Energy Efficiency in Industry and Agriculture: Lessons from North Carolina[1]

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ABSTRACT

This paper looks at how energy is used and the opportunities for increasing energy efficiency in agriculture and industry in North Carolina based on fourteen years experience in these sectors. Specific examples of energy saving technologies are presented along with a discussion of how these opportunities were identified, implemented and what benefits resulted. Suggestions are made on how to structure utility and government energy efficiency programs to overcome institutional barriers.

INTRODUCTION

Objective

The objective of this paper is to share the lessons learned from working with North Carolina industry and agriculture on energy issues for fourteen years. This paper will attempt to provide a perspective of how energy is used by industry and agriculture in North Carolina, the opportunities for increasing energy efficiency and providing other benefits, the barriers to realizing these improvements, and the strategies that will most effectively overcome these barriers.

Demography of Energy Use in North Carolina

North Carolina is a diverse state, geographically and economically. While high technology hubs, like the Research Triangle, exist as international centers for pharmaceutical and semiconductor research and manufacturing, agriculture still undergirds the state's economy. The agricultural sector directly accounts for about 2.5 percent of the gross state product, with agriculturally related manufacturing industries increasing the importance of this sector. Manufacturing industries account for about 30 percent of the gross state product (BEA, 1991). The state's total 1991 energy consumption of 1. 9 Quads was broken down by sector as shown in *Figure 1.* Electric consumption in 1991 of 92.3 terawatt-hours was about evenly distributed among the industrial, commercial and residential sectors as is shown in *Figure 2* (EIA, 1993a).

Industry consumes about a third of both the total energy as well as the electricity (EIA, 1993). The textile industry (SIC 22) is the leading manufacturing industry in North Carolina accounting for almost a third of the manufacturing jobs and over a quarter of the energy consumption as shown in *Figures 3* and *4,* reported in *Table I* in the appendix. This figure is based on 1983 data, which is the most recent breakdown of energy use by SIC code. When one looks at electricity consumption, the fraction increases to over 36 percent as shown in *Figure 5.* To appreciate the true importance of the textile industry to the state, it needs to be combined with the allied synthetic fibers (SIC 2823 and 2824) and apparel industries (SIC 23). Combined, these industries account for over a third of the state's industrial energy use (Hinkle, et al., 1983).

