ENERGY EFFICIENCY PROGRAMS FOR SMALL AND MEDIUM-SIZED INDUSTRY

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EXECUTIVE SUMMARY

Designing successful programs to address the small and medium-sized industrial market segment has been a challenge because of the large number of facilities, limited staff resources within plants, and the relatively small energy savings at each plant. As a result, many utility and federal government programs have focused on larger industrial plants and provided only limited services to smaller plants. Many efficiency programs have offered customized rebate programs targeted at their largest industrial customers while offering only prescriptive recommendations and rebates with little implementation assistance to smaller customers. While customized rebates may work well for a large facility, which has staff dedicated to energy issues, this approach has not worked for smaller customers. Prescriptive programs may not be flexible enough and configured adequately to guide efficiency improvements for a smaller facility.

In this study, we examine the concerns of managers of small and medium-sized facilities and explore the ways in which industrial decisions are made in these facilities. The technical areas for significant energy savings in plants as well as specific industries are outlined. We present a review of existing energy efficiency programs geared toward these plants and analyze how well the programs address the concerns of managers of small and medium-sized facilities. We also look into some of the failures of the existing programs and suggest areas for improvement.

We have found that energy is just one of many concerns of the industrial manager. For peak environmental, energy, and production efficiency, the processes and operations in a plant must be optimized. No single factor should be optimized to the detriment of the others. This task is more readily accomplished at the design phase of a project rather during later retrofits and process improvements. Most current programs for energy efficiency focus on offering prescriptive recommendations or rebates for retrofit energy improvements. It is evident that small and medium-sized firms require much more assistance in order to implement economically viable efficiency improvements. In order to bridge this energy gap, we believe that a more comprehensive program that involves a combination of education, prescriptive recommendations, and implementation assistance is needed. A program option that includes design advice for new product lines and plants should also be included in order to take advantage of the full economic and efficiency potential that a truly optimized facility offers.

Following are the key services that should be included in a successful program targeted at small and medium-sized manufacturers:

(1) Program marketing and outreach;
(2) Opportunity identification;
(3) Technology identification and project design;
(4) Financial analysis;
(5) Purchasing and procurement;
(6) Financing;
(7) Installation; and
(8) Startup and training.

These elements are all necessary for a program to be successful (and by successful we mean that a small or medium-sized industrial facility implements and maintains efficiency improvements that result in energy savings and decreased utility costs per unit of product). Inherent to this type of program would be recognition by and trust of the customer. All of the proceeding eight factors combined will not result in savings if the industrial customer is not aware of program availability or if the perceived risk of participating in this type of program is too high. The entity or entities that administer the program must reach out to the customer and establish a relationship first and foremost.

Many of the elements of a successful program are already embodied in some form in many existing programs targeted to small and medium-sized industrial customers. In order to be a step above the others, a new program must be a more holistic approach, one in which all the elements of the energy efficiency improvement process are taken into account. In some cases, this approach would be too costly and/or difficult for any one entity to provide alone. Partnerships between utilities, public benefit programs, state energy offices, and private contractors may be the method in which the elusive goal of efficiency can be delivered to small and medium-sized manufacturers.

The potential for energy efficiency improvements in small and medium-sized manufacturing facilities is quite large, and may prove to be larger as the face of industry continues to grow and change. The road to efficiency is quite challenging but well worth the trouble.

INTRODUCTION

The energy industry is in the midst of a time of change. In some localities, power providers are becoming privatized and are preparing to compete with each other in a deregulated market. In others, regulated providers are seeking ways to encourage reduced customer demand. Thus, energy providers are reevaluating their range of services and changing the way they do business with their customers. Moreover, due to recent shortages and price increases, many industrial decision-makers are now showing an increased interest in energy issues.

There is a need for successful programs that assist small and medium-sized industrial facilities in implementing and maintaining efficiency improvements that result in energy savings and decreased utility costs per unit of product. The small to medium-sized industrial facility has received limited attention in the past from utilities and energy service providers. This customer category has relatively small energy usage at each facility, but in aggregate represents a significant energy demand for the utility, local economy, and nation.

Designing successful programs to address the small and medium-sized industrial market segment has been a challenge because of the large number of facilities, limited staff resources within plants, and the relatively small energy savings at each plant. As a result, many utility and federal government programs have focused on larger industrial plants and provided only limited services to smaller plants. As will be discussed later, many efficiency programs have offered customized rebate programs targeted at their largest industrial customers while offering only prescriptive recommendations and rebates with little implementation assistance to smaller customers. While customized rebates may work well for a large facility, which has staff dedicated to energy issues, this approach has not worked for smaller customers. Prescriptive programs may not be flexible enough and configured adequately to guide efficiency improvements for a smaller facility.

In this report, we explain the concerns of industrial managers of small and medium-sized facilities and examine the way in which decisions are made at these facilities. We also detail the technical areas for potential savings. Next, we present a review of existing energy efficiency programs geared toward these facilities and analyze how well these programs address the concerns of the industrial managers. Finally, we look into some of the limitations of the existing programs and suggest areas for new program development.

THE IMPORTANCE OF SMALL AND MEDIUM-SIZED INDUSTRY

A multi-organizational study of the potential for energy efficiency in the U.S. economy (Energy Innovations 1997) found that significant potential for efficiency improvement exists in all industrial sectors. The authors also found that abundant, low-cost efficiency opportunities exist in some of the least energy-intensive industries. These industries tend to have a higher representation of small and medium-sized manufacturing plants than the more energy-intensive industries (Bureau of the Census 1996). It is worth noting that small and medium-sized plants exist in all industries, both energy-intensive and non-energy-intensive.

In this report, we will focus on industrial facilities with less than approximately 500 employees and that have power requirements of less than 1 megawatt (MW). We also limit our discussion to facilities that are not part of a large corporation that provides dedicated corporate energy management staff.

CHARACTERIZING SMALL AND MEDIUM-SIZED INDUSTRY

The industrial sector encompasses more than 250,000 establishments engaged in various types of manufacturing. According to the *Manufacturing Energy Consumption Survey 1994* (EIA 1997), these establishments consumed 21,663 trillion British thermal units (Btu) of energy in 1994. In the United States, over one-quarter of the industrial energy use is by small plants with less than 250 employees and almost half of the energy use is by medium-sized plants with less than 500 employees. In fact, according to the *1992 Census of Manufacturers* (Bureau of the Census 1996), over 80 percent of all manufacturing establishments have an average of 250 employees or fewer. Very small establishments (with 1 to 19 employees) account for 67.9 percent of all manufacturing facilities but only 2.5 percent of the value-added by manufacturer. It is interesting to note that the value-added per employee of the larger establishments is almost twice that of smaller establishments. The value-added per employee can be seen as a measure of labor productivity, but also as a measure of the degree of automation and equipment investment in a facility. Later in this report, we will discuss how differing degrees of equipment investment affect the deployment of programs in the small and medium-sized industrial sector.

In the industrial sector, the diversity of processes and ways in which energy is consumed makes it difficult to single out characteristics that drive energy consumption activities for all industries. At the two-digit SIC level, there are no consistent physical units that can be used to measure energy demand per unit of product output. For this reason, we have chosen to use certain monetary-based figures as indicators for demand (EIA 1997).

The United States has taken great strides in identifying the energy savings potential in many of the highly energy-intensive industries. Programs such as Industries of the Future (IOF), administered through the U.S. Department of Energy's (DOE) Office of Industrial Technologies (OIT), focus their efforts on reducing the energy consumption of nine of the most energy-intensive industries in the United States (OIT 2001). The IOF program has had success due to the partnerships that have been forged between DOE and the chief technical officers and staff of many large, energy-intensive corporations. For many of these industries, even small efficiency improvements can result in large energy cost savings.

The IOF program has helped to increase the awareness of the benefits of energy efficiency among large industrial firms. The program requires that all research and development projects that receive funding be cost-shared with at least one corporation (OIT 2001). This approach helps to ensure that the firms that receive the funds maintain a vested interest in the progress of the research.

While this method works very well within corporations that have staff specifically dedicated to energy efficiency, for reasons that will be elaborated upon later in this report, this approach does not work well for the smaller businesses.

Successful programs can benefit small and medium-sized industries. Experience from existing programs like the DOE's Industrial Assessment Centers (IAC) and the New York State Research and Development Authority's (NYSERDA) *FlexTech* indicates that 10 percent reduction in energy use is achievable at these facilities with limited effort. More significant savings can be achieved with some additional effort and investment (Muller, Simek, and Mak 1995). Smaller industrial plants may have a larger relative saving potential than larger facilities because these facilities have not yet taken advantage of many of the efficiency opportunities that have already been implemented at the more energy-intensive facilities. Small plants have more limited capabilities to identify and implement these savings opportunities because internal technical staff must deal with a broad range of issues and may not have the time or resources to focus on energy issues.

This reduced ability to realize energy efficiency exists despite the fact that energy costs are of a greater importance to the financial viability of many smaller firms. Smaller manufacturers often pay higher prices for energy than do larger firms and use the energy less efficiently. There are a number of reasons for this: smaller facilities do not qualify for the large volume discounts; they often use less efficient equipment and processes; and they lack the capital and technical skills to invest in efficiency improvements. Small facilities also do not have the power to negotiate utility rates the way that larger ones do. In addition, they may not have the choice of where to procure energy. Utilities are more likely to negotiate rates and conditions of service when they fear that a large customer may take its business elsewhere.

