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Energy efficiency : the impact of energy costs on business concerns

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ENERGY EFFICIENCY: THE IMPACT OF ENERGY COSTS ON BUSINESS CONCERNS

BY

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INTRODUCTION

Statement of the Problem

American businesses often spend twice as much for energy use than they need. In fact, the inefficient use of energy costs American businesses billions of dollars annually. However, energy prices do not include costs associated with national dependence on foreign oil or the environmental costs affiliated with oil and coal burning or toxic waste disposal.[1] "It is precisely because of this cheap-energy climate, and the consumption pattern it fostered, that there is now so much room for improvement in the efficiency of energy use."[2]

"Energy is a necessary component in the production process, and over time, U.S. energy consumption has tended to rise in tandem with the Gross National Product."[3] Energy use in commercial facilities include lighting, heating ventilating and air conditioning (HVAC), the operation of office equipment, as well as the operation of mechanical systems used in the production process.[4] Managerial cost accounting treat these energy expenses simply as fixed cost and provides no analysis as to the efficiency of energy consumed. While there are a number of variances used to address the efficient operation of variable expenses of production such as direct labor hours and materials, fixed costs such as utility expenses are neglected in financial analysis. As a result, businesses allow utility concerns to dictate what often amounts to a large portion of operating overhead. This study identifies the efficiency variance associated with energy use and its application.

As energy prices rise, energy conservation will return to the forefront of government legislation as it did in the 1970's. Oil imports to the U.S. are continuing to increase the widening trade deficit. The result will surely be increasing pressure on Congress to take action in the form of oil import fees or gasoline tax hikes both of which took place during the oil crisis of the 1970's.[5]

Methods of Research

To better understand the energy use profile of a given facility, energy engineering firms employ a multiple linear regression model.

> A regression equation for each year relating monthly energy use to degree days is fitted. In the equation there is no income or energy price variable because, during a given year, income and price are essentially constant and so the only reason for energy use to fluctuate on a month to month basis is weather.[6]

The equation reads:

$$Y_1 = a + (b_1 x_1) + (c_1 x_2)$$

where Y_1 = monthly use in kilowatt hours (KWH)

x_1 = heating degree days (HDD)

x_2 = cooling degree days (CDD)

The estimated intercept (a) identifies the energy use at zero degree days, and as such, is an approximation of non-weather sensitive energy load. This is also known as the baseline, meaning that amount of energy which will be used by the facility no matter what the weather is. The heating slope is the coefficient b, and is a measure of heating use and is interpreted as kilowatt hours per heating degree day. The cooling slope is identified by the coefficient c, and is a measure of cooling use and interpreted as the kilowatt hours used per cooling degree day. As a result of the regression analysis, total energy use is subdivided into these three parts: baseline, heating, and cooling. To obtain potential energy savings, engineers compare actual equipment energy use to designed energy use. For example, by knowing the manufacturer's requirements for energy inputs to achieve a designed cooling capacity for an air conditioning system and measuring these same data points on an operational system, one can readily determine the difference. It is this difference which translates into potential savings.

Primary research for this paper involves a diagnostic energy study conducted by the author and validated by licensed professional engineers who specialize in energy engineering. The subject of this energy audit is a dental facility in Great Falls, Montana. Secondary research is derived from actual engineering studies conducted by qualified, licensed energy engineering consulting firms. The studies have been selected for their uniqueness in the industries they represent and the variety of business necessary to afford this report a broad perspective.

Scope of Study

Energy cost savings potential is not limited to any specific business or industry. As a result, this study takes a cross-section of American enterprise illustrating the vast application of energy conservation methods and related financial rewards. Service sector facilities evaluated in this report include an office building, sports complex, computer facility, a church, and a multi-use bus depot. Manufacturing operations are also included and are addressed by a Department of Energy study on small and medium size manufacturers. To minimize the impact of changing utility rates, reports cited are less than 5 years old. While cost variations do occur between geographic locations, no geographic constraint is imposed on this study as the reports are not compared to one another. The effects of employee comfort on morale and productivity have been previously addressed in a number of studies. While not addressed here, the benefits of a comfortable work environment should not be ignored.

Terminology

A number of acronyms will be used throughout this report which may be unfamiliar and merit definition. These are:

HVAC: Heating, Ventilation, and Air Conditioning. Identifies those pieces of equipment used in the processes of each unique operation. This includes furnaces, air conditioners, fans, motors, cooling towers, and the like.

KWH: Kilowatt hour. That amount of electrical energy equal to 1,000 watts used during a one hour time frame.

BTU: British Thermal Unit. A quantity of heat required to raise one pound of water by one degree fahrenheit.

Limitations

The greatest limitation to this study involves the selection of engineering firms to provide the case studies. The authors' past affiliations with Texas Energy Engineers, Inc. and Entek Associates, Inc. not only provided the impetus for this study but also allowed for the availability of these detailed reports on service sector operations. Manufacturing cases are a compilation of three hundred case studies conducted by the Energy Analysis and Diagnostic Center (EADC) under direction of the U.S. Department of Energy.

Geographical limitations are also prevalent. With the exception of the manufacturing operations identified in the EADC report, each business examined in this report is located in the south central United States. The EADC report encompasses small and medium size manufacturing operations throughout the U.S.

While financial constraints are minimized and standardized throughout this report, they do exist. Energy costs and savings are based upon actual energy costs at the time each study was conducted. Additionally, Internal Rates of Return (IRR) and Net Present Value (NPV) calculated for each recommended Energy Conservation Opportunity (ECO) are based upon fifteen years at ten percent. The fifteen year time frame is based upon industry standards for engineering retrofits. The ten percent figure is a conservative figure for a rate of return on investments if one considers the fact that the multiplier - utility dollars saved in the current year - is actually subject to increase as utility rates rise.

Order of Presentation

The bases for potential overhead cost reductions for business vis-a-vis energy expenditures are identified as energy conservation opportunities (ECO) in chapter two. This report begins by defining the concept of ECOs. Reasons for implementing ECOs and barriers to their implementation are also identified in chapter two. Chapter two turns to actual case studies conducted by both government and private sector engineering firms. An actual energy analysis conducted by the author and validated by qualified professional engineers follows. Finally, in chapter four a summary of findings concludes the paper.

NOTES

1. Committee on Economic Development, Achieving Energy Independence, (New York: Committee on Economic Development, 1974), 32.

2. National Academy of Sciences, Energy In Transition: 1985-2010, (San Francisco: W.H. Freeman and Co., 1980), 76.

3. Glenn R. DeSouza, Energy Policy and Forecasting, (Lexington: Lexington Books, 1981), 20.

4. Ibid., 50.

5. Editor, "No Gas Lines Soon, But . . .," Changing Times, February 1989, 9.

6. DeSouza, 41.

CHAPTER 2

ENERGY CONSERVATION OPPORTUNITIES

Definition

Energy Conservation Opportunities (ECO) are engineering recommendations designed primarily to reduce energy use and costs. ECOs are typically associated with suggestions on operating procedures and preventive maintenance to prolong the operational life of equipment and minimize energy expenses. However, ECOs can address such items as fire hazards and violations of city ordinances and national codes. Building owners found in violation of city ordinances and national codes are often heavily fined. This condition alone would suggest that reasons for implementing recommended ECOs merit identification.

Reasons for Implementation

Business owners are often unaware of mechanical and electrical systems in their facilities. Yet, the U.S. courts have held in Overstreet V. Norman that business owners have a "...duty to furnish employees a reasonably safe place and appliances for the work."[1] This duty of care extends to electrical and mechanical systems ensuring proper maintenance and installation are completed and compliance with national codes and city ordinances governing these systems are met. Common law duties relating to liabilities such as these merit high consideration by business owners.