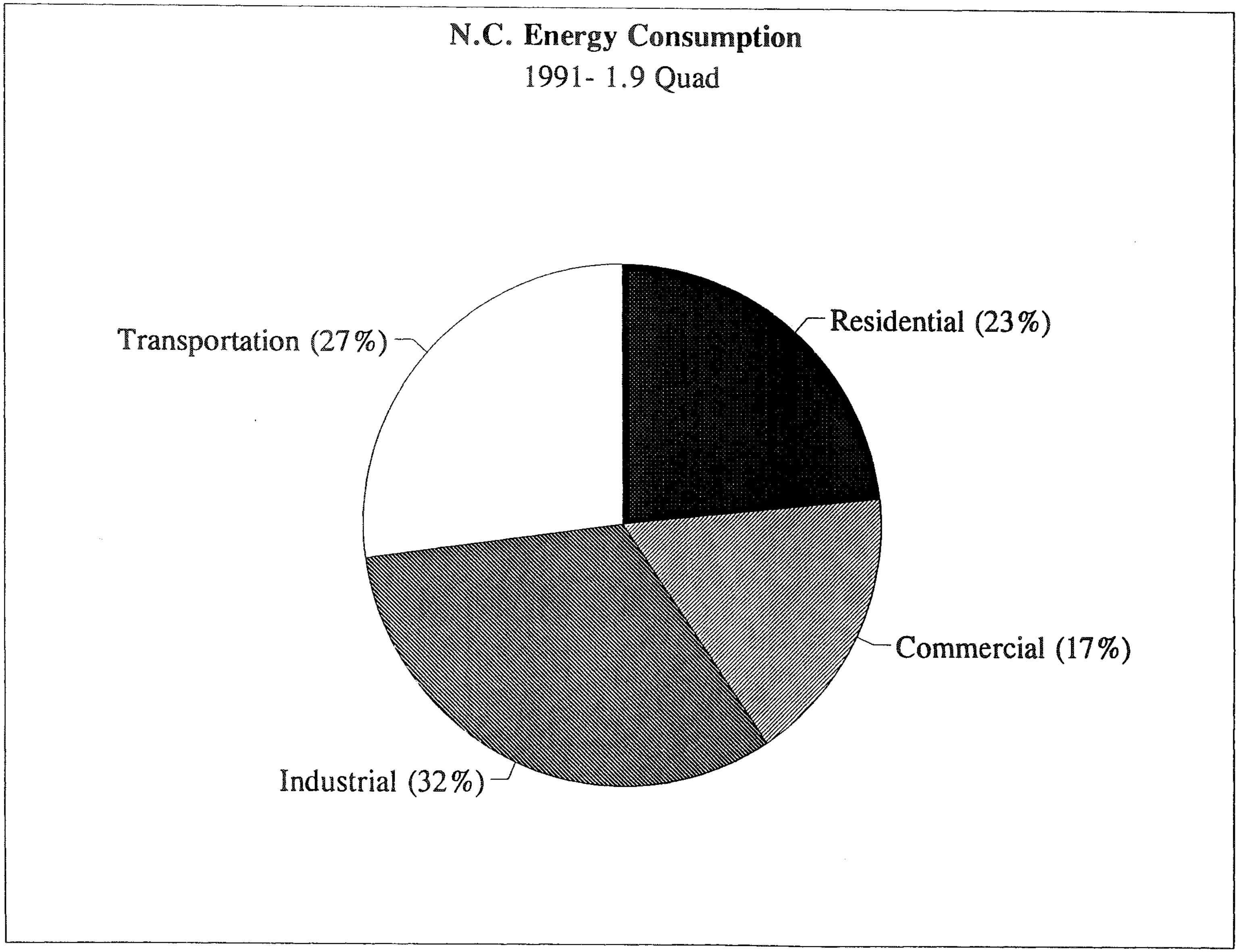


Figure 1 **(Source: EIA, 1993)**

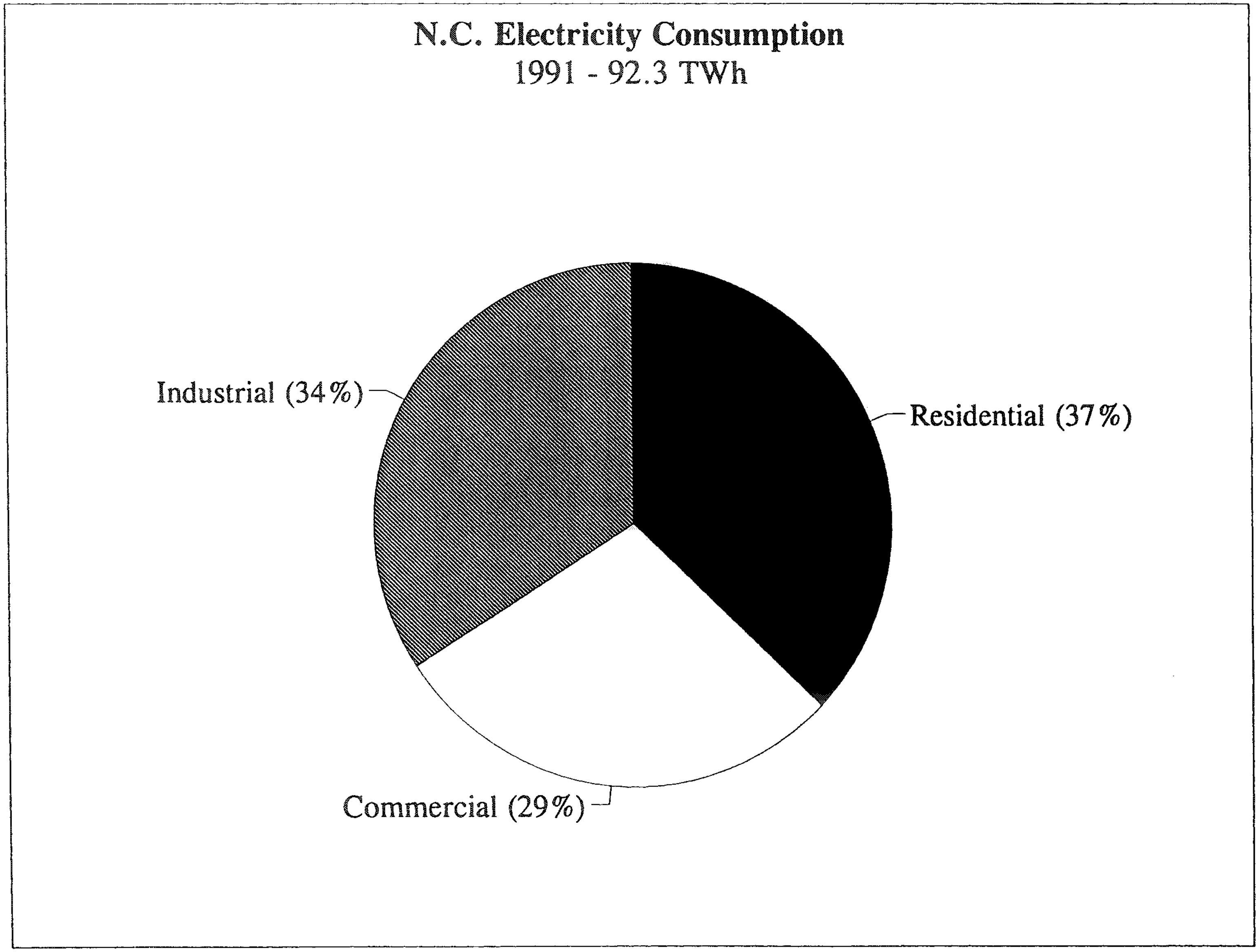


Figure 2 (Source: EIA, 1993)

