Industry, Energy Efficiency and Productivity Improvements

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ABSTRACT

A detailed review of more than 77 industrial case studies from widely available published databases suggests that energy efficiency investments yield significant non-energy benefits which are often not calculated. The description of energy-efficient technologies as opportunities for larger productivity improvements not only has significant implications for re-thinking how we quantify the savings associated with capital investment and the leverage points for promoting energy efficiency but may even challenge methods used for conventional economic assessments. The paper explores the implications of how this change in perspective might affect the evaluation of energy-efficient technologies for a wide range of industries.

Introduction

In 1990, executives at a North Carolina textile firm decided to install a radio frequency dryer to replace a natural gas system that was used to dry cashmere wool. The radio frequency dryers vibrate the water molecules in the fabric. The process creates sufficient heat to turn the water into steam, effectively removing it from the material. The process is more efficient and less damaging to the wool than directly heating it in the natural gas dryer. As a result, the project not only reduced the energy required for drying by nearly half, it also reduced fiber loss from over-drying by more than five percent. The energy savings was about $0.05 per pound of cashmere, while the savings from reducing the fiber losses (at a cost of $30 per pound of material) was more than $1.50 per pound of dried fabric (Cato, Crabtree & Flora 1991).

At first the total benefits of this so-called "cashmere effect" may seem to be an extreme example of larger productivity gains from an energy efficiency investment. Yet, a review of the relevant literature (see, for example, Sullivan, Roop and Schulz 1997; and Elliott, Laitner and Pye 1997) and a detailed assessment of 77 industrial case studies completed for this paper (Laitner and Finman, 2001) both suggest that this may not be a case in isolation. Indeed, it appears that many energy efficiency investments can provide a significant boost to overall productivity within the U.S. economy.

Productivity as a Function of Energy-Efficient Investments

Before examining the productivity issue further, it is helpful to review what is meant by the term "productivity." In general, productivity expresses a relationship between the quantity of goods and services produced by a business or an economy and the quantity of labor, capital, energy, and other resources that are needed to produce those goods and services.

For example, if an aluminum wheel manufacturer reduces scrap rates from 30 percent to only 10 percent, the number of aluminum ingots necessary to produce those wheels can be reduced. Similarly, if energy consumption in paper making is reduced from 18,500 Btus per dollar of sales to 15,000 Btus per dollar of sales, total energy consumption is reduced relative to the same level of sales. Finally, if steel making reduces energy consumption by 4 million Btus (MBtu) per ton of raw steel produced, for a savings of about $10 per ton, another $18 of savings may be realized in the form of lower operating and maintenance costs, increased products, and improved product quality. In all three cases, the manufacturer is said to be more productive when such changes lead to lower operating costs per unit of product.

One recent paper by Evan Mills and Art Rosenfeld (1994), in particular, provides a nice framework for understanding the many benefits of energy efficiency investments that extend beyond the energy bill savings alone. Although recognizing the national benefits (e.g., improved competitiveness, energy security, net job creation, and environmental protection) as important, the authors provide a detailed description of user benefits made possible by efficiency technologies. The full set of non-energy benefits reflect: (1) improved indoor environments, (2) noise reduction, (3) labor and time savings, (4) improved process control, (5) increased amenity or convenience, (6) water savings and waste minimization, and (7) direct and indirect economic benefits from downsizing or elimination of equipment.

Mills and Rosenfeld note that these non-energy benefits play a key role in consumer decision making. As a result, efforts to incorporate them in program design and marketing will help accelerate the uptake of energy-efficient technologies. Focusing on the non-energy or productivity benefits discussed in the 77 case studies reviewed below, we identified five broad categories or common themes. As Table 1 on the following page illustrates, these include (not in order of importance): reduced waste, lower emissions, improved maintenance and operating costs, increased production and product quality, and an improved working environment. We've also included an "other" category to identify those benefits which were outside of the other categories, but still worthy of noting.

Manufacturing Case Studies

In order to gain an overview of the costs and benefits of a wide variety of energy efficiency upgrades, we identified a total of 77 case studies with sufficiently documented non-energy benefits. The projects were drawn from examples in 10 states and 6 countries. They included the full spectrum of manufacturing activities. However, only 52 had sufficient data to quantify or assign a monetary value to some portion of the reported non-energy benefits. These case studies were drawn from reports or studies from the Alliance to Save Energy, American Council for an Energy Efficient Economy, the CADDET Energy Efficiency Web site, the Climate Wise case study compendium, Cool Companies, the Office of Industrial Technologies, among others.