The issue of liability is often complicated by contractors. For example, many contractors may prefer to sell clients new equipment rather than perform maintenance on older heating and air conditioning systems. By installing new equipment and certifying the hook up, contractors effectively avoid liability for any malfunction by transferring potential fault to the system manufacturer.

"Speculative construction sometimes sacrifices operating costs, including those for energy, in order to minimize the initial purchase price."[2] Speculative construction refers to the omission of quality engineering in HVAC, electrical, and plumbing systems in order to have the lowest bid. These shortcomings must be identified and overcome for the firm to fully realize profit potential and discontinue wasteful use of company resources.

The most significant reason for implementing ECOs is cost savings. As technology advances the efficiency of manufacturing processes and HVAC systems, businesses must concern themselves with the impact of such technology on the industry. For example, energy efficiency in aluminum smelting, uranium enrichment, and steel making can be improved 10 to 90 percent with the implementation of newly discovered processes.[3] Additionally,

> ...electric heat pumps for space heating deliver about three times more heat than electric resistance heaters per unit of electricity consumption, and can also be reversed for cooling.[4]

Failing to address possible reductions in overhead costs vis-a-vis energy consumption may prove even costlier during increased competitor activity.

Health care facilities are turning toward energy conservation and management to reduce overhead costs and provide improved medical care. Savings in HVAC as well as specialized equipment are significant contributors to energy efficiency.

Perhaps the most important savings, however, can be achieved by installing equipment that combines both good business and good medicine: a central monitoring and control system. Within a hospital there are vast numbers of extremely complex mechanical and electrical systems that require a large number of people to monitor and maintain them. With a centralized system, critical areas can be monitored remotely by electronics. Fewer people are needed to operate it and the possibility of human error is reduced. Filters that need to be replaced occasionally cannot be forgotten, because the system sends a warning when replacement is necessary.[5]

The impact of technological advances in manufacturing processes are also easily illustrated. For example, "...a new cement manufacturing plant can be made (25) percent less energy intensive than today's twenty year old average plant by capturing and using the high temperature waste heat now released to the atmosphere."[6] According to Department of Energy studies, this process, known as heat recovery, accounts for annual cost savings of approximately $350,000 on the average for retrofitted operations.[7] These figures emphasize the most common reason ECOs are implemented, but certain barriers are raised in objection to changes and merit consideration.

Barriers to Implementation

The Director for the Office of Industrial Programs, U.S. Department of Energy, offers three major institutional objections to the implementation of ECOs: "union objections, fear of the unknown, and fear of change."[8] Union objections to changes in process manufacturing relate to manpower. Equipment operators are often retained in their current jobs due to their technical expertise in running the older machinery. Replacement of this equipment could strip employees of their technical expertise and potentially threaten job security.

Additionally, adoption of advanced technologies may reduce the number of employees required.

A second barrier raised is the fear on the part of a business to be the first, or even the second firm to adopt new technologies. Many businesses prefer to allow industry competitors to adopt the new technology and observe the change in performance. This ties into the third barrier which is fear of the impact on production. Dealing with unknowns, business often opts to forego potentially higher contribution margins in lieu of known profit levels.

Economic barriers to implementing ECOs include project costs, energy costs, and interest rates. Once a diagnostic energy analysis is completed, ECOs are recommended and associated costs and savings are attached with a simple payback calculation or a Net Present Value (NPV) and an Internal Rate of Return (IRR). While an ECO may be as complex as a retrofit of the entire HVAC system or as minor as the relocation of a thermostat, total energy cost savings resulting from implementation of these ECOs will almost certainly exceed the cost of implementation. Organizational funds may not allow for large capital expenditures. In this case, the cost of borrowing should be addressed by the business. The cost of borrowing money may also prove to be a barrier to implementation.

Lower energy costs tend to be a barrier to implementation as business ignores the energy consumption of its facilities. Conversely, higher energy costs serve as a catalyst for ECO implementation as contribution margins begin to dwindle. As energy costs soared in the 1970's, businesses scrambled to find ways to reduce their demand for energy. Business may be better served by being proactive rather than reactive in energy consumption reduction as energy audits and required retrofits may exceed one year to complete. With planning, energy retrofit work can often be completed during down time for the firm allowing for uninterrupted production and service schedules.

Government Assistance

The Energy Analysis and Diagnostic Center (EADC) is a Department of Energy activity sponsored by the Office of Industrial Programs. "This program is designed to help manufacturers control energy costs and improve efficiency."[9] Energy audits and recommendations on conservation are provided to small- and medium-sized plants throughout the United States.

"Energy and economic savings as a result of the audits conducted by EADC have been impressive and amount to an average per plant savings of $169,000 to $104,000 per year."[10] The program is conducted by thirteen engineering schools serving areas in thirty-six states throughout the continental U.S.

Other than the EADC, there are other initiatives conducted by the Office of Industrial Programs. The Industrial Energy Conservation Program (ICP) supports research and development to improve the energy efficiency of industrial processes and to develop technologies that use multiple types of fuels.

> Many manufacturing processes have energy efficiencies far below theoretical limits and far below competing processes in other countries. An improvement of one percent in the rate of industrial energy use in the U.S. would save approximately $1 billion annually.[11]

The ICP has supported a number of technological developments. A few of these jointly developed advancements are presented here.

> High-Temperature Burner Duct Recuperation Systems: installed on steel forging equipment, reducing fuel requirements up to fifty percent.
>
> Cement Particle Size Classification Technology: addresses the high costs associated with classification and grinding of coarse cement particles. Implementation saved the producer $400,000 per year in finish grinding costs and increased grinding capacity by twenty-five percent producing a superior quality cement.
>
> Impulse Drying of Paper: uses an electrically heated roll to remove water at up to 1000 times the conventional rate. Tests indicate impulse drying requires between 200 - 1000 Btu to remove a pound of water from linerboard, as compared to 1600 - 1800 Btu for conventional cylinder drying.[12]

The ICP program, also known as the "Schools and Hospitals Program," is:

> ...a voluntary grant program designed to provide matching federal grants to help non-profit institutions - schools, hospitals, local governments, and public care facilities - reduce energy costs.[13]

A prime example of the ICP program at work is the study conducted on Cooper Green Hospital in Birmingham, Alabama. This study "...identified 18 specific energy conservation measures with a total implementation cost of $940,000 and a projected energy cost saving potential of over $310,000 per year."[14] Applying a required rate of return of 10 percent for fifteen years, these figures suggest a net present value of $6,209,734 and an internal rate of return of 32 percent.

Case Studies

Manufacturing Operations

The EADC 1985-86 program study reveals significant information for energy cost reductions affecting manufacturing operations throughout the

United States. The study, which involved three hundred manufacturing facilities across the country, is the only federally sponsored program of its kind in the United States. To better identify those areas where savings opportunities exist, the EADC categorizes operations into four distinct divisions. The energy conservation opportunities and cost savings for each category are identified in Table 1.

Production: Energy consumed directly in manufacturing a product, e.g., gas used for heat treating steel.

Services: Energy used to supply heat or power in an auxiliary manner to the process or product, e.g., steam, compressed air, refrigeration.

HVAC: Energy used for personal comfort or regulating environmental conditions for operating equipment, e.g., air conditioning offices, heating personnel work areas.

Housekeeping: Energy to be conserved by normal routine operations and maintenance, e.g., turning off unused lights and idle equipment, adjusting thermostats, shades, windows, and closing doors.[15]

Table 1

TOTAL ENERGY AND COSTS SAVED BY CATEGORY

Category	Energy Conservation		Savings of Use	
	BTU x 10^6/yr	% Total	$/year	% Total
Production	449,761	33.1	2,435,037	18.1
Services	541,297	39.9	7,454,588	55.3
HVAC	298,821	22.0	2,474,020	18.4
Housekeeping	67,632	5.0	1,111,229	8.2
Total	1,357,511	100.0	13,474,874	100.0

Source: F. William Kirsch, Energy Conserved and Costs Saved by Small and Medium-Size Manufacturers, University City Science Center, March 1988, 23.

