A comparison of energy efficiency of Iowa public school buildings

Denis Edmund Zeimet
Iowa State University

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A comparison of energy efficiency of Iowa public school buildings

by

Denis Edmund Zeimet

A Dissertation Submitted to the Graduate Faculty in Partial Fulfillment of the Requirements for the Degree of DOCTOR OF PHILOSOPHY

Major: Industrial Education

Approved:

Signature was redacted for privacy.

In Charge of Major Work

Signature was redacted for privacy.

For the Major Department

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For the Graduate College

Iowa State University
Ames, Iowa
1982

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CHAPTER I. INTRODUCTION

School district personnel realize that from a cost factor standpoint an energy crisis exists. Whether related to an actual lack of fossil fuels or through manipulation of supplies, high energy costs are a reality.

School boards, superintendents, school business managers and other administrators were more concerned with having classroom space for the student population increases of the 1950s and the 1960s than they were with energy efficiency. Buildings of this era were constructed with the most expedient methods and materials available. No one was seriously concerned about the cost of energy. Little thought was given to insulation, the amount of window area, or the quality of material used. The bulging classrooms demanded immediate action and expansion, while energy costs were considered a minor budget line item.

Because of these and other factors, school energy costs are rapidly increasing for schools today. Costs doubled between 1973 and 1978. Present indications are that they will double again before 1983. Energy costs are now a major consideration in most school districts and, in some cases, threaten the quality of the educational program presently offered. Districts already struggling to maintain educational programs with reduced funding due to declining student enrollments will find it even more difficult in a time of state
budget cutbacks, taxpayer dissatisfaction, and deregulation of fuel prices.

Industry and the private sector of the economy have also been faced with increasing energy costs. In order to combat the situation and protect the profit margin, money has been invested into programs and equipment to increase operational efficiency and reduce energy consumption. "Energy audits" have been conducted, past records of energy usage analyzed, and specialists in energy management have been employed. Although schools are not motivated by profit, they should be concerned with maintaining high quality education for each individual for the betterment of humanity as an ultimate goal. Specific statements which reflect the nature of the problem:

1. Schools have been labeled "energy wasters." They use 11 percent of the nation's total energy for space heating alone. Energy use could be cut through proper management, retrofit, and general energy conservation measures.

2. Energy costs in schools are rapidly increasing. Money is being used from the general fund to pay for these increased costs. This reduces the amount of money available to maintain a quality educational program.

3. Budget cutbacks at the national and state levels will reduce the impact and number of energy programs offered by tax supported agencies. Other agencies and/or forms of leadership are needed to continue the present impetus and trend toward energy conservation.
4. From a philanthropic point of view, energy resources should be conserved for production of material goods (e.g. medicines, plastics, fertilizers, herbicides, etc.). They should not be misused for avoidable inefficiencies in energy systems.

From the concerns stated above, it is this writer's opinion that an investigation into the factors which are related to energy efficiency of school buildings is desperately needed. If specific factors can be discovered which are correlated with energy efficiency, innumerable amounts of time and effort wasted by the trial and error method would be avoided. In addition, the natural resources saved could be used for other humanitarian purposes.

Problem Statement

The problem of this study was to investigate the differences in energy efficiency of public elementary and secondary schools in Iowa and determine factors which are correlated to energy efficiency of school buildings.

Purpose of the Study

The purpose of the study was to provide information which will help to reduce the current impact of energy costs on the budgets of Iowa school districts. Specifically, this information will serve two functions:
1. Help administrators of public schools become more knowledgeable in the areas of energy management, energy conservation, and methods of energy utilization, thereby assisting them in coping with the energy related problems of the schools, and

2. Identify those areas which are significantly correlated to the energy efficiency of school buildings, thus serving the best interests of administrator time management and the school district budget.

Need for the Study

It has been estimated that at the present usage of known reserves, the world has enough petroleum to last through the year 2000, natural gas through 1990, and coal through 2276 (Graves, 1977). A rather embarrassing but known fact about the United States is that the 226 million people residing in this country use about one-third of the total energy used in the world. That is, 6 percent of the world population consumes over 30 percent of the total energy used. A high standard of living has produced a nation with some serious energy wasting habits. According to Ms. Mary O'Halaran, former regional representative of the United States Department of Energy office in Kansas City, Americans waste 50 percent of the energy they consume (Skarda, 1977). In addition, the following facts must be admitted (Anderson, 1975):
1. Americans, as a nation, use five times more energy per capita than any other.

2. People of the United States use more energy on air conditioning alone than the Chinese use for all purposes.

3. Although the West Germans enjoy relatively the same standard of living as Americans, they do it with one-half the amount of energy used by the average American (p. 193).

With the increasing cost of energy, it is obvious that some "belt-tightening" has occurred since these statements were made. However, our society has gone through a period when energy was inexpensive. Wasteful habits were formed, and little concern was given to this waste since energy seemed so abundant and relatively inexpensive.

These energy using habits have permeated all of society in the United States. It is not unfair to say that students, teachers, and school administrators acquired some energy wasting patterns. It is hard to recognize one is doing something wrong if it is accepted as common practice. The question then arises, is energy wasted simply because people have not been taught the proper energy conservation techniques? This study should provide insight into answering that question as it pertains to school personnel.
As mentioned earlier, schools have not been isolated from the events of society. The economic issues which have affected so many people are also filtering through the school structure. Increasing energy costs are becoming a real threat to the quality of the educational program. As Calvin E. Anderson (1975), project director of the Interstate Energy Conservation Leadership Project, stated, "... there is a direct and corrosive relationship between dollar energy costs to the schools and the type of educational programs they can provide" (p. 194). This same project found from preliminary investigations "that the nation's schools were largely unprepared for the barrage of energy problems that have befallen them" (p. 194). Such statements indicate the pressing need to evaluate the feelings school administrators have about the establishment of an energy management program and differences which may result in relation to energy efficiency of school buildings.

According to Kruza (1979), the most important element in any school conservation program is commitment by the school board and top administration. This is not surprising since superintendents and principals form the organizational structure necessary to systematize and initiate--through directives, financial incentives and administrative prerogatives--specific energy conservation measures with a central office thrust. In addition, educators have long known about the importance of a "role model" in any successful program. Top administrators, knowledgeable in energy management techniques and striving to
reduce energy consumption in an effort to maintain the quality of the educational program, would serve as good examples which occupants of the school building could emulate. This study can provide the necessary impetus for school boards to evaluate the present energy management structure within their district.

It is clear from the above statements that energy conservation will not happen automatically. Administrators of school buildings/districts need to be conversant with energy management concepts which have been found to be successful in other school systems. Specifically, principals and superintendents should know:

1. how to organize energy teams at the building and district levels
2. the different types of energy audits available for analyzing the "energy fitness" of the school
3. immediate, low-cost energy saving steps which have been shown to reduce energy consumption (these steps should take into consideration the thermal comfort and health of the individuals within the environment)
4. methods of establishing priorities for energy conservation opportunities when dealing with a limited budget.

An "in-depth" review of the literature was conducted to aid school administrators in their efforts to assemble up-to-date knowledge pertaining to energy management of school systems.
With the current impact that energy awareness has had on United States society, it is apparent that some energy management (conservation) knowledge is being learned by administrators and applied in schools. In addition, maintenance practice and the physical condition of the school buildings are undoubtedly being examined as ways to improve overall energy efficiency of the school. However, little appears to be known about which of the variables involved have the greatest impact on energy conservation. If they exist, specific factors within the areas mentioned above which correlate highly with energy efficiency of school buildings should be identified.

Most educators would agree that energy conservation relating to school systems is in the embryonic stages of development and each new bit of information must be disseminated as efficiently and directly as possible. An organized and systematic effort to assemble this information is needed. This study will provide insight for those involved in reducing the impact of energy costs on the school district budget and help facilitate the knowledge dissemination process. Secondly, it will serve as an initial organized effort to identify those areas (variables) especially critical to energy efficiency of school buildings.

Assumptions of the Study

The following assumptions were made in conducting this research:
1. Factors which affect the overall energy efficiency of a school building do exist. These factors can be identified and controlled.

2. The instruments developed in this study for administrators and maintenance personnel are valid as used.

3. Energy consumption data are a valid measure of energy efficiency of a school building. In addition, the preliminary energy audit (PEA) forms submitted to the Iowa Energy Policy Council (IEPC) and used in this study have accurate information pertaining to fuel and occupancy data.

4. The respondents involved in this study are appropriate for the types of information sought and gathered.

5. Measurements taken for use as variables in the study are accurate within an acceptable margin of error. In addition, data taken by visual inspection, reading of blueprints, or reports by the custodian are valid and equivalent.

Limitations of the Study

1. The instruments developed are valid to the extent which knowledge about the areas of energy management and energy conservation are presently recognized by experts in the field. There may be other factors which are equally important but not as yet known.
2. The instruments developed for this study have not undergone the extensive and repeated tests of reliability and validity which occur only after many applications and refinements.

3. The population sampled was made up of school personnel in the state of Iowa. Likewise, school buildings selected in the study were located within the geographical boundaries of the state of Iowa.

4. Individuals responding to the respective survey forms have a wide range of educational background and work experience.

5. The data collected in this study will be pertinent to the extent that respondents of the survey forms were honest in their choices and answers.

Questions of the Study

1. Is it possible to classify school buildings in terms of their energy efficiency based on a standard unit of measurement—such as the Building Energy Management Index (BEMI) or the Energy Utilization Index (EUI)?

2. Is there a difference in energy efficiency of school buildings based on district student enrollment?

3. Do school buildings matched on date of construction, number of stories, rural or urban environment, cooling facilities, and elementary or secondary function differ in energy efficiency?
4. Are there variables which correlate with energy efficiency of school buildings?

Procedure of the Study

This study was conducted at Iowa State University in cooperation with the Iowa Energy Policy Council. Fuel consumption and occupancy data from nine hundred and eighty elementary and secondary school buildings in Iowa were used for identifying thirty-six buildings involved in the study. Eighteen school buildings from this group were identified as having relatively high energy consumption (energy excessive) as determined by the Building Energy Management (BEMI) method. These buildings were matched with an equal number of school buildings identified as being relatively energy efficient (energy superior) by the BEMI method.

Survey instruments were developed both for the administrators of the buildings (principals and superintendents) as well as the head custodian (director of maintenance). In addition, a visit was made to each selected building by the researcher. Measurements pertaining to the physical characteristics of the structure and type of construction materials used in the building envelope were recorded. From the information gathered, factors significant in relation to energy efficiency of school buildings were delineated.
A basic outline was followed in conducting this research:

1. A thorough review of the literature was conducted. A broad informational background was presented pertaining to energy management and energy conservation in public schools.

2. Sample buildings from nine hundred eighty Iowa public elementary and secondary school buildings were selected. Eighteen energy excessive buildings were matched with eighteen energy superior buildings on five factors commonly accepted as being related to energy efficiency.

3. Survey forms for maintenance personnel and school administrators were developed. Instruments were field tested to establish validity. Appropriate respondents were used for both areas surveyed.

4. Pilot tests for the survey instruments were conducted in the Ames Community School District.

5. Superintendents of districts with school buildings selected in the sample were contacted:
   a. Acceptance to participate in the research study was obtained.
   b. Permission to visit the selected building was granted.
   c. Date of the visitation to the sample building was scheduled and the data to be collected were specified.
6. School buildings selected in the study were visited:
   a. Completed survey instruments were collected.
   b. Appropriate "area" measurements were taken from the blue prints of the building or directly from the building structure.
   c. Construction materials used in the building envelope were recorded.

7. Data were assembled and values for the independent variables were calculated.

8. Data analyses were conducted:
   a. Descriptive statistics pertaining to the data included in the two survey forms were presented.
   b. Highly correlated variables in the study were examined through the construction of a product moment correlation matrix.
   c. "Paired" t-tests were performed between school building classification types (within size categories).
   d. An analysis of variance (ANOVA) mixed design was employed to determine the effect of school district size on energy efficiency of school buildings.
   e. A regression analysis was conducted to determine significant variables in relation to energy efficiency of school buildings.
9. A summary and recommendations for the research study were presented.

Definition of Terms

The following terms of the study were defined:

**Administration**: (1) The scheme or plan used in the assignment of duties and responsibilities and the determination of staff relationships so that all phases of operating a school system may be efficiently managed, produce maximum results in meeting educational objectives, and result in optimum personnel relationships. (2) The personnel responsible for the management and direction of the affairs of a school or school system, regarded collectively.

**Air infiltration**: The inward air leakage through cracks and other separations in the building envelope, around windows and doors, and through floors and walls of a space or building.

**Board of Education**: In Iowa, a board of elected officials in charge of a local public school with established district boundaries.

**Boiler capacity**: The maximum rate of heat output for a given boiler. Output is typically measured in units of Btu/hour.

**Building Energy Management Index (BEMI)**: A method of determining the relative energy efficiency of a building using fuel consumption, human occupancy, and environment temperature.
data as criteria. Categorization of buildings in relation to energy efficiency is made on the basis of a confidence band designated for an "average building" for the specific group of buildings under examination.

Building envelope: The elements of a building which enclose conditioned spaces through which thermal energy may be transferred to or from the exterior.

Certification: The act, on the part of a State Department of Public Instruction, of granting official authorization to a person to accept employment in keeping with the provisions of a certificate; applies chiefly to professional services such as teaching, supervision, and administration of education below college level.

Declining enrollment: A reduction in the number of individuals enrolled during a given term or school year. The term usually refers to future forecasts of enrollment for an institution or group of institutions based upon enrollment predictions and other factors.

Educational administrator: Any educational official responsible for the management or direction of an educational establishment or system or an administrative unit of it; typically includes such officers as superintendents, assistant superintendents, school business managers, principals and their assistants.
Educational program: The entire offering of the school, including the out-of-class activities, and the arrangement or sequence of subjects and activities.

Energy audit: A methodical examination and/or review of the present energy situation—usually of a building or equipment—with the intent to verify or identify energy problems or inefficiencies in energy systems. This process usually involves an evaluation of the associated costs.

Energy excessive building: In this study, a school building which has been found to have below average energy efficiency as determined by the Building Energy Management Index (BEMI).

Energy management: The administration, leadership, and exercise of authority in managing, directing, and implementing energy saving measures. These conservation practices are initiated with the intent of reducing energy costs for the school district.

Energy program: A program sponsored and conducted by a school for the purpose of reducing energy costs through utilization of energy conservation practices and increased efficiency of energy systems within the school.

Energy resources: Immediate and possible sources of energy available through present technology. This generally implies known reserves of fossil fuels but may also include reasonable potential for solar, nuclear, and other forms of energy.
Energy superior building: In this study, a school building which has been found to have above average energy efficiency as determined by the Building Energy Management Index (BEMI).

Energy team: A designated group of individuals at the school building level who are actively involved in the process of reducing energy costs of the school district. These people also serve as liaisons in the organizational structure between the central office and the school building level.

Energy Utilization Index (EUI): A standard method of ranking (measuring) energy consumption of buildings in terms of Btu/square foot per year.

Heating-Ventilating-Air Conditioning (HVAC) system: A system that provides either collectively or individually the processes of comfort heating, ventilating, and/or air conditioning within or associated with a building.

Instrument: A device for measuring the value or extent of functioning of a variable.

Iowa Energy Policy Council: A state governmental department created by the Sixty-Fifth General Assembly of the Iowa Legislature to formulate energy policy and carry out energy programs. Since its creation in 1974, this Energy Policy Council has expanded to include more duties and responsibilities. The agency is presently authorized by the legislature to carry out energy management needs of the state until 1983.
**Life cycle costing:** Cost analysis of an energy conservation opportunity in terms of first costs, and all other costs over the "life" of the proposed energy conservation measure.

**Preliminary Energy Audit (PEA):** A very brief energy audit that gives only general information about the energy consumption characteristics of the building. These include size and type of the building, rate of energy consumption, and major energy systems of the building.

**Pupil costs:** The annual cost of operating the school computed on the basis of the pupil as the unit. In this study, cost per pupil will be based on the total number of students enrolled.

**Retrofit:** Modifying or renovating an existing structure for the purpose of making the area of concern more functional and energy efficient.

**R value:** A measure of thermal resistance of a material, body or assembly. The reciprocal of thermal conductance.

**Simple payback period:** The net investment for an energy conservation opportunity divided by the annual energy savings expected.

**School district:** (1) The area that is under the supervision of a given board of education, or (2) that territory within which children may attend a given school building or center.
Schoolhouse tax levy: An issue, when voted upon by the patrons of a school district, may generate additional money beyond that already provided by law for the purpose of improving the school building and/or grounds.

U factor: Thermal transmittance. The thermal transmission in unit time through unit area of a particular body or assembly, including its boundary films, divided by the difference between the environmental temperatures on either side of the body or assembly.

Summary

This chapter presents an overview for this research study involving energy efficiency of school buildings. An introduction to the general area of energy conservation in schools was presented in addition to the problem statement and purpose of the study. Need for the study was expressed primarily from a standpoint of energy wastefulness and the resulting energy cost factor in relation to the American society in general, and specifically to school personnel.

Assumptions and limitations of the study were listed in numerical fashion while the procedures followed in the research were presented in outline form. Finally, a number of the terms used in this study were defined in an effort to acquaint the reader with the vocabulary used in the field of education and some of the technical terms used in the field of energy conservation.
CHAPTER II. REVIEW OF THE LITERATURE

Introduction

Background

In the twentieth century, the United States has gone from a period of very inexpensive energy—when the standard of living in a highly industrialized society reached new peaks to a sudden immersion into an energy crisis. Long gas lines and skyrocketing energy costs became the norm. To many, the crisis was at first thought to be only political and they believed the situation would soon pass. In the eight years since the OPEC oil embargo, however, Americans have slowly adapted to the new life style of living with less energy and realizing—for whatever reason—the era of abundant, inexpensive fossil fuel energy is behind us.

Schools are also witnessing the skyrocketing energy prices. In the words of Shirley Hansen, former associate director of the American Association of School Administrators, "The educational dollar is going up in smoke" (1978, p. 176). She contends that "education is rapidly becoming energy poor" while more than 50 percent of the energy used by schools is wasted (p. 176). The sobering thoughts of Calvin Anderson (1975), director of the Interstate Energy Conservation Leadership Project, seem all too true: ". . . energy costs reflect waste as well as scarcity; and energy waste has become an ingrained habit for too many educators" (p. 194).
A statement by Wayne Stebbins, senior staff engineer for Faber Industries in South Carolina, relating to an industrial plant's energy attitude, has the same implications for a school plant (1980): A positive attitude toward energy management is difficult to develop because only recently have energy costs become a significant part of the plant's operating costs" (p. 67). According to a study by Anderson and Bottinelli (1980), in 1979 the "nation's schools spent three billion dollars to heat, cool and light their buildings and the trend is toward higher costs in the future" (p. 3). The authors also found that per pupil costs for energy tripled in the six-year period from 1973 to 1979 ($20 to $60, respectively). The typical energy dollar spent for energy in educational institutions was divided as follows:

1. Heating, ventilating and air conditioning  \$0.65
2. Lighting, special education and equipment \$0.25
3. Food services \$0.07
4. Hot water \$0.03

In the past decade, energy costs have risen over 800 percent for oil, 500 percent for natural gas and about 500 percent for coal (Turner and Estes, 1980). In addition, "experts predict that energy costs will continue to rise 3 percent to 10 percent above the rate of inflation" (p. 66). Irving R. Peterson, director of facility planning services for the New Jersey Department of Education, states that in the 1976-77 school year between 6 percent and 7 percent of the annual
budget was used for utility bills in the nation's schools. This figure is up from the 1966-67 school year when utility bills comprised only 3 percent of the annual school budget (Peterson and Colavita, 1980, p. 1). In 1978, a typical elementary school in Madison, Wisconsin, used about 4 percent of the total budget on energy alone; 9 percent of the total budget was used for energy in the typical high school (Olsen, 1978, p. 1.10). See Appendix A for the complete budget breakdown for a typical Wisconsin school.

More frustrating, however, is the fact that few districts have implemented a comprehensive energy management program (Fredrickson, 1980). In fact, this same source contends that "many schools are approaching the situation as though it were a temporary inconvenience" (p. 1). Fredrickson continues, "While some efforts have been made to turn off lights, lower thermostats, and do some minor insulation, a complete investigation of energy problems has not been accomplished" (p. 1).