Table 1. Non-Energy Benefits From Efficiency Improvements

Waste	Emissions	Maintenance and Operating
Use of waste fuels, heat, gas	Reduced dust emissions	Reduced need for engineering controls
Reduced product waste	Reduced CO, CO2, NOx, SOx emissions	Lowered cooling requirements
Reduced waste water		Increased facility reliability
Reduced hazardous waste		Reduced wear and tear on equipment/machinery
Materials reduction		Reductions in labor requirements
Production	**Working Environment**	**Other**
Increased product output/yields	Reduced need for personal protective equipment	Decreased liability
Improved equipment performance	Improved lighting	Improved public image
Shorter process cycle times	Reduced noise levels	Delaying or Reducing capital expenditures
Improved product quality/purity	Improved temperature control	Additional space
Increased Reliability in Production	Improved air quality	Improved worker morale

Data for each case study were entered in an Excel workbook. Typical data entries included project cost, energy savings, non-energy savings when applicable, the "energy only" payback, and payback associated with total project savings. Fifty-two case studies that documented non-energy savings- or for which non-energy savings were calculable- were tracked in a single spreadsheet. Twenty-five case studies without quantifiable non-energy savings were tracked in a separate spreadsheet. This paper analyzes trends in both categories of projects.

For case studies that quantified non-energy benefits but did not assign a dollar value to those savings, we generated an avoided cost estimate based upon published data found elsewhere in the literature. All costs and prices were converted into U.S. 1997 dollars and all energy prices and savings were evaluated on the basis of U.S. average energy costs. Energy savings were calculated on a fuel delivered basis rather than a primary energy basis.

Conversion factors and calculations that were used in the analysis were documented within the workbook.

One note of caution is warranted in that the compilation of case studies reported here does not comprise a statistically valid sample. In other words, the case studies were not selected at random and therefore are not necessarily representative of the universe of case studies. In addition, the sample size of case studies is too small to be representative. However, the data provide useful insights that might assist in the evaluation of energy technology investments and understanding investment behavior in energy efficient technologies.

The Impact of Total Productivity Benefits

The assessment described in this section focuses primarily on the 52 monetized case studies only. Out of hundreds upon hundred of case studies in the literature, only 52 were found that quantified a large portion of the non-energy benefits associated with the investment. Despite the small sample, it is clear that including the non-energy benefits of a project, and incorporating that information into the engineering analysis when making a decision about a capital upgrade, may have a profound effect upon decision making process of a given project.

A look at the 52 monetized case studies reveals a 4.2 year payback based only on the energy savings. This falls to 1.9 year payback for projects when including the full productivity impacts of a project (i.e., dividing the total investment by both the energy savings and the non-energy benefits of a project). Clearly energy savings alone can not account for these investments.

Amongst the data there is no discernable pattern in the frequency of projects based on standard industrial classification (SIC) code. One might expect capital rich industries and industries with high energy or raw materials costs to engage in efficiency improvements more often that of other sectors. Perhaps with a wider range of industries represented in the case study literature, such an assumption might be better tested. Below is a breakdown of projects of the most frequently occurring SIC codes among the monetized case studies. The "energy intensive" industries are most significantly represented in the sample.

The types and frequency of investments documented in the case studies are consistent with the sizable representation of heavy industry. Out of the 77 case studies examined for this analysis, 13 focused on energy savings from more efficient de-watering or water re-use in water intensive industries such as pulp and paper and food processing. Fourteen of the 77 case studies documented improved equipment pre-heating or recycling heat in the manufacturing process. Again, the industries that engaged in these improvements tend to generate and/or use significant amounts of energy in their manufacturing. Other types of process/technology improvements documented in our sample include motor replacements, fans/duct/pipe insulation, improved sensors and controls, and new state-of-the-art technology designs.

