual projections for the year 2050. Capturing this energy efficiency resource could generate from 1.3 to 1.9 million jobs while saving all residential and business consumers a net $400 billion per year, or the equivalent of about $2600 per household annually (in 2010 dollars). At the international level, the *World Energy Outlook 2012* produced by the International Energy Agency (IEA, 2012) highlighted the potential for energy efficiency to save 18% of the 2010 global energy consumption by 2035 – while increasing global GDP by 0.4%.

There are two final aspects of the evidence to briefly review. The first is associated with the non-energy benefits that typically accrue to energy efficiency investments. The second reflects the changes one might normally expect in the cost and performance of technologies over time.

When energy efficiency measures are implemented in industrial, commercial, or residential settings, several non-energy benefits such as maintenance cost savings and enhanced productivity (with associated revenue increases) can often result in addition to the anticipated energy savings. The magnitude of non-energy benefits from energy efficiency measures is significant. These added savings or productivity gains range from reduced waste of both water and chemicals to increased product yield and greater product quality. In one study of 52 industrial efficiency upgrades, all undertaken in separate industrial facilities, Worrell et al. (2003) found that the non-energy benefits were sufficiently large that they lowered the aggregate simple payback for energy efficiency projects from 4.2 years to 1.9 years.

Another study for 81 separate industrial energy efficiency projects showed that the simple payback from energy savings alone was less than 2 years, indicating annual returns higher than 50%. When non-energy benefits were factored into the analysis, the simple payback fell to just under one year (Lung et al., 2005). In residential buildings, non-energy benefits have been estimated to represent between 10 and 50% of household energy savings (Amann, 2006). Unfortunately, these non-energy benefits from energy efficiency measures are often omitted from conventional performance metrics. This leads, in turn, to overly modest payback calculations and an imperfect understanding of the full impact of additional efficiency investments.

There is also a significant body of evidence that indicates that technology is dynamic, and facilitates continual improvements in efficiency over time. The rapid technological change seen especially in semiconductor-enabled technologies, for example, has led to cheaper, higher performing, and more energy-efficient technologies (Laitner et al., 2009). The increasing penetration of information and communication technologies interacting with energy-related behaviors and products suggests that energy efficiency resource may become progressively cheaper and more dynamic as the 21st century moves on (Ehrhardt and Laitner, 2008). Given this and many other comparable studies, one might conclude with the very strong likelihood that progress in the cost and performance of energy efficient technologies will continue, and that stringent, well-focused public policies will greatly increase the continued rate of improvement (McKinsey and Company, 2009; Koomey, 2008).

4. Overcoming barriers to improving energy efficiency

There is a range of market imperfections, market barriers, and real world behaviors that leaves substantial room for public policy to induce behavioral changes that produce economic benefits. One classic example is the misaligned incentive that exists for those living in rental units when the renter pays the energy bills but the landlord purchases the large appliances such as refrigerators and water heaters. In this case, the purchaser of the durable good does not reap the benefits of greater energy efficiency. The Market Advisory Committee of the California Air Resources Board (California Air Resources Board, 2007) provides a nice short overview of key market failures.[3] A deeper exploration of the types of market barriers is beyond the scope of this paper, but others have done work to map this terrain (Sathaye and Murtishaw, 2004; Murtishaw and Sathaye, 2006; Levinson and Niemann, 2004; Levine et al., 1995; Brown, 2001; Geller et al., 2006; Brown et al., 2009).

The importance of reflecting policies that might be directed at market failures was explored, in part, by Hanson and Laitner. In one of the few top-down models that explicitly reflects both policies and behavioral changes as a complement to pricing signals, they found that the combination of both price and non-pricing policies (e.g., performance standards, eco-labeling, and product information more broadly) actually resulted in a significantly greater level of energy efficiency gains and a lower carbon permit price to achieve the same level of emissions reductions (Hanson and Laitner, 2004).

One critical comment on the rebound effect may be appropriate at this point. Lower energy prices and a positive income effect are likely to follow these energy efficiency improvements. These, in turn, may erode some of the net energy savings as lower prices and a slightly higher income encourage more energy use. But as Ehrhardt-Martinez and Laitner (2010) point out, this rebound effect is likely to be limited to 10–30% of the initial energy savings in the short term. Moreover, just as we learn how to manage efficiency improvements, we can also learn over time how to mitigate the rebound effect with improved resource management strategies and people-centered energy initiatives. On balance, the net energy savings and benefits are likely to remain significant – if we choose to pursue the full set of energy efficiency opportunities.

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[3] Following are examples of three important market failures and suggested remedies: (1) step-change technology development in which there may be many uncertainties about appropriate technologies, as well as both market, and policy risks. Temporary incentives might be used to encourage companies to deploy new technologies at sufficient scale in ways that benefit the public good. Other remedies might include energy efficiency resource standards, energy or fuel performance standards and low-carbon fuel standards. (2) Fragmented supply chains – where economically rational investments (for example, energy efficiency in buildings) are not executed because of the complex supply chain. Examples of remedies are building codes or incentives for performance upgrades. (3) Consumer behavior where individuals have demonstrated high discount rates for investments in energy efficiency. Examples of remedies are vehicle and appliance efficiency standards and rebate programs (California Air Resources Board, 2007, p.19).

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