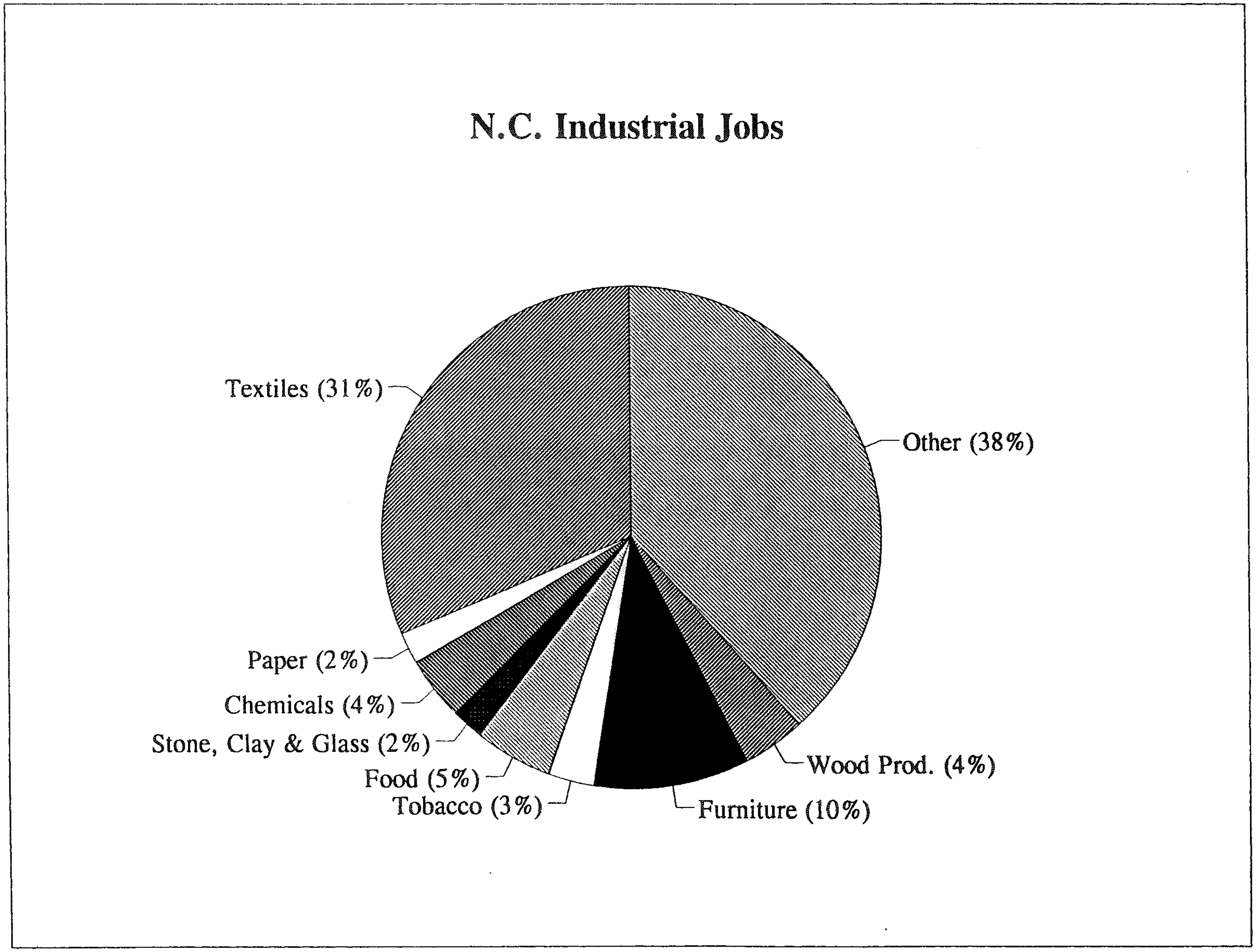


Figure 3 **(Source: Hinkle, et al., 1983)**

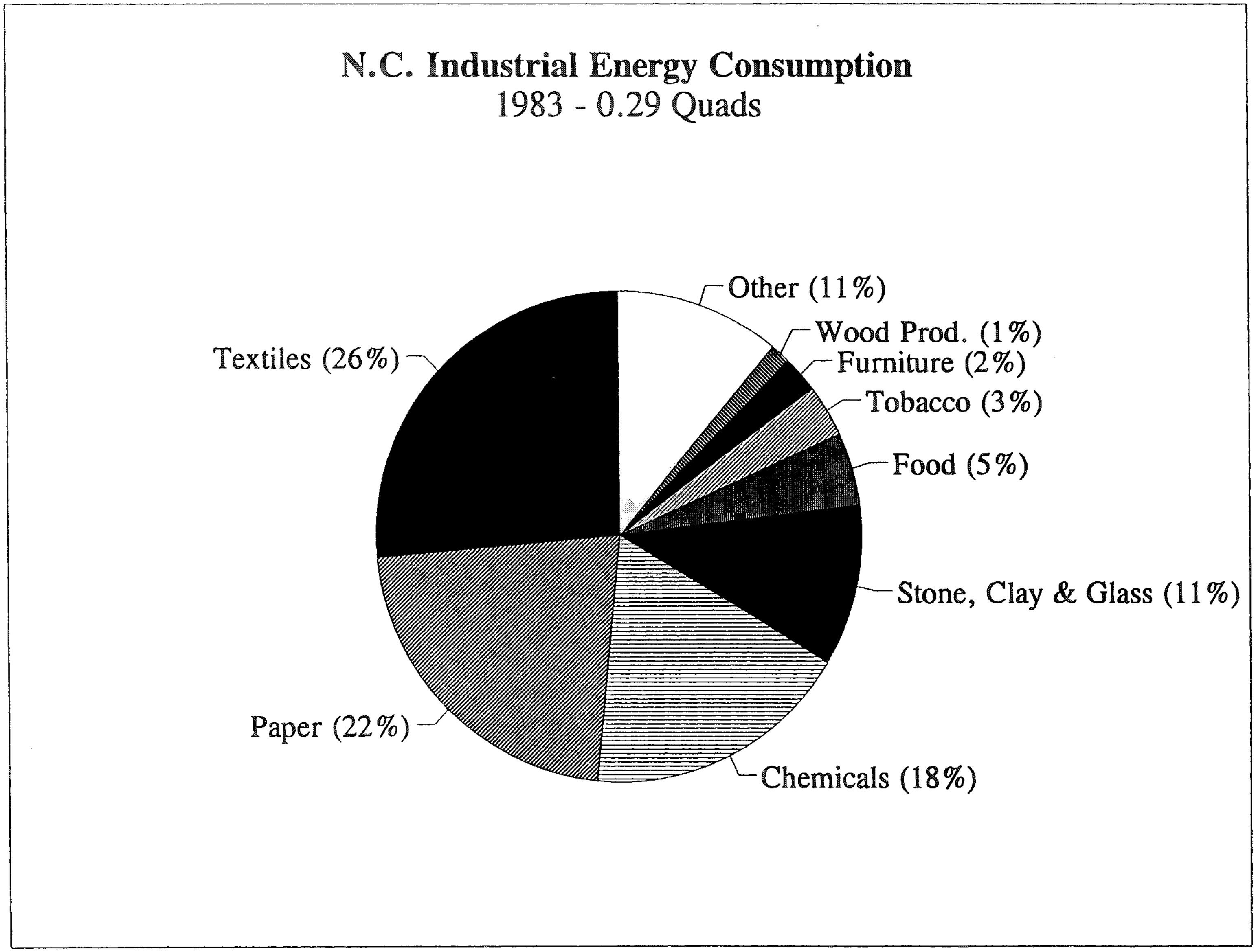
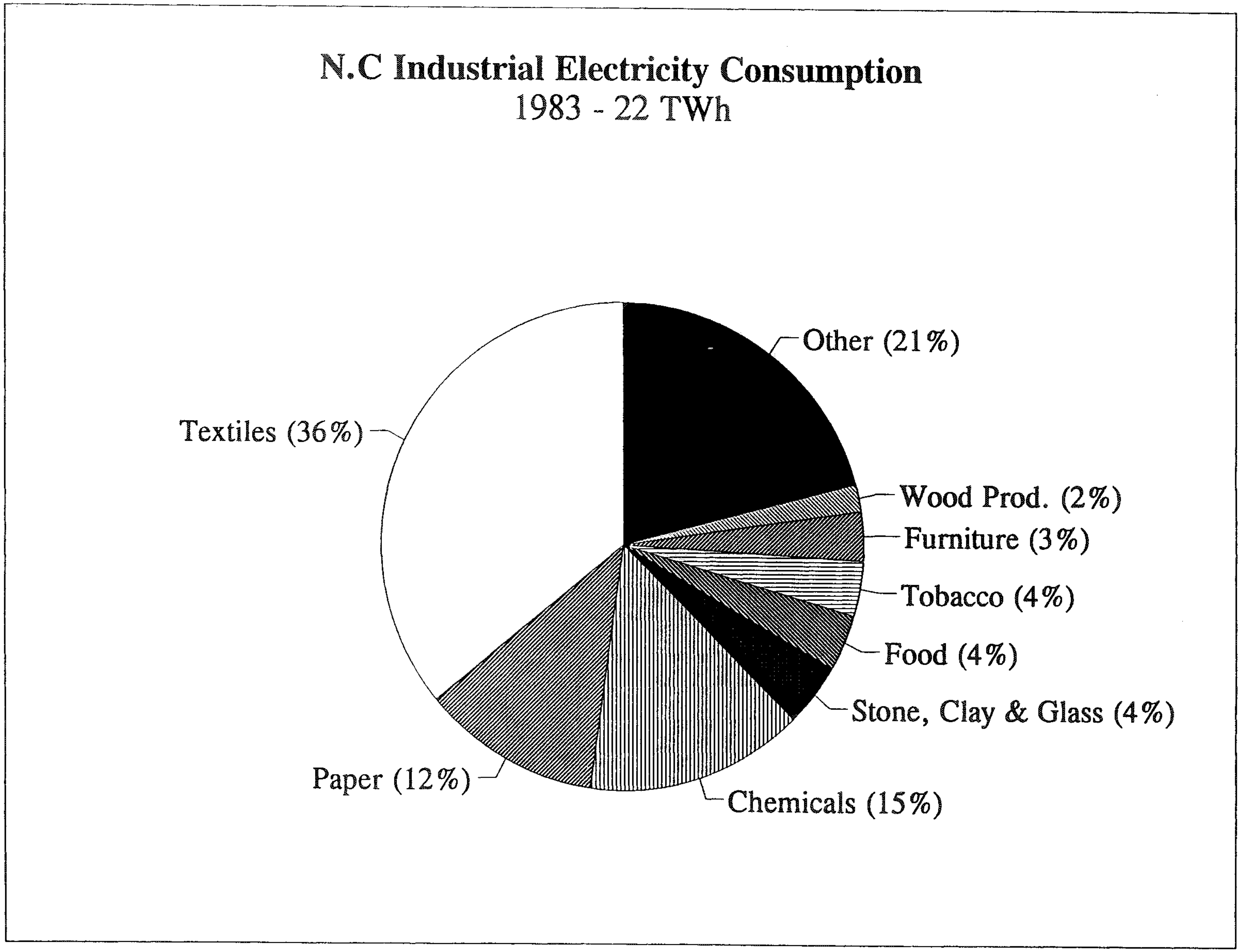


Figure 4 **(Source: Hinkle, et al., 1983)**



N.C Industrial Electricity Consumption
1983 - 22 TWh

Figure 5 **(Source: Hinkle, et al., 1983)**

Table I
1983 N.C. ENERGY USE BY MAJOR INDUSTRIAL GROUPS

SIC	Groups	Mfg. Jobs (%)	Electric (GWh)	Fossil (Quads)	Total (Quads)	% Total
20	Food	5	813	.011	0.014	4.8
21	Tobacco	3	805	.007	0.010	3.4
22	Textiles	31	7,933	.050	0.077	26.5
24	Wood Prod.	4	397	.003	0.004	1.4
25	Furniture	10	721	.004	0.007	2.4
26	Paper	2	2,622	.055	0.064	22.0
28	Chemicals	4	3,259	.041	0.052	17.9
32	Stone, Clay, Glass	2	927	.028	0.031	10.7
Others		38	4,614	.016	0.032	11.0
All Industry			22,150	.216	0.291	

Source: Hinkle, et al., 1983.