Table 2. Monetized Case Study Investments and Paybacks

SIC/ Industry	No of Projects	Total Investment	Energy Savings	Other Savings	Energy Pay-back (Years)	Total Pay-back (Years)
20/ Food Processing	9	$4,407,867	$881,078	$2,167,628	5.0	1.4
22 & 23/ Textiles	6	$3,959,946	$288,305	$1,053,313	13.7	3.0
26/ Pulp & Paper	6	$8,502,333	$3,882,754	$2,181,040	2.2	1.4
28/ Chemicals	6	$23,478,920	$4,569,876	$2,009,542	5.1	3.6
32/ Building Materials	7	$7,498,060	$942,925	$1,349,482	8.0	3.3
33/ Steel	7	$3,991,385	$1,819,908	$6,204,594	2.2	0.5
Misc	11	$2,340,549	$548,409	$729,983	4.3	1.8
Total	52	$54,179,060	$12,933,255	$15,695,582	4.2	1.9

Table 3. SIC Code Frequency Among Monetized Case Studies

SIC Code	Industry	Number of case studies
20	Food Manufacturing	9
32	Building Materials	7
33	Steel Manufacturing	7
26	Paper Manufacturing	6
28	Chemicals Manufacturing	6
22& 23	Textiles	6

It is interesting to note the greater documentation of state-of-the-art case studies compared to conventional projects. Forty-one out of the 77 case studies examined in this review were what we categorized as state-of-the-art projects while 35 dealt with more conventional upgrades and technologies. This could indicate a bias in the documentation towards more new and/or radical approaches or could indicate a bias in our search towards programs that focus on new technologies. The conventional projects were usually far less expensive than the state-of-the-art projects and, surprisingly, yielded greater energy savings per dollar invested. The average state-of-the-art projects cost $863,872,000 and provided an average of $343,279 in energy savings and $183,855 in non-energy savings. The average payback time was 2.5 years without non-energy benefits and 1.6 years with non-energy benefits. In comparison, the conventional projects cost an average $494,550 and provided an average $218,139 in energy savings and $142,152 in non-energy savings. The average payback time was 2.3 years without non-energy benefits and 1.4 years with non-energy savings.

Clearly, the projected cost savings figure into the decision to move forward with a project. However, what initially stimulates a company to consider efficiency investments? In analyzing the initial motivation behind the project in the sample, 28% of all 77 projects and 39% of the 41 state-of-the-art projects cited the need to relieve a production bottleneck or increase productivity as one of the primary reasons for pursuing the project. Productivity benefits include enhanced yields, better equipment performance, shorter process times and improved product quality. Other motives for capital investment cited include energy savings, diversifying product lines, and complying with new regulations. To prevent the reader from over-simplifying the calculus of investment decisions, the authors feel it is important to state that there are many other decision making factors a company considers apart from the derived user benefits. Money made available for capital investments are resources made unavailable to other crucial functions that a company may value more.

According to an analysis of the data by ICF Consulting, of the 52 monetized case studies, the dollar ratio of savings from non-energy benefits to savings from energy efficiency ranged from .03 to over 70, initially indicating a wide range of added value derived from the non-energy benefits. However, in 63% of the cases, the non-energy benefits were equal or greater than the energy savings. In nearly 30 percent of these case studies the non-energy savings were three times more than the energy savings, and in about 25 percent of the cases, the non-energy savings were more than four times the energy savings (Fine and Ogonowski, 1999).

Non-energy benefits clearly yield significant and positive results in these case studies. Some 224 non-energy benefits were cited from the 77 case studies culled for this paper. The most common form of cost reduction observed under the heading of waste/materials reductions are reductions in materials, 12 cases, followed by reductions in water used, 5 cases. The most common abatement of air pollutants among the case studies were reductions in SO_2, NO_x and CO_2 from lessened on site fuel and electricity consumption, followed by reductions in CO, VOCs, and hydrocarbons. There were six cases of reduced dust emissions. The most common benefit cited in the improved maintenance and operation category was lower costs from reduced equipment wear and tear, reported in 20 cases. Reductions in required labor costs were noted in eight cases. Non-energy benefits categorized as other include reductions in noise, reported in five cases, and improved worker morale, reported in two cases.

Conclusions

As this study has shown, a diverse group of industry decision-makers have already discovered the important benefits of energy efficiency technologies as a productivity investment. To achieve the full potential of such investments, however, requires that the analytical tools used to evaluate such projects be significantly upgraded. Many of the case studies in the literature fail to assign a monetary value, or even measure, the non-energy benefits associated with the investment. In short, companies and case study authors need to incorporate methods which better track both the energy and non-energy benefits of a given investment. With better documentation of the user-benefits, we may be able to enhance overall conventional economic analyses which currently tend to overlook the larger productivity benefits from investment-led energy efficiency strategies.

Following this course can go a long way toward breaking the stalemate over environmental issues. It can help forge for new business partnerships and help others understand the full economic benefits for the entire nation. By working together, industry, environmental concerns and governmental interests can advance a more efficient and environmentally sound economic strategy.

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