ENERGY USE AND INDUSTRIAL TRENDS

Manufacturers use energy sources in two major ways. The first way is to generate heat, mechanical power, and electricity. The other is as a raw material input to the manufacturing process or for some other non-fuel use purpose, collectively labeled *feedstock energy*. This energy is equal to the heat content of the product coming out of a process plus the energy used in the process minus the heat content of all the materials and energy entering the process. For example, feedstock energy is very large in petroleum refining since the products (generally fuels) have such an inherently high heat content. According to the *Manufacturing Energy Consumption Survey 1994* (MECS), the feedstock components of the first use of energy for all purposes includes 3.2 quadrillion Btus (Quads) of natural gas, coal, fuel oil, and other major energy sources; 0.4 Quads of offsite waste, byproducts, and other materials; and 3.1 Quads of crude oil input to non-energy products. Of the 6.7 Quads of site energy used for feedstock, 5.1 Quads were used in finished products (such as fertilizer ammonia and wax) and 1.6 Quads were reclaimed for use in producing heat and power and generating electricity onsite (EIA 1997).

To determine how energy is used in the manufacturing sector, DOE's Energy Information Administration (EIA) gathers information from a sample of companies that represent over

250,000 manufacturing establishments. These establishments account for approximately 98 percent of the U.S. economic output from manufacturing. The first manufacturing survey was held for reporting year 1985. Since then, data has been collected for reporting years 1988, 1991, 1993, and 1998. For the purposes of this study, we used the data obtained from the 1994 Manufacturing Energy Consumption Survey (EIA 1997). The recently published 1998 MECS has utilized the North American Industrial Classification System (NAICS) instead of the U.S. Standard Industrial Classification (SIC) system. Most industrial program managers are familiar with the SIC system and have tracked data according to this system since 1998. In order to best serve our audience, we have chosen to use the older data set. Table 1 presents energy consumption data for many of the two-digit SIC manufacturing segments and Table 2 presents energy intensities and changes in efficiencies.

According to the MECS data, the largest decreases in energy intensity were in the Furniture and Fixtures group (SIC 25) and the Industrial Machinery and Equipment group (SIC 35), which cut their energy use per unit of output by 33 percent and 18 percent, respectively. Conversely, the Petroleum and Coal Products group (SIC 29) and the Food and Kindred Products group (SIC 20) increased in energy intensity by 32 percent and 17 percent, respectively.[1] In 1994, manufacturers required more offsite-produced energy per unit of production output than in any of the three earlier survey years, consuming 4.01 thousand Btus for each constant dollar (1992) value of shipments. This ratio gradually rose from 3.84 in 1985 to 3.88 in 1988, and then to 3.97 in 1991 (EIA 1997). Between 1985 and 1994, the manufacturing production mix moved toward less energy-intensive industries. Also, the amount of purchased energy increased, indicating increased vulnerability to fluctuations in electricity and fuel pricing.

Table 1. Energy Consumption in the Manufacturing Sector

Industrial Energy Consumption (Quads)	1985	1988	1991	1994
Food SIC 20	0.95	1	0.95	1.18
Textiles SIC 22	0.25	0.28	0.27	0.31
Apparel SIC 23	0.03	0.05	0.04	0.06
Lumber SIC 24	0.33	0.4	0.42	0.44
Furniture SIC 25	0.06	0.05	0.07	0.07
Paper SIC 26	2.2	2.35	2.47	2.63
Chemicals SIC 28	2.41	2.86	3.04	3.27
Petroleum Refining SIC 29	2.63	3.12	2.99	3.26
Rubber and Misc. Plastics SIC 30	0.21	0.25	0.24	0.29
Stone, Clay, and Glass SIC 32	0.9	1	0.89	0.95
Primary Metals SIC 33	2.39	2.62	2.29	2.57
Fabricated Metals SIC 34	0.3	0.34	0.31	0.37
Machinery SIC 35	0.24	0.28	0.24	0.25
Electronic Equipment SIC 36	0.21	0.22	0.2	0.23
All Manufacturing	13.62	15.49	15.03	16.52

Source: EIA 1997

[1] A large portion of the energy use in Food and Kindred Products (SIC 20) is attributable to water treatment. Many facilities (especially large ones) have onsite wastewater treatment capabilities that account for a large portion of the onsite energy use. It isn't known if the increase in energy intensity in the food industry can be accounted for by an increase in onsite wastewater treatment, but that possibility is worth noting.

Table 2. Energy Intensity in the Manufacturing Sector

	Energy Intensity (thousand Btu per 1992 constant $)				Change in Energy Efficiency (%)
Major Group	**1985**	**1988**	**1991**	**1994**	**1985–1994**
Food SIC 20	2.23	2.44	2.33	2.54	-14.1
Tobacco SIC 21	0.53	0.69	0.74	1.27	-141.24
Textiles SIC 22	4.07	4.12	4.25	3.92	3.80
Apparel SIC 23	0.47	0.60	0.73	0.39	16.59
Lumber SIC 24	2.66	2.29	2.9	2.46	7.55
Furniture SIC 25	1.18	1.28	1.20	0.96	18.33
Paper SIC 26	10.84	9.94	12.56	11.91	-9.88
Printing and Publishing SIC 27	0.62	0.73	0.77	0.76	-21.44
Chemicals SIC 28	9.99	9.51	9.69	10.44	-4.52
Petroleum Refining SIC 29	6.79	6.90	7.33	8.74	-28.78
Rubber and Misc. Plastics SIC 30	2.80	2.75	2.35	2.19	21.65
Leather SIC 31	1.29	1.39	1.34	1.04	19.34
Stone, Clay, and Glass SIC 32	14.46	15.42	16.26	13.89	3.92
Primary Metals SIC 33	12.58	12.48	12.16	12.44	1.12
Fabricated Metals SIC 34	1.90	2.05	1.98	2.03	-6.69
Machinery SIC 35	1.14	1.09	1.04	0.85	25.99
Electronic Equipment SIC 36	1.11	1.18	1.05	0.91	17.51
Transportation Equipment SIC 37	0.90	0.85	0.88	W	W
Instruments and Related Products SIC 38	0.93	0.80	0.79	0.87	6.16
Misc. Manufacturing SIC 39	1.08	1.10	0.93	1.17	-8.10
All Manufacturing	3.84	3.88	3.97	4.01	-4.43

Source: EIA 1997

Historical data such as this is quite valuable when trying to predict future energy use. However, since 1994, there has been an important change in the fabric of industry and society as a whole. The increased use of the Internet and the expansion of the semiconductor and computing industries is resulting in an important shift in the way business is done. The historical data does not reflect the effect that the Internet has had on manufacturing. It will be several years before data becomes available to truly reflect the effect of the Internet. In an attempt to examine the impact of this revolution, we include a brief review of the *Annual Energy Outlook 2000* (EIA 1999).

DOE releases an annual forecast of how it believes energy usage will change over the next 20 years. This forecast is based on the National Energy Modeling System. The model is based on various macroeconomic indicators and other industry-specific indicators. Because of the many variables that influence the characteristics of energy usage, this model may or may not hold true, but it is worth exploring for the purposes of this study.

Annual Energy Outlook 2000 (EIA 1999) indicates that the gross domestic product of the United States is projected to increase by 2.2 percent a year between 1998 and 2020. This estimate is slightly higher than the 2.0 percent growth projected in the *Annual Energy Outlook 1999*. Energy consumption in the industrial sector is expected to increase by only 0.9 percent, while the overall consumption per unit of output is expected to decrease by 1.0 percent. The projected growth rate for manufacturing production is 2.0 percent per year, a figure that is slightly lower than the 2.2 percent annual economic growth rate that is projected for the aggregate economy (see Figure 1). The growth in the electronic equipment sector is the fastest of all the manufacturing industries. This growth is attributed to the increased use of data storage and internet technologies.

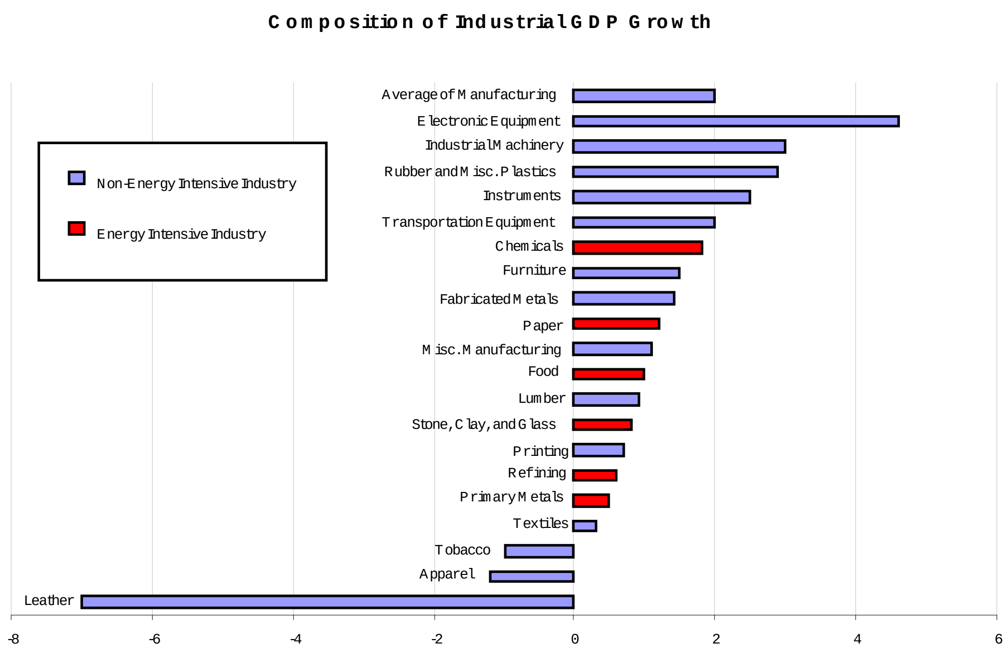

Figure 1. Industrial GDP Growth by Industry Group with Energy Intensive and Non-Energy Intensive Industries noted

Potential for Energy Savings in Small and Medium-Sized Industry

Many government energy efficiency and conservation programs have focused their efforts on the most energy-intensive industries. The rationale behind this focus was that even small increases in efficiency in one of these energy-intensive industries would result in a large overall energy saving. While this approach has resulted in marked improvements in efficiency throughout much of industry, some of the less energy-intensive industries have had more limited attention. As our economy switches from manufactured product-based to service-based products, the products that are produced by manufacturers are changing. The energy-intensive manufacturing sectors are projected to grow more slowly than the non-energy-intensive manufacturing sectors. The *Annual Energy Outlook 2000* (EIA 1999) indicates that the five fastest growing industries are electronic equipment, industrial machinery, rubber and miscellaneous plastics, instruments, and transportation equipment. Energy-intensive industries such as food, paper, chemicals, refining, and primary metals are growing at a much slower pace. The forecasts are showing that in general, smaller, less energy-intensive manufacturing will be playing an increasingly important role in the nation's economy.