The paper, chemical, and stone, clay and glass industries together account for only 8 percent of manufacturing jobs in N.C., but these industries are very energy intensive, accounting for over half the total industrial energy use. Most of the energy consumed by the paper industry is at a few very large pulp mills that generate a significant portion of their energy from process waste (Hinkle, et al., 1983).

Energy is not a significant cost of production in most industries. Nationally, average industrial electricity costs represent only 1.2 percent of the value of shipments. This contrasts with production labor cost of almost 10 percent and materials cost of over 50 percent. None of North Carolina's industries differ dramatically from the national average as can be seen in *Figure 6.* The most electrically intensive is Stone, Clay and Glass at 2.5 percent while in tobacco the costs are an order of magnitude less at 0.2 percent (EIA, 1993b and Census, 1993).

Agriculture is not broken out separately, but is included in all of the above categories. On-farm agriculture does not directly consume large amounts of energy. Transportation fuel represents the largest component. Most on-farm electricity is not separated out, but is billed as residential energy use except for a few large farms that are billed as commercial customers. Agricultural electric consumption is about 2 percent of the state total (Gregory, 1986-90). Farms do use many products with high embedded energy content such as water, feed, fertilizers and agricultural chemicals. Four manufacturing industries have an agricultural base: paper, tobacco, food and wood products. Paper (SIC 26) is the second largest energy consuming industry as shown in *Figure 3*. The food processing industries (SIC 20) are significant energy users, being the fourth largest industrial energy consumers. Tobacco processing, which is the second most important agricultural commodity in the state after poultry, accounts for an additional 3.4 percent of the industrial energy use while wood products accounts for 1.4 percent (Hinkle, et al., 1983).

OPPORTUNITIES FOR IMPROVED ENERGY EFFICIENCY

Energy uses in industry and agriculture can be separated into two categories: 1) "utility" energy uses and 2) "process" energy uses. The utility energy uses, such as motors, lighting, compressed air and steam, can be changed without directly affecting processes and can yield significant energy savings. The Congressional Office of Technology Assessment describes "utility" energy efficiency measures as "house keeping, maintenance and equipment changes." Utility energy efficiency measures are often very cost effective. Replacing a motor at failure with a high efficiency motor can have a payback of less than a year on energy savings alone, and with proper planning can provide additional savings from reduced down time as will be discussed in a later example (IEL, 1993).

Many sources agree that the greatest potential for industrial energy savings lies in process modifications (Ross and Steinmeyer, 1990) (OTA, 1983 & 1993). As an example, the energy savings potential of converting from standard to high efficiency motors is about 5 percent (AEC, 1990), while the savings potential from a change in the process, as a later example from the wood products industry demonstrates, is about 50 percent. A recent study initiated and prepared for B.C. Hydro looked at technical and economic potential for electricity conservation in industry including both equipment substitution as well as alternative process configurations. It estimated a conservation potential of 37 percent relative to existing the technology mix. The study also found that many previous studies had underestimated conservation potential because they did not consider process changes (Jaccard, et al., 1993). Process modifications however confront the significant barrier of requiring fundamental changes to the primary activity of the facility: production. Thus it may be much easier to implement energy efficiency improvements in the utility area as compared to the process area.

As mentioned in the previous section, agriculture makes use of many products that have a high imbedded energy content. Unique opportunities exist for changing the energy use patterns on the farm through better utilization of these high energy content products. These changes can result in dramatic co-benefits such as improved product quality and reduced losses, along with significant energy savings. For example, the production of poultry feed is an electrically intensive activity. If something can be done to increase the feed conversion rate in meat production (i.e, how many pounds of feed are required to produce a pound of final packed chicken), it will reduce the energy required to produce a pound of meat. The N.C. Alternative Energy Corporation (AEC) and Carolina Power and Light undertook a demonstration of evaporative cooling of poultry houses with a North Carolina producer, Townsend Foods. This

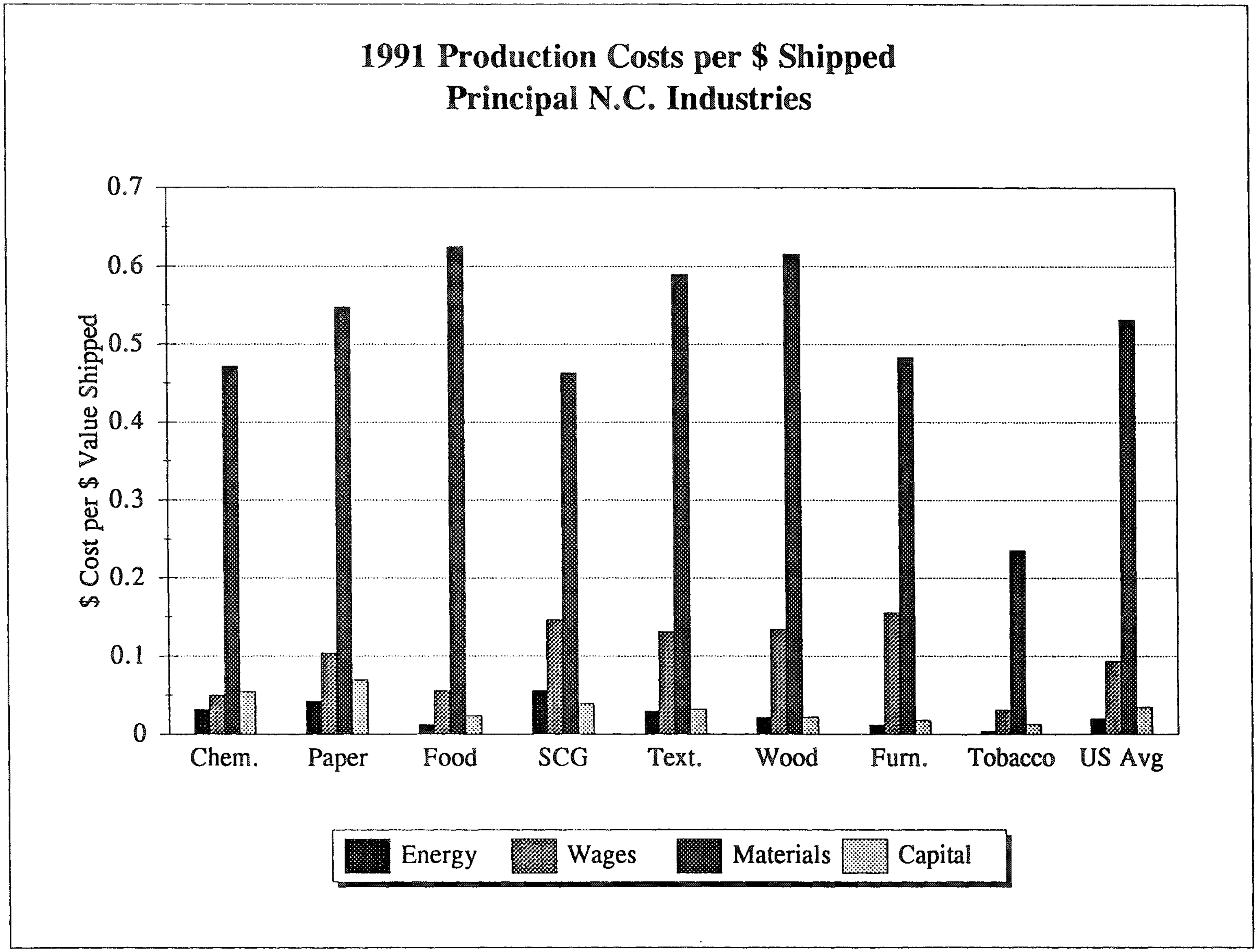


Figure 6 (Source: EIA, 1993b and Census, 1993)