To better understand the various types of ECOs and their respective impacts on energy savings, the Directory of Industrial

Energy Conservation Opportunities (DIECO) was designed. Table 2 illustrates the quantities of conservation opportunities and related savings in the principal DIECO groups discovered during the EADCs energy audits.[16] It is worthy to note the average savings per manufacturer for each category particularly in the areas of heat recovery.

The EADC report applies standard financial analysis to the cost/benefit of ECO implementation. By utilizing the Internal Rate of Return (IRR) and Net Present Value (NPV) approach, EADC is able to demonstrate the financial opportunities related to ECO implementation to its clients. "The report indicates that after tax IRRs for manufacturers were between 393 and 547 percent. Additionally, the government enjoys an IRR of 65 to 116 percent."[17]

The NPV approach produced equally significant figures. The figure represents the ratio of all future cash flows, resulting from ECO implementation, to the capital expenditure required to implement the ECO.

> These figures varied from 3.59 to 5.47 for the manufacturer and 2.57 to 4.44 for the U.S. government. This indicates that for every dollar a manufacturer contributed to implementing an ECO, he or she received $3.59 to $5.47. The government enjoyed $2.57 to $4.44 for every dollar it invested. The government's returns are expected revenues generated by increased income taxes levied upon the manufacturer's incremental earnings, which are the results of cost savings realized by implementing EADC recommendations.[18]

Office Building

A regression analysis has been applied to this Baton Rouge, Louisiana, facility to better understand the energy use profile of the building. The analysis indicates that a high baseline condition exists. This condition often presents itself when high energy users are left

TABLE 2

TYPES OF MAJOR ECOs IMPLEMENTED 1985-86 EADC PROGRAM PERIOD

DIECO	DESCRIPTION	CONSERVATION 10^6BTU/YR	SAVINGS, $/YR
11	Equipment Efficiency	142,714	542,635
12	Equipment Maintenance	1,095	4,885
13	Combustion heat Recovery	120,411	467,872
14	Combustion heat Confinement	6,046	30,971
	Total DIECO 10	270,266	1,046,363
51	Equipment repairs and replacement	43,825	564,859
52	Process operations and designs	19,553	74,107
53	Techniques specific to certain processes	26,049	250,883
54	Process heat Recovery	116,679	343,108
55	Process heat Confinement	29,816	222,664
	Total DIECO 50	235,922	1,455,621
61	Lighting	39,043	661,937
62	Heating and Cooling	137,572	1,159,660
63	Buildings and Grounds	7	140
	Total DIECO 60	176,622	1,821,737

Note: ECO = Energy Conservation Opportunity and EADC = Energy Analysis and Diagnostic Center.

Source: F. William Kirsch, Energy Conserved and Costs Saved By Small and Medium-Size Manufacturers, University City Science Center, March 1988, 14.

running constantly. This situation can create significant problems for equipment and poses new problems for the engineering staff who must interpret the regression analysis. Lighting loads are often part of the problem as lamps continue to burn during non-duty hours. The high baseline created by these conditions actually masks the heating and cooling slopes forcing these to be underestimated by the model.

ECO #1 is to install a multi-stack chiller for low-load after hours use. Currently, the chillers and air handling units are running continuously including after hours use. This recommendation will allow the system to be shut back during low load hours. Running the larger chiller at night with little or no load demanded of the unit, serves only to damage the equipment, increase energy charges, and shorten the effective life of the chiller. After business hours, the only portion of the facility actually requiring air conditioning is the computer center. Based upon dimensions, BTUs produced by the equipment, lights, and personnel, 40 tons of cooling should be adequate. Running the 125 ton chiller drawing 100 amps is extremely costly when compared to the 40 ton unit recommended. The cost of this ECO is estimated to be $34,700 with annual savings of $11,600.[19]

ECO #2 is to install automatic light controls and install new fixtures. The current fluorescent light fixtures are 18 years old and contain ballasts of the same age. The acrylic diffusers have yellowed and are restricting effective illumination. A greater concern rests with the ballasts. The ballasts in these fixtures contain Poly Chlorinated Biphenyls (PCB) and have been identified as a cancer causing agent. This condition poses a serious health risk to the employees in the facility. Replacing the existing four lamp fixtures and PCB ballasts with 4 lamp deed cell fixtures with energy saving lamps and ballasts, lighting efficiency will be drastically increased. Installation of automatic light switching controls on office and demo-classroom areas via motion sensor switches is also recommended. Mechanical timers can be set to reduce "all-on" lighting hours. The cost of implementation would be $38,000, but $10,000 must be used to remove the PCB laden ballasts regardless of ECO implementation. This would be a capital requirement in ensuring a safe work environment. The potential savings to be realized by implementing this ECO would be approximately $10,330.[20]

ECO #3 involves the reactivation of the HVAC economizer cycle on each air handling unit (AHU). The economizer has been disabled and is no longer operational. Additionally, the pneumatic controls used to control the AHU are virtually ineffective. By reactivating the economizer cycle the firm can expect to save $20,560 annually for an implementation cost of $63,251.[21]

ECO #4 recommends installation of solar film on the exterior windows due to the single pane glass used throughout the facility and the solar load on the building due to geographical location. The single pane glass provides a low U-value, increasing the summer cooling load requirements on the chillers and decreasing employee comfort. Solar film would increase the U-value to .90 and reject a minimum of 73 percent of the total solar energy affecting the facility through the glass. Cost of this project would be $42,000 with an annual energy cost savings of $11,284.[22]

ECO #5 suggests the installation of an energy management system to more efficiently run the mechanical systems. Periodic maintenance and contracted HVAC work have created a hodgepodge of the controls on the equipment. Currently the systems are running out of control and this condition is costly. New control will allow for greater efficiency and less human intervention. Total cost for the control system would be $59,751 with an annual savings of $18,500.[23] By implementing all five of the recommended ECOs at a cost of $227,702, the building energy use would be reduced by $72,274 for a simple payback period of 3.15 years.

Sports Complex

Designed in 1963, the Houston Astrodome was touted as one of the engineering wonders of the world. By 1972, the dome became one of the engineering nightmares of the world. Energy costs for operating the sports complex were originally projected to be $100,000 annually. But by 1972, the charge was exceeding $115,000 a month with no end in sight. While energy costs had indeed grown over the years, the effect of rising rates was marginal. The Astrodome was simply an energy abuser.

The building was originally designed to host 100 baseball games and 10 football games per year. These figures were quickly exceeded. The addition of the Houston Convention Center, which drew its power and cooling requirements from the Astrodome, contributed significantly to the energy consumption problems. Changes in the dome itself led to further complications.

> The air conditioning system was originally designed to remove condensation from the inside of the dome resulting from the watering of the football field and baseball diamond. At the time of this study, the natural grass had been replaced with what

is now known as Astroturf. The excessive water in the air was gone.[24]

During a walk through of the facility in October of 1976, engineers noted the following:

> Both steam boilers were operating at 50% of capacity, using 40,000 cubic feet of gas per hour to produce 27,000 pounds of steam per hour. This condition equates to an efficiency rating of 70%.
>
> All AHUs are running and maintaining 65 degrees fahrenheit in the stadium. Office heating and cooling are cancelling each other out due to the BTUs produced by the equipment, lights, and personnel combating the inefficient distribution of air in the space.[25]

These two major observations illustrate that there is a large amount of reheat - simultaneous heating and cooling - taking place. For example, the AHUs are trying to cool while the boilers are trying to heat. Additionally, there is a low load on the system as there are no sporting events taking place. The gas and electricity are being used without limitation and the net result is absolutely no effect on the facility at all.