Another measure of an industry's potential for energy savings is through the examination of the value of new capital expenditures. Many industries are capital intensive by nature. These industries, which accomplish the hefty task of converting a raw material into finished product through a variety of chemical and mechanical reactions and processes, include the chemicals, food, petroleum, and pulp and paper industries. Facilities that perform chemical reactions require a larger amount of temperature and pressure control equipment than mechanical facilities due to the specific conditions that are required for many reactions. Other industries, such as electronics, transportation equipment, and industrial equipment, assemble their products through solely mechanical means.

Mechanical and assembly industries such as electronics, transportation equipment, and industrial equipment are near the top of the list for new capital expenditures. This may be an indication that production in these facilities is increasing, thereby requiring new equipment expenditures. Data from MECS show a marked decrease in the energy intensity of these industries between 1985 and 1994. This decrease may be attributed to more energy-efficient equipment and practices or better design of new facilities and product lines.

Fortunately, many of the opportunities for increasing energy efficiency and decreasing utility bills in the smaller manufacturing facilities are in areas such as motors, lighting, and compressed air systems (Muller 2000). Improving the efficiency of these systems is more straightforward and replicable than it is at large process-intensive industrial plants. For example, the efficiency of a smaller plant's lighting system can be readily improved by replacing incandescent fixtures with high-efficiency fluorescent fixtures (Martin et al. 2000). This type of improvement does not require special equipment or a shutdown of process lines. However, other types of improvements may be not cost-effective at smaller facilities. For example, improving the energy efficiency of a heat exchanging process may involve removal and replacement of an old and inefficient heat exchanger. An improvement such as this may require installing a custom-sized piece of equipment as well as a shutdown of the process, both of which may be too much of a burden on time and finances for small facilities.

Another measure of the savings potential of small and medium-sized industrial facilities is available in the data from DOE's various industrial assessment programs. DOE's Industrial Best Practices Program collects information on the results brought forth by plant-wide industrial assessments of both large, medium-sized, and small manufacturing facilities. Data collected from five large facilities reveal that the ratio of annual savings to DOE funds equals 47. In other words, for every dollar invested by DOE, the plant reaped $47 in annual savings (ACEEE 2001).

This ratio contrasts with $5 saved per each DOE dollar in small and medium-sized facilities. While this figure may lead one to believe that there are not as much savings available in the smaller industrial segment, this is not the case. It is important to understand that large facilities spend six to seven times the DOE dollars per assessment than smaller facilities do ($73,000 vs. $10,000 on average per assessment) (ACEEE 2001). The large facilities also contribute their own funds, which frequently exceed the DOE funds in this effort. The larger facilities therefore begin with a significantly larger budget than the small plants. The total energy savings at a facility are limited by the facility throughput. Similar improvements implemented in small plants will understandably result in lower dollar savings than in large plants; however, the percentage improvement will be the same. However, the cost necessary to realize the saving will not be correspondingly smaller.

The important point to take from this discussion is that there is still a very good ratio of annual savings to investment dollars that can be achieved in small and medium-sized industrial facilities. This opportunity should not be overlooked simply because the side-by-side comparisons to the large facilities may not look as impressive. Keep in mind that 80 percent of all industrial facilities have an average of 250 employees or fewer and that even these more moderate savings figures can result in remarkably large savings potential.

TIMING OF EFFICIENCY INVESTMENTS

Project Start vs. Retrofit

One of the easiest ways of increasing the energy efficiency of a facility is to select energy-efficient equipment when replacing or installing new equipment. Some generic equipment is replaced relatively frequently in manufacturing facilities, such as small motors, pumps, fans, and lamps.

The retrofit potential for existing facilities is limited, however. The operators of an existing plant can't fully adjust to a new economic optimum even if they want to. The new economic optimum is the optimum efficiency that could be achieved in a facility if an integrated efficiency and productivity approach is followed from the beginning of the design process. The operators do not have the same options open to them that the designers of a new plant do. For example, they can't afford to throw away their 6-inch diameter pipes and increase to 8-inch to match the new economically optimum pressure drop. Another example is adding more insulation to an existing pipe. The designers of a new plant simply look at the incremental costs of going from 2 inches of insulation to 4 inches of insulation. The plant maintenance engineers looking at a retrofit have to add the costs of going back to change things, including changing scaffolding, adding a new weather barrier and new hangers, and re-engineering and organizing the effort. The net is that operators of existing facilities face a prohibitive cost. They will retrofit where possible but this tends to be limited to things added in series, such as additional heat exchangers. To make an analogy to an individual buying an appliance, once the appliance is built, there are limited things that can be done to improve the efficiency (Steinmeyer 1998). While the process of convincing plant owners to install designs that optimize energy use can be difficult, it is evident that a simpler area (from a decision standpoint) in which energy efficiency improvements can be implemented is in the initial design of a new plant or process line.

New Capital Expenditures and Attractive Industrial Segments

While the chemicals industry leads the pack in new capital expenditures (due mostly to the boom of the specialty chemical industry), some of the same industries with the most rapid growth also spend the most on new equipment (see Figure 2).

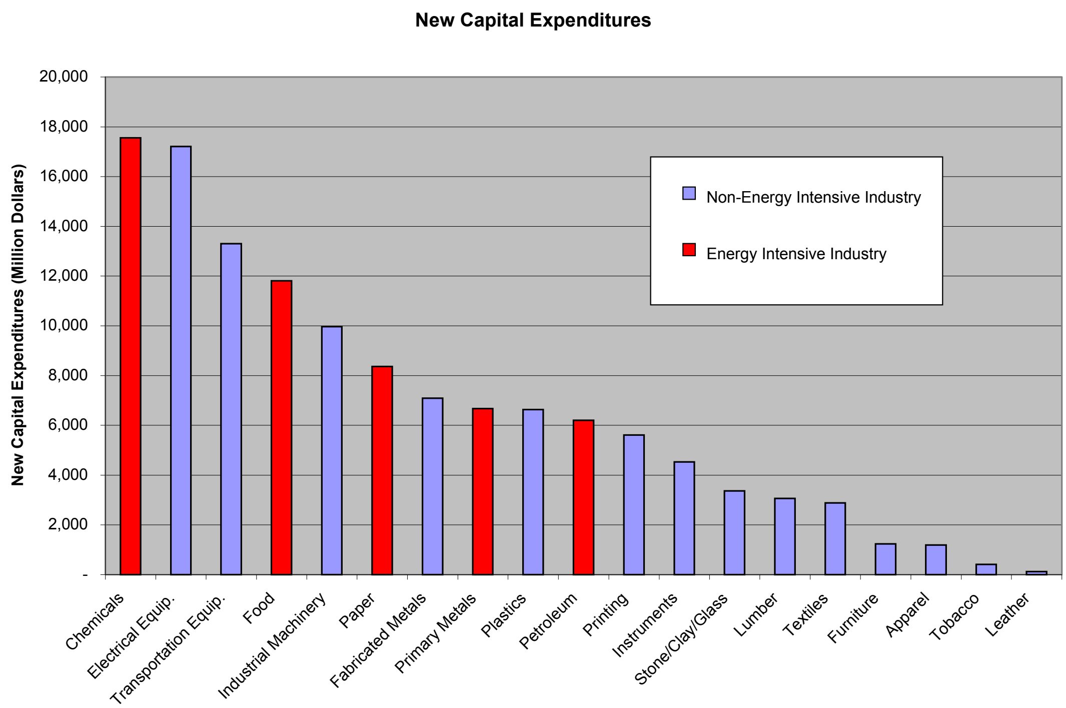

Figure 2. New Capital Expenditures by Industry Group – Source: DOC 1998

The rapid growth of the electronic equipment industry has been fueled by the increased dependence on semiconductors. By the mid-1990s, the semiconductor industry had become one of the most rapidly growing segments of the economy. The demand for semiconductor chips is driven not only by the increasing sales of personal computers, but also by the use of chips in consumer electronics, telecommunications, and networking. The history of the semiconductor industry has been cyclical, with semiconductor products having short life-cycles caused by rapid technological innovations with resulting pressures on prices. Despite fluctuations such as these, the semiconductor industry continues to grow as the use of semiconductors as components in almost all industries continues to accelerate (EIA 1999).

The general industrial machinery and equipment industry is heavily dependent upon sales to other manufacturing businesses. Growth in U.S. capital spending slowed in the 1980s as foreign-manufactured goods reduced the U.S. producers' share of the capital goods market. The traditional manufacturing industries recovered in the mid-1990s and are forecasted to grow at a slower than average pace over the next two decades. The growth of the semiconductor, biotechnology, and pharmaceutical industries has resulted in increased orders for industrial equipment (EIA 1999).

The rubber and plastics industry is expanding globally, but it has undergone considerable consolidation through the formation of joint ventures that have resulted in the dominance of large, vertically integrated, multinational companies. Because many of the production facilities are part of larger corporations, they may not have the same concerns as small or medium-sized manufacturers.