technology improved feed conversion by reducing heat stress on the birds during the summer which reduced mortality and improved the growth rate of the birds. This had the double benefit of reducing the financial losses from heat related mortality (since bird are most susceptible to heat stress at the end of a grow-out cycle) and increasing the number of flocks that could be raised in a house each year. In addition the reduced stress allowed Townsend to eliminate the prophylactic use of antibiotics, which is both costly and slows growth rate (Gregory, 1986-1990).

Utility Uses

Utility energy represents generic forms of energy with well-defined parameters. *Table I* presents many utility energy forms with their relevant parameters. As long as these parameters are matched, different end-use technologies or energy sources can be readily substituted without affecting the process.

The list in *Table II* is subdivided into two categories: energy carriers, and intermediate and end uses. Energy carriers are media that transport energy to a process, like electricity. They have well defined and straight forward parameters that are generally well understood. For example, chilled water is characterized by its temperature and pressure. It can be produced by various types of vapor compression chillers, absorption chillers, or from the melting of ice. In some facilities, there may be several kinds of chillers operating together, as well as perhaps an ice storage system, all linked to a common distribution system. The water becomes an energy carrier much as the electrons in the electric grid.

The two remaining energy uses present more complex parameters that are more difficult to match, thus making substitutions more complex. In addition, many users may not be familiar with all the parameters and how changes in these parameters can affect the production process.

Table II
Forms of Utility Energy

Utility Energy Forms	Parameters
Energy Carriers	
Electricity	Voltage, frequency and number of phases
Steam	Pressure and quality/superheat
Compressed air	Pressure, temperature and cleanliness
Chilled water	Temperature and pressure
Intermediate and End Uses	
Shaft power	Power, torque, speed and load-speed curve
Illumination	Intensity, distribution, color temperature and color rendering

Shaft power might at first glance appear a straight forward matter of matching motor size and speed. Other important considerations can include the actual load/speed and torque/speed curves, which are continuous functions rather than single values. Depending upon the application, these values may not be too critical, so any drive source can be used. The sources of shaft power can vary from different types of electric motors, to turbines, to internal combustion engines. It is common to see turbines and electric motors on the same shaft in critical applications at boiler plants. The turbines can be used to maintain boiler operations in case of an electric failure. Some textile plants in North Carolina still use central power shafts that were originally driven by water turbines, but are now powered by electric motors.

For speed-sensitive applications like conveyers, fans and pumps, the substitution can become more complex. In the case of centrifugal loads, like fans, pumps and chillers, the magnitude of the electricity consumption is very sensitive to motor speed since the load varies as the cube of the speed (IEL, 1992c). If we add the ability to vary the shaft speed, we then move the drive application into the area of a process energy use since changes in speed can have profound impacts on process, as will be discussed in an example in the next section.

Increasing the energy efficiency of lighting in agriculture and industry may appear to be a simple matter of substituting higher efficacy lighting systems for lower efficacy systems (i.e., combinations of lamps, ballasts and fixtures). But many applications require an experienced lighting designer to achieve the best results from both visual performance and energy efficiency standpoints. The more complex parameters of color temperature, color rendering, and restrike characteristics of the different light sources need to be considered.

In applications where the color of light is critical, the selection of different light sources can prove complex. In these cases, the first test is that lighting quality is not reduced. If the color requirements are well understood, the wide variety of lighting sources available today can offer the potential for significant improvements in energy efficiency along with improved defect detection in manufacturing operations or improved productivity in agricultural production operations like greenhouses. Sometimes energy savings can be realized only from a lighting design that provides appropriate illumination of the task without wasting light on illuminating spaces like the tops of machines.

Task Lighting in Textile Spinning

An example of appropriate illumination is the lighting of open-end spinning frames in the textile industry. These are long, narrow machines that are located in rows with a narrow isle between them for worker access. Traditionally, spinning rooms are lit with eight-foot fluorescent strips on the ceilings. An automated doffing rail, at the top of the machine, shadows the visually critical spinning area that is located under the rail. By placing a light source over the aisle that directs light into the spinning area, the total wattage of lamps in the room can be reduced. This approach has been taken by a South Carolina lighting firm, Mor-Lite, which uses a custom-formed fluorescent reflector fixture mounted over the aisle to direct light onto the task. At one mill, two-lamp hooded high-output fluorescent fixtures were replaced with custom single-lamp reflector fixtures. Lighting level on the task increased from 40 to over 70 foot-candles, while reducing the lighting energy consumption by 38 percent (Hubner, 1993).

Poultry Lighting

Another example comes from the poultry industry, where artificial lighting has been used in chicken houses since the 1950s. The AEC undertook a project, in partnership with the electric utilities and the cooperative extension service, to promote the use of high efficiency lighting technologies for poultry houses. Previously farmers used incandescent lamps because they were the only readily available, practical source of artificial lighting. Conventional fluorescent lamps did not withstand the harsh environment (i.e., heat and corrosive gases) found in poultry houses. In the mid-1980s, compact fluorescent and high intensity discharge (HID) lamps became available. These lamps offer improved efficiency and lower operating costs, and can be obtained with sealed ballasts which withstand the high temperatures and corrosive environment. The payback from energy savings for the conversion is very short as shown in *Table III* with additional labor savings coming from the longer lamp life. In addition, a range of light colors are available.

While it is easy to substitute these higher efficiency lamps in the poultry houses and dramatically reduce power consumption for an equivalent light level, the mixture of light spectra can have profound effects on how animals behave. In the poultry industry these behaviors include aggressiveness, weight gain, egg production, egg quality and fertility. No information was available about what mixture of light spectra is optimal for the different sectors of poultry production: table egg production, fertile egg production (breeding), and meat production. Initial field trials, conducted jointly by AEC, the electric utilities and N.C. State University in cooperation with major poultry companies, showed that 2700K compact fluorescent lamps, which have a warm color with an appearance close to incandescent lamps, performed at least as well as incandescent lamps for table egg and meat production, but not for breeding. Parallel tests with 4100K lamps, which have a bluer color showed, reduced rates of feed conversion and egg production making them inappropriate for poultry use.

More basic research was required to look at light requirements for breeding. Initial results of research at N.C. State University indicate that potential exists for productivity, as well as energy, improvements by switching from incandescent to high pressure sodium lamps in breeder operations (Siopes, 1992).