One must be careful, however, not to assume that this inaction on the part of school administrators stems only from a nonchalant attitude about energy consumption. As pointed out by a spokesperson for the U.S. Department of Energy, "Energy awareness, conservation, use, prices, and sources are as complex and little understood issues as any that we have faced in the history of our nation" (U.S. Dept. of Energy, (DOE/CA/0012-01), 1980, p. iv). Words such as the following by Smith and
Fazzolare (1979) offer hope for better days in the future: "Clearly, there are no simple answers. Energy management, however, can relax the pace of resource depletion and provide more time to ponder and develop alternative energy supplies" (p. 182). Such statements have led the Council of Educational Facility Planners to conclude: "Within any school district's energy management program there should be an individual with training and expertise to serve as an energy manager" (Nickell, 1981, p. 15).

To most superintendents, even the term energy management may conjure up ideas of complicated job descriptions and laborious paperwork. In reality, "energy management is the application of the same basic techniques to the use of energy resources that one would apply to administration, finance, marketing, purchasing or production in any soundly run business endeavor" ("How to Start an Energy Management Program," 1973, p. 1). The most important thing for the administrator to remember is—as always—the prime ingredient to any successful program is motivated people; technology will not provide all the answers. Smith and Fazzolare (1979) offer the following observation to parrot the above statement: "Unless people are willing to make it work, energy management will not be effective. In short, technology or 'technical fixes' is not the total answer" (p. 212).

To better understand what is meant by energy management, Ed Stephan of the Department of Energy suggests the following
criteria for certification of energy managers: The energy manager should:

1. Know the function of energy management.
2. Know how to organize an energy management program in his institution or company.
3. Know the scope of potential energy reductions in buildings.
4. Be familiar with the key sources of energy savings.
5. Be able to develop an energy plan that provides for an evolutionary progression of fuel energy management actions.
6. Be able to plan for and deal with curtailments, interruptions and restrictions.
7. Know how to assess the risks associated with a proposed energy management action.
8. Know what information and assistance is available from professional associations, government agencies, utilities and research organizations.
9. Be thoroughly familiar with the technical aspects of:
   a. Checklists, surveys and audits.
   b. Energy use monitoring procedures, equipment, costs.
   c. Load management, utility generating costs, demand metering, demand control.
   d. Energy turndown and shutoff.
   e. Maintenance and operation for energy efficiency.
f. Life-cycle costing.
g. Creative analysis techniques for developing new solutions to energy problems.

10. Have a thorough understanding of U.S. and world energy use patterns. In addition the energy manager should be familiar with:

a. Conventional energy resource estimate, their assumptions and limitations.
b. Resources, uses and rates of growth.
c. The institution's use in relation to the overall use/supply picture.
d. Major social and environmental impacts, including public attitudes and water requirements/availability for energy.
e. Limitations on mining, drilling and utility construction.
f. Effects of various policies.
g. Making input to policy deliberations.
h. Effects of fuel price escalations.
i. How and why utility rates are set.
k. Reports required for new facilities and equipment.
l. Federal and state audit programs.
As school personnel gain energy management knowledge, the practice of energy conservation will continue to reach higher and higher levels of sophistication. For the present it must be said that energy conservation and management in schools remains in an embryonic stage.

A point should be made to clarify the difference in meaning between reduction of energy consumption and reduction of energy costs. With the initiation of an energy conservation effort there is a tendency to evaluate the measure in terms of reduction of energy costs. However, considering the escalating cost for a given unit of energy, it is perhaps more appropriate to set goals in terms of reduction of energy consumption. That is, due to the increasing costs per unit of energy, utility bills may increase even though energy consumption has decreased. Without considering "energy cost savings" the conservation effort may seem ineffective. This point emphasizes the need for a cost factor analysis (such as rate of return on each energy conservation opportunity) to validate whether a given energy conservation measure is financially sound. The costs attached to the initial energy conservation measure may take a number of years to "payback" through reductions in energy consumption. In addition, operating expenditures--such as those for maintenance--may actually increase operational costs beyond the expected energy savings. Therefore, any conservation measure contemplated should be analyzed for actual cost savings and
expenditures as well as the effects on operational characteristics.

According to Anderson and Bottinelli (1980), excellent sources of contact for assistance with energy management practices and information pertaining to energy conservation of school facilities are as follows:

1. United States Department of Energy
2. State Energy Agency (Iowa Energy Policy Council)
3. American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE)
4. American Institute of Architects (AIA)
5. American Association of School Administrators (AASA)
6. Local engineering firms (p. 8).

In addition, the National Bureau of Standards has published a handbook, with sources to contact for help and technical information pertaining to energy conservation (Gatts, Massey and Robertson, NBS Handbook 115, 1974). A list of important conversion factors taken from this source is found in Appendix B.

The transition from a period of relatively inexpensive energy to a time of strikingly high energy costs for school districts has been rather abrupt. Many people, including school administrators, had become accustomed to the former situation and acquired somewhat wasteful energy using habits. Since a large amount of the total energy used in this nation is consumed in schools, it is paramount that districts start investigating and implementing measures to reduce energy waste.
Although there are no simple answers, one of the first steps in this process is the appointment of a person knowledgeable in the field of energy management. The position of energy manager should be occupied by a person with expertise in the management area as well as in energy systems.

Quick-fix measures (low cost/no cost)

Although the field of energy conservation in schools is a relatively new practice, a surprising number of checklists and saving measures have been published. The measures suggested are usually of the "turn down" or "turn off" variety.

It is important to remember, however, that implementation of any energy conservation measure suggested below, without consideration of the human thermal environment, would be very unwise. In fact, some of these recommendations may be very detrimental in consideration of the more important health and safety standards which must be maintained in the school building. These lists are presented with the intent to provide an overall picture of what has been published rather than what has been found by research to reduce energy consumption while maintaining health and safety standards within the building.

In an "Energy Report" of comments made at the 109th Annual Convention of the American Association of School Administrators, Skarda (1977) singled out a number of significant energy saving practices. Those which are particularly applicable to schools of all sizes are listed below:
a. Keep boiler tubes clean for greater efficiency. (A boiler can drop from 80 percent to 50 percent efficiency in two years with a corresponding rise of 60 percent in fuel consumption (U.S. Dept. of Energy, (DOE/CA/0012-01), 1980, p. 7).

b. Check the night control system for proper functioning.

c. Check the air intake at the burner area for proper adjustment. The flame should be blue.

d. Turn off lights in areas and rooms which are not in use.

e. Weatherstrip and caulk windows and doors.

f. Add extra insulation where warranted. (This usually involves a very short payback period. Savings of up to 35 percent in fuel costs can result (Woodbury, 1980).)

A more recent publication of Kohler (1980) divides energy saving measures into two categories, those with little or no expense and others which require a monetary investment. The suggestions for energy savings were listed under the following headings:

**Lighting**

1. Place decal reminders on switchplates.
2. Open blinds, drapes and shades.
3. Reduce lighting in corridors to fifteen footcandles.
4. Reduce classroom lighting to fifty footcandles.
5. Remove ballasts when lamps are removed from fixtures.
6. Redo control circuits.
7. Install lower wattage lamps.
8. Direct custodians to light areas only where they are working.
9. Eliminate display, showcase and decorative lighting except during public meetings.

INVEST TO SAVE:
1. Replace incandescent with fluorescent; mercury with high pressure sodium.
2. Convert outside lighting to quartz.
3. Install separate switches on outside row of classroom lighting.

Heating - Ventilation - Air Conditioning (HVAC)
1. Lower thermostat settings. 68°F for winter, 78°F for summer (Woodbury, 1980).
2. Begin night setback at 3:30 p.m.
3. Test boilers for efficiency. (High stack temperatures may indicate scaled or sooty heat transfer for surfaces; low temperatures may cause corrosion of ducts and fans ("Energy Management in Health Care Facilities," 1975).)
4. Shut down boilers when outside temperature is above a certain point (30°F to 50°F).
5. Install thermostat guards.
7. Control the thermostats.

INVEST TO SAVE:
1. Equip boilers with air atomizing burners.
2. Install properly engineered control devices on air handling units.
Building Envelope

1. Keep doors and windows closed.
2. Do not tie doors open during recess.
3. Draw classroom curtains to keep out cold and heat.
4. Reduce fresh air intake and ventilation rates.
5. Modify skylights.

INVEST TO SAVE:

1. Replace leaky windows; use dual glazing.
2. Reduce window areas.
3. Add insulation wherever possible.

Plumbing

1. Check for leaks.
2. Reduce domestic water temperature. Set at 100°F. Local boosters can be applied for cafeteria and other areas which require higher temperatures (Woodbury, 1980).
3. Reduce pool water temperature.

Vehicles

1. Cut idling time.
2. Operate at fifty-five mph maximum.
3. Encourage car pooling by staff and students.
4. Limit car and bus trips.

INVEST TO SAVE:

General
1. Hold conservation seminars for staff; implement educational programs for staff and students.
2. Cut night meetings.
3. Turn off office equipment when not in use.
4. Keep accurate records of energy costs and projected savings.
5. Instruct food service employees in good conservation measures.

INVEST TO SAVE:
1. Install computerized energy management systems.
2. Lower ceilings in classrooms.
3. Install central switch to turn off energy at the end of the day.
4. Plant quick-growing evergreens as windbreakers.

Woodbury (1980) has described still more steps to energy conservation. In addition to some of those previously mentioned, he suggests the following should be reconsidered on a regular basis as escalating energy costs may make the retrofit or expenditure cost effective. (Anything with a payback period of less than five years is commonly accepted as cost effective.)

Plant and Program Curtailment
1. Close off any unused areas in the building to reduce air handling, heating, air conditioning, and unnecessary lighting.
2. Inspect pipes, controls, valves, and regulators. Eliminate and repair any leaks or faulty equipment.

3. Check steam traps on the condensing equipment for steam heating systems. Several faulty traps can compound the problem. These devices are a major source of steam loss.

4. Rearrange the schedule for better utilization of the building and classrooms. Close wings or areas not needed.

**Heating/Ventilation/Air-Conditioning**

1. Install humidifiers for forced air systems. This allows lower temperatures with the same degree of comfort and is better from a health standpoint.

2. Install attic fans to exhaust hot air on warm days, thus reducing the demand on air handling and air conditioning systems.

3. Install automatic key operated thermostat controls to lower temperatures during the heating system or raise them during the cooling season. (Provide manual override for emergency purposes.)

4. Maintain ventilating and air conditioning at a constant temperature, if possible. Shut off exhaust systems and outside dampers when the building is unoccupied.

5. In air conditioned buildings, install return air troffers and provide shades and sunscreens for windows.

6. Replace old windows - consider smaller fenestration area to reduce heat loss.
7. Examine kitchen refrigeration systems for maximum efficiency of condensers. These may need cleaning and better ventilation.

8. Consider implementing a heat recovery system (heat recovery wheel, heat pipes, counter-flow heat exchangers, or heat pump).

9. Inspect and maintain the boiler at regular intervals. This includes pressure and temperature controls, water level controls, filters, relief valves, traps, regulators, and lubrication.

**Insulation**

1. Install insulation around steam and hot air pipes as well as hot water tanks.

2. Install wind stops on doors.

3. Replace singlehung windows with double thermopane or triple glazing.

4. Institute a program of installing storm windows. North and west sides should be given first priority.

5. Examine the possibility of installing urethane roof systems for built-up roofs (R-value is better and there is less likelihood of roof expansion and contraction.

6. Provide entrance vestibules. Consider the possibility of revolving doors.
Lighting

1. Replace fluorescent fixtures with sodium lamps where appropriate. The advantage is that sodium lamps produce more lumens/watt. Energy costs will be equivalent.

2. Install combination time clock and timer switches with possibility of manual override.

3. Install photocell and timeclock controllers for parking lots and exterior building (facade) lighting.

4. Conduct an illumination audit. Adjust lighting according to recommended levels of the Illuminating Engineering Society.

5. Clean panels and globes covering lights on a regular basis.

6. Install timers to automatically turn on, reduce, and turn off lighting when appropriate.

Dorsey (1980) has suggested certain lighting levels for given task areas when analyzing a school's present lighting situation:

<table>
<thead>
<tr>
<th>Task</th>
<th>Footcandles</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Reading printed material</td>
<td>30 ESI</td>
</tr>
<tr>
<td>B. Reading pencil writing</td>
<td>70 ESI</td>
</tr>
<tr>
<td>C. Chalkboards</td>
<td>150</td>
</tr>
</tbody>
</table>

Classrooms

<table>
<thead>
<tr>
<th>Task</th>
<th>Footcandles</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Art</td>
<td>70</td>
</tr>
<tr>
<td>B. Drafting rooms</td>
<td>100</td>
</tr>
</tbody>
</table>
Classrooms

C. Home economic rooms

1. Sewing 150 ESI
2. Cooking 50
3. Ironing 50

D. Laboratories 100

E. Lecture rooms

1. Audience area 70 ESI
2. Demonstration area 150

F. Shops 100 (p. 32).

(ESI refers to equivalent sphere illumination, a factor which considers reflectance and glare properties.)

The University of Wisconsin - Extension for Engineering and Applied Sciences (Olsen, 1978) has provided what it calls the "Top Twenty" energy conservation measures for schools (p. 2.42). The uniqueness of this list lies in the order which the conservation measures are given; a gradual change from no cost (low cost) measures to more expensive retrofit. The entire list is shown in Appendix C.

In addition to the general measures indicated above, the UWEX-Engineering and Applied Science Manual also delineates specific tasks to be considered for ventilation, lighting, air conditioning, etc. The extensive list below is for the area of ventilation (p. 2.60):
1. Reduce cubic feet per minute/occupant outdoor air requirements to the minimum, considering the task they are performing, room volume, and periods of occupancy.

2. Adjust the timeclock day-night settings to operate ventilation units fewer hours during the day cycle.

3. Take credit for infiltration as part of the outdoor air requirements for the building occupants and reduce mechanical ventilation accordingly.

4. Increase the mixed air temperature setting on units to 65°F. If this is not practical, consider adjusting the fresh air linkage so that the mixed air temperature cannot go below 55°F.

5. Operate the ventilation system only when the school is occupied. Also, consider shutting off the air handling units on normal heating days before school is out. If the radiators are located properly, they should be able to maintain space temperature above freezing.

6. Clean debris from unit ventilators to permit more efficient operation.

7. Clean the filters more often to increase the overall efficiency of the air handling units.

8. Do not operate the ventilation units at all during the spring and fall if many of the windows in the classrooms are open during this time of the year.
9. Operate the ventilation units with no outside air whenever the outside temperature is 25°F or below. There may be sufficient fresh air leakage through the dampers to provide adequate ventilation.

10. In the summer when the outdoor air temperature at night is lower than indoor temperature, use full outdoor air ventilation to remove excess heat and pre-cool the structure to reduce air conditioning load.

11. Increase the ventilation unit's summer mixed air temperature to minimize the air conditioning and reheat requirements.

12. Operate the gym outside air ventilation unit on a reduced operating schedule that coincides with occupancy of the gym. The gym fan unit should not be turned on until the first class occupies the gym and should be turned off immediately after the class leaves in the afternoon.

13. Change all fresh air limit control settings to make them consistent.

14. Readjust fresh air limit controllers from winter to summer earlier than the middle of May.

15. Turn off electric reheat coils during the summer. With increased supply air, temperature reheat may not be necessary.
16. If possible, use permanently sealed windows to reduce infiltration in climatic zones where this is a large energy user.

17. Outdoor air dampers should be closed tightly during unoccupied periods. Low leakage, fully gasketed dampers must be used. The position of the damper should be checked relative to the mechanical or automatic indicator.

18. Re-examine the assumptions that were made regarding occupancy, usage and environmental standards when the building was originally designed.

19. Post a small sign next to each operable window instructing occupants not to open window while building is being heated or cooled.

20. Inspect all automatic door closers to ensure they are functioning properly. Consider adjustment to enable faster closing.

21. Place a small sign next to each door leading to the exterior or nonconditioned spaces advising occupants to keep door closed at all times when not in use.

22. Where practical, cover all window and through-the-wall cooling units when not in use. Specially designed covers can be obtained at relatively low cost.

23. Establish a ventilation operation schedule so that the exhaust system operates only when it is needed.
24. Inspect filters carefully. If necessary, create a filter replacement schedule. Utilize high-efficiency, low-cost filters.

25. Inspect all outdoor air dampers. They should be as airtight as possible when closed. Check operation of position indicators for accuracy. Install, repair or replace position indicators as needed.

26. Reduce outdoor air to the minimum required to balance the exhaust requirements and maintain a slight positive pressure to retard infiltration-caused heat losses and heat gains.

27. If possible, concentrate smoking areas together so they can be served by one exhaust system.

28. If a food preparation area exhaust hood is oversized, adjust it so no more air than necessary is exhausted. This can be done easily by blocking off a portion of the hood, or reducing fan speed, or lowering hood, or by utilizing a combination of these techniques in compliance with applicable health regulations (p. 2.60-2.63).

Dr. Louis Lipp (1978), engineer for food services in Baltimore Public Schools, contends that the kitchen area is one which is often overlooked by school administrators when considering energy cost reduction. He states that "administrators who are concerned with turning off lights and lowering room temperatures rarely consider one medium sized fryer uses
as much energy as 300 fluorescent lamps. . ." (p. 20). In addition to conserving energy by monitoring appliances, there are several ways to reduce energy waste generated through poor kitchen ventilation practices. Some of these are:

1. Space equipment closer together to decrease hood size and air flow required.

2. Make the most of walls. Aligning equipment against the wall requires much less air flow than an island arrangement.

3. Specify hoods with high capture velocities instead of high air flow (i.e. fast stream of low volume air rather than slow steam of high volume air).

4. Use hoods that use partially tempered make-up air (returning 70-90 percent of the air to the cooking area, yet not coming in contact with the employee).

5. Use of energy recovery units to reclaim heat normally ventilated over the entire school (p. 20).

As witnessed from the above lists, many conservation checklists exist. Much repetition occurs. A particularly comprehensive list compiled by the Minnesota Energy Agency is shown in Appendix D ("Minnesota Mini Energy," 1975). The appealing factor of this report is the classification of suggestions according to school size.

The Flack & Kurtz Engineering firm of New York assisted the Educational Facilities Laboratories in constructing the
Public School Energy Conservation Survey (PSECS) computer model program. The executive Vice President of the Environmental Control Section, George Rainer (1976), noted the following points concerning energy cost reduction:

1. Fan horsepower frequently can be reduced when an air distribution system is rebalanced.

2. Replacement of single pane glass with double glazed for reduction of heat losses is very expensive. Treatment of large glass areas to reduce solar loads is very cost effective.

3. Pumps are often found to be oversized for the intended service.

4. During warm weather, large boilers operate inefficiently at part load. Idling boilers can consume up to 25 percent of the energy used for heating during a school year.

5. One of the factors most conducive to the waste of energy is oversized equipment (p. 82-84).

From a more general standpoint, Fredrickson (1980) has identified the following activities currently used by "progressive districts" across the nation. Along with some recommendations previously mentioned, he suggests that schools:

1. Conduct a "walk-through inspection.

2. Determine effectiveness and efficiency of all building mechanical systems.

3. Review temperature settings of all thermostats and lower them, based on function and learning efficiency.
4. Establish light levels which will support specific learning tasks.
5. Reduce illumination levels in auditorium, cafeteria, gym, and all well-traveled hallways.
6. Adjust energy control systems for appropriate nighttime and weekend setback.
7. Re-evaluate building requirements for morning warmup.
8. Consider the restructuring of the school day and year.
9. Contract for a comprehensive technical assistance audit by professionals.
10. Investigate the feasibility of building renovation.
11. Consider an energy conservation incentive program (p. 5).

William B. Haessig (1978), director of the New York State Education Facilities Planning Services, has suggested a more sophisticated list (with higher cost implications) than most found in the literature. Examples of items in his checklist are listed below:

1. Consider possible purchase of transformer from the utility pursuant to existing Public Service Commission regulations when building has large electric heating and electric load requirements.
2. On-site electric generation equipment for elimination of erratic peak loads may be practicable for electrically heated, air conditioned school buildings which also have heavy welding and/or kitchen equipment loads so that an
even demand load from the electric utility is maintained.

3. **Install automatic temperature control management centers** which can provide automatic and personal control over heating and ventilating units and electrical equipment, as well as control electric peak demands.