A plan was established to provide controls on existing equipment and to retrofit the inefficient machinery. The engineering study and control modification cost $25,000 resulted in the majority of the $503,577 saved during the next twelve months of operation.[26]

Computer Facility

An electrical systems analysis was conducted on this Dallas, Texas, building in June of 1986. While costs and savings are not identified, legal issues of liability and worker safety are prevalent.

The study was requested by the operator of the building due to an electrical accident at the facility which occurred during routine plumbing.

There were seven electrical panel disconnects with no main building disconnect. This is a violation of the National Electrical Code. The panels are not marked and therefore no worker can be sure all power to the panel is off prior to repair or maintenance.

The HVAC system was inspected and the heating elements were noted as being on. As this study was conducted in June, this condition indicates the HVAC controls are not functioning properly.

A set of 500 MCM cables connected to the main electrical service bus have been damaged. One of these cables has apparently separated and the other two have high resistance on them indicating potential problems in the near future.

The heat shrink tape installed on one of the main service cables to insulate the wiring, has gotten so hot that it has melted away.

The 500 MCM cable at chiller 2 in the penthouse has frayed strands at the connector to the bus which has lead to excess overheating due to resistance and resulted in possible damage.

In the MCC panel, containing the frayed connector, a phase to phase short is very possible due to the limited clearance in the panel. This condition may result in human injury as well as the shut down of the building entirely.

There were no fault current protection (circuit breakers) in place. This could lead to damage to the entire electrical system as well as serious human injury.

The ground wires throughout the facility have over one ampere of load. This is dangerous. Ground wires are supposed to have loads in the milliamp range. This condition is the likely culprit of the plumbing incident previously mentioned.[27]

These conditions are direct violations of the national electrical code, local ordinances, and fire safety standards. In the result of an electrical malfunction, no safety devices would trip. Subsequently, energy would continue to be supplied to the building resulting in fire and probable loss of life.

Church

This church is located in College Station, Texas. The building operation had changed over the years. As a result, minor modifications had been made along the way resulting in stop gap measures which were consequently costing the church more for energy than was budgeted. Church attendance had grown over recent years and the physical facilities of the church had grown as well. However, no plan was ever established for the mechanical systems in the church. For example, the decision to install duct board, rather than metal ducts, was cost effective during construction, but now made it more costly to improve efficiency by reducing duct leakage. The direct expansion freon units being used for cooling were nearly 20 years old. Given the condition of the facility, any recommendation made to realize energy savings was going to cost a substantial amount of money.

ECO #1 strongly recommends modification of the office air conditioning and overhauling the chilled water system. Due to years of neglect, these systems need major improvements in order to gain better efficiency. Additionally, once the new systems are installed, controls should be added to insure the proper operation of the system. Cost of this project is projected to be $65,000 with an annual savings of $9,146.[28]

ECO #2 recommends modification to the sanctuary HVAC, placing the sanctuary compressor on the central plant, and auto heat/cool changeover. Current configuration of the system requires human intervention in changing over from hot water in the winter to cold water in the spring and summer. This condition places the system in jeopardy of being destroyed should a check valve inadvertently allow cold water into the boiler. Cost of this ECO is approximately $68,000 with an annual savings of $6,713.[29]

ECO #3 deals with the power source and the lack of insulation throughout the facility. Insulation and increased ventilation should be added to bring the facility within national standards and codes. Additionally, the power source was also noted as being unbalanced. This condition seriously affects the operation of all electrical systems throughout the facility and contributes directly to early failure of electric components. Cost of this ECO will run $27,500 with an annual savings of $1,700. However, failure to correct the unbalanced power source to the facility will surely cause premature failure of electrical systems bringing the potential savings of this ECO to a much greater number.[30] Total cost of implementing all ECOs would be $160,500 with an annual savings of $17,559 for a simple payback period of 9.14 years.

Multi-Use Bus Depot

An 11 acre strip in downtown Houston, Texas, is the site of this facility. The terminal is used to provide the full spectrum of bus operations to include maintenance, washing, storage, and other activities. Approximately 180 busses a day are serviced in this facility.

ECO #1 recommends installation of reflectors in the existing acrylic lamps. Since the fixtures currently have two ballasts and actually will require only one after installation of the reflector, retrofit of the ballasts to provide a more efficient unit is highly recommended. Additionally, the reflector will allow for the removal of two of the four fluorescent tubes currently in use for each fixture while providing the same amount of light. Cost of this project is estimated to be $11,400 with an annual savings of $5,522.[31]

ECO #2 deals with the HID lamps used in the work bays. These are high energy users and are currently allowed to remain energized throughout the day and night. Though switches for the lamps do exist, employees are allowing the lights to remain on as the lamps require up to five minutes to become fully energized. Installation of lighting controls to extinguish the outside lamps and pushbutton switches to control the bay lamps with overrides should correct this problem. Cost of this project is $11,400 with annual savings of $5,522.[32]

ECO #3 is to install timers and a timer override system for control of the heating and cooling units. Many of the air conditioning units are running 24 hours a day when not required. This is costly and can easily be eliminated. Cost of implementing this recommendation is $1,600 with an annual savings of $1,829.[33]

ECO #4 suggests eliminating the heating and cooling currently being supplied to the restrooms. These rooms are often satisfied with the air in the hallways being drawn into the space by exhaust fans required for ventilation. Cost of this ECO would be $500 with an annual savings of $1,067.[34] Total cost of implementing all ECOs would be $24,900 producing a cash inflow of $13,940 annually from energy cost savings. This provides a simple payback of 1.78 years.

Bank Facility

Located in Bryan, Texas, this bank was saddled with dissatisfied customers and employees alike. The air conditioning system was improperly adjusted resulting in areas with no cooling air. Additionally, maintenance on the HVAC systems resulted in considerable down time. The humidity in the bank made dollar bills soggy and produced jamming in adding machine printers due to condensation levels.

ECO #1 identifies the need for humidity control of the building when the chiller is deactivated. Currently, the chiller is deactivated for seven hours a day. During the period from November to March, a small amount of water (5 gallons) is brought into the building in the air daily. Since the facility is warmer than the outside air, water remains airborne and is exhausted. However, during the period of April through October, a great deal of moisture (205 gallons) enters the facility daily. Because the walls are cooler than the air, condensation forms causing paper to go limp, drapes and carpets become musty, and the structural integrity of the building is subjected to weakening. By installing a remote humidity indicator to override the current control system, the chiller would not be required to run as often. Additionally, water intake into the facility would be drastically reduced. Cost of this project would be $11,730 with an annual savings of $1,500.[35]

ECO #2 requires an overhaul of the standby chiller. This unit is ten years old and is producing cool air at 75 percent of rated capacity while the efficiency of the unit is 30 percent poorer than it should be. The standby chiller is currently used to supplement the main chiller in the summer months. Once the main chiller is properly maintained, it will be able to handle the load required of it, thus, negating the need for the standby chiller during peak periods. During the winter months, the main chiller is often operated at 35 percent of capacity producing high energy costs and detracting from the operational life expectancy of the main chiller. This condition can be eliminated by using the standby chiller in off peak months. Cost of this recommendation would run $5,722 producing an annual savings of $5,940.[36]

ECO #3 recommends the installation of a variable speed control on the main AHU fan motor. This motor draws 100 horsepower and the high torque of the motor is causing premature wearing on the bearings during startup. This has resulted in considerable down time, motor replacement, and maintenance costs. The motor currently uses 688,800 kwh annually at a cost of $42,912. To allow the AHU fan to be off when the building is unoccupied and the requirement for air volume is significantly less than during the day, the installation of the variable speed fan is recommended. This will also allow for soft start of the motor in the morning hours prior to the work day and reduce bearing damage during start up. Cost of this project is $ 5,250 with an annual savings of $ 23,940.[37]