Providing adequate technical information on all aspects of measures with potential for improved energy efficiency is a necessary but not sufficient condition for changing real world practices. Other factors such as interest in energy costs, financial incentives, promotion and market timing affect the degree to which cost-effective and technically viable efficiency measures get adopted. The initial trial results concerning the viability of converting to compact fluorescent lamps became available at an opportune time for the poultry industry. The industry was undergoing a major expansion with a large volume of new housing being constructed. The vertical structure of the industry was such that the poultry company, called the integrator, was responsible for the chick, feed, processing and technical support costs, leaving only labor, energy and the capital cost of housing to the farmer. Since energy represent about half the farmer's operating costs, and lighting costs represented a third of energy bills, the impact of improving lighting efficiency on the farmer's bottom line is significant.

The agricultural extension service, with support from AEC, the state's electric utilities and lighting vendors, undertook an aggressive promotional effort involving meetings with farmers arranged by the poultry companies. The integrators supported the program by publicizing the meetings to their growers, providing technical support, and in some cases arranging group purchases of lamps to reduce the farmer's costs. Compact fluorescent lamps made a 40 percent penetration into the table egg and chicken meat production sectors of the market within three years, before an industry-wide recession slowed market implementation. The technology has achieved widespread market acceptance with much of the new construction installing compact fluorescent lamps (AEC, 1989).

Table III
COMPACT FLUORESCENT
POULTRY HOUSE CONVERSION
PAYBACK (YRS)

Cost/ Fixture	Electrical Cost ($/kWh)			
($)	$0.04	$0.06	$0.08	$0.10
8	0.4	0.3	0.3	0.2
12	0.6	0.5	0.4	0.3
16	0.8	0.6	0.5	0.5
20	1.0	0.8	0.7	0.6
24	1.3	1.0	0.8	0.7

Source: AEC, 1987.

Process Energy

Process modifications can be approached at several levels. At the most superficial level, the process modification may only involve replacing one energy source with another as in replacing gas-fired infrared drying with electric infrared drying. This approach tends to provide only limited process improvement and energy savings.

If a technology substitution is considered along with an analysis of the actual process energy requirements, more substantial amounts of energy can often be saved. For example, several textile plants in the southeast that have considered installing industrial heat pumps have analyzed their process heat requirements only to discover that they can simply lower steam pressure or water temperature and realize significant energy savings without modifying the process (Puciano, 1991).

A more rigorous approach would be to analyze the particular process, or in many instances the system of processes, with respect to how best the production goals can be realized. Through reengineering the process, taking advantages of the latest technological innovations, the potential frequently exists for dramatic improvements in productivity, product quality, and energy intensity. Providing multiple benefits is a critical strategy for convincing plant management to modify a functioning process. On the other hand, these potential benefits come at the cost of significant amounts of time, money and increased risks from unforeseen impacts of what may initially appear to be only minor changes in the production process.

Process modifications can be grouped by generic category: thermal, chemical and mechanical. In many cases with more significant modifications of the process, there may be at least a partial substitution of one type of energy category for another.

Thermal Processes

Thermal processes are used extensively in many industries. All three forms of heat transfer, conduction, convection, and radiation are used, in many cases in combination. A thorough assessment and understanding of an individual process or system of processes will often reveal opportunities to reduce or eliminate thermal inputs to the process. By selecting a process temperature as close to ambient as possible to reduce heat loss, an initial level of improvement can be achieved. This change will reduce the driving force of the heat transfer.

Convective heat transfer processes are inherently inefficient because they require the heating of a transfer medium that in turn heats the process material. This problem is particularly evident in forced air drying processes.

Radio Frequency Drying of Textiles

Drying is the largest energy end use in textile dyeing and finishing operations. Conventional dryers operate by blowing heated air through the wet product to evaporate the moisture and transport it away. To accomplish this, both the moisture and the product must be heated. This wastes the energy required to heat the product, which must be dissipated when the drying is completed, and much of the heat is discharged with the exhaust air. The heating of the product also results in thermal degradation of the fibers due to the heating of the already dry surface necessary to dry the interior of the product. Radio frequency (RF) drying (a form of dielectric heating) selectively heats the water molecules by exciting them in an oscillating electromagnetic field in the same manner as a microwave oven. As a result, the drying is accomplished faster, more uniformly, and with less heating of the fibers. In addition, the energy cost per pound is less than for the most efficient conventional dryers, since the RF dryer frequently uses less electric energy and no steam, compared to the conventional dryer which uses both steam and electricity (Dawson, 1989).

Industry's motivation for investing in these dryers is not necessarily the energy savings but the other previously stated benefits. A dramatic example is a North Carolina firm that installed an RF unit to dry cashmere (Cato, 1991). Cashmere is a very expensive fiber costing as much as $35 per pound in its raw state and over $70 when processed. Over-dying of cashmere during processing damages some fiber resulting in a loss of the product. By using an RF dryer the temperature of the fibers never exceeds 140°F, and the plant was able to increase its yield by 2 percent resulting in a savings of $1.40 per pound processed. This compares to an average energy savings of 4.8¢ per pound due to the switch from conventional to RF drying. The firm in this case justified the purchase on product quality improvements alone.

Ultrasound Enhanced Textile Dyeing

Sometimes the task performed by the thermal energy can be accomplished by the substitution of other energy, such as chemical or mechanical. An example is the application of ultrasound energy to the textile dyeing process. The N.C. State University College of Textiles is developing a new process in which ultrasound energy (sound waves) replaces some of the thermal energy (in the form of steam, hot water and direct fired gas) and some of the chemical energy (in the form of catalysts and surfactants) used to wet-out fiber, apply dye stuffs, fix reactive dyes, and wash-off excess dye stuffs (Smith and Clapp, 1989-1992). Not only does this process promise to use less energy with reductions in:

- hot water volumes,
- the temperature of the process, and
- the volume of chemicals, including dyes required by the process,

but, also offers several co-benefits including:

- reduction of both the volume and temperature of the waste water stream,
- reduction the cost of chemicals required by the process,
- reduction of processing time,
- improvement in product quality,
- allowing for more accurate shade control, and
- reduction of dyes in the effluent stream.

These co-benefits, as with RF drying, offer greater economic benefits than the energy savings alone.

Mechanical Energy

In N.C. industries, mechanical energy is used predominantly to operate manufacturing machines, such as looms, saws and cigarette makers, and for moving fluids by using pumps, compressors or fans. Other than the option of changing the motor, machines are very difficult to modify because of the complexity of the operation. In the case of fluid flow, opportunities do exist to save energy by accurately matching flow to process requirements. The advent of reliable and affordable variable speed drives allows many of these opportunities to be realized. The challenges are to gain an understanding of what the process requirements are, how to sense indicators of the requirements, and how to control the flow.

Variable Air Flow in Lumber Dry Kilns

The AEC, in cooperation with the furniture industry and the state's electric utilities, undertook a project to demonstrate the potential of controlling airflow in hardwood-lumber dry kilns. The first step was to understand the physics of the lumber drying process. The process involves three distinct phases: release of the mechanical or chemical bonds that hold the water in the wood; transport of the water to the surface; and transport of the water away from the surface by air flow. In furniture grade lumber, especially some hardwoods like oak, it is important that the moisture gradients within the wood be limited to minimize drying stresses that result in degrading of lumber quality. Since the first two phases of the drying process are driven by the wood temperature and the relative humidity at the surface, the amount of water requiring transport away from the surface will vary during the drying process. In conventional operations, the maximum air flow required is estimated and the requisite fan capacity is installed (usually with some excess capacity for good measure). The drying rate is controlled by regulating the kiln temperature and recirculating air to control relative humidity. This means that the total fan capacity installed is required for only a short period for the drying cycle.