The industrial and analytical instruments industry includes instruments to measure electricity, laboratory instruments, and other measuring and controlling instruments. The growth in this industry has been led primarily by the increased sales of computerized process control equipment. Process control instruments are used in the chemical and energy industries to optimize manufacturing efficiency. The growth of this industry will continue as facilities modernize their processes.

CONCECRNS OF SMALL AND MEDIUM-SIZED INDUSTRY AND THE ENERGY PARADOX

It would seem that the potential impact of energy savings would help to motivate the managers of small facilities to implement energy-efficient technologies and strategies. However, as discussed later in this report, limitations on staff and finances frequently limit the comprehensiveness of energy management.

In order to understand how to encourage energy-efficient practices in facilities with limited resources, it is first necessary to understand the priorities that exist in the operation of a small industrial plant. The primary concern of industries both large and small is to increase shareholder value. This can be done in many ways, including (but not limited to): cutting costs; increasing revenues; increasing productivity; improving product quality; reducing risk; and enhancing reputation (Pye 1998). This concern is even more pressing for small firms with generally high energy costs and slim profit margins. Therefore, in order to make energy efficiency attractive to these businesses, the benefits of increased efficiency must be stated in terms of economic (shareholder) benefit. However, even when energy efficiency improvements appear cost-effective, they are not always implemented. This discrepancy has been called the "energy efficiency gap" or the "energy paradox" (Harris, Anderson, and Shafron 1998). There has been a great deal of research in this area, most of which follows two major themes. The first notion is that traditional business theory is sound and should apply to energy markets, though a market failure may exist. The second research theme follows the idea that traditional business theory on investment behavior may need to be modified.

Many analysts using traditional business theory have suggested that there may be both economic and engineering explanations for the energy efficiency gap. Sources of potential market failure include lack of information, decisions being made by parties who aren't aware of energy issues, and relatively low energy prices (Jaffe and Stavins 1993). Another explanation of the efficiency gap offered by Jaffe and Stavins is the frequent underestimation of the costs of adoption of energy efficiency technologies. The hidden costs that are frequently left out of the economic calculations may include a variety of items such as the training of plant operators and the true costs of a process line shutdown. The lack of information that deters many small and medium-sized industrial managers from making beneficial decisions is also an expense that rarely is factored into engineering calculations.

The other area of research for bridging the energy efficiency gap involves developing new models to describe market behavior. One of the suggested models includes modifying the traditional investment rule of net present value (Dixit and Pindyck 1994). Net present value does not necessarily apply in situations where the implications of future technology or process changes are not yet known (as is the case in highly changeable operations in the biotech and semiconductor industries). One frequently cited model by Johnson (1994) outlines the following approach to illuminating the uncertainties that lead to the energy paradox:

(1) Uncertainty about the amount of future cash flows can be represented explicitly.
(2) With cash flow uncertainty represented explicitly, the discount rate can be used to isolate the time value of money.
(3) The "state of information" of the decision-maker can be represented explicitly, and the value of changing this state of information by gathering information or hiring experts can be calculated in monetary terms.
(4) Project stages, including immediate decision points, can be represented (Johnson 1994).

Assessing the Factors and Barriers that Play in Decision Making

In order to bridge the energy efficiency gap, it becomes necessary to delve into the many factors that play in developing an investment decision. These factors can be thought of as variables in an equation. Plant managers attempt to optimize the equation for all variables involved. This multi-dimensional optimization technique is sometimes referred to as goal programming (Laitner and Hogan 2000). In this section, we explore some of these factors and assess the barriers to effective plant optimization.

Life-Cycle Analysis

Understanding the true costs of implementing energy efficiency improvements is key in bridging the energy efficiency gap. The concept of life-cycle analysis is slowly entering the decision-making process of managers of smaller industrial facilities. Life-cycle analysis is the science of estimating the true installation, operating, and closure costs of a piece of equipment or production line. This science attempts to quantify all of the environmental, energy, and economic benefits and liabilities of a piece of equipment. While some large multi-national corporations have been using the concept of life-cycle analysis to their advantage for many years, smaller manufacturers have not had the same luxury. Most frequently, managers of smaller facilities will base a purchasing decision on a simple payback analysis (Muller 2000).

The life of a manufacturing plant can be divided into four stages:

(1) New Plant: At this stage, all initial equipment investments in a plant are complete. No more investment is required.
(2) Operating Plant: At this stage, the plant expenses include operating and maintenance costs.
(3) Old Plant: This is the stage at which much of the equipment is so old or outdated that not even basic maintenance is often performed.

(4) *End of Life*: This is the point at which a plant is either completely refitted or demolished.

Most current industrial energy efficiency programs concentrate their efforts on improving efficiency in the operating plant. It is evident that retrofitting energy-efficient equipment and practices in existing industrial firms has limited total potential. The greatest benefits can be reached when energy efficiency is planned for before a new plant is constructed or when an existing plant is completely refitted.

Payback

One of the most common methods for determining whether or not an improvement is implemented is calculation of the simple payback. The payback period is defined as the period of time during which the initial capital expenditure of an investment is recouped. Many firms select a specific payback period as a method of investment appraisal. In a survey of 104 business managers of small and medium-sized facilities that was conducted by the Industrial Assessment Program, over 86 percent of the respondents stated that a payback period of 24 months or less would make an energy efficiency recommendation financially attractive. Fifty-five percent of the respondents replied that they would like to see a payback period of 12 months or less (Muller, Barnish, and Polomski 1995). This is in contrast to some larger companies, or companies with a large amount of corporate backing, which may consider a 3-year payback. Firms may also use internal-rate-of-return calculations to help evaluate discretionary investment opportunities. Extensive energy efficiency projects must frequently be approved on a capital budgeting basis. In other words, funds must be identified prior to the budget cycle, the budget for the items must be approved, and the project must be initiated during the fiscal cycle (Jones and Verdict 1995).

The most important part of a financial analysis, be it a life-cycle cost or public benefits analysis, is the estimation of project costs and benefits (Pye 1998). This concept is generally only employed superficially by managers in smaller facilities. True life-cycle analysis is the only way to fully understand the costs and benefits of a project. What generally holds true is that benefits achieved after the payback period are ignored. This situation is especially true for smaller firms (Harris, Anderson, and Shafron 1998).

Another important factor that plays into payback is the value of non-energy benefits. Many technologies that improve energy efficiency also offer benefits in productivity, safety, or environmental performance (Martin et al. 2000). While energy and environmental concerns factor into technology investment decisions at many industrial facilities, it is frequently the productivity and product quality benefits that ensure adoption of a technology. Improvements in productivity and quality contribute significantly to the economic attractiveness of a given technology and may indeed be the largest dividing factor in technology investments (Martin et al. 2000). Unfortunately, many industrial firms, both large and small, fail to account for these ancillary benefits. Small firms in particular may have difficulty quantifying these benefits and rarely include them in their cost analyses.

Risk

Risk and uncertainty is perhaps one of the biggest barriers for a small and medium-sized manufacturer to overcome when energy decisions are being made. Smaller manufacturers face many risks when it comes to making investments in energy-saving projects. These risks include general economic conditions and that the new technology may not work. The overwhelming consideration on whether to investigate an energy efficiency project hinges

critical piece of equipment breaks down, there is frequently little time to evaluate an alternative investment adequately. Manufacturers' primary motivation is to keep their production operating; this generates their income (and increases shareholder value). Anything, including a seemingly simple energy efficiency improvement, that can be perceived as threatening that primary motivation needs to be carefully sold to the decision-maker.

One interesting field of risk research has explored the idea that in an ideal competitive economy with complete risk markets, the uncertainty about future technology changes and energy prices would not affect decision making since all risks could be insured (Hinchy et al. 1991). However, we do not live in an ideal competitive economy, therefore uncertainty is a great barrier to energy investments. A shorter payback period may be necessary for investments whose risk is deemed to be quite high. A short period would allow earlier scrapping of a past investment to take advantage of changed relative prices and new technology. Also, a firm's business may change during the potential lifetime of an asset, and a short payback period lowers the risk associated with future changes (Hinchy 1991).

EFFICIENCY PROGRAMS FOR SMALL AND MEDIUM-SIZED INDUSTRY

Since energy efficiency programs were introduced in the 1970s following the first energy price shocks, some energy efficiency programs have targeted small and medium-sized industries. Both government and utilities have administered the efficiency programs. The programs offered by utilities became known as demand-side management (DSM). The purpose of DSM was to attempt to balance customer demand with electricity supply (Pye and McKane 1999). In the 1980s, as new electricity generation began to provide more power than there was demand, the programs began to be de-emphasized by some utilities. Funding for DSM programs peaked in the early 1990s, with funding diminishing in the late 1990s as utilities cut expenses to prepare for restructuring. The California energy crisis of 2000 and 2001 and the renewed interest in energy brought about by the Bush administration's 2001 energy policy have begun to again generate interest in DSM. Today, these programs (though not always referred to as such) manifest themselves in one of three ways (Elliott 2000):

(1) Public Benefit: These programs are funded by ratepayers. An example of a public benefit program is the Northwest Energy Efficiency Alliance. Most frequently, it is these programs that currently offer services to the small and medium-sized industrial customer.

(2) Utility Marketing: Utilities, especially those in deregulated markets, are seeking new ways in which to attract and retain customers and therefore are offering energy

efficiency programs as part of a package of energy services. This makes the utilities appear to care about their customers, and gives the customers the opportunity to take advantage of otherwise unavailable services.

(3) *Energy Service Companies (ESCOs)*: Energy service companies, both independent and utility affiliated, are seeing the concept of DSM as a business opportunity. ESCOs may charge a fee for implementing electricity demand-reducing technologies and practices in a given facility.