4. **Install self-contained temperature control radiator or convector valves for two-pipe steam or hot water systems where no temperature control systems exists.**

5. **Increase the size of domestic hot water storage tanks of electric domestic hot water boilers and heat such water during off-peak hours and at night.**

6. **Disconnect re-heat coils in air conditioning systems and remove tempered air heating coils in heating and ventilating systems, where practical, and where the thermal environment will still meet the minimum ventilation requirements of the Manual of Planning Standards (p. 42-43).**

One area which may easily be overlooked when analyzing possibilities for conservation of energy is general water consumption. Energy used to power pumps, maintain systems, and replace equipment can amount to a considerable sum if left unchecked. An American School and University publication ("You've Turned Off The Light," 1977) outlined a program to be used in a water crisis. However, the following suggestions may be considered for general conservation purposes (p. 29):
1. Inspect and adjust all spring loaded flush valves to insure minimum flow.

2. Install flow restrictors in all shower heads.

3. Repair any water leaks including leaky faucets. (One drop per second from a dripping faucet amounts to 2,500 gallons per year. "A costly reservoir, especially if it is heated" (Beerman, 1977, p. 9).

4. Revise cooling of campus refrigeration equipment and freezers to eliminate flow through of domestic water.

5. Install spring loaded faucets on all basins and sinks.

From the lists presented in this section, general comments pertaining to energy conservation measures can be specified. Those energy conservation measures which appear to be consistently reported in the literature are included below:

1. Reduce light levels only if they exceed standards set for the specific task by the Illuminating Engineering Society.

2. Reduce unwanted air infiltration (such as that through the building envelope). However, proper ventilation for the occupants of the building must be considered at all times. Building code levels must be maintained to comply with health and safety standards.

3. Maintain energy systems to insure they are functioning at optimum performance levels. Coordinate the function and operation of energy systems to maintain human comfort levels rather than maximum energy efficiency. Turn off, turn down, and setback methods are inappropriate unless
considered in conjunction with their impact on the human thermal environment.

4. Examine the building for energy waste and misuse of energy systems. Energy conservation can be achieved by shutting off unused equipment, fixing leaky faucets, eliminating excessive air infiltration, and repairing malfunctioning energy systems.

5. Educate occupants of the building about energy conservation methods. An increased awareness of energy problems and costs may be quite important to the overall reduction in energy consumption. A feeling of involvement is essential.

It is of utmost importance to consider the overall impact of any energy conservation opportunity in relation to the human thermal environment and the health and safety of the building occupants. This investigator has classified the recommendations listed in this chapter according to the three areas identified below:

1. Conservation measures which are consistently recommended in the literature and currently are not believed to have a deleterious effect on the human thermal environment or health and safety standards.

2. Conservation measures which may be appropriate under certain conditions, and

3. Conservation measures which
   a. have been shown by research to have no effect
(or a negative effect) on energy conservation, or

b. may be detrimental in consideration of the human thermal environment and/or the health and safety of the building occupants.

The classification of the proposed recommendations in the three areas specified are included in Appendix M.

Many low cost/no cost energy conservation measures can be found in the literature. Most of these are in the form of checklists and are written as specific steps which have been initiated in individual school districts. It is the responsibility of the energy manager to choose the most appropriate energy conservation opportunities in consideration of other political, social, and educational factors pertaining to his/her particular district. More sophisticated lists of energy conservation opportunities are also available. These measures usually require larger investments of money than those mentioned above and normally require the assistance of a professional engineer or engineering firm. As school districts become more and more involved in the energy management process, advanced energy systems will become more commonplace and detailed analysis regarding the decision to implement the measure will be employed.
Specifics of an energy management program

The most important element in any school conservation program is commitment by the school board and superintendent to create good energy conservation policies and provide leadership for the certified and noncertified staff. Kruza (1979) suggests the following as "common elements" in any energy management program:

1. Top Administration Commitment.
   a. This is the most essential ingredient to a successful program.
   b. Old outdated policies must be changed and new ones created.
   c. Top administrators provide leadership and a good example.
      "The superintendents will need to work closely with their local energy coordinators and take an active part in the system-wide energy program" ("The Local Energy Program Manual," 1980, p. 8).

2. Establish Accountability
   a. Assignment of accountable responsibilities at each level of school organizational structure (i.e. there must be a line-staff organization in each building).
   b. Energy conservation cannot be done in the central office alone. Involve as many people as possible.
3. Appointment of an Energy Coordinator (manager).
   a. This should be a full-time assignment (if possible). It requires imagination and ingenuity as well as a workable understanding of mechanical systems.
   b. The job will include analyzing energy data, overseeing energy audits, and implementation of energy conservation projects and practices.
   c. The problems associated with this position will necessitate conferring with experts and using other means of technical assistance.

4. Establish An Advisory Committee.
   a. The committee's main objective will be to formulate plans of action and determine goals for consideration by the administration and board.
   b. The committee should be made up of a diverse and yet representative membership of the district (i.e. interested parents, community members, faculty, board members, administrators, curriculum director, facilities director, food services director, etc.).

5. Set Energy Conservation Goals and Monitor Program Progress.
   a. Goals should be tough, specific and measurable. It is also important to retain these goals once they are accomplished.
   b. Assign monitoring responsibilities and schedule progress reports.

   a. Consider the possible retention of professional services (architect and/or engineering firm) with experience in energy conservation. Perhaps a consultant on an hourly basis would be best for some districts. Fuller (1978) has outlined the process of selecting a reputable firm including major points that a contract should include (p. 16).

   b. Determination of life cycle costing and other analyses of cost payback time for certain energy conservation measures. Utility companies may also provide a valuable service to schools in energy conservation (i.e. walk through audits, metering equipment, billing rate information, demand-charge reduction techniques, etc.).

7. Implement Improvements.

   a. Take advantage of the skills of existing maintenance personnel where possible (i.e. preventive maintenance, insulation, tightening building envelope, etc.). (An important spin-off of this application is to pay workmen in accordance with their abilities. This implies increasing salaries for people with extraordinary skills and abilities.)

   b. Keep accurate and updated logs for recording and monitoring purposes. Develop record keeping guide-
lines for each area of the school (i.e. kitchen, offices, learning centers, etc.).

c. The principal is an important facilitator at the building level.

8. Launch an Energy Conservation Program.
   a. Attitudes of the people within the building must be changed. They use energy; buildings don't.
   b. Determine what can be done to conserve energy.
   c. Prepare and actuate a publicity program to develop awareness. Work for "... publicity that is continual, imaginative, educates, and compliments progress..." (p. 66).

   a. This requires an integrative approach. It should include more than fields of science and math.
   b. Establish energy education and conservation programs for teacher workshops and curriculum development sessions.
   c. Consider establishing a base year and give rewards for energy conservation in individual schools.

10. Formulate Contingency Plans.
    a. Consider alternative fuels in time of short supply, etc. Coal and electricity appear to be most reliable at the present time.
   a. An initial expenditure of money will probably be necessary to reduce energy costs. Small investments for operation and maintenance equipment usually reap big returns.
   b. Incorporate life cycle costing into purchases.
   c. Make long-range plans for retrofit. Establish a list of priorities for retrofit measures.

Duties of the energy management team are listed below (Anderson and Bottinelli, 1980):

1. Record consumption of fuels.
2. Compare current consumption with baseline data.
3. Conduct walk-through audits for each season and when the building is occupied and unoccupied.
4. Determine energy and dollar savings or extra costs.
5. Communicate results with attractive posters.
6. Encourage total program involvement (p. 10).

In addition, the energy management team should:

A. Determine whether goals have been achieved.
B. Identify strong and weak areas of the program.
C. Modify procedures to increase program effectiveness, motivation, and involvement.
D. Inform everyone of proposed programmatic changes.
E. Review commitment to the program (p. 11).
The essence of all that has been written above has been put quite succinctly by R. J. Ingalls (1978), executive director for the Energy Conservation Department of the Houston Independent School District: "A good hard rule of management is that the program must be properly monitored or it will fail" (p. 8). Figure 1 on the following page shows the basic elements of the New York State Energy Management Program ("A Report of the Development," 1978, p. 12). This source summarizes the major activities and concerns of the energy management program as follows:

1. Conducting energy audits as needed.
2. Scheduling education and training activities.
3. Promoting good communication by publicizing energy conservation measures and stressing the importance of the program.
4. Conducting energy studies.
   a. Analyzing costs of various retrofit measures.
   b. Evaluating energy efficiency of buildings.
   c. Determining energy consumption patterns and other energy analyses (p. 62).

A specific structure showing support groups and members of a Central Policy Committee for Orange County Public School District in California has been described by Boyd and others (1978). The following organizational pattern reflects the commitment necessary by the top administration and central office personnel:
Figure 1. The essential elements in the NY state energy management program
Central Policy Committee

- Deputy Supt. - Support Services
- Deputy Supt. - Instruction
- Asst. Supt. - Faculty Services
- Supervisor of Energy Utilization
- Director of Maintenance
- Board Member
- Program Coordinator
- Elementary School Principal
- Junior High School Principal
- Senior High School Principal

Advisory Committee

↓

Supervisor of Energy Utilization

Technical Support

- Director, Maintenance
- Director, Planning
- Supervisor, Mechanical
- Coordinator, Capital Outputs
- Director, Health Services

Awareness Support

- Program Coordinator
- Director, Media Services
- Information Specialist
- Env. Educ. Specialist
- Elementary Principal
- Junior High Asst. Princ.
- Supervisor, Vo. Tech.

Figure 2. Energy management structure of the Orange County Public School District

To initiate the above organization, the Supervisor of Energy Utilization works to coordinate the energy program. This person is directly responsible to the Director of Maintenance and serves as a liaison between groups.

Responsibilities of the Central Policy Committee are as follows:

1. Establish a basis for the development of a district wide energy management program/mission.
2. Establish the goals and objectives which will lead to fulfillment of the mission statement.


4. Develop components which will be utilized in determining the effectiveness of other support groups.

5. Develop policy recommendations to be submitted to the school board through the superintendent.

6. Develop budgetary recommendations relative to the Energy Management Program.

7. Assist in the implementation of components upon request of the Supervisor of Energy Utilization.

8. Establish operational/organizational procedures for the Central Policy Committee.

9. Appoint members of the Advisory Committee.

10. Review all grant proposals prior to submission to the superintendent for recommendation to the school board.

   The Technical Support Group is critical to the efficiency of the Supervisor of Energy Utilization and the Central Policy Committee; technical information provided will form the basis for energy conservation and management decisions. Responsibilities of the Technical Support Group include:

   1. Conducting Mini-Audits.

   2. Recommending procedures for Maxi-Audits.

   3. Implementation of energy conservation features in new construction.
4. Providing other technical assistance (e.g. grant proposals, cost benefit analysis, and budgetary proposals).
5. Insuring the compliance of energy mandates by governmental agencies.

The other support group provides "Awareness Support." These individuals should primarily come from outside the formal organization of the school. Their main function is to provide a realistic reaction to energy conservation proposals and serve as a liaison between the school, industry, and the community.

Considering the above as examples for an organizational structure and commitment, an energy conservation program and subsequent energy cost savings can be realized with the utilization of a definite plan of action. The Educational Facilities Laboratory ("The Economy of Energy Conservation," 1978) has outlined this plan of action identifying seven steps:

1. Define the goal (e.g. reduce energy costs by 10 percent).
2. Define the problem (e.g. energy is wasted by uninformed individuals).
3. Establish a data base.
   a. How much energy does the building use (determine energy/square foot, and energy/pupil)?
   b. What are the climatic conditions which effect energy consumption?
   c. Determine occupancy times and loads.
d. Record other pertinent information such as age of the building, construction materials, mechanical system used, etc. This is a very time consuming but necessary step.

4. Review collected data.
   a. Connect data with original goal.

5. Determine objectives and recommendations.
   a. For example, faculty training programs, reduced air changes/hour for the building, etc.

6. Implementation.
   a. Priorities will be set according to life cycle costing, simple payback times, or some other cost-benefit analysis.

7. Verification monitoring and evaluation.
   a. Insure the goals of the program are met.
   b. Check areas which are not working.

Although these steps are general in nature, they form a basic plan which can be followed by both large and small school districts.

Anderson and Bottinelli (1980) state that an effective plan should emphasize:

1. Communication--frequent, concise and consistent.
2. Incentives -- rewards and continued education.
3. Total involvement -- all must feel a part of the program (p. 7).
The authors further suggest the "continued education" specified above could be implemented in the following ways:

a. Training workshops for the energy team.

b. Inservice days for faculty and support staff to keep enthusiasm high.

c. Establishing a committee and implementing energy education into the curriculum (p. 8).

One specific area which has been recognized as critical to both energy conservation (management) and reduction of future energy problems is that of operation and maintenance of equipment and energy systems. In fact, Brewin and Racich (1979) have suggested that schools seriously consider an operation and maintenance training program for school custodians—due to their "direct responsibility" in maintaining the school building (p. 4). The key to the operation and maintenance training procedure is to reduce energy costs by developing a "preventive maintenance program."

A preventive maintenance program deals with "inspecting testing, preserving, and repairing features and systems of the building at regular intervals" (p. 5). Instruction for such a program primarily consists of "on the job training" with self-study and a trainer coming directly to the school to work with the custodians. The intention of the preventive maintenance training is to help the custodian identify potentially serious problems in the early stages through quick,
general, and routine inspections of energy systems. A major factor in the preventive maintenance program is accurate record keeping—that is, establishing equipment service and life-expectancy patterns. The four major areas outlined by Brewin and Racich (1979) are:

1. Study of proper tools, inspection techniques, loads, and distribution of energy systems—including typical repairs.

2. Study of the heating, ventilation, and air conditioning systems (HVAC).
   a. Filters
   b. Temperature controls
   c. Air-flow meters
   d. Boiler and furnace efficiency
   e. Minor repairs.


3. Water and sanitation.
   a. Familiarity with valves, pipes, and faucets
   b. Function of systems and repair techniques

4. Food services equipment.
   a. Familiarity with electric and gas burner systems and other equipment in the school kitchen
   b. Repair and replacement of faulty parts (p. 4-9).
In addition to energy cost reduction due to better operating and more efficient systems, the Educational Facilities Laboratory has suggested that implementation of a successful preventive maintenance program can result in reduced energy equipment costs ("The Economy of Energy Conservation," 1978). Recent figures indicate that operation equipment costs can be reduced by one-third since potentially expensive operational equipment problems are detected early and repairs made at a fraction of the usual cost.

At the building level, the staff, students, and principal must also be involved in the energy conservation program if major reductions in energy costs are to be realized (Bickle and Emry, 1979). Bamberger (1979) suggests that the role of the principal is particularly unique. As educational leader, the main responsibility for implementation of the energy conservation recommendations and practices rest with him/her; with administrative guidance, faculty and students will become educated in simple conservation measures such as closing windows, turning off lights, etc. In order to operate at this level, principals must become "more conversant with all the physical aspects of their building than they have been in the past" (Fredrickson, 1979, p. 59).

As information about energy management programs has been accumulating, elements are surfacing which are consistently found in successful programs. Included in these elements are
(1) top administrative commitment, (2) establishment of goals, and (3) efficient record-keeping. In short, successful energy management programs are organized and well monitored with added emphasis on accountability. Many types of organizational structure for energy management programs exist—becoming quite elaborate for larger districts. However, most proceed with a definite plan of action which includes goal definition, data collection, implementation, and evaluation. One particularly vital area in the energy management process is that of operation and maintenance procedures. Preventive maintenance programs, which place an emphasis on periodic checks and increasing operational efficiency, have been found to reduce substantially energy related equipment costs and energy costs in general. Many preventive maintenance programs include on-the-job training for maintenance personnel. Here, up-to-date methods of servicing and maintaining equipment are reviewed.

The energy audit

One of the most important steps in energy conservation relating to school buildings is the completion of an energy audit. Coad (1979) calls the energy audit a "necessary tool in any energy management program" (p. 105). The first organized step in this process is known as the "walk-through audit" (Anderson, 1977). It is conducted by an "energy team" from the building under consideration and should include the following people:
1. Energy manager
2. Building principal
3. A school board member
4. Teachers and students
5. Maintenance staff director or head custodian
6. Food services personnel or head cook
7. Leaders of community/school organization

Olsen (1978) describes the purpose of the walk-through audit: "The overall objective is to identify the possible scope for energy conservation" (p. 1.21). Coad (1979) draws on the experience an energy team may have in dealing with a financial audit: "what is being accounted for is the energy consumed" (p. 105). Simply stated, the energy team walks through the building, noting all the measures which could reduce energy consumption with little or no cost to the district. According to the Department of Energy, the energy team investigation basically accomplishes the following ("Energy Audit Workbook for Schools," 1978):

1. It allows energy team members to become familiar with building operations. This information can be invaluable for future audits. Stebbins (1980) suggests the team "develop a list of equipment that should be checked regularly" (p. 68).
2. It allows the energy team to site some of the energy waste areas, focus on primary problems, gather data, and
discuss the more practical cost effective steps.

3. It provides a very visual step toward energy conservation which others will begin to emulate.

4. It provides the basis for the beginning of data collection relative to building energy consumption.

Coad (1979) suggests that the data collection from the walk-through audit should result in a "building energy profile." He adds that this accumulation of building energy use characteristics be the first step in any audit program (p. 105). An excellent source which has forms to help complete the "profile" is the "Wisconsin Educational Facilities Energy Conservation Manual" (Olsen and Thomas, 1979).

The Council of Educational Facility Planners Journal has published what is called a "Preliminary Energy Audit" to help facilitate the walk-through evaluation of a building by the energy team (Sullivan, 1978). The PEA form is meant to be utilized under the supervision of a licensed professional engineer. The final evaluation of the "energy efficiency" of the building is found by using a predetermined "relative importance factor" in conjunction with a varying scale of "weight factors." "Relative importance factors ranging from 0.03 to 0.16 have been assigned to each of the thirteen items listed on the preliminary energy audit form" (p. 10). Proper weight factors from a range of possibilities listed are decided upon by the energy team depending on the condition of the
building being investigated. The higher the weight factor chosen, the poorer the energy efficiency of the system and the larger the potential for energy savings. An example of some of the weight factor choices and the PEA form are shown in Appendix E.

A very inexpensive follow-up to the walk-through audit is the public School Energy Conservation Survey (PSECS)—a computer model developed by the Educational Facilities Laboratory (Boice, 1976). By filling out a registration form and including a nominal fee (less than $100 per building), the school will be sent a questionnaire and asked basic information about each school to be analyzed. Included in the basic information will be the generic type of the building (i.e. construction date, envelope materials, heating systems, etc.) and details about energy usage patterns of the building. The generic type of a building has a particular significance in that it has been found that buildings have very typical energy usage patterns according to the generic type. By computer analysis, a very detailed and surprisingly exact diagnosis of possible energy waste can be determined for the building being investigated. The summary report from PSECS includes a self-help audit for each school, and a survey of both operational changes and capital modifications analyzed on a simple life cycle cost basis (p. 4-5). A flow chart of the entire PSECS process is shown in Appendix F (Boice, 1976). (Other computer models are available through several engineering firms. One
such example is that developed by McQuire and Shook Architects, Engineers, and Planners of Indianapolis, Indiana, in cooperation with the Army Corp of Engineers (Smith, 1980, p. 32).

The greatest advantage of the PSECS model is that it allows the school district to "spot" areas which need immediate attention (at a low cost or no cost implementation expense). It gives factual information which can be presented in justification for retrofitting buildings. PSECS also serves as a very valuable resource in the situation where further (mini and maxi) audits are indicated. However, it must be remembered the PSECS program is only as good as the information provided by the school district (Boice, 1976, p. 4, 6).

A summary of the PSECS program is provided by Campbell (1977):

What: PSECS is a computerized simulation that assesses "real life" school building functions. It relates energy need and energy use to that of a typical building of the same vintage and type.

How: The school district provides energy patterns of the building, student enrollment, type of educational program, building size, and weather data.

Who: Energy manager, school administrator, energy team, and head custodian or maintenance director.

Time: 1/2 to 1 hour, if records are updated.
Cost: Less than $100 per school building

Feedback: "Hands on" report through computer simulation printout. Life cycle costs of operational modifications are included (p. 154).

If a more detailed investigation of a building is indicated by either the energy team "walk-through" investigation or the PSECS report, a mini audit is the next logical step. Here, the "walk-through" characteristics are upgraded by contracting the services of an expert (Fuller, 1978). Much has been written about how many and what type of experts should be employed in conducting the mini audit. General agreement seems to fall on the following choices (Anderson, 1977; Dorgan, 1978; Piper, 1978; Drake, 1980):

1. A professional engineer experienced in energy conservation of buildings and cost analysis.
2. Utilities engineer or technician—gas and/or electricity where appropriate.
3. Custodian or maintenance director knowledgeable and comfortable with systems operations.
4. Principal and energy manager
5. One or more members of the energy team.