An AEC study indicated that the required rate of air flow could be determined by measuring the wet bulb depression in the air immediately after it had passed through the lumber stack. Using this reading as an indicator, a control strategy was developed by AEC to vary the fan speed. A field trial with an industrial firm confirmed that varying the air flow resulted in at least as good a lumber quality with no effect on production rates. Though tests were not conclusive, the dry kiln operators felt that lumber quality was better with the variable air flow, particularly on difficult woods to dry like oak. The total energy required for a kiln charge was reduced by about half as shown in *Figure 7.* Paybacks for the fan control systems vary from 2.4 to 8.7 years depending upon motor size and kiln configuration (IEL, 1992b).

The AEC, with its partners including the electric utilities and the Southern Dry Kiln Club (the regional technical association), is now letting the hardwood lumber industry know about this technology. The demonstration partner is considering implementation of the technology company-wide. A side benefit of this educational effort has been the opportunity to inform the hardwood lumber industry about electric motor selection and management.

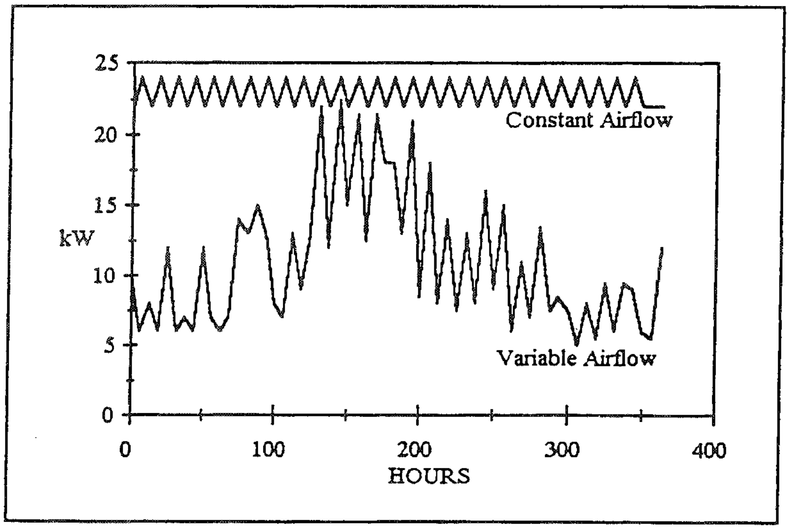


Figure 7. Fan Energy Comparison for Constant and Variable Speed Dry Kiln Trials.
Source: IEL, June 1992

THE DECISION MAKING PROCESS

In order to appreciate energy decision making, it is important to have an understanding of the context and range of issues affecting an industrial facility. While competition for capital is frequently a problem (Alliance to Save Energy, 1983), some improvements can be realized with little if any additional capital expenditure. Often, it is competition for the attention and time of the work force that limits the improvements carried out. Industry often operates in a crisis mode, with whatever has the most immediate impact on the operations of a plant receiving staff attention. Anything that affects the ability of the facility to produce and meet customer requirements receives first priority. Next come issues that affect whether the plant will stay open. These lately have involved compliance with environmental regulations. After these issues are addressed, if any time remains, most plants look to preventing operating problems from occurring through preventive maintenance. It is frequently suggested that energy efficiency measures can be implemented during annually scheduled plant shutdowns to prevent disruptions in the manufacturing process. During this period, the competition for time becomes even more intense since the engineering and maintenance staff usually are working overtime to install new equipment and do maintenance that cannot be done during normal operations. Discretionary tasks, like energy efficiency improvements, are usually deferred.

Plant engineering and maintenance staff in North Carolina have generally been supportive of energy efficiency improvements. But changes with both energy efficiency and productivity benefits can be stymied by a purchasing system in many companies that operates on the basis of lowest first cost. With a focus on first cost, life-cycle operating costs are frequently ignored. Carolina Power & Light's audit program has shown that opportunities with greater than a two-year payback are unlikely to be carried out unless there is a unique situation where the change is necessary for the customer's survival (Jordan and Nadel, 1993).

One cause is the complexity of the energy decision-making process. Energy decisions are not made independently, but rather as a part of the operation of the plant system as a whole. Changes requiring process modifications may have to pass many reviews before receiving final approval. Many larger corporations have an established hierarchy for decisions starting at the plant level and then moving up to the division and corporate level. In many plants, facility operations are separated from the process operations. Depending upon the company, these parallel tracks may extend to the corporate level.

During the 1970s, it was common to find an individual or entire department devoted to managing energy use and coordinating activities related to energy between departments. The decline in energy prices and the financial problems most manufacturing companies experienced during the 1980s caused many of these individuals or departments to disappear. The energy efficiency advocacy role, when it remains, has been assumed by the engineering and maintenance staffs. A case in point in North Carolina is Burlington Industries, which used to have a department devoted to energy conservation and management. It served as an intermediary between corporate engineering and purchasing, and provided support to the plants on energy issues. This department shrank in size as the 1980s progressed, eventually disappearing by the end of the decade, with its role being assumed in part by the engineering department (Lohr, 1988-1992).

Along with the loss of energy professionals, the research and development resources at many companies have shrunk or disappeared. For example, Burlington Industries closed their major research facility, losing their ability to develop and evaluate production modifications. R&D departments provide the technical expertise and dedicated staff necessary for the implementation of many process improvements. They identify the energy savings available through process modifications, work with plant personnel to design the process modifications, and provide the support to the plant necessary to carry out these changes. Of course the ramifications of these cuts extend beyond energy efficiency to other process advancements.

At the plant level, cuts have also been made in engineering and maintenance staff. Sometimes, the plant staff is so overworked that they don't have time to even identify and implement utility energy improvements. Since many process decisions are not made at the plant level, plant staff have limited input to improving the efficiency of the process, even if they have the technical expertise and time to make such recommendations. With the cutbacks in corporate staff, a void now exists that is only partially being filled by external groups such as the university extension services and utility technical staff.

While some utility and governmental energy efficiency programs directed toward industrial customers have been successful (Jordan and Nadel, 1993), it is not easy for outside parties to play a useful role in influencing energy decisions within industry. These external parties often lack familiarity with the particular plant operations and are unable to stay with a modification from identification through design and implementation. Few, if any, changes go as anticipated. There is a shakedown period in which the modifications are fine tuned to work within the plant system. It is difficult for a utility, industrial extension service, or state agency to stay involved through all stages of this process.

OVERCOMING BARRIERS TO IMPROVED ENERGY EFFICIENCY

Appealing to the Bottom Line

An important concept that strikes a resonant cord with many industrial managers is the idea that "wasted" energy is lost profit, and that to make up for the loss, additional product must be sold. As the textile industry has discovered over the last fifteen years, often there is no market for that additional product. Opportunities for "utility" energy savings are frequently appealing in this regard. The savings are frequently easily documented, and the risks are low. Lighting in warehouses and outside buildings are particularly good candidates since the savings can be substantial and the paybacks are short. Motor projects can be more difficult because the energy savings are small and may not be readily detectable.