Programs targeted toward small and medium-sized industries can be compared with programs targeted toward large industrial energy users, where there are significant process uses, often with some major energy and operating cost savings potential. Often, these projects start with some detailed process audit. ESCOs, who make improvements to these larger facilities on a performance-contract or shared-savings basis, have initiated some of these projects. In some cases, these services are bundled with power supply contracts, both in regulated and deregulated markets (Kelly 2000).

For the small and industrial sector, in order to keep program costs reasonable, most of the programs have been prescriptive-based and have focused on crosscutting, low-cost/no-cost lighting, efficient motors, HVAC, and hot water measures. In general, the programs are not targeted toward any specific processes or involved systems, such as compressed air, which may be in a given facility (Elliott, Pye, and Nadel 1996).

Services Currently Offered by Programs

While most programs targeting small and medium-sized industrial customers have targeted simple prescriptive retrofits, several programs have approached the small and medium-sized industrial sector in a more concerted fashion. These programs have evolved over the years, with programmatic activity generally falling into two areas: technology improvement opportunity identification (generally through energy and/or process audits or other technical assistance); and direct financing or other implementation facilitation of the identified opportunities. The most successful programs bring together both elements to maximize the chance that opportunities will not be missed. A description of some of these more successful programs along with promising new strategies is included later in this section.

The types of services offered to small and mediums-sized manufacturers by these programs fall into the following general categories:

- onsite assessments
- specific recommendations
- referrals to technical resources
- rebates/grants/financing
- information dissemination and education
- technology demonstration
- manufacturing research

The benefits and limitations of some of these services are outlined in the following sections. Most of these programs are dedicated to serving industry at little or no cost to the individual facility.

Energy Audits

Energy audits or feasibility analyses are performed on industrial facilities as a way to determine the benefits of implementing energy efficiency improvements. Energy audits (especially when supplied free of charge) are generally looked favorably upon by industrial managers. In a recent survey of small and medium industrial facility managers in Utah, 20 percent of respondents indicated that they would be in favor of having an energy audit performed on their facilities for cost, and almost two-thirds of the respondents would like to have a no-cost audit performed (Case 2000). The audits can reveal many cost-effective opportunities that would otherwise be overlooked.

This method of analysis, however, does not take some of the non-energy related technical and economic barriers or risks into account. As was stated earlier in this report, it is the non-energy benefits of efficiency improvements that frequently offer the economic impetus for going forward with investments. There is a movement in the energy management field to begin including some of these issues into audit analysis. Taking a cue from the insurance industry, actuarial tables and life-cycle analysis calculations are being developed for industrial facilities. The purpose of this type of 'real world' audit is to evaluate the conditions in a facility and reduce the level of uncertainty as to how proposed energy efficiency measures will really behave over time. Specific human factors must be weighed and converted to price tags. In this type of life-cycle analysis, monetized values are assigned not only to equipment purchases, installation costs, and equipment maintenance, but also to energy savings, improved worker safety, improved product quality, reduced production costs, and reduced waste disposal costs (Pye 1998).

The impacts of an energy audit can be limited by the lack of resources that are frequently required to implement recommendations. For example, a recommendation to replace an old piece of equipment with a newer, more efficient model requires capital, staff, and frequently the shutdown of a process. Small and medium-sized facilities many times do not have the resources for these types of improvements.

The quality of the energy audit is also critical to the ultimate goal of improved energy efficiency. Energy audits performed by various entities vary from thorough engineering studies to a very cursory analysis of just lighting and motor systems. While the energy audit is probably the most important step in determining efficiency opportunities in a facility, it should be noted that the audit must be thorough and non-prescriptive in order to offer maximum benefit. However, these audits are the most costly, so a balance needs to be struck between comprehensiveness and cost. A strategy to address this quandary is discussed later in this report.

Rebates and Financing Incentives

Rebates have been the most common strategy used by utilities to encourage the purchase of energy-efficient equipment. The rebate lowers the initial cost of a piece of equipment to make it more economically competitive on a first cost basis with the less efficient options. Motor systems programs have long used rebates to encourage the purchase of energy-efficient motors (Elliott and Pye 1997). Financial incentives such as low-interest loans are also sometimes offered (Elliott, Pye, and Nadel 1996).

One limitation of rebate programs is that equipment purchases will sometimes revert back to the lowest initial cost option once rebates are lifted (Horner 2000). This phenomenon is referred to a snapback (Elliott and Pye 1997). Rebates, however, may be valuable in introducing a market segment to an otherwise overlooked product, thereby building consumer trust. This trust can be used as a foundation upon which other programs can be built (Pye and Elliott 1997). However, the long-term use of rebates alone has not proven to be a good strategy; rebates are most effective when combined with other incentivation strategies.

Information and Education

Almost all existing industrial programs offer some form of information and education. This can take the form of informational pamphlets and brochures, as well as low-cost training. In a 1997 analysis of utility motor systems programs, it was found that more than two-thirds of the programs offered training, publications, or software tools (Elliott and Pye 1997).

One of the ancillary benefits of the Industrial Assessment Centers' program is the education value to the student auditors. The energy audits of small and medium-sized industrial facilities are performed by engineering students at the participating university-based assessment centers. The students receive extensive training and experience in analyzing the energy efficiency opportunities in industry. Engineering curricula at most universities does not generally include coursework in energy efficiency. The graduates of the IAC program have obtained a valuable skill that most likely would not have been obtained otherwise. These engineers will carry their energy efficiency knowledge throughout their careers.

Education is critical in establishing an increasingly energy-efficient industry. Managers of small and medium-sized facilities will not take advantage of efficiency opportunities if they are unaware of both the energy and non-energy benefits.

Manufacturing Research and Technology Demonstration

Manufacturing research is generally offered by the federal government in an effort to encourage U.S. competitiveness and domestic security. These programs generally fund pre-competitive research that is cost-shared with universities and corporations. Many energy efficiency breakthroughs have come from these programs, and these discoveries eventually benefit all segments of industry. While only large corporations can afford to leverage with the federal government on basic research, there are a few state offices that offer manufacturing research assistance. For example, NYSERDA offers research grants and cost-sharing opportunities that may not be out of the reach of smaller firms (NYSERDA 2001).

Many state energy offices such as NYSERDA also offer funding for project demonstrations (National Association of State Energy Officials 2001). The demonstrations serve the purpose of moving a technology from the research and development stage to full commercialization. Frequently, technologies (especially new and emerging technologies) are too costly to be economically viable without additional incentives. The demonstrations allow the new technology to be applied in "real-world" situations, thus engendering a measure of trust in potential users. Technology demonstration is a very important step in the adoption of new efficiency technologies (Martin et al. 2000).

Availability of Programs

While the number of programs focusing on energy efficiency in small and medium-sized industries may be limited, other programs exist to assist these firms in other ways. Over 300 government-sponsored manufacturing assistance programs and centers exist in the United States, many specifically intended to serve the needs of small and medium-sized industrial firms.

U.S. Department of Energy: DOE sponsors 26 universities that participate in OITs' Industrial Assessment Center Program. This program, which will be discussed in more detail later in the report, offers free energy, waste, and productivity audits to qualifying facilities.

U.S. Department of Commerce: The National Institute of Standards and Technology's (NIST) Manufacturing Extension Partnership (MEP) Program is a nationwide network of nonprofit centers in over 400 locations throughout the country, whose purpose is to provide small and medium-sized manufacturers with the help they need to succeed. The type of cost-shared assistance that MEP delivers includes: process improvement; quality management systems; business management systems; human resource development; market development; materials engineering; plant layout; product development; energy audits; environmental studies; financial planning; and electronic commerce (NIST 2001a). Since its inception, the program has assisted more than 62,000 firms nationwide. While energy efficiency is among the services offered, it does not currently represent a major focus.

Other Federal Agencies: The U.S. Department of Defense, National Air and Space Administration, National Science Foundation, Department of Agriculture, Environmental Protection Agency, and Small Business Administration collectively offer 20 programs. Most of these programs fund and cost-share basic research and development (Alliance to Save Energy 1998).

State and Regional Technology Programs: There are approximately 30 programs that are dedicated to assisting industrial firms in their region with the adoption of new technologies. Many of these programs are participants in the MEP program mentioned above, and offer technical support to small and medium-sized industrial firms (NIST 2001b).

State Energy Offices: Many of these 50 offices offer some form of technical assistance to local manufacturers. The mission of the state energy offices is to maximize energy efficiency while promoting economic development, reducing reliance on foreign energy supplies, and improving the environment. The state energy offices advise the governors on directions, policies, and changes in the various segments of the energy market as demand/supply competition, technological innovations, and policy changes by the federal government cause changes in the market-sensitive energy sector (National Association of State Energy Officials 2001).

Public and Private Organizations: Approximately 100 programs are sponsored by a variety of organizations such as utilities, nonprofit organizations, trade associations, and professional societies (Alliance to Save Energy 1998). Programs such as the Northwest Energy Efficiency Alliance offer support to commercial, residential, and industrial customers in the form of information dissemination and cost-sharing. The scope of programs and benefits offered varies widely by program, and very few of these programs offer support geared specifically to the smaller manufacturer (Northwest Energy Efficiency Alliance 2000).

Utilities: In addition to the government-sponsored manufacturing assistance programs, many utilities also offer some sort of program for commercial and industrial customers. Many of these programs come in the form of partnerships between the customer and the utility. These partnerships take many form. However, the great majority of these programs do not tailor their benefits to the industrial customer; programs that focus solely on small and medium-sized industrial customers are rare. Many of the partnerships have focused on identifying the customers' needs and becoming responsive to them. Because utilities are in the energy business, they often can offer unique perspective and expertise to their customers. These services can be bundled with electricity sales to create a value-added service that will help retain customers, and in some cases will provide additional profit opportunities for the utility. These programs represent more of an approach than a structure. Inherent to the success of many of these programs is the ability to understand, communicate with, and provide flexibility to the customer (Elliott, Pye, and Nadel 1996).