The total inspection will take only about two hours if energy usage patterns for the building are up to date (Olsen, 1978, p. 1.6). Reporting what is found and the recommendations by the engineer take an additional day. In 1980, one engineer-
ing firm estimated the cost of a mini audit for smaller schools in Iowa ranged from .5¢ to 1¢ per square foot of building floor space (W. G. Potter and Associates, Ames, Iowa). The added advantage of the mini audit over the team's initial "walk-through" is the analysis of sophisticated systems by individuals trained in the audit area, insuring not only the functional performance but the optimal efficiency as well. What might seem to be operating quite well to the casual observer may in actuality be very inefficient ("The Local Energy Program Manual," 1980, p. 23). The mini audit also has the advantage over the PSECS assessment since mini audit recommendations will be specifically adjusted for the building rather than the more generalized indications of the PSECS computer model.

In general, the mini audit is designed to establish those energy conservation measures which will result in little or no cost to the school district. Mini audits, however, usually do not involve detailed calculations for proposed energy conservation measures (Piper, 1978). The measures suggested by the audit members are usually implemented quite easily. Further importance of the mini audit is suggested by the fact that it can serve as an indicator of whether a maxi audit should be conducted. An outline similar to that of Campbell (1977) is included:
MINI AUDIT

What: "Walk-through" inspection of building HVAC system and other operational systems relating to energy consumption.

How: Energy usage patterns and building statistics are needed. Updated information is also needed on the building condition, i.e. repairs and retrofit.

Who: a. Licensed professional engineer or consultant from an architectural/engineering firm.
   b. Technician from each appropriate utility and fuel company representative.
   c. Head custodian or maintenance director.
   d. Building principal and energy manager.
   e. One or more members of the energy team.

Time: "Walk through," 1 to 2 hours; report, 1 day.

Cost: Approximately 1¢ per square foot of building floor space.

Feedback: Easy to implement energy conservation measures. Emphasis is placed on low cost or no cost retrofit by existing maintenance personnel. Results and recommendations are specific to the building investigated (p. 154).

The maxi audit involves an even more complete analysis of energy consumption in the school building. The service of a licensed professional engineer is contracted (Williamson,
Historic energy consumption patterns of a building are studied and detailed information is gathered about weather, climate conditions, building construction, building energy systems, instrumentation, and any other information the engineer feels is pertinent (Vanderweil, 1976). (A publication by the Center for Occupational Research and Development has assembled a list of "energy audit instruments" used by engineers in analyzing building systems ("Energy Conservation and Use Technology," 1981); see Appendix G.) After accumulating sufficient data, the consultant will either perform manual computations or use computer simulation models to decipher the energy retrofit data for a particular building. The latter method has been shown to give good comprehensive results (Campbell, 1977).

According to Campbell (1977), the major benefit of the maxi audit over the previously mentioned audits is the detailed cost benefit analyses of retrofit suggestions. The energy manager can use "payback" information included in the analyses to justify or discourage any major revisions in building structure or systems. The final maxi audit report by the engineer should include the following:

1. A complete inventory of energy using equipment.
2. A calculated energy budget for the building.
3. Current deviation from the calculated energy report.
4. Fuel and cost savings that would result from recommended changes in operation and maintenance practices.
5. Capital investment and payback periods for recommended retrofitting measures (p. 134).

The above information is also important to the energy manager in that it can be used at some future date should cost factors change or additional monies become available. W. B. Potter and Associates, engineering firm in Ames, Iowa, estimated the 1980 cost of a maxi audit at about 5¢ to 6¢ per square foot of school building floor space. Campbell (1977) states that "maxi audits are not inexpensive—usually costing $3,000 to $10,000 or more." (p. 134).

A summary of the basic ideas in a maxi audit is as follows:

MAXI AUDIT

What: A very detailed analysis of school building operational systems. Weather conditions, past energy patterns, instrumentation, and many other quantitative data are accumulated.

How: Accurate and detailed information is gathered by the engineer and used in calculations to predict energy waste and cost benefit analysis. A high degree of sophisticated equipment is used including computer analysis.

Who: Licensed professional engineer—certified as a Class A energy auditor with past experience in energy audits.
Time: Varies with building statistics, systems and operations.

Cost: As much as $10,000 or more.

Feedback: Projections of energy cost benefit analysis.
    Priorities for implementation procedures.
    Detailed information which may be useful in the future (p. 155).

Speaking of the energy audit in general, Peterson and Colavita (1980) contend it serves the following purposes:
1. It shows where energy money is going and therefore pinpoints areas where energy savings are possible by providing monthly energy cost comparisons.
2. It makes possible the preparation of an "energy budget" so that administrators can begin to think dollars and BTU's in the same terms. (Energy use should be translated into the energy use index (EUI); energy costs are expressed in BTU's/ft²/year.)
3. By showing graphically where energy costs are concentrated, it encourages students, teachers, and administrators to try harder to cut energy waste (p. 3).

Olsen (1978) further states: "The energy management process can be summarized in four key words: identify, quantify, modify, and verify" (p. 1.20).

The Iowa Energy Policy Council has participated in the National Energy Conservation Policy Act for schools and
hospitals (Hansen, 1979). The original law was passed in 1979. The program which included an energy audit, energy conservation measures and technical assistance phase is in the third year of the cycle. Fifty-fifty (50/50) matching funds were granted to qualified schools and hospitals. Iowa's original share for the "energy audit" portion of the bill was $309,000, while the allotment for the energy conservation measures and technical assistance phase was $3,152,000 ($900 million was appropriated in the national act over a three-year period). The program is presently in the "technical assistance" (TA) phase of the cycle. Reports to the State for technical assistance (compiled by an engineer) must include:

1. A description of building characteristics and energy data (including weather and climate data, operating characteristics, etc.).

2. Analysis of estimated energy consumption of the building and optimum operating costs in terms of energy usage.

3. Building potential for solar conversion (particularly for water heating systems) and other implementations for renewable sources of energy if appropriate.

4. A description and analysis of all retrofit recommendations.

5. Cost factor analysis in terms of energy cost savings as related to simple pay back period (1 to 15 years).

To be eligible for the Energy Conservation Measures Grant a school system must (1) complete all requirements established for the technical assistance program; (2) implement all recommendations according to cost-benefit analysis of TA; (3) have no plans to close the building within the simple payback period for which financial assistance is requested, and (4) submit an application according to the state plan (p. 1591).

One of the most popular studies dealing with energy audits of school buildings was known as the Schoolhouse Energy Efficiency Demonstration (SEED). Twenty schools across the nation were chosen by the Tenneco Corporation of Houston, Texas, and participated in an energy audit conducted by Calvin M. Wolff and Milton Meckler (Carnell, 1979). As stated in the resulting technical manual for educators entitled "Something Special From SEED," the program goal was to "assist schools in reducing the impact of the rising costs of energy by defining good energy management programs and by implementing quick-fix, low-cost energy efficiency improvements" (p. 1). In addition to the technical component of the study, an effort was made through workshop applications, to increase public awareness and "encourage management program" (p. 1). The whole emphasis of the study was to reduce energy costs and thereby avoid reductions in the quality of the existing education program.

In the manual mentioned above, information is given on formation of an energy management team and suggestions about
areas where the largest energy losses occurred: windows, infiltration, poor insulation, and excessive lighting. In addition, checklists are provided which can be used by the energy team for the following areas:

I. Human Systems

II. Structural Systems (doors, walls, roofs, and interior)

III. Lighting Systems (interior and exterior)

IV. Mechanical Systems (heating, ventilating and air-conditioning)

V. Special Systems (water, kitchen, cafeteria, laundry, office and electrical equipment).

The publication also includes examples of report forms for the Human, Structural, and Energy Systems. A form for General Administration purposes is also provided. Other valuable forms from the collection of energy data are found in a publication by the Province of British Columbia ("Energy Conservation for Schools," 1978).

Important energy tips mentioned by the SEED project are as follows (Carnell, 1979):

A. About half the energy used by a domestic hot water heater goes toward maintaining a set tank temperature.

B. It saves money to turn off fluorescent lights if a room is going to be vacant for more than 2½ minutes.

C. A 10 mph wind will force as much as three times the desired amount of cold fresh air into a room. By covering
the exterior grill of the unit ventilator with pegboard, the problem is minimized.

D. Reducing the temperature one degree at night saves as much energy as reducing the temperature three and one-half degrees during school hours.

E. Windows consume energy in three ways: conduction, radiation through the glass, and infiltration through cracks. Using window shades to reduce conduction and radiation results in a 10 percent energy savings. The implication is to lower shades at night.

F. Infiltration allows for 250 cubic feet per minute of air into the classroom even after improving window seals. Since the usual code is 125-150 cubic feet per minute, buildings may be made much tighter than they are now being designed and built (p. 13).

An energy audit is an inspection of the energy systems within a building to account for energy being used. Three types of energy audits have been identified in this paper: (1) walk-through inspections by the energy team, (2) mini audits with the aid of a professional engineer, and (3) maxi audits—detailed examination of energy systems using technical equipment and advanced systems analysis. The Public School Energy Conservation Survey (PSECS) computer program, developed by the Educational Facilities Laboratory, is one example of a computer-assisted (walk-through) audit. The
PSECS program is available at a moderate cost. Cost of different types of audits vary from district to district depending on energy usage patterns and need for professional assistance. Maxi audits may cost up to ten thousand dollars or more. Financial help is available to schools and hospitals on a fifty-fifty matching basis through the Iowa Energy Policy Council ("Technical Assistance and Energy Conservation Measures," 1979). Iowa has received over three million dollars from the Federal Act to be disseminated in the form of grants to schools and hospitals for the energy conservation measures and technical assistance phase of the program.

Reports of nationwide studies are available which show the impact of energy audit programs. The Schoolhouse Energy Efficiency Demonstration by the Tenneco Corporation is just one example of how schools have benefited from energy audits by reducing energy waste. Findings from studies of this type can be applied in schools across the nation.

Energy Management Applications

Many reports of "retrofit" and implementation of energy conservation measures by schools exist in the literature. In the Tenneco study mentioned above, Friends School of Baltimore, Maryland, was cited as a good example since it was distinguished as "the most complex audit" of all the schools in the study due to the number of separate buildings at the location (p. 12).
Energy cost reduction efforts were primarily directed at "tightening the building envelope" (Carnell, 1979, p. 11). With an initial cost of $46,336—payback time of 20 months—it was estimated that the school could "reduce fuel oil consumption by 58 percent and its electric power use by 30 percent" (p. 11). Conservation efforts for reduction of heating costs were directed in the following three areas:

1. Reduction of air infiltration (weatherstripping and caulking).
2. Reduction of heat transmission by insulating windows (using translucent material).
3. Reduction of fresh air intake systems by eliminating excess flow (pegboard was placed over the large ventilators' air intake).

Two major suggestions made to reduce electric power waste were:

1. Replace incandescent lamps in the gym with high intensity discharge lamps.
2. Eliminate use of fluorescent lamps which provide no lighting benefit near windows.

As a result of the energy audit by a professional engineer, the following specific recommendations (including initial cost and payback times) were made:
<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Cost</th>
<th>Payback (Mos.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Recaulk and gasket windows</td>
<td>$3,585</td>
<td>27</td>
</tr>
<tr>
<td>B. Insulate two-thirds of windows</td>
<td>$2,471</td>
<td>35</td>
</tr>
<tr>
<td>C. Weatherstrip doors</td>
<td>$763</td>
<td>7</td>
</tr>
<tr>
<td>D. Reduce fresh air intake by two-thirds</td>
<td>$540</td>
<td>2</td>
</tr>
<tr>
<td>E. Tune thermostat system</td>
<td>$500</td>
<td>1</td>
</tr>
<tr>
<td>F. Install independent hot water heaters</td>
<td>$3,750</td>
<td>55</td>
</tr>
<tr>
<td>G. Shut down boilers on warm days</td>
<td>$1,500</td>
<td>36</td>
</tr>
<tr>
<td>H. Shut down steam boilers on nights and weekends</td>
<td>$1,000</td>
<td>36</td>
</tr>
<tr>
<td>I. Reduce boiler firing rates</td>
<td>$750</td>
<td>33</td>
</tr>
<tr>
<td>J. Reduce hot water flow rates</td>
<td>$1,650</td>
<td>17</td>
</tr>
<tr>
<td>K. Reduce ventilator flow rates</td>
<td>$6,000</td>
<td>20</td>
</tr>
<tr>
<td>L. Reduce exhaust fan flow rates</td>
<td>$3,061</td>
<td>6</td>
</tr>
<tr>
<td>M. Turn off empty refrigerators</td>
<td>$0</td>
<td>0</td>
</tr>
<tr>
<td>N. Deactivate fluorescent lighting near windows</td>
<td>$10,000</td>
<td>48</td>
</tr>
<tr>
<td>O. Re-lamp gyms and auditorium</td>
<td>$7,900</td>
<td>20</td>
</tr>
<tr>
<td>P. Improve lighting quality in classrooms</td>
<td>$0</td>
<td>0</td>
</tr>
<tr>
<td>Q. Mount energy conservation plaques</td>
<td>$100</td>
<td>soon</td>
</tr>
</tbody>
</table>

Once this list is submitted by the engineer, the question of which energy conservation opportunities will be implemented
becomes an administrative (and board) decision—subject to the usual political, social, and educational ramifications.

When calculating the relative value of an energy conservation opportunity, it is often customary to calculate the simple payback period (SPP):

\[
SPP = \frac{\text{First costs of energy conservation measure}}{\text{Yearly retained savings}}
\]

By dividing the cost of implementing the measure by the amount of energy cost savings per year, the number of years it will take for the measure to "pay for itself" can be found (U.S. Dept. of Energy/CS-0143, 1980, p. 15).

However, in order to determine the true worth of the energy conservation measure, one should take into account an "escalation factor" (i.e. price inflation over the period of time the measure is operational). A table of "escalation factors" taken from a publication entitled "Practical Energy Management in Health Care Institutions" (1977) is shown below:

<table>
<thead>
<tr>
<th>Energy Saving Life Cycle, Years</th>
<th>5</th>
<th>7</th>
<th>10</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>10%</td>
<td>6.72</td>
<td>10.44</td>
<td>17.53</td>
<td>34.95</td>
</tr>
<tr>
<td>15%</td>
<td>7.75</td>
<td>12.73</td>
<td>23.34</td>
<td>54.72</td>
</tr>
<tr>
<td>20%</td>
<td>8.93</td>
<td>15.50</td>
<td>31.15</td>
<td>86.44</td>
</tr>
</tbody>
</table>

(p. 15).
To use the chart, multiply the escalation factor times the savings retained for one year. Therefore, at a 10 percent inflation rate for fuel and a life cycle expectation of 10 years, the true amount saved with an energy conservation measure retaining $1000/year would be $17,530, ($1000 X 17.53), rather than $10,000, ($1000 X 10 yrs.).

In each case, the appropriate escalation factor--found by matching the percent inflation with the life cycle (years)--multiplied times the amount saved each year through implementation of the ECM is the true amount saved. Still more detailed evaluation of the investments can be made by taking into account depreciation, tax bracket of the investor, salvage value, and other specifics dealing with cost-benefit analysis ("Manual of Procedures," 1979).

Fairfield University in Connecticut is perhaps atypical in the approach taken for energy conservation ("Energy Audit Pays Off," 1980). Even prior to undergoing an energy audit, a computerized system to control the 18-building campus heating system was installed. In the words of John Hickson, Vice-president of Business and Finance, "We went after the quickest return and that was the Honeywell Delta 1000" (p. 78). The monitoring system has a payback time of two and one-half years. Including the retrofit suggested by energy audits after the computerized system was installed, $3,820,000 in energy costs is expected to be saved over the next 10 years. The savings
are especially noteworthy since the original audit phase of the program was to simply insure the existing mechanical equipment was working at optimum efficiency. Recommendations of the low-cost nature at the university included "retuning boiler burners seasonally, lowering domestic hot water temperatures, rescheduling and relocating summer activities, and shutting down equipment accordingly" (p. 79). Evidence of savings such as these only reinforce the words of a spokesperson for the Atlanta firm involved in conducting the audits: "Good energy conservation is all in the approach. It is a management problem, not an engineering one. What is important is the quality of judgements made, the objective being the highest possible return for the lowest possible investment. It is the sum total of these judgments which makes up a maximum energy conservation program" (p. 79). This statement reiterates the need for knowledgeable people in the decision-making process. These people must be good managers and must be especially sensitive to the ramifications of energy conservation opportunities within the school district.

As testimony to the statement above, Michigan State University has implemented a "phased energy management program" to consider energy conservation opportunities ("Energy Management Yields Results," 1980). The complete program is outlined below:
1. Feasibility Study
   a. Analysis of energy management opportunities
   b. Priority of points to be managed
   c. Priority of buildings based on cost/benefit
   d. Phasing of the project
   e. Budget estimate
   f. Time value of money considered for payback

2. Implementation of the Program
   2.1. Central Equipment Specifications
       a. Specify hardware to be centrally located
       b. Produce detailed specs for hardware and software
       c. Establish fixed escalation factor for all bidders
       d. Initiate competitive bidding
       e. Receive guaranteed prices
       f. Estimate total project cost
       g. Select successful bidder based on total life cycle cost

2.2. Installation Documents
       a. Specific supplier
       b. Manufacturer's wiring diagrams for each plant
       c. Detailed local temperature control retrofit
       d. Detailed electrical drawings
       e. Competitive bidding
          1. Temperature control
          2. Electrical systems
3. Mechanical systems

4. Central control from central equipment specifications

3. Update of Feasibility Study based upon saving realized from previous phases (p. 35).

Using this structure, the feasibility of establishing a central control system for five campus buildings was examined. The eventual implementation, under the guidance of Louis Trama, Director of the Energy Management Department at Hoyem-Busso Associates, Inc., in Michigan, showed a savings of 21 percent in electrical energy and a 19.7 percent savings in thermal energy. First year dollar savings were greater than $111,000. Extending the centralized control system to all fifty-five buildings on campus (within five to ten years) is expected to result in an annual savings of $800,000.

Lessons learned through energy management and retrofitting older structures can be quite advantageous when constructing a new school. Sharon Elementary School in Newburgh, Indiana, is just one of many examples where a new school was designed and built using energy conservation measures found to be practical even in older structures with high renovation (retrofit) costs ("Bright, Light and Energy Efficient," 1981). Perhaps the most innovative energy savings measure is the school's ability to use three types of fuel for heating and cooling the 90,000 sq.ft. area. The choice of which energy
source to use depends on cost and availability during the warm
and cold seasons. Although natural gas is the main source
anticipated, the system can also utilize oil and propane gas.

Other energy conserving measures included in the original
construction of the building were:

1. A climate control center which can reclaim and reuse heat
   via a heat recovery system.
2. Corridor lights using parabolic reflectors to reduce glare
   and disperse light.
3. Insulated acrylic skylights and area lighting.
4. Efficient space utilization using attractive colors and
   special materials.
5. Double-glazed windows set in wooden frames.

Numerous applications of the energy management process are
found in the literature. To report and prioritize energy con­
servation opportunities resulting from the analysis of energy
systems, it is convenient to list both the cost to implement
the energy reducing measure (i.e. investment) plus the simple
payback period or time for the energy reducing measure to pay
for itself. In doing so, administrators can visually display
possible energy measures in decreasing order of importance—
based on managerial judgment and expertise. To a large degree,
energy conservation is more of a management problem than it is
a technical problem. What is needed are good managers cognizant
of energy related problems and committed to an effective energy
conservation program. The procedures followed to investigate energy conservation opportunities can be outlined by a district or described in a model for simplification. With definite energy management programs such as these, coupled with the experience gained in retrofit of older schools, new structures can be designed and built to operate in an even more energy efficient manner.