ECO #4 suggests replacement of the main AHU fan motor. The efficiency of the 100 horse power motor is .88 and should be at least .93. Installation of a high efficiency motor would provide a rating greater than .93 and a life expectancy of 20 years. Cost associated with the implementation of this recommendation is $5,280 with an annual cost savings of $1,680.[38]

ECO #5 recommends a modification of the present dual duct air conditioning system into a variable air volume configuration. The system is currently creating simultaneous heating and cooling, or reheat, effectively neutralizing each other. This condition is caused by poor air distribution throughout the facility resulting from modifications to building design not encompassing changes to the air system, the addition of machinery and computers, and the relocation of work centers. With a variable air volume system, the building is zoned and the heating and cooling needs of the facility satisfied by inserting the appropriate amount of air into the space. The system will annually reduce the main AHU use by $8,568, chiller output by $10,485, and boiler heating requirements by $8,952 for a total annual cost savings of $27,978. Cost of this project will run $117,600.[39]

ECO #6 suggests that air infiltration should be reduced to recommended ASHRAE standards. The building was designed to have an infiltration level of 6,500 cubic feet per minute (CFM), but was measured at 9,000 cfm. The air intake damper can be controlled to reduce the load by providing 10 cfm per person during the working hours (8-5) and reducing that air to 0 cfm during the non-working hours. This new level of air infiltration will effectively be 3,000 cfm. Cost of this project is a modest $2,000 with an annual savings of $7,392.[40] Annual cost savings of $68,430 can be realized by implementing all ECOs at a cost of $147,582. This provides a simple payback of 2.15 years.

Table 3 identifies the net present value (NPV) and internal rate of return (IRR) for each ECO by facility title. The NPV figures are derived using a 15 year payout discounted at 10 percent as previously discussed. The internal rate of return is also derived using fifteen years.

TABLE 3

NPV/IRR FOR RECOMMENDED ENERGY CONSERVATION OPPORTUNITIES

Facility	ECO	NPV($)	IRR
Office Building	1	53,530	35%
	2	50,571	35%
	3	93,130	27%
	4	58,051	23%
	5	80,961	29%
Total		322,021	31%
Church	1	4,565	11%
	2	-16,940	5%
	3	-14,570	<3%
Total		-26,944	6.8%
Bus Terminal	1	30,600	50%
	2	20,912	23%
	3	12,311	>40%
Total		81,129	>40%
Bank	1	87,719	>40%
	2	39,458	>40%
	3	176,840	>40%
	4	7,498	35%
	5	95,203	23%
	6	54,224	>40%
Total		372,903	>40%

Note: NPV = Net Present Value and IRR = Internal Rate of Return.

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9. Office of Industrial Programs, 14.

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15. F. William Kirsch, Energy Conserved and Costs Saved By Small and Medium-Sized Manufacturers, University City Science Center, March 1988, 14.

16. Ibid., 3.

17. Ibid., 3.

18. Ibid., 6.

19. Texas Energy Engineers, Inc., "Diagnostic Energy Study of the ... Baton Rouge Branch Building," 34.

20. Ibid., 40.

21. Ibid., 48.

22. Ibid., 48.

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26. Ibid., 307.

27. Texas Energy Engineers, Inc., "Electronic Systems Analysis...Las Colinas," 1.

28. Entek Associates, Inc., "Diagnostic Energy Survey...Church," 13.

29. Ibid., 15.

30. Ibid., 17.

31. Texas Energy Engineers, Inc., "Diagnostic Energy Survey...Bus Terminal," 31.

32. Ibid., 33.

33. Ibid., 35.

34. Ibid., 43.

35. Entek Associates, Inc., "Diagnostic Energy Survey...bank," 96.

36. Ibid., 100.

37. Ibid., 102.

38. Ibid., 104.

39. Ibid., 106.

CHAPTER III

DIAGNOSTIC ENERGY SURVEY

The Family Dental Center located in Great Falls, Montana, has been providing dental care to residents of Cascade County for more than twenty-five years. Situated on Tenth Avenue South at the eastern end of the city, the facility is a single story structure with state of the art dental equipment and a full basement used primarily for storage. The lack of employee and client comfort in the building due to poor heating and air conditioning has caused the owner to seek advice.

Building Efficiency

The main power using systems in the facility are the heating and air conditioning systems, office equipment, and lighting. Both the heating and air conditioning units use the same air handling system located in the basement. Upon inspection, the return air plenum was noted as being dirty. Large deposits of dust and a clogged air filter were inhibiting the efficient operation of this unit. The air conditioner compressor is located on the roof and appears to be in good condition. However, annotations in the maintenance records concerning an on-going leak in the freon line raise concerns about past maintenance.

Recessed high-hat incandescent lamps are located in the waiting room and reception areas. Bulbs ranging from 75 to 150 watts are currently installed. These fixtures provide little light and create unneeded heat. Fluorescent lamps are used in the reception area as well as in each operatory. These fixtures appear to be original and the acrylic diffusers have discolored due to age, greatly reducing the illumination in the rooms.

A single thermostat controls the temperature throughout the facility. The thermostat is located in the hallway near the operatories. While this location is typically ideal, the control panel for the x-ray machine is located just beneath the sensor. When energized, the x-ray control panel emits 80 degree fahrenheit heat falsely satisfying the thermostat in the winter and calling the air conditioner on in the summer.

The air distribution system was designed for the original building specifications. In recent years, additions to the facility have been made with no subsequent upgrade of the air distribution system. Consequently, the system is in great need of balancing and possible retrofit. The addition of the waiting room added approximately 400 square feet to the existing facility with much of the exterior wall being made of glass. The air handling system was designed for 1,900 square feet and was never upgraded to satisfy the new space. As a result, the heat created by the inefficient high hat lamps in the waiting area coupled with the solar heat load of the large glass wall, develops a heat load that cannot be overcome by the existing air distribution system.

Energy Use Profile

A multivariate regression analysis is employed to determine where the actual energy use is being allocated. Using actual billing data and heating and cooling degree day data provided by the National Oceanic and Atmospheric Administration (NOAA) for Great Falls, the building use profile is determined. By employing the regression equation identified in chapter one, a baseline and slopes for heating and cooling are ascertained.