Later in this report, we will further examine some of the programs that are intended for the small and medium-sized industrial customer group. Two of these programs, the Industrial Assessment Centers and NYSERDA's *FlexTech*, are long running. We will also explore some of the newer programs that, while they may not have been designed specifically with smaller customers in mind, take a more innovative approach to energy efficiency programs. The other programs that are discussed are either new or have been recently redesigned.

Elements of a Successful Program

The goal of energy efficiency programs is to enable the implementation of projects that save energy. The program's role can be viewed as project facilitation. Implementing an energy efficiency project involves more than just identifying the opportunity. The implementation process can be viewed as having seven sequential elements (Elliott, Pye, and Nadel 1996):

(1) Opportunity identification;
(2) Technology identification and project design;
(3) Financial analysis;
(4) Purchasing and procurement;
(5) Financing;
(6) Installation; and
(7) Startup and training.

In addition to these seven steps, one critical element remains unspoken. Before any opportunity identification can take place, the industrial customer must be aware of the program's existence and convinced of its efficacy even before participation begins. An essential marketing of the program's availability and benefits must also be included in the design of a successful program (Giffin et al. 2001).

Most industrial and utility technical assistance programs have focused on only one or two of these steps. To achieve high implementation rates, it is important that resources be available for all steps. Final project phases, particularly startup and employee training, can often be the most critical for maximizing long-term savings potential (Elliott, Pye, and Nadel 1996). As an example, New York's *FlexTech* program (discussed in the next section) has achieved impressive results by facilitating the entire implementation process at a modest cost.

DESCRIPTIONS OF EXISTING PROGRAMS

We now profile in greater detail six of the more successful, long-running programs and promising new programs. Successful programs are those that have brought documented value (in the form of increased energy efficiency) to their customers in a consistent manner.

Industrial Assessment Centers

DOE's Office of Industrial Technologies has supported the Industrial Assessment Center Program since 1978 (this program began earlier as the Energy Analysis and Diagnostic Center Program, which was originally initiated at the Department of Commerce). In the IAC Program, direct, one-to-one contact with industrial end-users and plant site managers significantly increases the adoption of commercially available and emerging energy-efficient technologies. In addition to traditional energy streams, IAC targets waste streams and productivity improvements. The program is focused on preparing energy and waste audits of small to medium-sized manufacturing facilities (DOE 2001). IAC is implemented through 26 schools. To be eligible for an IAC assessment, a manufacturing plant must meet the following criteria:

(1) Be within Standard Industrial Codes (SIC) 20–39.
(2) Be within 150 miles of a host campus.
(3) Have gross annual sales below $75 million.
(4) Have fewer than 500 employees at the plant site.
(5) Have annual energy bills more than $75,000 and less than $1.75 million.
(6) Have no professional in-house staff to perform the assessment.

A university professor leads a team on a 1-day site visit at an industrial plant. Prior to the site visit, pertinent information regarding the facility is gathered through telephone interviews, e-mail, and fax. The products of the facility, wastes, and material flow diagrams are obtained prior to the site visit. The site visit includes discussions with plant managers, plant tours, and measurements of operational parameters. Following the site visit, the assessment team prepares a written report for the manufacturer, which includes information about the plant's energy use, processes, and waste handling. The report contains specific recommendations that include sufficient engineering design to provide anticipated savings, implementation costs, and simple payback. After approximately 6—9 months, IAC contacts the manufacturer to gather information on the level of implementation of the recommendations.

OIT's 1998 Information Resources Catalog states, "IAC participating manufacturers achieve on average $20,735 annually in energy savings and $34,195 in waste and productivity savings, totaling $54,930 per assessment. Since 1996, the program has provided 750 assessments each year" (DOE 1998). All of the findings of the IAC assessments are compiled into a centralized database maintained at Rutgers University. This database of plant and related assessment information (individual plants are not identified in keeping with program policies) records the actual results of approximately 9,000 assessments, with over 57,000 specific recommendations, conducted by the program since 1980. The database can be accessed via Rutger's website (http://oipea-www.rutgers.edu).

Overall, a little more than half of the improvements suggested through the IAC program have been adopted by industrial users. According to the database, about half of the measures that cost less than $1,000 have been adopted, while only a third of the measures over $10,000 have been installed (Hopkins and Jones 1995). The average cost per recommendation (for all recommendations) is $12,316, and the average cost per actual implemented recommendation is $7,349 (Muller 2000). The typical payback period is 6–12 months, and the median return is about $6,000 (Muller 2000). The IAC program averages $4–5 of energy savings per program dollar.

Information regarding annual energy and cost savings is included in Table 3 on the next page.

NYSERDA's FlexTech Program

The FlexTech program is a custom-tailored technical assistance program designed to lower facility operating costs, increase productivity, improve indoor air quality, and reduce air emissions. Participants share in the cost of services delivered by engineering consultants competitively selected by NYSERDA. Following the identification of efficiency improvements through FlexTech assistance, NYSERDA also works with financial institutions, through the Energy Smart program, to provide low-interest financing to assist customers in implementing the measures (NYSERDA 2000a).

Table 3. Annual Energy and Cost Savings for IAC Program

	Annual Energy Conserved per Recommendation (Mbtu) (average)	Annual Cost Savings per Recommendation (average)
Primary Resource		
Electric	346	$6,148
Natural Gas	1,727	$6,859
LPG	1,190	$6,807
Fuel Oil	2,034	$8,072
Coal	24,395	$37,812
Secondary Resource		
Electric	107	$1,168
Natural Gas	-2,234	-$7,156
LPG	-1,048	-$6,119
Fuel Oil	-158	-$1,943
Coal	194	$15,586
Tertiary Resource		
Electric	-177	-$1,394
Natural Gas	-10,504	-$42,658
LPG	-1,325	-$7,855
Fuel Oil	-3,932	-$22,429
Coal	-3,800	-$5,374
Average Cost of Recommendation		**$12,316**
Average Cost of Implemented Recommendations		**$7,349**
Typical Payback Period		**6–12 months**
Median Return on Investment		**$6,000**
Annual Cost of Energy Savings per Program Dollar		**$4–5**

Sources: Muller 2000; Rutgers 2000

A key feature of the *FlexTech* program that helps in its success is the fact that there is a "stable" of 24 prequalified technical assistance consultants around the state. Many of these firms are already working in industrial facilities on real projects and are familiar with the facilities and the customer decision-making processes. This aspect of the program mirrors some of the "performance contracting" programs that are administered by many utilities. The consultants that work with the *FlexTech* program have established close relationships with NYSERDA and are quite familiar with the issues that face many of the small and medium-sized industrial facilities that the program targets. This variety of available technical assistance, the fact that the cost of the technical assistance is partially paid by the customer giving buy-in from the front, and the availability of financing for those customers that need it (see below) lead to higher levels of implementation (NYSERDA 2001).

Recently, as part of utility restructuring in New York State, a public benefit program called *Energy Smart*^{SM} was established, which is administered by NYSERDA. An element of that program is *Energy Smart*^{SM} *Loans,* which buy down the interest rates by 4.5 percentage points. These interest rate subsidies are available through commercial lenders for any project that implements energy efficiency measures or renewable energy projects (NYSERDA 2000a).

According to a survey of NYSERDA's clients, more than two-thirds of the recommendations made by *FlexTech* contractors have been implemented. Each dollar spent on *FlexTech* engineering services has resulted in $17 in capital improvements and $5 per year in energy savings (NYSERDA 2000b).

The key to the success of the *FlexTech* programs is that it combines many of the elements that other programs offer primarily in discreet pieces. Energy audits, technical assistance, cost sharing, loans, and performance contracting are offered as bundled services to the customers of the program. What the *FlexTech* program does best, however, is offering the services of consultants with whom the customers already have established relationships. This service helps to establish trust with the customer from the very beginning of the process.

National Grid Industrial System Optimization Services (ISOS)

National Grid USA (formerly the NEES Companies, whose operating companies included the Massachusetts Electric Company and Narragansett Electric Company) offers a comprehensive set of energy efficiency programs to all customer groups and specifically targets small to medium-sized industrial customers with its ISOS program. This program works with existing audit and technical assistance programs (including the regional IAC) to find interested customers with efficiency improvement opportunities. In order to leverage declining program funds, the program ties in with other manufacturing assistance programs and activities. It also ties into National Grid's commercial and industrial programs such as Energy Initiative, which pays a portion of the cost of qualifying, cost-effective improvements in existing facilities, and Design 2000, which is a comprehensive design assistance and incentive program for new facilities (Massachusetts Electric 2001). In 2000, Massachusetts Electric established the goal of adding four to six industrial projects involving energy efficiency and significant environmental, production costs, or productivity benefits. During the year, sixteen ISOS studies were initiated and seven customer agreements were signed. Overall (including commercial facilities), actual benefit-to-cost ratio achieved in 2000 using the modified total resource cost test was 1.48 (Massachusetts Electric 2001).

National Grid also offers a Small Commercial and Industrial Program that provides direct retrofit installation of energy-efficient lighting and other measures (Massachusetts Electric 2001). Customers with an average monthly demand of less than 100 kilowatts (kW) or an annual energy usage of less than 300,000 kilowatt-hours (kWh) are eligible for this program. The company pays for 80 percent of total project costs, and customers may finance the remainder for up to 24 months interest-free. Some of the available technologies offered through the program include: energy-efficient fluorescent ballasts, lamps, and fixtures; hard-wired and screw-in compact fluorescent systems; high-intensity discharge systems; occupancy sensors; programmable thermostats; hot water tank insulation wraps; and fan control and door heater control devices for walk-in coolers. Customers in the targeted market segment tend to have a significant lighting load (as a percentage of total load) and a historical reluctance or inability to fund efficiency improvements. Also, their small size tends to exclude them as potential beneficiaries of ESCo services (NEES Companies 1997).