Energy Conservation Research Dealing with School Facilities

A study conducted in the early 70s by the Educational Facilities Laboratory in Fairfax County, Virginia, was one of the first to reveal general areas of energy waste in schools (Stephan, 1975). Seven schools were selected from a group of 176 which would be representative of schools across the nation. The objectives of the study were "to identify any changes in operational procedures, plant maintenance practices, and the kinds of physical changes or modifications to the building and its systems that would yield significant savings in energy consumption" (p. 51). The schools received a detailed inspection (audit) including:

1. Examination of on-file plans and specifications of the building envelope.
2. Examination of operating systems.
3. Interviews with principals, heat custodians and others to ascertain all factors affecting the operation of the school.
To obtain a high degree of accuracy in a minimal amount of time, a computer energy analysis program was used. Profiles of operating conditions on the computer model were found to be within a 7 percent range of accuracy. Simulated changes "ranged from fresh air intake to installation of double-glazed fenestration. The most obvious areas of waste discovered were:

1. The energy required to both cool and heat fresh air
2. The wastes resulting from inadequate operating practices and maintenance procedures (p. 51).

It was also determined that excessive outside air being used by high schools increased fuel consumption by 23 to 31 percent. Fuel consumption excesses of nearly 50 percent were found in situations where temperature controls were not maintained and setback did not occur during unoccupied times.

A national study was conducted by the American Association of School Administrators (AASA) to determine if the reported energy waste was decreasing due to energy conservation methods being used in schools ("American Association," 1980). (Data collected were compared to that of a similar survey conducted five years earlier.) A systematic random sample was drawn from the AASA membership list (stratified by district size). A survey instrument developed in consultation with the Department of Energy was utilized with mailings in January, 1979, and again in March. Data were gathered which indicated consumption of energy in the nation's schools. Due
to the complexity of the information collected, only 30 percent of the surveys were returned in usable form. The data were not adjusted for differences in heating degree days for either of the surveys.

Results of the study are as follows:

1. Over the five years from 1973 to 1978, energy consumption in the nation's schools decreased. However, there is still much that can be done.

2. Median BTU's/sq.ft. of school area was down by 35.25 percent compared to a 1973 study (average usage down from 161,312 to 104,445 BTU's/sq.ft.).

3. Consumption is a function of district size. Schools with student enrollment greater than 5,000 consumed 11.6 percent less energy/sq.ft. than those with fewer than 5,000 students.

4. Larger schools use a disproportionate amount of natural gas for heating purposes, while smaller schools use a disproportionate amount of electricity in that area.

5. The breakdown of consumption (by fuel type) by schools is:

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Percent of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Natural gas</td>
<td>54.89</td>
</tr>
<tr>
<td>b. Oil</td>
<td>25.01</td>
</tr>
<tr>
<td>c. Electricity</td>
<td></td>
</tr>
<tr>
<td>1. Heating &amp; cooling</td>
<td>7.40</td>
</tr>
<tr>
<td>2. Heating only</td>
<td>8.80</td>
</tr>
<tr>
<td>d. Propane</td>
<td>2.01</td>
</tr>
</tbody>
</table>
A specific example of what schools were accomplishing in energy cost reduction during this period is given by Paige and Schreiber (1976). This particular project began in 1973 with the Herricks Union Free School District in New York. An energy management program was instituted under the direction of Gruman Aerospace Corporation's Energy Conservation Systems Department. After two and one-half years into the program, oil consumption was reduced by 34.3 percent while a 20.3 percent reduction was noted in district-wide electricity consumption (p. 3). Turner and Estes (1980) suggest the average savings by instituting an energy management program is about 30 percent; Anderson and Bottinelli (1980) claim that it can be as much as 50 percent for schools.

At the beginning of the study, the "disparity in energy use" for the individual buildings was quite large; ranging from .74 to 1.113 gal/ft²/year for the seven schools under investigation (p. 3). In order to establish the "energy conservation condition" a "thermal balance" was performed on each of the buildings. Fuel use, occupancy, weather data, transmission losses in the envelope, lighting, and motor loads were all taken into account.
At the conclusion of this examination, it was determined that too much energy was being used during unoccupied times. Most of the retrofit and other modifications recommended had a payback time of less than one year. Average fuel used was reduced from \(0.87 \text{ gal/ft}^2/\text{year}\) to \(0.57 \text{ gal/ft}^2/\text{year}\) or 34.3 percent. Reduction in electricity was primarily achieved through reducing motor horsepower and light usage (23.7 percent) (p. 7). More importantly, "the energy management system installed in no way sacrifices comfort levels to those occupying the building" (p. 10).

In another study conducted by the American Association of School Administrators—known nationally as the Saving Schoolhouse Energy Project—ten elementary schools across the nation were selected as representative buildings because of the following characteristics ("Public Schools Energy Conservation Measures," 1977):

1. Type of structure
2. Predictably consistent usage patterns after modifications
3. Building longevity
4. Building size
5. Student enrollment
6. Available energy consumption data
7. Expected energy savings as predicted through the use of the Public School Energy Conservation Service (PSECS) computer program (p. iv).
An effort was made to find typical schools rather than bad examples. (See Appendix H for location of the schools and various degree day zones).

The project was designed to have the following five phases:

1. Select ten schools and analyze the possible energy conservation opportunities (ECO)
2. Undertake needed architectural or engineering design work
3. Complete recommended modifications
4. Monitor and record post-modification energy use
5. Disseminate the findings (p. iii).

The following detail is presented for Central Elementary School of Glen Rock, New Jersey, (one of the schools chosen for the study) since its size and construction date appear similar to many Iowa schools.

Size: 45,384 sq.ft., 18 classrooms, library, multipurpose area, and administration center. Central also has an auditorium and the district administration office (p. 1).

Occupancy: 300 students, k - 6, 30 staff (includes district and administration personnel).

School day: 9:00 - 3:00 (Sept. to late June)
8:00 - 6:00 (staff and administration)

Construction: Original structure - 1925, two levels, 33,000 square feet.

Walls: 4" face brick, 2" air, 8" concrete block with plaster finish (35 percent double hung single pane glass)
Roof: Built-up roofing over plywood deck, interior ceiling drop with plaster board or acoustical tile; no insulation

1st Addition - 1939 similar in structure but single level (3840 sq.ft.)

2nd Addition - 1958, single story (8544 sq.ft.)

Walls: 4" brick, 8" concrete block, no insulation (60 percent single pane casement glass)

Roof: Built-up over wood sheathing air space; 2" insulation and acoustical tile over steelrock.

Heating, Ventilating and Air Conditioning:

Unit ventilators and radiators in classrooms and auditorium. One pump for original structure and first addition; second pump added for 1958 addition, controlled manually.

Heated by (2) 1925 oil fired boilers - low steam (converted from coal) and (2) 1957 hot water converters (changed from steam to hot water)

Cooled by (9) window air conditioners

Illumination: Fluorescent all but gym which has twenty-four 300 watt mercury vapor lamps - typical illumination = 1.7 W/ft². Dropped ceiling area = 2.85 W/ft² and 1956 addition = 1.9 W ft².
Energy Consumption:

<table>
<thead>
<tr>
<th>Year</th>
<th>Gals.</th>
<th>Gals/sq.ft.</th>
<th>Degree Days</th>
<th>Gal/DD</th>
<th>KWH</th>
<th>KWH/ft²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1972-73</td>
<td>42682</td>
<td>.94</td>
<td>4,707</td>
<td>9.07</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1973-74</td>
<td>40324</td>
<td>.89</td>
<td>4,452</td>
<td>9.06</td>
<td>164000</td>
<td>3.6</td>
</tr>
<tr>
<td>1974-75</td>
<td>45538</td>
<td>1.00</td>
<td>4,594</td>
<td>9.90</td>
<td>153240</td>
<td>3.4</td>
</tr>
</tbody>
</table>

Using this data, several computer programs—including the Public Schools Energy Conservation Survey (PSECS)—were utilized with "as built" drawings and on-site inspections to investigate energy conservation opportunities. This complete analysis and computer simulation revealed the following "energy breakdown" of annual heating and electric energy required by the Glen Rock School ("Public schools . . .", 1977, p. 17):

**Heating Energy**

<table>
<thead>
<tr>
<th>Component</th>
<th>Percent of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof Transmission</td>
<td>15.5%</td>
</tr>
<tr>
<td>Infiltrated Air Heating</td>
<td>32.0%</td>
</tr>
<tr>
<td>Walls and Glass Transmission</td>
<td>34.0%</td>
</tr>
<tr>
<td>Outside Air Heating</td>
<td>18.5%</td>
</tr>
</tbody>
</table>

**Electric Energy**

<table>
<thead>
<tr>
<th>Component</th>
<th>Percent of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lighting</td>
<td>31.0%</td>
</tr>
<tr>
<td>Power</td>
<td>60.0%</td>
</tr>
<tr>
<td>Air Conditioning</td>
<td>9.0%</td>
</tr>
</tbody>
</table>

After the energy audit was completed by the project engineer, the following recommendations were made (based on fuel costs of 34¢/gal escalating at only 10 percent per annum):
<table>
<thead>
<tr>
<th>Energy Conservation Measures (ECM)</th>
<th>Est. Cost</th>
<th>Recov. Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Reduce outside air</td>
<td>$5,000</td>
<td>5 yrs.</td>
</tr>
<tr>
<td>2. Replace boilers</td>
<td>$20,000</td>
<td>6 yrs.</td>
</tr>
<tr>
<td>3. Reduce thermostat settings</td>
<td>0</td>
<td>immediate</td>
</tr>
<tr>
<td>4. Install motor operated damper</td>
<td>$1,350</td>
<td>2 yrs.</td>
</tr>
<tr>
<td>5. Install roof insulation</td>
<td>$7,200</td>
<td>7 yrs.</td>
</tr>
<tr>
<td>6. Reduce infiltration</td>
<td>$6,000</td>
<td>6 yrs.</td>
</tr>
<tr>
<td>All Recommendations</td>
<td>$39,550</td>
<td>6 yrs.</td>
</tr>
</tbody>
</table>

For this particular study, "cost effective" recommendations were based on a 12-year payback time with a fuel escalation of 10 percent per annum. Engineers predicted a 50 percent reduction in energy for all ten schools in the study if all the energy conservation opportunities were implemented. In this case, the average expenditure for energy conservation measures would be twenty-six thousand dollars (Hansen, 1978).

The key energy saving measure for the research was designated as more energy efficient lighting. This energy conservation opportunity was particularly popular because:

1. Administrators can authorize changes with little capital investment required, and
2. Energy costs are reduced without sacrificing lighting levels (p. 176).

The New York State Education Division of Research has studied questions dealing with the feasibility of energy savings through the re-arrangement of the school calendar.
year (1978). The study was specifically designed to:

A. Determine if schools would save energy by closing for an extended period of cold weather and

B. Determine if energy savings by schools during a winter closing are offset by increased use of energy in homes.

To conduct the research, ten school districts (24 buildings) provided energy consumption data--meter readings for gas, oil, and electricity--for the month of February. Seven of the ten districts asked students to collect home gas and electric meter readings. These readings were used to estimate the total energy consumption for homes in the district with school-aged children. Data were assembled into "in school" and "out of school" sessions; weekends and school vacation time comprised the period school was not in session (i.e. "out of school"). Meters were read at approximately the same time on a daily basis.

There were some sample restrictions in the study. School buildings chosen had to be heated with natural gas. Other selection factors included:

1. Length of vacation time in February
2. Age of the building
3. Type of program
4. Type of community
5. Location of school district in the state.
The findings are summarized as follows:

A. Energy may not be saved by closing school during the cold winter months. Older schools did save energy under the closed situation, but some schools showed no savings. (It was speculated that the schools which showed no savings were the better constructed newer schools, although the study did not attempt to deal with that question.)

B. More energy was used in sample homes when schools were open. However, the difference was not statistically significant.

C. Although the sample size was small, implications are that energy would not be saved by closing schools during cold weather and sending the students home.

In a related study, the New York State Education Department analyzed the energy cost implications of nine different school calendars ("School Calendars and Energy Use," 1978). In particular, the study was to determine the amount of energy required to operate a "typical" elementary school in each of four climates using nine designated operating schedules. The different types of calendars studied were as follows:

1. Traditional nine-month calendar
2. Ten-month school year
3. Mid-August start, two semesters
4. Four-day school week
5. Four-day school week, 7.5 hours/day
6. Four and five-day weeks
7. Twelve month, multiple variations
8. Five eight-week learning periods
9. 45-15 plan (i.e. forty-five school days followed by fifteen days of vacation, on a rotating basis).

In order to get a representative sample, four schools were selected which exemplified the range in heating degree days across the state of New York. Daily temperature averages (compiled over a 32-year period) were provided by the National Weather Service for the four locations. This information was used in a computer simulation to model each calendar.

The following factors were considered in the analysis:
1. Daily weather patterns
2. Schedule of operation
3. Building characteristics

Findings of the study were:
A. Use of fuel varied in relation to the severity of the climate.
B. Only the four day, 7.5 hour/day calendar produced more than a 10 percent change in all four climates (the 45-15 plan showing no variation in energy savings).
C. The advantage of Calendar five is due to fewer (but longer school days.
The research concluded with the following statements:

1. "It would be difficult to make a strong case for one calendar over the others on the basis of its energy saving potential" (p. 35).

2. "Variations in energy use from calendar to calendar are too small to be significant" (p. 31).

A study of state-owned buildings in Minnesota (Twin Cities) provides information regarding energy savings on a large scale audit basis. Energy audits are required by law for all state-owned buildings in that state (Hirst, 1980). Over 41 different institutions (270 buildings) were energy audited in this study. Results of the energy audit costs and average payback times for energy conservation opportunities found are listed below (p. 48):

<table>
<thead>
<tr>
<th>Institution</th>
<th>No. Audited</th>
<th>Annual Energy Used</th>
<th>Audit Cost</th>
<th>Average Payback Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Community colleges</td>
<td>18</td>
<td>130 MBtu/ft²</td>
<td>3.6 ¢/ft²</td>
<td>12 yrs.</td>
</tr>
<tr>
<td>State universities</td>
<td>5</td>
<td>138</td>
<td>2.7</td>
<td>9</td>
</tr>
<tr>
<td>Hospitals</td>
<td>4</td>
<td>205</td>
<td>2.9</td>
<td>11</td>
</tr>
<tr>
<td>Transportation Dept.</td>
<td>7</td>
<td>164</td>
<td>1.8</td>
<td>9</td>
</tr>
<tr>
<td>Office buildings</td>
<td>7</td>
<td>132</td>
<td>4.7</td>
<td>14</td>
</tr>
</tbody>
</table>

Results of the energy audits indicated that energy use could be reduced by at least 32 percent of the total (an average of 71 MBtu/ft²). A total of 2,010 energy conservation opportunities were indicated for the institutions audited. If audit recommendations were followed, 85 percent of the energy saved
would be of fossil fuel nature (730 trillion Btu) while the remaining 15 percent savings would be in electricity.

One important finding indicated that measures with 0-5 years payback accounted for 60 percent of the total energy savings at only 18 percent of the estimated capital costs for implementation. If all 2,010 measures were implemented the total cost would be $23.3 million with an annual savings of 3.0 million—or an average payback time of less than 8 years (p. 48).

As far as overall implications, short-term payback times were found for HVAC changes while long-term payback times were calculated for envelope changes (23.0 years). It appears that auditors should spend their time wisely when gathering data and making calculations dealing with envelope changes unless unusual situations exist (i.e. obvious building deterioration) (p. 49).

Research dealing with energy conservation in school facilities is more than just a recent undertaking. A particularly notable study was completed in the early seventies in Fairfax County, Virginia. The project utilized computer simulation techniques to evaluate wasteful areas in school buildings. Results and information from this research—and others like it—are apparently being used by schools across the nation. A study by the American Association of School Administrators indicates schools reduced energy waste between the five-year period from 1973 through 1978. However, much
more still remains to be done. Recent studies such as the Saving Schoolhouse Energy Project have reconfirmed the need for energy conservation in schools. It is estimated that schools could reduce energy waste by as much as 50 percent. In the study just mentioned, typical schools were chosen rather than examples of poor energy efficiency. Such evidence indicates that the need for energy conservation in schools is not limited to a few isolated cases.

One area other than the building envelope which continues to receive attention as a possible avenue of energy reduction is the revision of daily class schedules and the school calendar year. Evidence at this point, however, does not indicate significant energy cost reduction through manipulation of the traditional school calendar. More investigation is needed before any definite conclusions can be made.

Research in Energy Management

Little has been found in the literature dealing with research in the area of energy management and school administrators. However, a dissertation by Hicks (1978) called "Energy Guidelines for School Facilities" does address the question of which energy conservation practices are being implemented by selected schools in Tennessee. The following research questions were posed:
1. What are needed current practices in energy conservation as indicated by the review of literature and interviews?

2. What energy conservation methods are being practiced in the selected area?

3. What are practical guidelines for energy conservation in school facilities?

To add validity to the information found in a review of the literature augmented by personal interviews, a "jury of experts" rated the energy conservation practices found. These "guidelines" were shortened to single words or phrases (called elements) to simplify the rating sheet. Judges rated the elements as essential, highly significant, significant, little significance, or not applicable. Points of 5, 4, 3, 2, and 1 were assigned to the choices in the rating scale, respectively. The top ten "elements" and the corresponding "guidelines" are (p. 102):

<table>
<thead>
<tr>
<th>Element</th>
<th>Guideline</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Insulation</td>
<td>Adequate insulation for facility that meets specifications for temperate zone.</td>
</tr>
<tr>
<td>2. Administrative Commitment</td>
<td>Total commitment to energy conservation by top level administrators in the system.</td>
</tr>
<tr>
<td>3. Maintenance</td>
<td>Proper maintenance of all appliances and equipment.</td>
</tr>
<tr>
<td>Element</td>
<td>Guideline</td>
</tr>
<tr>
<td>------------------------------</td>
<td>---------------------------------------------------------------------------</td>
</tr>
<tr>
<td>4. Air Infiltration</td>
<td>Correction of unwanted air infiltration.</td>
</tr>
<tr>
<td>5. Weatherstripping and</td>
<td>Use of sealants for correction of unwanted air infiltration.</td>
</tr>
<tr>
<td>Caulking</td>
<td></td>
</tr>
<tr>
<td>6. Ventilation</td>
<td>Adequate ventilation to maintain proper moisture control and to meet</td>
</tr>
<tr>
<td></td>
<td>exhaust requirements.</td>
</tr>
<tr>
<td>7. Night/Holiday Setback</td>
<td>Use of night/holiday setback controls to conserve heating/cooling and</td>
</tr>
<tr>
<td></td>
<td>lighting energy use during unoccupied intervals.</td>
</tr>
<tr>
<td>8. Water Temperature</td>
<td>150° temperature is adequate for general water usage (most water heater</td>
</tr>
<tr>
<td></td>
<td>thermostats are set much higher).</td>
</tr>
<tr>
<td>9. Energy Audit</td>
<td>Complete audit of facility to determine energy conservation opportunities.</td>
</tr>
<tr>
<td>10. Heating/Cooling</td>
<td>Heating/cooling plan that makes efficient use of units without sacrificing</td>
</tr>
<tr>
<td></td>
<td>thermal comfort.</td>
</tr>
</tbody>
</table>

(The entire list of elements and corresponding guidelines is shown in Appendix I.)

Those elements which received an average score of 2.0 or better were included in a survey form later sent to administrators. Superintendents in the selected schools were asked to respond (by checking yes or no) as to whether the element had been implemented or was in the process of being implemented.
in their districts. A rank order of the guideline elements (and some elements added by the administrators) according to frequency of adoption is shown below (p. 76):

1. Night holiday setback
2. Maintenance
3. Unconditioned zones
4. Weatherstripping
5. Room decor
6. Information dissemination (added by administrators)
7. Effective dissemination (added by administrators)
8. Timers
9. Training - some
10. Administrative commitment
11. Weatherstripping (inspection)
12. Heating/cooling
13. Air infiltration
14. Lighting
15. Energy audit
16. Energy committee
17. Water temperature
18. Ventilation
19. Insulation
20. Water conservation
21. Landscaping
22. Training - all
23. Written goals
24. Written philosophy

A comparison was made to determine if a difference existed in adoption practices between the six city and seven county school systems which participated in the study. To check for a significant difference, the Mann-Whitney U test was employed. A significant difference was found (Probability = .051). City districts were implementing more energy conservation opportunities than county districts.

The adoption practices were then divided into nine "cost effective" and fifteen "minimal/no cost" measures. The Spearman Rank-order Correlation Coefficient was calculated to determine if any differences existed in these categories between city and county school systems. Significant differences were found at the 95 percent confidence level (the minimal/no cost analysis showed a significance at the 99 percent level).