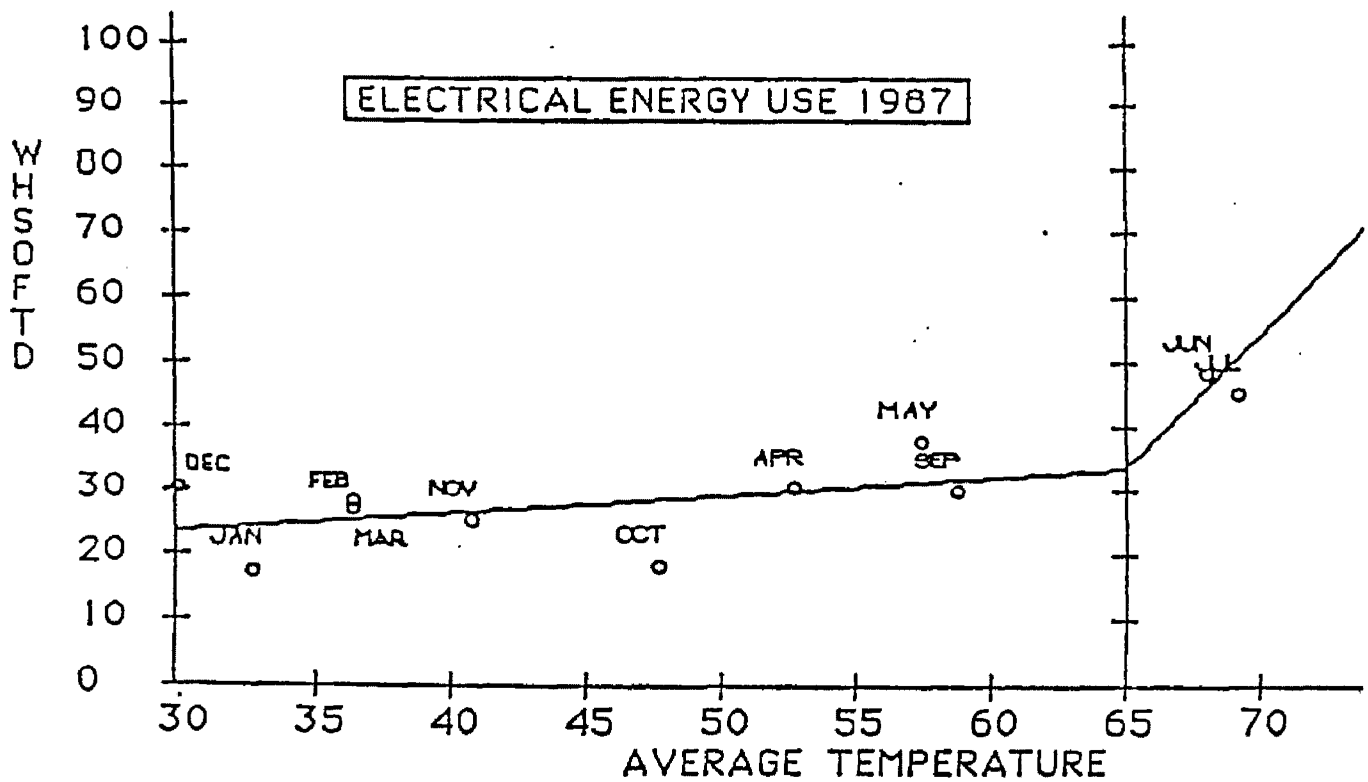
The regression analysis identifies a baseline of approximately 35 watt hours per square foot per day for electrical usage. This figure could be reduced to 18 by employing the ECOs noted in this report. By doing this, the baseline would decline better illustrating the heating and cooling slopes. The high baseline is partly the result of the reheat, or simultaneous heating and cooling, coupled with the use of the air conditioner on moderate days.

The negative heating slope identified in Figure 1 illustrates a classic reheat pattern. That is, cooling and heating are used at the same time. A trend line drawn in Figure 2 shows that heating and cooling are both used when the average outdoor temperature is about 47 degrees fahrenheit. A strong correlation with the weather is shown in this figure indicating obvious use of electric heat in addition to the central gas unit in the facility. Figure 3 depicts the expected energy use pattern if simultaneous heating and cooling are eliminated.

The gas usage for the facility is shown in Figure 4. The summer baseline and the slope are within normal limits. The expected improvement in gas usage should be as shown in Figure 5. The usage for the month of April is undoubtedly influenced by the heat load added by the air conditioning unit.

FIGURE 1

REGRESSION PLOT OF 1987 ELECTRICAL BILLS VERSUS WEATHER DATA

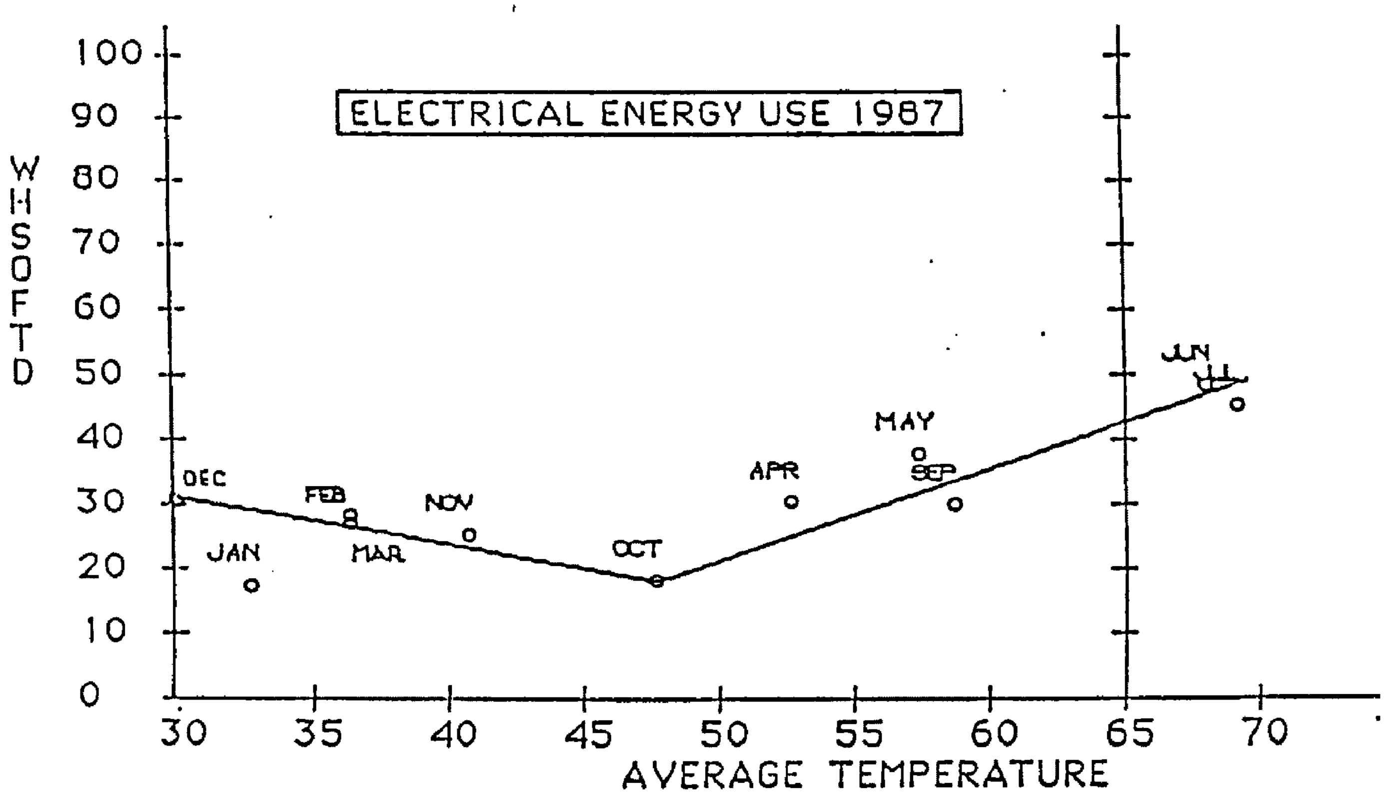


Note: Actual Billing Data by Montana Power Company for Great Falls Dental Office versus Weather Data Provided by NOAA.

WHSQFTD = Watt hours per square foot per day.