Energy Center of Wisconsin Industrial Projects

The Energy Center of Wisconsin (ECW), a private, nonprofit organization promoting energy efficiency, has several activities aimed at the small and medium-sized industrial market. ECW has organized the Consortium for Industrial Efficiency, a group of private and public organizations that offer free and fee-based services to help Wisconsin industries improve their efficiency and competitiveness. This consortium has compiled (and regularly updates) a *Resource Guide for Wisconsin Industries,* available at ECW's website (http://www.ecw.org). The focus of the program is primarily to educate industrial managers and disseminate information. The center also provides project demonstrations and fact sheets in areas such as compressed air, motors, and lighting.

ECW has set up a cooperative relationship with the Wisconsin Manufacturing Extension Partnership (WMEP), a fee-based service provider whose activities are subsidized through NIST. WMEP bills itself as "the manufacturers' resource for improving productivity, profitability and competitiveness." WMEP has a cadre of manufacturing specialists with real world industrial experience who work with manufacturers to modernize their operations and help them manage their business. In the cooperative relationship between ECW and WMEP, ECW supports the costs of energy experts accompanying the WMEP manufacturing specialists during their visits to a facility. The recommendations of the energy experts are included in the overall packages that the WMEP could recommend to the manufacturers. The energy experts would then assist in whatever follow-up work is needed to be sure that the recommendations are carried out. Additionally, representatives from the local utilities are brought in to explain any other assistance programs, such as financing (WMEP 2001).

ECW has particularly targeted the metal casting and metal finishing industries as having large potential energy savings. For metal casting manufacturers (90 percent of which are less than 100 employees in Wisconsin), ECW has tagged onto a national program, DOE's Roadmapping Process, and is working with a group of key Wisconsin metal casters to develop a state roadmap. This Wisconsin roadmap will not be focused on energy efficiency but instead will look at what are the issues that would help make the metal casters more competitive and what are the problems the casters want to solve, recognizing that energy efficiency improvements will be part of the solution. Similarly, ECW has a project with metal finishers that is an outgrowth of the U.S. Environmental Protection Agency's (EPA) Strategic Goals Program, which has challenged the metal finishing industry to reduce energy usage by 25 percent by 2002. ECW is working with the Wisconsin Department of Natural Resources to develop a "best practices" guidebook, which will detail simple and effective ways that the metal finishing industry can save energy, reduce pollution, and improve operating procedures (Presny 2000).

ECW measures the success of its programs through the amount of interest and participation in demonstration events and through participant evaluations. The program is beginning to move towards serving several industry segments such as metal casting and metal finishing. It has been found that developing contacts and relationships within an industry segment can be very beneficial (Presny 2000).

Wisconsin Focus on Energy

Wisconsin Focus on Energy is a $16.75 million, 2-year pilot energy efficiency program for Wisconsin whose main goal is to help prepare the market for a time when energy efficiency goods and services are no longer mandated by state governments. The program is a partnership, funded by a public utility, overseen by a state agency, and delivered by private sector contractors. This program takes an integrated approach to delivering energy efficiency in commercial and industrial facilities. Focus on Energy aims to educate service contractors regarding energy efficiency in order to bring results to businesses. The contractors benefit through additional business, and the industrial facilities benefit through the implementation of efficient equipment and practices. The program was designed around EPA's ENERGY STAR®—Industries program (Giffin et al. 2001).

Each commercial and industrial participant receives:

(1) Technical assistance in identifying energy opportunities and completing action plans;
(2) Help in identifying technical opportunities and project financing sources;
(3) Forums and workshops for business-to-business exchanges on processes, technologies, and management practices;
(4) Assistance in developing or furthering a corporate policy regarding energy efficiency and pollution prevention; and
(5) Energy tracking software at no cost.

A preliminary evaluation of the program conducted by Hagler Bailly states, "the key ingredient in overcoming the barriers to participation seems to be focused one-to-one attention provided by a technically competent, independent third party. What remains to be seen, however, is whether this third party expertise must always be provided free by the state or some publicly funded organization" (Wisconsin Department of Administration 2000).

PG&E's Small Business Standard Performance Contract Program (SBSPC)

Pacific Gas and Electric's (PG&E) Standard Performance Contract (SPC) Program was begun in 1998. In 1999, the program was divided into small and large non-residential portions. The small non-residential program serves individual facilities with a demand of less than 500 kW. The Small Business SPC (SBSPC) program is funded by California utility customers and administered by the state's investor-owned utilities, under the auspices of the California Public Utilities Commission. In this program, utility customers cannot directly apply for benefits, but rather service providers (ESCOs, contractors, etc.) act as sponsors and apply for the incentives. The program is intended to empower the third-party service providers to be the primary source of energy efficiency information and incentives, rather than the utility. It provides standard incentives for project sponsors to achieve energy savings. Rather than providing rebates, the SBSPC program pays project sponsors based on measured or deemed energy savings. This program is intended to: (1) encourage entrance of new participants in the energy efficiency marketplace; (2) stimulate transactions between project sponsors and customers; and (3) increase customer awareness and acceptance of the energy services industry (Kelly 2000).

In 1999, applications for over 200 projects were received. These projects were estimated to result in annual energy savings of 19.5 million kWh. The estimated utility incentive pay-out for these savings was $1,928,000 (Sterret et al. 2000). A review of the program's first year revealed that most small and medium-sized customers are unaware of the program. Many service providers also are unaware of the program or do not believe that the program is intended for their customers. Several changes are being implemented in 2000 to help streamline the program process. The program application and verification process is being simplified and the minimum project size is being reduced to 10,000 kWh per year to allow very small customers to participate (Sterret et al. 2000).

Program Successes

These existing programs for small and medium-sized industries have encouraged energy efficiency in a largely under-served sector of power users. The challenges that face these smaller manufacturers are large—the lack of dedicated staff and the lack of capital create a difficult environment for fostering efficiency. Regardless, these programs have achieved some success. The following strategies have proved efficacious:

- Plant energy efficiency assessments
- Development of a network of energy efficiency service providers
- Leveraging other market resources
- End-user education

Energy Audits and Energy Efficiency Assessments

Perhaps the most successful program strategy for small and medium-sized plants has been plant assessment. Free energy audits, such as those offered through the DOE-funded IACs, allow the managers of small facilities to see how their facilities can be made more energy efficient. Manager surveys of have shown that many managers think that audits are valuable and would like one conducted at their facility (Case 2000). The relatively high implementation rate of recommendations in the IAC program indicates that audits are a successful component in fostering energy efficiency. The energy audit is the first step in realizing energy efficiency improvements in small and medium-sized facilities.

Development of Network of Energy Efficiency Providers

In order to promote efficiency, it is important to educate service providers and vendors as well as customers (Case 2000). Small and medium-sized manufacturing facilities are likely to hire a third party to update or repair a piece of equipment. This vendor or service provider is generally relied upon to install the proper type and size of equipment. It is important that the third party be aware of energy-efficient equipment and willing to present it as an option to the customer. Some of the performance contract and education programs have succeeded in making service providers aware of efficiency.

Managers of smaller facilities tend to be more risk averse than their larger and more heartily financed brethren; therefore, methods to instill trust are essential to the success of energy efficiency programs. NYSERDA's *FlexTech* program has been particularly successful in establishing a circle of contractors and consultants that are intimately familiar with both the NYSERDA program and the energy efficiency needs of the small and medium-sized manufacturers in New York State. This stable of consultants helps resolve some of the human-factor barriers to increasing efficiency in this portion of the industrial market. Many of the utility energy efficiency performance contract programs, such as PG&E's Small Business Standard Performance Contract Program, also excel in the area of trust-building. While PG&E's program offers primarily a pool of contractors with a marked interest in improving the performance of a facility, NYSERDA's program takes the customer from the project identification stage all the way through to the contractor selection and project completion.

Leveraging of Market Resources

Frequently the motivating factor in choosing to implement an energy efficiency investment in a small or medium-sized industrial facility is first cost/rate of return: it is key for small and medium-sized manufacturers to be able to keep costs low. These manufacturers typically have small capital budgets. Programs that offer cost-sharing or rebates succeed in helping lower first costs for efficiency investments. The Industrial Assessment Centers have been successful primarily because they can deliver a detailed plant assessment and technical recommendations at no cost to the customer.

The more successful programs attempt to remove efficiency barriers by leveraging other funded activities and coordinating activities to keep costs down, while maximizing the credibility of the information delivered. The programs also seek to address all of the barriers to energy efficiency that manufacturers face, including financing. One of the most successful is PG&E's performance contract program, which stimulates efficiency improvements by primarily offering incentives to the third-party energy efficiency consultant. This allows the utility to keep its program implementation costs low, since the services are offered not by the utility but by a third party. As with *FlexTech*, PG&E's program uses a stable pool of contractors, which engenders trust in the customer and increases the credibility of the information being offered.

End-User Education

Practically every energy efficiency program offers some sort of educational service (Elliott, Pye, and Nadel 1996). These services come in the forms of hands-on technical training, energy self-assessment manuals, brochures, and websites. One model in successfully providing end-user education is the IAC program. While IAC does not conduct detailed training for its customers' plant operators, it does offer in-depth training to the engineering students who conduct the energy audits. Many of these students go on to work in industry after graduation and take their knowledge of energy efficiency project design and implementation with them.