Finally, the Chi Square test was used to determine if cost-effective measures were being implemented to a different degree than minimal/no cost measures. No significant difference was found (p. 80-81).

From this research, it is apparent that some districts are doing more than others when implementing energy conservation measures. Low cost/no cost measures are being implemented to a greater extent in some districts. The same pattern has
also been shown for implementation of cost effective measures. All other factors being equal, it is only logical to assume a district which has implemented many energy conservation measures has reduced energy waste more than a district which has done little toward reducing energy waste. Significant differences in implementation of these measures in the Hicks study (1978) is an indication that differences between districts do exist in their individual energy management programs. It is not unfair to conclude that some schools have developed better energy management programs than others and have reduced energy waste to a greater degree in their districts.

One important question which needs to be answered is this: "Are there factors which can be positively correlated with the successful energy management programs?" Kruza (1979) has already indicated that "common elements" in successful programs do exist. These appear to be more related to structure and organization of the program. In addition, physical and behavioral characteristics may exist which are correlated with successful energy management programs. School districts designated as "good" and "poor" on an energy management spectrum should be investigated to see if differences in these characteristics exist. If found, knowledge of these factors could be disseminated to school districts across the nation as an aid in further reducing energy waste through the establishment of better energy management programs.
CHAPTER III. METHODS AND PROCEDURES

This chapter includes a discussion of the methods and procedures that were used to obtain and analyze the data in this study. The study was conducted at Iowa State University in cooperation with the Iowa Energy Policy Council. Fuel consumption and school occupancy data (over a one-year period) were submitted for nine hundred eighty school buildings within the state of Iowa in applying for federal energy conservation grants. These data were used to determine relative energy efficiency for each of the buildings. A visitation was made to thirty-six school buildings selected for the study.

The purpose of the study was to investigate the differences in energy efficiency of public elementary and secondary schools in Iowa and to determine factors which are correlated with energy efficiency of school buildings.

This chapter describes the following activities:

1. Questions of the study
2. Variables to be examined
3. Selection of schools in the study
4. Criteria for matching buildings
5. Survey instrument development
6. Field and pilot tests
7. Administration and collection procedures
8. Data analysis
Questions of the Study

1. Is it possible to classify school buildings in terms of their energy efficiency based on a standard unit of measurement [such as the Building Energy Management Index (BEMI) or the Energy Utilization Index (EUI)]?

2. Is there a difference in energy efficiency of school buildings based on district student enrollment?

3. Do school buildings matched on date of construction, number of stories, rural or urban environment, cooling facilities, and elementary or secondary function differ in energy efficiency?

4. Are there variables which correlate (positively or negatively) with energy efficiency of school buildings?

Variables to be Examined

The following variables were examined in this study:

1. An examination of the response of superintendents to energy management, conservation, and cost reduction statements which were reported as being effective methods in the review of the literature.

2. An examination of the response of principals to energy management, conservation, and cost reduction statements which
were reported as being effective methods in the review of the literature.

3. An examination of differences between school district adoption practices and energy conservation guideline elements as reported in an earlier dissertation completed by Hicks (1978).

4. An examination of the frequency of preventive maintenance procedures for the energy systems of the school buildings.

5. An examination of the degree to which energy efficient maintenance practices have been implemented for the energy systems of the school building.

6. An examination of the patterns of energy use by the occupants of the school building.

7. An examination of the physical characteristics of the building (such as overall U factor, age, and estimated infiltration of air) in relation to energy efficiency.

Selection of Schools in the Study

The original population of the schools selected was obtained through the cooperation of the Iowa Energy Policy Council. In applying for federal energy conservation grants made available by the National Energy Conservation Act, schools submitted a "preliminary energy audit" (PEA) for each of the buildings to be considered for the matching funds (50/50) made available by the 1979 legislation. The PEA contained fuel consumption and occupancy data for the building on a month by
month basis for a period of one year. The majority of the PEAs for school buildings in the study contained data from the 1978-79 or 1979-80 school year.

Efficiency ranking

The Building Energy Management Index (BEMI) developed at Iowa State University (Woods and Reynolds, 1980), was used to identify buildings for the distribution of energy grants in Iowa. The primary concern was to single out those school buildings which were most energy excessive. To do this, a regression analysis was performed using the Building Energy Characteristic (BEC—measured in BTU/day-ft²-°F) plotted against the Building Function Characteristic (BFC—measured in Man Hours/day-ft²-°F) for all buildings in a defined category. Twelve reference points for every building were used in the analysis. A "best fit" line was found for the combination of all plotted points and a 60 percent confidence interval was established for this line. The confidence interval and calculated regression line (BEMI) formed the basis for which buildings indicated in the study were separated into different "efficiency" classifications. Buildings within the 60 percent confidence interval were labeled as energy efficient.

To investigate each building using the BEMI method, a regression line was obtained from the twelve monthly points (BEC vs. BFC) calculated from data on the Preliminary Energy Audit. If two or more monthly points for a particular building
fell outside the upper boundary established by the BEMI confidence interval, the building was labeled "energy excessive."

An R square value was calculated for each set of points as an indication of linearity.

For this study, the computer statistical program originally used to determine buildings with excessive energy usage was modified to also identify "energy superior" buildings. To be labeled as energy superior, eleven or more points found by plotting BEC versus BFC for the building had to fall below the 60 percent confidence interval (i.e., the lower boundary established by the BEMI). Figure 3 on the following page shows an example of both an energy excessive and energy superior building based on an established BEMI and corresponding confidence interval.

Breakdown of school size

In this study, data from preliminary energy audits of public elementary and/or secondary school buildings were used to establish the building energy management index (BEMI). A 60 percent confidence interval was used. Nine hundred-eighty buildings were identified and included in the analysis. The population was then divided into three (3) arbitrarily chosen size categories as follows:

<table>
<thead>
<tr>
<th>School District Size/Student Enrollment</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 0-999</td>
<td>Size 1</td>
</tr>
<tr>
<td>2. 1000-2999</td>
<td>Size 2</td>
</tr>
<tr>
<td>3. 3000 and over</td>
<td>Size 3</td>
</tr>
</tbody>
</table>
Figure 3. Comparison of two similar buildings by the BEMI method. Building 112 is classified as energy excessive while Building 111 is classified as energy superior.
These subgroups contained approximately equal numbers of buildings (i.e. 277-352 buildings). Size one schools included some buildings with both elementary and secondary functions.

Using the computer analysis described above, "energy excessive" and "energy superior" buildings were identified. In addition to the R square value calculation for each building, the monthly building energy characteristic (BEC) was also listed on the computer printout. From this information, the average BEC and energy utilization index (EUI) were determined. The units for the EUI are equated to BTU/ft$^2$-yr.

Criteria for Matching Buildings

Energy superior buildings within each size category having a high linear correlation of monthly points (indicated by a large R square) were matched with energy excessive buildings with equally large R squares. In addition, pairs of buildings were matched on the following criteria:

1. Date of construction (within five years)
2. Number of stories (floors)
3. Function--elementary or secondary
4. Cooled or uncooled facilities (air conditioning)
5. Environmental setting--urban or rural

An effort was also made to match buildings with similar gross square feet of floor space--even though the BEMI is calculated on a per square foot basis. The consideration was made
since the ratio of exposed surface area to gross square feet decreases with increasing physical size of the building. However, the first five criteria were given a higher priority in matching structures.

No consideration was made for location of the building within the state since the BEMI is calculated on a per degree basis using the average monthly temperatures for the particular area and year in question. To avoid negative numbers, an arbitrary number of forty was added to the average monthly temperature in each case (i.e. $T_{\text{average}} + 40$).

**Initial contact with school administrators**

The superintendents for each matched pair of school buildings were contacted by telephone and asked to participate in the study. Only one superintendent declined the invitation to participate in the study. Another matched pair was selected and asked to participate. Six energy superior buildings and the six matched energy excessive buildings were obtained for each of the three size categories. The total number of buildings participating in the study was thirty-six ($N = 36$).

Prior to the collection of data, participants were not told whether their building was energy excessive or energy superior. In a follow-up letter to district superintendents, the following points (discussed earlier by telephone) were reiterated:
1. The date and approximate time for visiting the school building was confirmed.

2. The superintendent was asked to distribute the surveys to the principal and head custodian (maintenance director).

3. The type of measurements to be taken to determine the overall U factor of the building were stated. Blueprints or building specifications were suggested as helpful instruments in collecting information about the building in question.

4. The intent of collecting the completed surveys on the day of the scheduled building visitation was emphasized.

A copy of the letter which was sent to the district superintendent is shown in Appendix J.

**Energy excessive and energy superior buildings within the same school district**

After the initial computer analysis, some districts were identified as having more than one building which was energy excessive and/or energy superior. These special cases were not overlooked. Each situation (building) was handled on an individual basis during the matching process. However, in no instance was it possible to match two permanent structures within the same district—although in one district, two mobile units were matched.


Special situations

It is important to note the following exceptions in data collection when special situations were encountered in the study.

1. In the larger districts where more than one building was selected to be included in the study, only one survey form was completed by the superintendent. Thus, the total number of superintendent surveys is less than thirty-six (N = 28). Those questions pertaining specifically to a particular building on the superintendent's form (survey) were noted and the superintendent answered separately for each district building included in the study.

2. In some of the smaller school districts, the building selected for this study served both as a secondary and elementary unit. These buildings were matched with buildings functioning under similar conditions. If more than one principal worked in the building in question, each was asked to complete a survey. An average of the principals' individual responses was calculated and used as input data.

3. In several smaller districts, the superintendent also served as the elementary principal. If the sample building was an elementary unit, only one administrator survey was collected. The data were entered as both the superintendent and principal responses.
Instrument Development

The survey instrument for administrators was developed after a thorough review of the literature. A large amount of information has been published and suggested as important in establishing a successful energy management program within schools. Twenty statements dealing with successful energy management, conservation, and cost reduction methods were formulated and field tested. In addition, five response levels denoting increasing involvement by the district were generated for each energy related statement. In writing the response levels, emphasis was placed on providing five realistic levels of possible achievement from which the administrator could choose. The first level in each case was stated as "no action taken." This level implied that no action would be taken on the part of the administrator to achieve the energy related statement delineated. Administrators were asked to rate the energy related statement on a scale of one to five (one = lowest, five = highest). In addition, they were asked to choose the response level they felt could be most realistically achieved by their district. The Administrative Survey, completed by both principals and superintendents, is included in Appendix K.

Field test for administrator survey

Fourteen public school administrators critiqued the initial administrator survey form. On two separate scales from
one to five (one = lowest, five = highest), the administrators rated each energy related statement and provided a group of responses in terms of their appropriateness to "discriminate between administrator attitudes about energy cost reduction in public elementary and secondary schools." On a third scale of the same type, clarity of the entire item was rated. Space for open ended responses was provided and comments were strongly encouraged.

Average scores for each of the three scales were calculated along with the standard deviations for each scale. Items which averaged a score less than four or had a standard deviation greater than 0.8 were analyzed for improvement. Written comments were taken into consideration in making changes.

In addition to those items field tested, the final administrator survey form contained energy conservation "guideline elements" found to be significant in an earlier study conducted by Hicks (1978). For this study, these elements were divided into "procedural elements" and "activity elements" before adding them to the survey. Administrators checked (✓) the elements YES or NO, indicating whether the practice had been implemented in that particular school district.

Maintenance survey and field test

Specific energy systems within a school building which require maintenance and a possible range of the frequency with which they are maintained were delineated after a thorough
review of the literature and consultation with experts in the field. These preventive maintenance patterns which enhance energy conservation were then field tested by fourteen head custodians (or maintenance directors) who had completed a Class B Auditors Workshop (sponsored by the Iowa Energy Policy Council). Respondents indicated the frequency of maintenance for the areas listed on the survey form. Typical time periods for the frequency of maintenance were listed for the respondents to facilitate ease of response. Maintenance personnel answering the form could either check (√) the appropriate frequency of maintenance or write in the proper response in a space provided on the form. These same individuals were asked to list any other areas of maintenance dealing with energy systems they felt had been excluded on the form. The ranges in frequency of maintenance gathered from this field test were used to provide appropriate responses on the final maintenance survey form. Since a number of the energy systems included in the final survey form might not exist in all buildings, a "not applicable" (NA) response was added to each item listed in the survey.

The final maintenance survey form also included statements pertaining to patterns of use and energy systems delineated in a national research project known as the Schoolhouse Energy Efficiency Demonstration ("Something Special . . .," 1980). In the present study, maintenance personnel were asked to rate the
degree to which each of the specific measures had been implemented in their building. A scale from one to five was provided (one = lowest, five = highest). A "not applicable" (NA) response was included for all statements since some procedures may not have been pertinent in every case. It should be mentioned that terms used in this section of the survey form may have been perceived differently by the respondents. This fact should be considered when examining the findings in relation to this section. The complete maintenance survey form is shown in Appendix L.

Pilot test

Both the administrator survey and maintenance survey were pilot tested in the Ames School District. Three elementary schools and one secondary school were arbitrarily chosen for this purpose. After completing the appropriate survey forms, the respondents (both administrators and maintenance personnel) were asked to critique their survey items in terms of clarity and appropriateness of items. After summative interviews with the respondents, final revisions were made to the surveys. Both surveys were then printed in a reduced size form to appear less bulky and more professional in nature.

Administration and Collection Procedures

Survey instruments were mailed to the superintendents of schools in the study approximately one week in advance of the
scheduled visit to the selected building. Upon arrival at the school, the researcher recorded the following building measurements and construction materials necessary to calculate the overall U factor of the structure:

1. Area of fenestration and type of materials used for all openings (e.g. steel frame windows, single pane glass, two-inch wood doors, percentage of glass in entrances, etc.).

2. Area of the roof, floor, and exterior walls.

3. Construction materials used in the building envelope (e.g. wall structure, roof structure, insulation thickness and type, etc.).

When available, the necessary measurements were taken from blueprints or building specifications of the building. In addition, construction materials used in the building envelope were obtained from these same sources. If changes in the building structure had been completed prior to the time the preliminary audit was submitted, an accurate record was made of the exact changes from the existing (original) blueprint.

If no blueprint for the building was available, a visual inspection was necessary to obtain the construction materials used in the building envelope. Interviews with the custodians (maintenance directors) proved very helpful in these cases. Changes which had occurred since the submission of the PEA were noted. Required measurements were obtained by using a rolling measurement device—commonly used by surveyors. This instru-
ment was found to be extremely fast and reliable.

In most cases, the completed survey forms were collected at the time of the visit to the building. However, several situations were encountered where the forms had not been completed as scheduled. In these instances, the forms were returned by mail. One hundred (100) percent of the maintenance and administrator survey forms were completed and returned.

Data Analysis Procedures

The following tests were completed in this study:

1. A "Student t-test" for two matched samples (Stoodley, Lewis, and Stainton, 1980, p. 30) was used to determine if the energy superior buildings were significantly different from the energy excessive buildings in
   a. average building energy characteristic—found by averaging monthly BECs for each of the sample buildings
   b. energy utilization index

(These tests were completed for all three size categories.)

The critical point at which the null hypothesis was accepted or rejected is given by the equation:

\[ t_{\text{critical}} = t(n - 1; \alpha/2) \]

2. An analysis of variance (ANOVA) was conducted to determine if there was a significant difference in energy usage
a. between size categories within each building classification
b. between the energy excessive and energy superior buildings
c. due to interaction between size and energy classification (a and b above).

In order to conduct the analysis, a type I "mixed" design was employed (Lindquist, 1953). A pictorial arrangement of the data for this type design is shown in Figure 4. The total sum of squares from Figure 4 may be summarized with the following equation:

\[
\text{ss}_t = \frac{\text{"between" components}}{\text{ss}_B + \text{ss}_{\text{error(b)}}} + \frac{\text{"within" components}}{\text{ss}_A + \text{ss}_{AB} + \text{ss}_{\text{error(w)}}}
\]

The tests for significance in this design were:

1. Test for "B effect," \( F = \frac{\text{ms}_B}{\text{ms}_{\text{error(b)}}} \)
   
   (An F statistic with 2 and 15 degrees of freedom was obtained at the .05 level of significance.)

2. Test of "A effect," \( F = \frac{\text{ms}_A}{\text{ms}_{\text{error(w)}}} \)
   
   (An F statistic with 1 and 15 degrees of freedom was obtained at the .05 level of significance.)
Figure 4. Mixed design and resulting statistical analysis.
(3) Test for the AB interaction, $F = \frac{ms_{AB}}{ms_{\text{error}(w)}}$

(An F statistic with 2 and 15 degrees of freedom was obtained at the .05 level of significance.)

3. A product-moment inter-item correlation matrix (Stoodley, Lewis, and Stainton, 1980, p. 143) was completed between all subvariables to be summed in forming an independent variable used in the analysis of data. This process was completed to insure negatively correlated items were not inadvertently added to the regression analysis. Under the statistical hypothesis $H_0$: $\rho = 0$ and $H_a$: $\rho \neq 0$, the test statistic is $r \sqrt{\frac{n-2}{1-r^2}}$ and has a Students' $t$-distribution with $(n-2)$ degrees of freedom.

4. A product-moment correlation matrix between all the dependent and independent variables was constructed to determine those combinations where a relationship possibly existed.

5. A multiple linear regression analysis (Stoodley, Lewis, and Stainton, 1980, p. 46) was conducted separately for both dependent variables (Energy Utilization Index and Building Energy Characteristic).
The model for this form of linear regression is given by:

\[ Y_i = \alpha + B_1X_{i1} + \ldots + B_kX_{ik} + \varepsilon_j \]

where,

- \( Y_i \) = the dependent variable
- \( X_{i1}, X_{i2}, \ldots, X_{ik} \) = the k independent variables
- \( \varepsilon_j \) = random experimental error
- \( \alpha \) = the y-intercept

The total variation of \( Y \) (sum of squares total) can be explained by the sum of squares due to regression (SSR) plus the sum of squares due to error (SSE).

The F test for the regression analysis is given by the equation:

\[ F_T = \frac{MSR}{MSE} \]

where,

- \( F_T \) = F test value for the analysis
- \( MSR \) = mean sum of squares due to regression
- \( MSE \) = mean sum of squares due to error

For the standardized partial regression coefficients, the F statistic with \( l \) and \( (n - k - 1) \) degrees of freedom was used at the .05 confidence level of significance. The symbol \( k \) stands for the number of independent variables used in the specific regression.
analysis. The symbol \( n \) is equal to the number of observations involved in the analysis.

To test \( H_0: B_i = 0 \) (where \( i \) represents the \( i \)th standardized partial regression coefficient), the following t-test was used (Steel and Torrie, 1980, p. 321):

\[
t_T = \frac{B_i}{S_{B_i}}
\]

where,

- \( t_T \) = t-test value
- \( B_i \) = \( i \)th standardized partial regression coefficient
- \( S_{B_i} \) = standard deviation of the \( i \)th standardized partial regression coefficient.

(Note: the t-test value was squared to obtain the F statistic mentioned above.)

Research Hypothesis I and II

It was hypothesized that the mean building energy characteristic (BEC) of school buildings designated as energy excessive does not differ from the mean BEC of buildings designated as energy superior beyond that suspected due to random sampling error.

It was hypothesized that the mean energy utilization index (EUI) of school buildings designated as energy excessive does
not differ from the mean EUI of buildings designated as energy superior beyond that suspected due to random sampling error.

The above hypotheses were made for energy superior and energy excessive school buildings grouped in three size categories. Superior and excessive buildings were matched on the basis of five factors commonly accepted as being related to energy use. The statistic of choice to test each hypothesis of equal means is therefore the matched-sample t test (Stoodley, Lewis and Stainton, 1980).

Statistical hypothesis

\[ H_0 : U_1 - U_2 = 0 \]
\[ H_a : U_1 - U_2 \neq 0 \quad \alpha = .05 \]

Research Hypothesis III and IV

It was hypothesized that classification of buildings by (A) energy superior versus energy excessive, (B) size of district, and (C) the combination of efficiency and size will not affect the mean building energy characteristic (BEC) value.

It was hypothesized that classification of buildings by (A) energy superior versus energy excessive, (B) size of district, and (C) the combination of efficiency and size will not affect the mean building energy utilization index (EUI) value.
The design selected for hypotheses III and IV was a "mixed" design in which the (A) effect is considered a repeated measure through matching of buildings in the energy superior and energy excessive groups, and where the three district sizes are considered between "subjects" effects. Three F ratios were obtained to test the null hypotheses below.