FIGURE 2

1987 ELECTRICAL DATA WITH TREND LINE

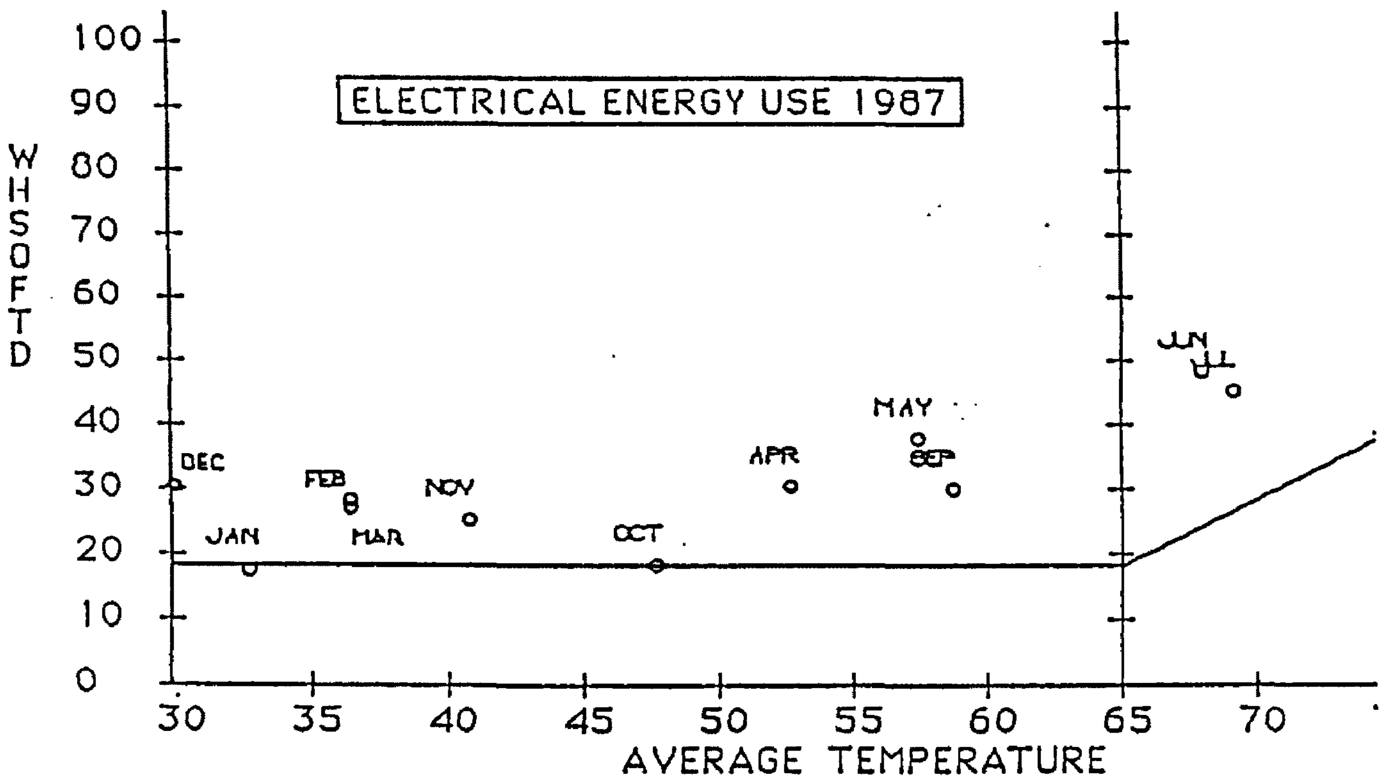


Note: Actual Billing Data by Montana Power Company for Great Falls Dental Office versus Weather Data Provided by NOAA.

WHSQFTD = Watt hours per square foot per day

FIGURE 3

EXPECTED ELECTRICAL BILL VERSUS WEATHER DATA FOR MODIFIED FACILITY

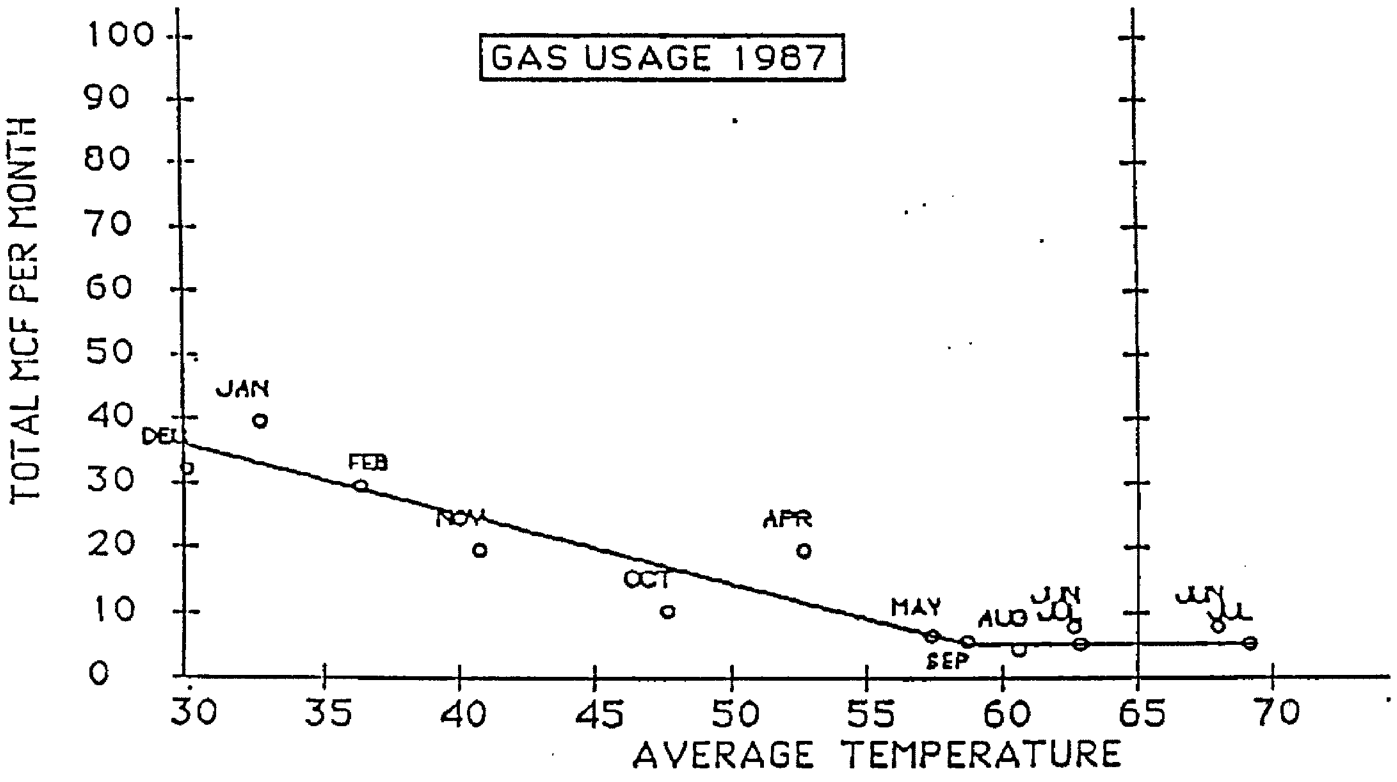


Note: Actual Billing Data by Montana Power Company for Great Falls Dental Office versus Weather Data Provided by NOAA.