Another lesson that has been learned from past energy efficiency programs (in particular programs that have been administered by utilities) is that information can sometimes be disseminated more effectively from sources other than the customer's utility. Information coming from consultants, nonprofit, and public benefit entities is frequently met with less resistance (NYSERDA 2001).

Program Failures

Despite many programmatic successes, the energy efficiency gap (between what is known to be economically viable and what is actually implemented) still exists. Existing programs have yet to fully surmount this barrier.

Education

Customer education is crucial to closing the gap, and while most efficiency programs offer this in some form, the customer often is unaware of its availability. This is primarily a marketing problem. In fact, most of the programs seem to suffer from a general lack of marketing.

A key challenge in programs aimed toward small and medium-sized manufacturers is how to effectively communicate the value of efficiency improvements at a reasonable programmatic cost. Plant managers and operators need to be convinced of the benefits of energy efficiency improvements, plus objections that these improvements may disrupt their critical manufacturing processes needs to be overcome. At the same time, the scale of the savings is not as great as with a large, energy-intensive industry, so it is critical to keep the delivery costs of the program low enough so that the costs do not outweigh the potential savings.

Rebates

The effectiveness of rebate programs is much more difficult to evaluate. Some researchers have shown that most programs have very little long-term effect on customer behavior, while other researchers have shown that these programs can be effective in some instances. As an example, with utility motor system programs, some prescriptive rebates have been found to be advantageous because they are easy to understand, administer, and promote. However, the disadvantage of prescriptive rebates is that they oversimplify complex systems and can encourage installation of technologies in inappropriate applications (Elliott and Pye 1997). Another disadvantage of rebate programs is that their programmatic and management cost is an issue of contention among industrial consumer groups and within utilities attempting to reduce program costs applications (Elliott and Pye 1997).

It is important to remember when considering the efficacy of rebates that while their effectiveness by themselves is questionable, rebates can be effective when integrated into programs with other elements. They should be used judiciously in strategic situations such as customer attraction in the early stages of program implementation. As programs grow and "word of mouth" spreads, rebate levels can often be reduced and in some cased eliminated.

POTENTIAL PROGRAMMATIC STRATEGIES

As has been described, creating a program or programs for improving energy efficiency in small and medium-sized manufacturing establishments is quite challenging. Some of the previously discussed issues (such as lack of capital and limited staff resources) facing the managers of these facilities indicate that external program support must truly be comprehensive. The program(s) must include energy assessment services as well as implementation support, all of which needs to have credibility in the given industry sector. The changes that are instituted in facilities must then be properly operated and maintained. Effective energy efficiency programs must include all of these components.

This combination of services would be quite challenging for any one federal or state entity to provide, but given enough funding, cost-leveraging, and partnerships, such a program could become a reality. It must be remembered that the cost-effectiveness of these energy efficiency programs is unlikely to approach that of larger facilities because the savings opportunities are more limited. Thus the programs must work "smarter" rather than "harder."

We have learned from existing programs that educational and prescriptive rebate programs targeted at small and medium-sized manufacturers are usually not enough to encourage the implementation of energy-saving strategies. Managers of smaller facilities require much more guidance and support than is currently available through existing programs. Service providers and equipment vendors also must be educated and willing to provide energy-efficient services and information to their customers. In particular, the establishment of a network of qualified energy service providers in a region is an important element of success.

Small and medium-sized industrial facilities invest much less in plant equipment and automation and have lower productivity per employee than similar facilities of larger size. The value-added per employee at larger establishments is almost twice that of smaller establishments (Bureau of the Census 1998). It is important to keep this figure in mind when developing programmatic strategies for this market segment.

The general lack of automation presents a problem for small and medium-sized industrial facilities in that equipment replacement is costly and rather disruptive to a process. Examples of simpler and less disruptive improvements include motor upgrades and light fixture replacements. For the small and medium-sized manufacturer, the energy audit is of utmost importance. More likely than not, a small facility has never conducted an energy audit. Therefore, a program for this sector should begin with a no-cost or low-cost energy audit, a key in determining the areas for improvement in these facilities.

Quasi-Prescriptive Programs

On potential solution to the individual facility cost issue is to develop "quasi-prescriptive" energy efficiency recommendations for a class of applications or facilities. As noted earlier, programs focusing on cross-cutting applications such as compressed air or motors have proven effective. Applications-focused efforts such as these begin to become limited when you move beyond generic equipment and begin considering systems because of the site-specific nature of the efficiency opportunities. In those cases, the most effective strategy may be one that focuses on specific industries for which there are multiple facilities in a program service area, such as dairies in Wisconsin or lumber mills in the Northwest. Detailed audits should be performed on a few facilities to identify likely efficiency opportunities at these facilities. These quasi-prescriptive recommendations can then be used to cost-effectively identify and implement efficiency opportunities at other similar facilities in the program service area. A similar strategy has been deployed in Australia by the government of New South Wales (Jutsen 200). The first step in this process is to identify candidate industries through regional analyses of the existing industry population.

Not only are the energy and environmental benefits greater in this type of "total systems" approach, the economic benefit to the manufacturer is more readily evident as well. As any plant manager knows, waste costs money. The form the waste takes is immaterial—be it in the form of unsellable byproducts, scrap, heat, or wastewater. Small and medium-sized manufacturers are more likely to implement waste-eliminating steps before a process is established than afterwards. Some of the industries that would truly benefit from this type of approach include the electrical equipment, industrial machinery, plastics, specialty chemicals, and transportation equipment industries. These are some of the industries with high rates of new capital expenditures and also high rates of forecasted growth as a percentage of the gross domestic product.

New Construction Programs

Through this analysis, we have attempted to identify the best methods for achieving greater energy efficiency at smaller facilities. By examining some of the industries with high economic growth and relatively large capital expenditures, we have identified some industries where energy efficiency can be integrated into the overall design process for a new plant or even for a new product line. While providing energy-efficient improvements to existing processes can incrementally improve a facility's overall efficiency, truly dramatic improvements in energy efficiency occur when a total concept of optimization and efficiency is integrated into a complete plant design.

It is important to remember that a manufacturing facility has four stages of life (new plant, operating plant, old plant, and end-of-life). It is evident that retrofitting energy-efficient equipment and practices at existing industrial firms has a limited potential (Steinmeyer 1998). The greatest benefits can be reached when energy efficiency is planned for before a new plant is constructed or when an existing plant is completely refitted. None of the existing energy efficiency programs for small and medium-sized industrial facilities that we identified had a component offering of full-system-optimization support, including energy efficiency for the design process.

A program that offers this type of support could benefit smaller firms immensely. Again, quasi-prescriptive recommendations can be developed for industries that have a concentration in a program service area. It is important to be attuned to these industries so that any plans for a plant refit, expansion, or new construction can be identified early enough to intervene in the design process. This can be accomplished several ways:

- Staying in touch with local and state economic development entities,
- Tracking utility requests for new or additional service; and
- Developing an ongoing relationship with the companies.

A combination of all these strategies would be the most effective approach. These program approaches are frequently applied for larger facilities, but often can be more effective for smaller facilities since decisions at many larger facilities are controlled at a national corporate level while decisions at smaller facilities are more likely to be made locally.

Future Work

None of these program ideas are fully formed. Development of detailed program strategies and their prototyping in a regional program setting is now needed to determine whether these services can be delivered in an effective and economically manner.

CONCLUSIONS

In this study, we examined the concerns of managers of small and medium-sized facilities and explored the ways in which industrial decisions are made in these facilities. The technical areas for significant energy savings in plants as well as specific industries were outlined. We presented a review of existing energy efficiency programs geared toward these plants and analyzed how well the programs address the concerns of managers of small and medium-sized facilities. We also looked into some of the failures of the existing programs and suggested areas for improvement.

We have found that energy is just one of many concerns of the industrial manager. For peak environmental, energy, and production efficiency, the processes and operations in a plant must be optimized. No single factor should be optimized to the detriment of the others. This task is more readily accomplished at the design phase of a project rather during later retrofits and process improvements. Most current programs for energy efficiency focus on offering prescriptive recommendations or rebates for retrofit energy improvements. It is evident that small and medium-sized firms require much more assistance in order to implement economically viable efficiency improvements. In order to bridge this energy gap, we believe that a more comprehensive program that involves a combination of education, prescriptive recommendations, and implementation assistance is needed. A program option that includes design advice for new product lines and plants should also be included in order to take advantage of the full economic and efficiency potential that a truly optimized facility offers.

Following are the key services that must be included in a successful program targeted at small and medium-sized manufacturers:

- Program marketing and outreach;
- Opportunity identification;
- Technology identification and project design;
- Financial analysis;
- Purchasing and procurement;

- Financing;
- Installation; and
- Startup and training.

These elements are all necessary for a program to be successful (and by successful we mean that a small or medium-sized industrial facility implements and maintains efficiency improvements that result in energy savings and decreased utility costs per unit of product). Inherent to this type of program would be recognition by and trust of the customer. All of the proceeding seven factors combined will not result in savings if the industrial customer is not aware of their availability or if the perceived risk of participating in this type of program is too high. The entity or entities that administer the program must reach out to the customer and establish a relationship first and foremost.

Many of the elements of a successful program are already embodied in some form in existing programs targeted to the small and medium-sized industrial customer. In order to be a step above the others, a new program must be a more holistic approach, one in which all the elements of the energy efficiency improvement process are taken into account. In some cases, this approach would perhaps be too costly and/or difficult for any one entity to provide alone. Partnerships between utilities, public benefit programs, state energy offices, and private contractors may be the method in which the elusive goal of efficiency can be delivered to the small and medium-sized manufacturer.

The potential for energy efficiency improvements in small and medium-sized manufacturing facilities is quite large, and may prove to be larger as the face of industry continues to grow and change. The road to efficiency is quite challenging but well worth the trouble.

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