Statistical hypotheses

1. Repeated measures
   \[ H_0 : U_{A1} = U_{A2} \]
   \[ H_a : U_{A1} \neq U_{A2} \]

2. between unit measures
   \[ H_0 : U_{B1} = U_{B2} = U_{B3} \]
   \[ H_a : U_{B1} \neq U_{B2} \neq U_{B3} \]

3. Interaction measures
   \[ H_0 : (U_{A1B1} - U_{A2B1}) = (U_{A1B2} - U_{A2B2}) = (U_{A1B3} - U_{A2B3}) \]
   \[ H_a : \text{Not } H_0 \]
   \[ \alpha = .05 \text{ for all tests.} \]

Research Hypothesis V

It was hypothesized that the standardized partial regression coefficient between standardized energy usage of a school building and the independent variables listed below does not differ significantly from zero beyond that expected by chance alone. Standardized energy use was measured by the EUI and the average of the monthly BEC. Both standardized units were used separately as the dependent variable.
Independent variables:

1. Average weighted response to energy management, conservation, and cost reduction statements made by the superintendent—coded SÚTPRESP

2. Average weighted response to energy management, conservation, and cost reduction statements made by the principal—coded PRINRESP

3. Adoption practices of energy conservation guideline elements as reported by the superintendent (these guideline elements were reported in an earlier study conducted by Hicks (1978))—coded ACTELEM and PROELEM

4. Frequency of maintenance procedures for the building as reported by the head custodian (or maintenance director)—coded MAINTPRO

5. Degree to which energy conservation practices have been implemented for the building's envelope and energy systems as rated by the head custodian (or maintenance director)—coded MSYSTEMS

6. Patterns of energy use by occupants of the building as rated by the head custodian (or maintenance director)—coded USEPATRN

7. Physical characteristics of the building:
   (1) Age—coded AGE
   (2) Reciprocal of the overall U factor—coded RVALUE
(3) Estimation of the overall air infiltration for the building as reported by the head custodian (or maintenance director) -- coded INFILEST

(Note: Size of the district was also entered into the regression analysis using a "dummy variable.")

Statistical hypothesis

\[ H_0 : B_i = 0 \]
\[ H_a : B_i \neq 0 \quad \alpha = .05 \]

The statement of the null and alternative hypothesis was repeated for each independent variable listed.

Organization of the Raw Data for Statistical Analysis

The final administrator survey form was sub-divided into three basic sections for analysis purposes. The first section (eleven questions) gathered information about the administrator and the specific school district in the sample. The responses for each specific item were tabulated and reported in Chapter IV using descriptive statistics.

The second section of the survey was comprised of twenty energy related statements and accompanying response levels described under Instrument Development. Response levels were given numerical weights from one to five in increasing order for letters a-e, respectively. The administrator made two
choices for each of the twenty items. The weight factor (determined by the response level chosen) was multiplied by the one to five rating given to each of the corresponding energy related statements. Therefore, the maximum score one item could receive was twenty-five (5 x 5) while the minimum score was one (1 x 1). The average score for the twenty items was calculated for each of the administrators completing the survey form. This value was used as an independent variable and appropriately recorded as "superintendent response" or "principal response.

The third section of the administrator form included energy conservation guideline elements found significant in an earlier study conducted by Hicks (1978). In the present research, these guideline elements were organized into eleven procedural elements and twelve activity elements. Only responses by the superintendents were used in the analysis of data. The superintendent simply checked YES or NO if the specific guideline had been implemented in the school district. The number of "yes" responses was summed for each sub-group and entered in the regression analysis as the independent variables "activity elements" and "procedural elements."

The final maintenance survey form was divided into five sections for analysis purposes. The first section was comprised of twelve questions relating to the frequency of maintenance for the energy systems of the school building. In each item, choices for selection by the respondent were written
in decreasing order of maintenance frequency. A value from four to one was assigned to first through fourth choices, respectively. The last choice was the "not applicable" response and was not assigned a numerical value. The average score for all items in the section was taken—excluding those items checked as "not applicable." This value was entered in the regression analysis as the independent variable, "maintenance procedures."

In the second and third sections of the maintenance survey form, a rating scale from one to five was utilized. The respondent chose a number on the scale indicating the level to which a particular item had been implemented in the school building. A "not applicable" (NA) response was included for those situations which did not apply. A rating of five represented the level of highest implementation while a rating of one represented the lowest level of implementation.

In the second section, patterns of energy use by occupants of the building were scrutinized. This section contained six questions. The independent variable was found by averaging the values chosen by the respondent on the rating scale. "Not applicable" responses were excluded from the averaging process.

Although the same rating scale was used in both Sections two and three of the maintenance survey form, the latter section was organized into four areas denoted in the survey as "Structural Systems," "Mechanical Systems," "Special Systems,"
and "Lighting Systems." Initially, the average value for each subsection was obtained as in Section two. However, the mean of those four values was then calculated as an independent variable and entered into the regression analysis model (the variable was coded MSYSTEMS).

It should be noted that "weights" were not determined for each of the individual questions within the subgroups comprising the variable MSYSTEMS. Each energy conservation measure rated by the respondent was considered equal in terms of impact on energy consumption. This approach presents restraints on the overall implications when considering the findings pertaining to this variable. However, studies dealing with the individual questions in this section of the survey have broad interpretations with respect to their relative importance to energy conservation. Due to a lack of convincing research data pertaining to weight factors appropriate to this population of buildings, this investigator did not believe an estimation of relative weights could be justified.

The fourth section of the maintenance survey form (with exception of the independent variable discussed below) is reported in the fourth chapter using descriptive statistics. Respondents checked (✓) the type of heating-ventilating-air conditioning (HVAC) systems and heating systems used in the building. In addition, the capacity of the heating systems was also listed. In several cases, however, the capacity of the heating system was unknown.
The final independent variable obtained from the maintenance survey form was an estimate of the amount of air infiltration for the building. On a scale of one to nine (one = poorest, nine = best), the head custodian rated how tightly constructed the building was in comparison to a "well constructed" building of the same age and type. The rating value chosen by the respondent was the score used for the building in the regression analysis. The independent variable in this case was coded INFILEST. (It should be noted that a definition of air infiltration was not provided for the respondent. Lack of a specific definition may have resulted in perception differences between respondents in relation to the term "air infiltration.")

Other independent variables

Another independent variable used in the regression analysis was age of the building. This value was obtained from the preliminary energy audit (PEA) submitted to the Iowa Energy Policy Council by the school district. (This is the same PEA from which the original fuel and occupancy data had been taken to determine the building standardized energy usage.) The specific age of the building (in years) was the value entered as data for the regression analysis.

The reciprocal of the U factor (coded RVALUE) was another independent variable used in the regression analysis model. The type of construction materials used in the building
envelope were obtained from blueprints, building specifications, or by an on-site visual inspection. Measurements were taken to calculate the specific "areas" corresponding to the major components of the building envelope such as windows, doors, walls and roof. Next, the "R values" for each of the components were determined by summing the individual R values of the construction materials making up the components ("American Society . . ., 1977). (The component "R values" were then converted into "U factors" -- $R_i = 1/U_i$ -- where i represents the ith major component of the building envelope.) Finally, the "overall U factor" ($U_o$) was found by using the following equation (Manual of Procedures . . ., 1979):

$$U_o = \frac{U_{\text{wall}} A_{\text{wall}} + U_{\text{windows}} A_{\text{windows}} + U_{\text{doors}} A_{\text{doors}} \cdots + U_{\text{roof}} A_{\text{roof}}}{A_{\text{total}}}$$

where,

$U_o$ = the overall U factor of the building

$U_{\text{wall}}$, $U_{\text{window}}$, $U_{\text{door}}$, \ldots = individual U factors of the basic components making up the building envelope

$A_{\text{wall}}$, $A_{\text{window}}$, $A_{\text{door}}$, \ldots = the corresponding areas for basic components under consideration.

The reciprocal of the overall U factor ($1/U_o$) was calculated and used as the independent variable. These values were determined for all thirty-six buildings in the sample.

**Summary statement**

These were essentially the methods and procedures employed in conducting this study.
CHAPTER IV. FINDINGS

The results of the analysis of data are presented in this chapter. The initial purpose for this study was to investigate energy efficiency of public elementary and secondary school buildings in Iowa and to determine factors which are correlated with energy efficient buildings. School buildings were classified by size and matched on factors commonly accepted as being related to energy efficiency. Surveys were completed by the superintendents, principals and head custodians (or maintenance directors) of the selected school buildings. One hundred percent of the surveys submitted to the school districts were completed and returned. Table 1 illustrates the number of surveys completed by each group in the study in comparison to the total number of members in each group for the state of Iowa.

Table 1. The number of survey forms completed and used in the study

<table>
<thead>
<tr>
<th>Respondent</th>
<th>Number</th>
<th>Population^a</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Superintendents</td>
<td>28</td>
<td>439</td>
<td>6.4</td>
</tr>
<tr>
<td>2. Principals</td>
<td>32</td>
<td>1265</td>
<td>2.5</td>
</tr>
<tr>
<td>3. Head custodians (or maintenance directors)</td>
<td>34</td>
<td>441</td>
<td>7.7</td>
</tr>
</tbody>
</table>

^aDepartment of Public Instruction statistics for the State of Iowa, D.P.I., Des Moines, personal communication, 1982.
The format for presenting the findings of the study in this chapter is as follows:

1. Utilization of descriptive statistics and tables to illustrate the responses and findings relating to the school administrators' background and educational experience are included in Tables 2a, 2b, 2c, and 3.

2. Utilization of descriptive statistics and tables to illustrate the responses and findings relating to procedures which may enhance energy conservation within a school building or school district are included in Tables 4 through 11.

3. Utilization of descriptive statistics and tables to illustrate the (a) type of heating system, and (b) heating-ventilating-air conditioning (HVAC) system used in the buildings within the sample. Capacity of the heating systems, in relation to the exposed exterior surface area of the buildings is also revealed. The above information is included in Tables 12a, 12b, and 12c.

4. Utilization of parametric statistics (as expressed in Chapter III) to examine the research hypotheses I through IV and the presentation of the findings supporting the rejection or acceptance of the null hypotheses based on predetermined levels of significance are included in this discussion. A .05 level of significance was employed throughout the study.

5. Utilization of a multiple linear regression model to examine research hypothesis V and presentation of the findings as partial regression coefficients for independent variables
found to be significantly correlated to the dependent variables (Energy Utilization Index and Building Energy Characteristic) are included in the findings chapter.

Descriptive Statistics Obtained from the Survey Instruments

The administrator survey: Section I

The first section of the administrator survey form was comprised of eleven questions. Several questions in this section were designed to elicit information relating to the school administrators' educational experience and background. Table 2a illustrates administrative work experience (in terms of years at the particular school selected in the sample) for both the principals and superintendents in the two types of building classification (i.e. energy excessive and energy superior schools). It should be noted that the superintendent of the district chosen in the sample was assigned to the energy superior building group if one building within the school district was identified as energy superior (even though other buildings within the district were classified as energy excessive). Two districts involved in the study had buildings assigned to both classification types. As shown in Table 1, twenty-eight school districts (superintendents) were involved in the study.

Table 2a shows the number of years of work experience in the "administrative career" for the same group of administrators
Table 2a. Administrative work experience at present school

<table>
<thead>
<tr>
<th>Years experience</th>
<th>Principal</th>
<th>Superintendent&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Relative frequency (%)</td>
</tr>
<tr>
<td>Energy superior buildings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No response</td>
<td>1</td>
<td>5.9</td>
</tr>
<tr>
<td>0 - 5 years</td>
<td>5</td>
<td>29.4</td>
</tr>
<tr>
<td>6 - 12 years</td>
<td>7</td>
<td>41.2</td>
</tr>
<tr>
<td>13 - 19 years</td>
<td>4</td>
<td>23.5</td>
</tr>
<tr>
<td>20 years and over</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>100</td>
</tr>
</tbody>
</table>

Energy excessive buildings

<table>
<thead>
<tr>
<th></th>
<th>Principal</th>
<th>Superintendent&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Relative frequency (%)</td>
</tr>
<tr>
<td>No response</td>
<td>1</td>
<td>6.7</td>
</tr>
<tr>
<td>0 - 5 years</td>
<td>5</td>
<td>33.3</td>
</tr>
<tr>
<td>6 - 12 years</td>
<td>3</td>
<td>20.0</td>
</tr>
<tr>
<td>13 - 19 years</td>
<td>5</td>
<td>33.3</td>
</tr>
<tr>
<td>20 years and over</td>
<td>1</td>
<td>6.7</td>
</tr>
<tr>
<td>Total</td>
<td>15</td>
<td>100</td>
</tr>
</tbody>
</table>

<sup>a</sup>Superintendent was assigned to the energy superior group if one building within the school district was classified as an energy superior building.
Table 2b. Total administrative work experience (career)

<table>
<thead>
<tr>
<th>Years experience</th>
<th>Principal</th>
<th></th>
<th>Superintendent</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Relative frequency (%)</td>
<td>Number</td>
<td>Relative frequency (%)</td>
</tr>
<tr>
<td>Energy superior buildings</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No response</td>
<td>1</td>
<td>5.9</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0 - 5 years</td>
<td>2</td>
<td>11.8</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6 - 12 years</td>
<td>8</td>
<td>47.1</td>
<td>3</td>
<td>21.4</td>
</tr>
<tr>
<td>13 - 19 years</td>
<td>2</td>
<td>11.8</td>
<td>1</td>
<td>7.2</td>
</tr>
<tr>
<td>20 years and over</td>
<td>4</td>
<td>23.5</td>
<td>10</td>
<td>71.4</td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>100</td>
<td>14</td>
<td>100</td>
</tr>
</tbody>
</table>

Energy excessive buildings

<table>
<thead>
<tr>
<th>Years experience</th>
<th>Principal</th>
<th></th>
<th>Superintendent</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Relative frequency (%)</td>
<td>Number</td>
<td>Relative frequency (%)</td>
</tr>
<tr>
<td>No response</td>
<td>3</td>
<td>20.0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0 - 5 years</td>
<td>1</td>
<td>6.7</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6 - 12 years</td>
<td>3</td>
<td>20.0</td>
<td>2</td>
<td>14.3</td>
</tr>
<tr>
<td>13 - 19 years</td>
<td>4</td>
<td>26.7</td>
<td>4</td>
<td>28.6</td>
</tr>
<tr>
<td>20 years and over</td>
<td>4</td>
<td>26.7</td>
<td>8</td>
<td>57.1</td>
</tr>
<tr>
<td>Total</td>
<td>15</td>
<td>100</td>
<td>14</td>
<td>100</td>
</tr>
</tbody>
</table>
with respect to each building classification. It should be noted that the number of principals responding to this question is less than the number of buildings in the sample. This is due to two extenuating circumstances: (1) principals having supervision responsibilities for the two mobile buildings in the sample were not required to complete a survey form since most of the questions did not pertain to those types of structures and (2) in some cases (three "size one" districts), the superintendent also served as the elementary principal of the building selected. In the latter situation, the information gathered was entered only as superintendent response data.

Table 2c illustrates the average number of years of administrative work experience for both groups of administrators in the two designated building types. No significant difference was found in either the variance or group means at the .05 level between the two types of building classification. However, a significant difference at the .05 level was found between administrators within the energy superior building classification. The mean number of years in the administrative career of the superintendents' group (22.16) was significantly different from the mean number of years in the administrative career of the principals' group (13.38) for the energy superior building classification. The Fisher F distribution was used to analyze difference in variance while the "student" t distribution with \( (n_1 + n_2 - 2) \) degrees of freedom was used to
Table 2c. Average number of years of administrative work experience in the present school and administrative career

<table>
<thead>
<tr>
<th>Item</th>
<th>Superintendent</th>
<th>Principal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>S.D.</td>
<td>Mean</td>
</tr>
<tr>
<td>Energy superior buildings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Average administrative experience in this school (years)</td>
<td>12.47</td>
<td>6.12</td>
</tr>
<tr>
<td>2. Average experience in administrative career (years)</td>
<td>22.16*</td>
<td>7.18</td>
</tr>
<tr>
<td>Energy excessive buildings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Average administrative experience in this school (years)</td>
<td>12.00</td>
<td>9.08</td>
</tr>
<tr>
<td>2. Average experience in administrative career (years)</td>
<td>21.27</td>
<td>10.09</td>
</tr>
</tbody>
</table>

*p < .01.

investigate differences in corresponding group means. These two statistical methods were used for all situations in the analysis of descriptive statistics where group means and sample variances were involved.

Table 3 illustrates the number and relative frequency of the various undergraduate degrees earned by administrators in the sample. The most frequent undergraduate degree stated for
Table 3. Undergraduate degree earned by administrators

<table>
<thead>
<tr>
<th>Discipline</th>
<th>Superintendent</th>
<th>Principal</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Relative frequency (%)</td>
<td>Number</td>
<td>Relative frequency (%)</td>
</tr>
<tr>
<td>Energy superior buildings</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Art Educ</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2. Bus/Bus Adm/ Admin</td>
<td>2</td>
<td>14.3</td>
<td>3</td>
<td>20.0</td>
</tr>
<tr>
<td>3. Economics</td>
<td>1</td>
<td>7.1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4. Elem Educ</td>
<td>1</td>
<td>7.1</td>
<td>3</td>
<td>20.0</td>
</tr>
<tr>
<td>5. English</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>6.7</td>
</tr>
<tr>
<td>6. Hist/Pol Sci/ Social Sci</td>
<td>4</td>
<td>28.6</td>
<td>3</td>
<td>20.0</td>
</tr>
<tr>
<td>7. Industrial Arts</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8. Music Educ</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9. Phys Educ</td>
<td>2</td>
<td>14.3</td>
<td>1</td>
<td>6.7</td>
</tr>
<tr>
<td>10. Science/Math</td>
<td>3</td>
<td>21.4</td>
<td>3</td>
<td>20.0</td>
</tr>
<tr>
<td>11. Vo Ag</td>
<td>1</td>
<td>7.1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>12. No response</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>6.7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>14</strong></td>
<td><strong>100</strong></td>
<td><strong>15</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

Energy excessive buildings

<table>
<thead>
<tr>
<th>Discipline</th>
<th>Superintendent</th>
<th>Principal</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Relative frequency (%)</td>
<td>Number</td>
<td>Relative frequency (%)</td>
</tr>
<tr>
<td>1. Art Educ</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>5.9</td>
</tr>
<tr>
<td>2. Bus/Bus Adm/ Admin</td>
<td>2</td>
<td>14.3</td>
<td>1</td>
<td>5.9</td>
</tr>
<tr>
<td>3. Economics</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4. Elem Educ</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>23.5</td>
</tr>
<tr>
<td>5. English</td>
<td>1</td>
<td>7.1</td>
<td>1</td>
<td>5.9</td>
</tr>
<tr>
<td>6. Hist/Pol Sci/ Social Sci</td>
<td>7</td>
<td>50.0</td>
<td>5</td>
<td>29.4</td>
</tr>
<tr>
<td>7. Industrial Arts</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>5.9</td>
</tr>
<tr>
<td>8. Music Educ</td>
<td>1</td>
<td>7.1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9. Phys Educ</td>
<td>2</td>
<td>14.3</td>
<td>3</td>
<td>17.6</td>
</tr>
<tr>
<td>10. Science/Math</td>
<td>1</td>
<td>7.1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>11. Vo Ag</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>12. No response</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>5.9</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>14</strong></td>
<td><strong>100</strong></td>
<td><strong>17</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>
both principals and superintendents was in the field of social sciences (History/Political Science/Social Science). Only seven of the sixty administrators in the sample indicated a technical (Science/Math) background. The disciplines studied by the administrators as undergraduates are listed on Table 3 in alphabetical order for ease of comparison.

Administrators were also asked to list any energy related courses or workshops they had completed. Of the sixty administrators in this research study, only nine indicated they had completed energy related workshops. No courses in energy related studies were listed by the administrators. Only one principal (from the energy superior building classification) indicated previous energy related training through a workshop. Four superintendents from each type of building classification indicated they had completed energy related workshops. All of the energy related educational training listed by administrators was conducted through workshops sponsored by various public utilities or governmental agencies.