Some inventive plant personnel have worked around the system to carry out energy-efficiency measures. At one textile plant in North Carolina, the maintenance supervisor wanted to purchase new, high efficiency motors to replace existing standard motors when they failed, rather than repair them. Since it was important to replace the motor as soon as possible, the motors it was routine to pay premium for a express repair. These overtime repairs often produced a poor quality motor which would fail prematurely. Often the cost of the overtime motor repair equaled the cost of a new motor, but purchasing regulations prohibit the purchase because they require a lengthy approval process for the new motor, while a standing purchase order exists with the rewinder. The maintenance supervisor started listing motors as replacement parts by catalog number and calling them "a drive assembly" rather than go through the normal motor procurement process. In his way he circumvented the lengthy procurement process and obtained high efficiency motors.

Securing Corporate Commitment

While plant staff may be interested, even enthusiastic about energy efficiency, practical demands and the conditions outlined above often don't allow most of them to advocate changes or work around the system. For those who do advocate change, the reality is that several years may be required to realize the fruits of their labors.

If corporate management becomes committed at the highest levels to improved energy efficiency, hurdles to energy efficiency can be eliminated. At Stowe-Pharr Mills, corporate management was convinced that motors were important. They empowered staff to work with their motor suppliers to arrange to have high-efficiency replacement motors to be delivered within an hour, twenty-four hours a day. In contrast, an overtime rewind required a minimum of one day. The savings in reduced down time more than made up for the cost differential of buying a new, high-efficiency motor. In addition, the new high-efficiency motor is more reliable and consumes less energy than a rewound motor (Morgan, 1990).

Demonstrating Multiple Benefits

As mentioned in the previous section, energy decisions are not made independently but in the context of overall plant operations. To receive approval of a major process modification, it is important that it also offer benefits with regard to at least one priority issue for the company. For example, a reduction in wastewater discharge temperature allowing compliance with municipal ordinances was a major consideration in the installation of the wastewater, heat-recovery heat pump installed at American and Efird's dyeing and finishing facility in Mount Holly, NC (Batson, 1989).

Similarly, industry's initial interest in technologies like RF drying and ultra-sound enhance dyeing discussed earlier come not from the potential energy savings but from process enhancements. While the example of textile machinery lighting was in large part justified by the energy savings, a less easily quantified benefit of improved worker visual performance was present. Even in the case of poultry house lighting, the industry was very aware of the potential for controlling bird performance through the use of a more flexible light source.

Providing Technical Assistance

Since one barrier to the implementation of energy efficiency is lack of staff time, making technical assistance available may help address this issue. This approach can be particularly effective when the technical expertise being offered is not readily available in the marketplace. North Carolina has been a national leader in this area. One early example was Wood Assistance Team effort that started in 1978. The goal of the program was to promote the use of wood fuels in non-wood products industries. A need was identified for three areas of technical assistance: wood fuel combustion and handling, wood resource procurement, and environmental permitting. N.C. State University, the N.C. Forest Service and the N.C. Division of Environmental Management each contributed expertise to a team that worked with potential candidates to assist them in evaluating and implementing wood fueled systems (Elliott, 1981). The program was very successful in convincing 35 percent of the firms for whom case studies were prepared to install wood boilers. Even after the fuel price advantages of wood were erased in the early 1980s by drops in the price of coal and natural gas, the program continued a reduced level until 1986. The Extension Wood Products Department at N.C. State University continues to provide limited support today and continues to work with companies who converted and are still using wood fuels (Jahn, 1993).

The AEC has used the same team model for many of its technology dissemination projects. The poultry lighting project mentioned earlier brought together expertise in poultry science, lighting, and engineering to provide the assistance and support necessary for farmers to convert to fluorescent lamps. The project was delivered in cooperation with the Cooperative Extension Service who offered the most extensive network of contacts and credibility with poultry farmers.

The Industrial Electrotechnology Laboratory (IEL) is AEC's most ambitious technical assistance effort. Its goal to establish a physical location where technical assistance is available to industry in the application of energy-efficient technologies such as RF drying and high-efficiency electric motors. AEC joined with N.C. State University's College of Textiles to make state-of-the-art, production class facilities available to assist industry. These facilities are used to conduct initial trials of process technology changes, with continue to support of the industrial facility through process development and startup, trouble shooting. IEL pooled research expertise from the university, with energy expertise from AEC and electric utilities, and hired staff from industry familiar with the needs of manufacturing companies. A partnership was formed with the electric utilities. The utility customer service representatives served as the contact between the customer and IEL. No other group in the state has more frequent or substantive contacts with manufacturing plants than the utility staff. In addition, the utility staffs are technically oriented with many being registered engineers already familiar with energy issues (IEL, 1992).

The IEL opened in April 1991 with RF dryer, vacuum microwave dryer and infrared dryer test equipment, and an industrial lighting demonstration. Since then additional lighting demonstrations and RF dryers, and a motor test facility have been added. As of April 1993, over 200 trials had been run using the test facilities for customers in North Carolina, South Carolina and Virginia (Dirisio, 1993).

One common characteristic of all these projects is an effort to develop an understanding of the particular issues facing the target audience and an attempt to identify benefits of the technologies, in addition to energy, which are important to the industry. Technical assistance is likely to be more successful if it makes use of an intermediary who is already in regular contact and has credibility with the target audience.

CONCLUSION

Experience in N.C. demonstrates that while energy issues impact economic viability, productivity, security and environmental compliance, energy by itself is not important. Energy savings alone will not usually motivate industry or agriculture to change its energy use patterns. Projects that produce economic, productivity or environmental co-benefits are more likely to capture industries' or farmers' attention, especially if the project addresses a current, pressing need.

If one is to influence the energy use of a group of companies , it is important to understand how the industry functions, their markets, their diversity and the critical issues affecting their future. Expertise with time to devote to developing and implementing energy efficiency projects is a commodity in short supply in industry. If industry sees a state or utility program as offering greater benefits to the company than the cost of participation (usually measured in time), then the program will likely receive a fair hearing.

The greatest potential for energy savings exists with changes in processes. These modifications frequently offer co-benefits whose value can exceed the energy savings. Projects involving process changes can be complex, costly and carry a high risk of adverse affects on the product. As a result, these projects can frequently involve a lengthy and difficult corporate approval process. However these process modification often can provide multiple benefits that are of great value to the plant, company, or farm.

While the elimination of waste and substitution of more efficient technologies in utility energy uses yields only moderate energy savings, these projects are usually low risk and frequently very cost effective. These projects can also be easier to implement since the approval process is often less complex. However, factors such as the lack an individual with energy responsibility or lack of available staff time can still inhibit energy-efficiency improvements in then "utility" area.

In view of the experiences in North Carolina and decision making in general, a successful state or utility program to increase energy efficiency in industry should embody the following characteristics:

- consider working through groups who already have established credibility and channels of contact with the target audience.

- build commitment to energy efficiency at all levels in a company. Plant staff are frequently receptive, and with support from top management, can become enthusiastic partners.

- program staff should understand the product, processes, structure and current condition of the industry as a whole as well as individual companies.

- make initial recommendations for utility energy changes since these projects can be cost effective and can more easily win approval than process changes.

- focus on projects that offers benefits in addition to increased energy efficiency.

- provide technical expertise and support throughout the decision-making process, from opportunity identification to final shakedown.

- persist for several years because of the long lead times often required to gain approval and implement energy efficiency projects in industry.

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