WHSQFTD = Watt hours per square foot per day

FIGURE 4

REGRESSION PLOT OF THE GAS BILLS VERSUS WEATHER DATA

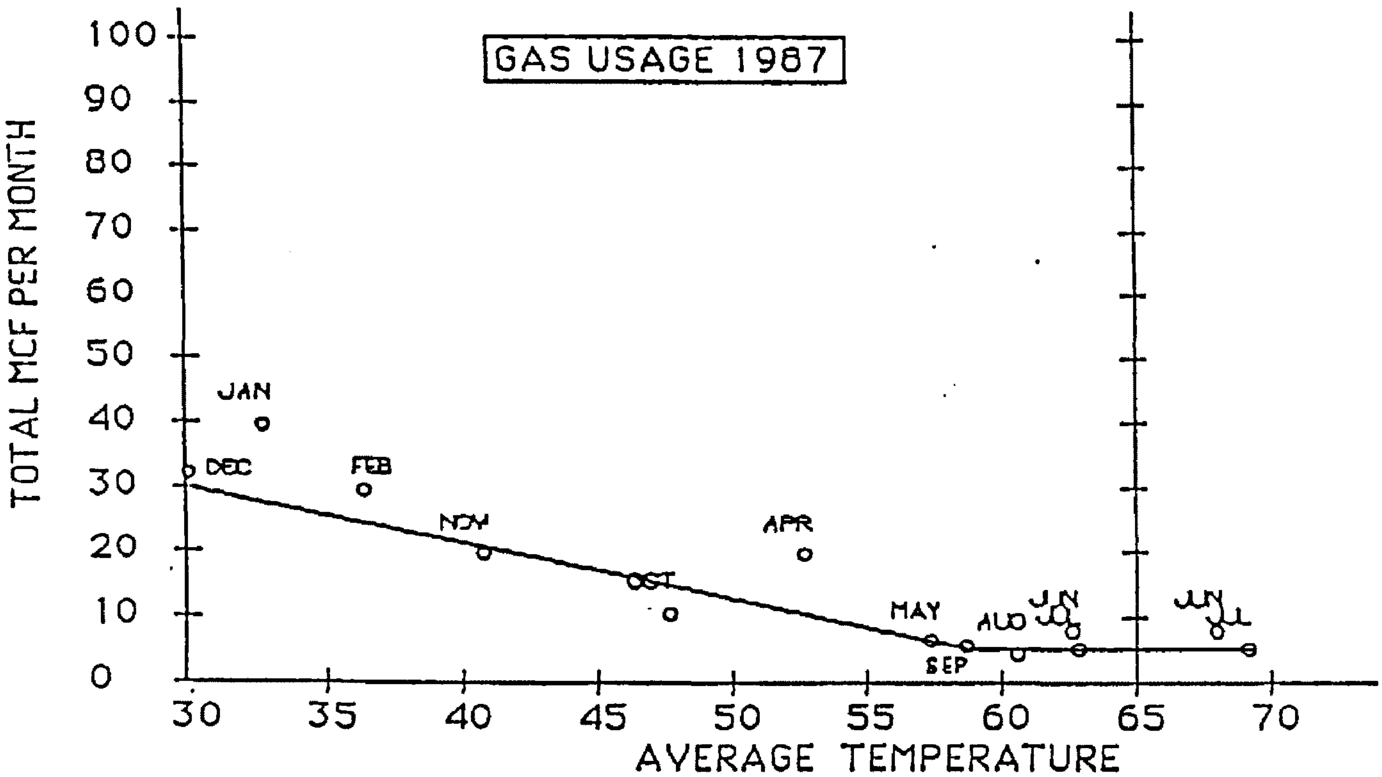


Note: Actual Billing Data by Great Falls Gas Company for Great Falls Dental Office versus Weather Data Provided by NOAA.

WHSQFTD = Watt hours per square foot per day

FIGURE 5

EXPECTED GAS BILL TREND LINE VERSUS WEATHER DATA FOR MODIFIED FACILITY



Note: Actual Billing Data by Great Falls Gas Company for Great Falls Dental Office versus Weather Data Provided by NOAA.

WHSQFTD = Watt hours per square foot per day

Recommended Energy Conservation Opportunities

ECO #1 is to install an in-line fan in the supply air duct and to modify the return air duct to permit drawing outside air when the outside air temperature is between 45 and 65 degrees fahrenheit. The addition of the waiting room and modification to the duct system has drastically changed the air distribution patterns in the southern portion of the facility. The large quantity of glass in the operatories located in this area results in heavy solar loads in the summer and poor insulative capacity in the winter. These conditions coupled with low air flow lead to year round discomfort. Furthermore, those rooms located in the northern portion of the facility suffer from excessive cold air in the summer and hot air in the winter. By placing an in-line fan in the main supply duct off of the air handling unit, air flow to these areas is increased while air flow in the northern quadrant of the facility is decreased. Use of outside air to eliminate the use of the chilling unit when the outside air temperature is sufficient to cool the facility will reduce the costs to condition the building.

ECO #2 is to remove the old fluorescent fixtures in the reception area and replace them with new ones. The ballasts serving the current fixtures are laden with poly-chlorinated biphenyls (PCBs). These units pose an energy as well as a health risk. Technology has allowed for new ballasts which utilize less energy to produce the same amount of light without the use of PCBs. PCBs have been identified as an insulator which causes cancer and have subsequently been banned in the United States. The diffusers for these units are also in poor condition as previously identified.

ECO #3 suggests relocation of the thermostat and installation of a new thermostat. The thermostat is currently subject to provide false signal to the heating and cooling system in its present location. Relocation to a central point in the return air stream unaffected by heat sources is a must. Additionally, a new thermostat will be required to allow for the new duct work in supplying outside air to the space.

ECO #4 is the installation of french storm doors over the existing sliding glass door. The aluminum sliding glass door is on the north face of the building and is a great contributor to air infiltration due to the lack of proper sealing. Installation of french storm doors outside this portal will provide greater insulation and sound protection from the noisy highway adjacent to the facility.

ECO #5 is the installation of insulated drapes in the operatories and northern exposed rooms. The single-pane glass in the operatories and front offices creates significantly cooler rooms during the winter months due to the low U-value of the uninsulated glass. The installation of aluminized mylar insulated drapes by a manufacturer such as Kirsch, will reduce the cooling significantly allowing the furnace to satisfy to the comfort zone and eliminating the need for space heaters.

Total costs for ECO implementation are $1,930 with annual cost savings expected to be $552.82. This produces a NPV of $2,274 and an IRR of 28% with a simple payback of 3.5 years. The greatest contributor to energy savings would surely be the installation of the in-line fan and the duct work to allow for cooling by outside air. The greatest cost contributor is the installation of insulated drapes. Due to the vast amount of glass in the facility, $1,200 will be required to accomplish this ECO. Table 4 identifies all ECOs and their respective costs.

Table 4

PROJECT ECOs AND ASSOCIATED COSTS

ECO	COST($)
Duct Modifications	250.00
Lighting Modifications	80.00
Rewire Thermostat	50.00
French storm doors	350.00
Install pleated shades	1,200.00
Total	1,930.00

Note: ECO = Energy Conservation Opportunity.

CHAPTER 4

CONCLUSION

Summary of Findings

The financial losses associated with inefficient energy use are simply unnecessary. This study has identified a number of long-term solutions to assist businesses in realizing larger profits by decreasing utility expenses. The associated qualitative advantages of increased employee and customer comfort and related increase in employee morale may lead to increased productivity.

Technological advancements have allowed for significant improvements in energy efficiency for manufacturing processes. Just as businesses recognize and implement new technologies in day-to-day operations, so too must they begin to implement energy reducing measures or face higher energy costs in the future. The EADC report clearly shows the savings potential which can be realized by manufacturers through a variety of options while the case studies illustrate the wide variety of savings opportunities for service sector concerns.

Office buildings generally see greater cost savings associated with HVAC systems. Oversized fans in the air handling units or inadequate water flow in a chill water system used for cooling, are large contributors to energy abuse. Additionally, improper design of air distribution systems or the failure to redesign air systems during modifications of the facility, lead to certain excess costs and discomfort in the workplace.

Though the energy analysis undertaken in this study was on a small business office and the potential for savings in dollars was not great, the 40 percent reduction of energy use that has been identified is significant. As energy rates may rise in the future, businesses and the country as a whole, would be better served by taking a proactive rather than a reactive position with respect to energy conservation. As businesses are able to minimize energy expenditures, the country will be able to reduce the demand for foreign fuels.

Recommendations

Given the apparent waste of energy and corresponding dollars spent by business annually, the need for education is apparent. While facilities management may be instructed at some institutions, others offer no training at all. As a consequence, many managers and business owners throughout the nation are unaware of the abuse of electricity and natural gas in their facilities. More important to the business, wasteful dollars are being spent without question. Small energy users like the dental office studied in chapter three, are often unconcerned about electrical costs as this is a small percentage of overhead. However, large energy users like the sports complex identified in chapter two, begin seeking professional guidance when energy rates rise and the cost of energy waste becomes exceptional.

The Department of Energy is engaged in a number of joint programs to assist in the development of energy conserving processes for manufacturers as well as improved efficiency in service sector appliances and machinery. However, implementation of these innovations is often stifled. In an era when international competition and trade barriers affect the vast majority of business, any device which may make a firm more competitive must be seriously considered.

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