Anticipated building modifications for both types of building classification are listed in Table 4. Administrators were asked to check (√) one of the following responses based on the anticipated building modifications (within the next five years) for the selected building:

(1) New construction (e.g. addition or wing)
(2) Remodeling or retrofit
Table 4. Anticipated building modifications for school buildings in the sample

<table>
<thead>
<tr>
<th>Item</th>
<th>Number</th>
<th>Relative frequency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energy superior buildings</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. New construction</td>
<td>2</td>
<td>11.1</td>
</tr>
<tr>
<td>2. Remodeling/retrofit</td>
<td>2</td>
<td>11.1</td>
</tr>
<tr>
<td>3. Demolition/closing</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4. No changes planned</td>
<td>14</td>
<td>77.8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>18</td>
<td>100</td>
</tr>
</tbody>
</table>

| **Energy Excessive Buildings**    |        |                        |
| 1. New construction               | 1      | 5.6                    |
| 2. Remodeling/retrofit            | 9      | 50.0                   |
| 3. Demolition/closing             | 1      | 5.6                    |
| 4. No changes planned             | 7      | 38.8                   |
| **Total**                         | 18     | 100                    |

(3) Demolition or closing of the school building

(4) No changes planned at this time.

Superintendents' responses were the only data used in displaying these results. (Principal responses were either identical or no response was made to the item.) The respondents for a majority (77.8 percent) of the buildings in the energy superior
building classification indicated that "no changes" were planned for these buildings compared to 38.8 percent of the buildings in the energy excessive building classification. However, superintendents of 50 percent of the buildings in the energy excessive group indicated plans for "retrofit" or remodeling" of the selected buildings. In comparison, only two of the eighteen buildings in the energy superior group were scheduled for "retrofit or remodeling" within the next five years.

Table 5 reveals the number of structures in each building classification which had undergone energy audits while Table 6 lists the year the energy audits were completed. For this sample, more buildings in the energy excessive classification had energy audits completed than in the energy superior building classification i.e. thirteen compared to nine. All the energy audits were completed within the past three years. Administrators of seventeen buildings in the sample reported having an energy audit completed. Of these energy audits, the majority (58.8 percent) were completed in the past year (1981).

Table 7 states the number of buildings in each classification in which the districts have an energy manager position designated. In all cases cited, the energy management responsibilities had been added to a previous (existing) job description. That is, no new part-time or full-time position had been
Table 5. Completion of an energy audit for school buildings in the sample

<table>
<thead>
<tr>
<th>Building classification</th>
<th>Number not completing audit</th>
<th>Number completing audit</th>
<th>Relative frequency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Energy superior buildings</td>
<td>9</td>
<td>9</td>
<td>50.0</td>
</tr>
<tr>
<td>2. Energy excessive buildings</td>
<td>5</td>
<td>13</td>
<td>72.2</td>
</tr>
</tbody>
</table>

Table 6. Year energy audit was completed in sample buildings

<table>
<thead>
<tr>
<th>Building classification</th>
<th>Number of audits completed</th>
<th>Number buildings not reporting</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1979 1980 1981</td>
<td></td>
</tr>
<tr>
<td>1. Energy superior buildings (7 buildings reporting)</td>
<td>1 2 4</td>
<td>11</td>
</tr>
<tr>
<td>2. Energy excessive buildings (8 buildings reporting)</td>
<td>1 3 6</td>
<td>8</td>
</tr>
</tbody>
</table>

Table 7. Energy manager position designated

<table>
<thead>
<tr>
<th>Building classification</th>
<th>Number having manager</th>
<th>No manager</th>
<th>Relative frequency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Energy superior buildings</td>
<td>10</td>
<td>8</td>
<td>55.5</td>
</tr>
<tr>
<td>2. Energy excessive buildings</td>
<td>10</td>
<td>8</td>
<td>55.5</td>
</tr>
</tbody>
</table>

*All energy management duties had been added to a previous job description (i.e. no new part-time or full-time positions are established.).*
created for the purposes of establishing an energy management position. An equal number of energy managers had been designated in both types of building classification \((N = 10)\). This number represents a majority for the buildings in each group (55.5 percent).

Table 8 illustrates the priority energy conservation was given by superintendents and principals in relation to other administrative duties. Administrators were asked to rank six areas in terms of the importance each had "in maintaining the present level of the educational program" in the building. These areas are listed below:

1. Curriculum
2. Energy conservation
3. Other administrative problems
4. Salaries
5. Staff development
6. Student discipline

Point values were assigned to the energy conservation response in terms of how it was ranked in relation to other areas by the administrators. Five through zero point values were given as an indication of the energy conservation priority for the first through sixth category in the rank order. The average score obtained for the energy conservation priority in the ranking process was found and the standard deviation was calculated. No significant difference was found within or between the
Table 8. Priority given to energy conservation by administrators with respect to other administrative duties

<table>
<thead>
<tr>
<th>Administrative position</th>
<th>Descriptive statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
</tr>
<tr>
<td><strong>Energy superior buildings</strong></td>
<td></td>
</tr>
<tr>
<td>1. Superintendents</td>
<td>14</td>
</tr>
<tr>
<td>2. Principals</td>
<td>17</td>
</tr>
<tr>
<td><strong>Energy excessive buildings</strong></td>
<td></td>
</tr>
<tr>
<td>1. Superintendents</td>
<td>14</td>
</tr>
<tr>
<td>2. Principals</td>
<td>15</td>
</tr>
</tbody>
</table>

corresponding group means or sample variances for the two types of building classifications (alpha = .05). The small average values obtained in both types of building classification indicated that energy conservation is not given a high priority by administrators in relation to other administrative duties deemed important in maintaining the present level of the educational program.

Administrators were also asked to state "the greatest opposition in working toward a solution of energy related problems" for the building selected in the sample. The following choices were listed:
(1) Subordinates
(2) Supervisors
(3) Bureaucratic "red tape"
(4) Lack of funds
(5) Other: ______

Space was provided for open ended responses. The number and relative frequency for each choice is shown in Tables 9a and 9b.

"Lack of funds" was indicated as the major opposition in working toward a solution of energy related problems by both groups of administrators in the sample. Five of the thirty-one administrators in energy superior buildings (16 percent) indicated they had no opposition to working toward a solution of energy related problems, (e.g. "no problems," "none," and "no opposition." None of the administrators of energy excessive buildings responded in this manner. Remarks elicited from administrators by the "other" response category are written immediately below the descriptive statistics for each building type.

Table 10 illustrates how the superintendents responded to a question asking whether funds had been "made available for upgrading the building envelope or energy systems." In addition to checking (✓) YES or NO responses in reference to the item, the administrator was given the opportunity to indicate the source of funds for those buildings which had received financial assistance. Four possible responses were listed:
Table 9a. Response given by administrators as the greatest opposition in working toward a solution of energy related problems of the selected energy superior building

<table>
<thead>
<tr>
<th>Item</th>
<th>Principal</th>
<th></th>
<th></th>
<th>Superintendent</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Relative frequency (%)</td>
<td>Number</td>
<td>Relative frequency (%)</td>
<td></td>
</tr>
<tr>
<td>1. Subordinates</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2. Supervisors</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3. Bureaucratic</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>7.1</td>
<td></td>
</tr>
<tr>
<td>&quot;red tape&quot;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Lack of funds</td>
<td>10</td>
<td>58.8</td>
<td>7</td>
<td>50.0</td>
<td></td>
</tr>
<tr>
<td>5. Other (specify)</td>
<td>7</td>
<td>41.2</td>
<td>6</td>
<td>42.9</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>100</td>
<td>14</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

**Superintendent remarks:**
A. "No problems," "none," and "We have not really had one."
B. "Directions on what can be done and paybacks involved."
C. "Failure to accept restrictions by students and staff as being necessary."
D. "Scheduling of weekend activities so heat must be kept up during the weekends."

**Principal remarks:**
A. "None" (2) and "No opposition."
B. "Expertise."
C. "Parents."
D. "Don't know," "Can't answer. Sorry."
E. "Subordinates and lack of funds."
Table 9b. Response given by administrators as the greatest opposition in working toward a solution of energy related problems of the selected energy excessive building

<table>
<thead>
<tr>
<th>Item</th>
<th>Principal</th>
<th></th>
<th>Superintendent</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Relative frequency (%)</td>
<td>Number</td>
<td>Relative frequency (%)</td>
</tr>
<tr>
<td>1. Subordinates</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2. Supervisors</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3. Bureaucratic &quot;red tape&quot;</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>7.1</td>
</tr>
<tr>
<td>4. Lack of funds</td>
<td>11</td>
<td>73.3</td>
<td>11</td>
<td>78.6</td>
</tr>
<tr>
<td>5. Other (specify)</td>
<td>4</td>
<td>26.7</td>
<td>2</td>
<td>14.3</td>
</tr>
<tr>
<td>Total</td>
<td>15</td>
<td>100</td>
<td>14</td>
<td>100</td>
</tr>
</tbody>
</table>

Superintendent remarks:
A. "Time to educate re: energy conservation."
B. "Apathy - people don't really believe there is an energy crisis."
C. "Funds and red tape."

Principal remarks:
A. "Red tape and funding."
B. "Not enough pressure from the principal. I need to do a better job!"
C. "Complexity of a large building."
D. "Bureaucratic red tape and lack of funds."
Table 10. Funds made available for upgrading the building envelope and/or energy systems

<table>
<thead>
<tr>
<th>Item</th>
<th>Number</th>
<th>Percentage^a (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energy superior buildings</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Buildings receiving funds</td>
<td>11</td>
<td>61.1</td>
</tr>
<tr>
<td>2. Buildings receiving funds from schoolhouse or site levy</td>
<td>4</td>
<td>22.2</td>
</tr>
<tr>
<td>3. Buildings receiving IEPC grant</td>
<td>2</td>
<td>11.1</td>
</tr>
<tr>
<td>4. Buildings receiving funds from the general budget</td>
<td>6</td>
<td>33.3</td>
</tr>
<tr>
<td>5. Major areas of applied funds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. insulation</td>
<td>6</td>
<td>54.5</td>
</tr>
<tr>
<td>b. lighting</td>
<td>5</td>
<td>45.4</td>
</tr>
<tr>
<td>c. windows/air infiltration</td>
<td>8</td>
<td>72.7</td>
</tr>
<tr>
<td>d. boiler or heating system</td>
<td>4</td>
<td>36.4</td>
</tr>
<tr>
<td>e. other (gym fans, vestibules)</td>
<td>1</td>
<td>9.1</td>
</tr>
</tbody>
</table>

| **Energy excessive buildings**                                       |        |                  |
| 1. Buildings receiving funds                                         | 14     | 77.8             |
| 2. Buildings receiving funds from schoolhouse or site levy           | 11     | 61.1             |
| 3. Buildings receiving IEPC grant                                   | 7      | 38.8             |
| 4. Buildings receiving funds from the general budget                 | 5      | 27.8             |
| 5. Major areas of applied funds                                     |        |                  |
| a. insulation                                                        | 6      | 42.9             |
| b. lighting                                                          | 6      | 42.9             |
| c. windows/air infiltration                                         | 7      | 50.0             |
| d. boiler or heating system                                          | 5      | 35.7             |
| e. other: reduced outside air                                        | 1      | 7.1              |

^aTotals are greater than 100. Respondents could check more than one response; therefore, 100% cannot be expected.
(1) Schoolhouse tax (or similar) levy
(2) Grant from the Iowa Energy Policy Council
(3) General budget
(4) Other

However, no responses were generated as a result of the fourth choice—even though space was provided. It is apparent from these data that the majority of the structures in both types of building classification are receiving funds for upgrading the building envelope or energy systems (eleven in the energy superior building classification as compared to fourteen in the energy excessive building classification). It is also noteworthy that eleven of the eighteen energy excessive buildings (61.1 percent) received financial aid for energy conservation measures from either a "schoolhouse fund levy" or "site levy." Only four of the eighteen energy superior buildings (22.2 percent) were supported by similar sources of revenue. Even so, of the expenditures reported for energy excessive and energy superior buildings (eight and six, respectively), the latter building type spent an average of $40,100 per building on energy conservation measures. Expenditures for the energy excessive buildings averaged only $17,200 per building for the same purpose.

Part "b" of this same item on the survey form asked administrators to state the major areas in which the above funds had been applied. The following major areas were listed for ease in response:
1. Insulation
2. Lighting
3. Windows and/or infiltration if air
4. Boiler or heating systems
5. Other energy conservation measures (please elaborate)

Respondents were allowed to check (√) more than one area relating to both the type of funds received and the application of the money for energy conservation measures. Therefore, percentages in Table 10 cannot be expected to total one-hundred.

The data compiled under Item 5 in Table 10 for the areas of applied funds indicate there is no major preference in either of the two building classifications to finance one particular energy conservation measure.

Table 11 illustrates the number of buildings in each classification which had "monthly fuel bills analyzed for energy use patterns." Superintendents' responses were used in this situation. (Principals' responses were either identical or no response was made for the item.) Respondents also indicated the person responsible for the analysis of fuel bills. This information is also tabulated in Table 11. Perhaps the most noteworthy comment about the data assembled in Table 11 is the apparent difference in background and experience of those persons assigned the responsibility of analyzing the monthly fuel bills for the sample buildings.
### Table 11. Monthly fuel bills analyzed for energy use patterns

<table>
<thead>
<tr>
<th>Task responsibility</th>
<th>Number</th>
<th>Relative frequency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energy superior buildings</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Board secretary</td>
<td>2</td>
<td>11.1</td>
</tr>
<tr>
<td>2. Business manager</td>
<td>1</td>
<td>5.6</td>
</tr>
<tr>
<td>3. Director of physical plant</td>
<td>2</td>
<td>11.1</td>
</tr>
<tr>
<td>4. Director of purchasing</td>
<td>1</td>
<td>5.6</td>
</tr>
<tr>
<td>5. Elem principal</td>
<td>1</td>
<td>5.6</td>
</tr>
<tr>
<td>6. Head custodian</td>
<td>2</td>
<td>11.1</td>
</tr>
<tr>
<td>7. Superintendent</td>
<td>2</td>
<td>11.1</td>
</tr>
<tr>
<td>8. Supervisor of buildings and grounds</td>
<td>5</td>
<td>27.8</td>
</tr>
<tr>
<td>9. No response</td>
<td>2</td>
<td>11.1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>18</td>
<td>100</td>
</tr>
</tbody>
</table>

| **Energy excessive buildings** |        |                        |
| 1. Board secretary            | 0      | 0                      |
| 2. Business manager           | 3      | 16.7                   |
| 3. Director of physical plant | 0      | 0                      |
| 4. Director of purchasing     | 2      | 11.1                   |
| 5. Elem principal             | 0      | 0                      |
| 6. Head custodian             | 3      | 16.7                   |
| 7. Superintendent             | 8      | 44.4                   |
| 8. Supervisor of buildings and grounds | 0 | 0                      |
| 9. No response                | 2      | 11.1                   |
| **Total**                     | 18     | 100                    |
The maintenance survey: Section IV

Three response areas on the maintenance survey form required the utilization of descriptive statistics. These areas dealt with the (a) type of heating system, (b) type of heating-ventilating-air conditioning (HVAC) system, and (c) capacity of the heating system. All of these data were collected in section IV of the maintenance survey form.

The head custodian (or maintenance director) for each of the selected buildings was asked to check (✓) the type of heating-ventilating-air conditioning (HVAC) system(s) used in the structure. In a similar fashion, responses relating to the type of heating system within selected buildings were elicited. Space for solicited responses was provided in both cases. Tables 12a and 12b illustrate the number and percent of each type of heating system and HVAC system being used in the two types of building classification. Since the respondents were allowed to check (✓) more than one area, percentages cannot be expected to total one-hundred. However, it is clear from Table 12a that the vast majority of structures in both types of building classification utilized "boilers" as the main heating system. Approximately 76.5 percent of the energy superior buildings and 87.5 percent of the energy excessive buildings were reported as having "boilers" for the heating system.
Table 12a. Types of heating systems utilized in sample buildings\(a\)

<table>
<thead>
<tr>
<th>Item</th>
<th>Number</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energy superior buildings(b)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Boilers</td>
<td>13</td>
<td>76.5</td>
</tr>
<tr>
<td>2. Purchases water or steam</td>
<td>1</td>
<td>5.9</td>
</tr>
<tr>
<td>3. Unitary direct fired</td>
<td>1</td>
<td>5.9</td>
</tr>
<tr>
<td>4. Furnaces</td>
<td>1</td>
<td>5.9</td>
</tr>
<tr>
<td>5. Packaged equipment</td>
<td>1</td>
<td>5.9</td>
</tr>
<tr>
<td>6. Other (c)</td>
<td>5</td>
<td>29.4</td>
</tr>
<tr>
<td><strong>Energy excessive buildings(d)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Boilers</td>
<td>14</td>
<td>87.5</td>
</tr>
<tr>
<td>2. Purchased water or steam</td>
<td>2</td>
<td>14.3</td>
</tr>
<tr>
<td>3. Unitary direct fired</td>
<td>1</td>
<td>6.3</td>
</tr>
<tr>
<td>4. Furnaces</td>
<td>2</td>
<td>14.3</td>
</tr>
<tr>
<td>5. Packaged equipment</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6. Other (e)</td>
<td>1</td>
<td>6.3</td>
</tr>
</tbody>
</table>

\(a\)Totals are greater than 100. Respondents could check more than one response; therefore, 100% cannot be expected.

\(b\)Seventeen buildings reported.

\(c\)Response obtained from "Other" category: "Electric" heating (4); "Roof top--gas fired."

\(d\)Sixteen buildings reported.

\(e\)Response obtained from "Other" category: "Hot water system."
Table 12b. Types of heating-ventilating-air conditioning (HVAC) systems utilized in the sample buildings

<table>
<thead>
<tr>
<th>Item</th>
<th>Number</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy superior buildings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Through-wall unit ventilator</td>
<td>8</td>
<td>50.0</td>
</tr>
<tr>
<td>2. Cast iron radiators</td>
<td>5</td>
<td>31.3</td>
</tr>
<tr>
<td>3. Other</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Reheat or duel duct</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>b. Multizone or induction units</td>
<td>2</td>
<td>12.5</td>
</tr>
<tr>
<td>c. Rooftop units or other wall units</td>
<td>5</td>
<td>31.3</td>
</tr>
<tr>
<td>d. Fancoil, VAV or heat and vent units</td>
<td>9</td>
<td>56.3</td>
</tr>
<tr>
<td>e. Other radiation unit heaters</td>
<td>4</td>
<td>25.0</td>
</tr>
<tr>
<td>(no fans)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>f. (Specify)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Energy excessive buildings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Through-wall unit ventilator</td>
<td>9</td>
<td>60.0</td>
</tr>
<tr>
<td>2. Cast iron radiators</td>
<td>5</td>
<td>33.3</td>
</tr>
<tr>
<td>3. Other</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Reheat or duel duct</td>
<td>1</td>
<td>6.7</td>
</tr>
<tr>
<td>b. Multizone or induction units</td>
<td>1</td>
<td>6.7</td>
</tr>
<tr>
<td>c. Rooftop units or other wall units</td>
<td>1</td>
<td>6.7</td>
</tr>
<tr>
<td>d. Fancoil, VAV or heat and vent units</td>
<td>4</td>
<td>26.7</td>
</tr>
<tr>
<td>e. Other radiation unit heaters</td>
<td>4</td>
<td>26.7</td>
</tr>
<tr>
<td>(no fans)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>f. (Specify)</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

a. Totals are greater than 100. Respondents could check more than one response; therefore, 100% cannot be expected.

b. HVAC systems for sixteen of the eighteen sample buildings in this classification were reported.

c. HVAC systems for fifteen of the eighteen sample buildings in this classification were reported.
It is worthy to note that four of the buildings in the energy superior classification utilized "electric" energy as the main heating source. No response of this nature was elicited from custodians in the energy excessive building classification. The data summarized in Table 12b do not indicate substantial preference for any one type of HVAC system for the two types of building classifications. However, it is clear that the "Through-wall unit ventilator" is popular as a HVAC system in both energy excessive and energy superior buildings included in the sample (60 percent and 50 percent utilization, respectively).

Table 12c reveals the capacity of the heating systems for each building classification in relation to the exposed exterior area of the buildings. The unit chosen for the investigation was BTU/hr-Ft$^2$, where Ft$^2$ represents the total exposed exterior area of the walls, roof, windows, and doors in the structure. Various energy units used in reporting the capacity of the heating system was converted to BTU/hr. It is noteworthy that only eight custodians from each building classification were able to locate the capacity (output) of the building heating system. For whatever reason, the figure was unknown. The fact that it could not be estimated may have important implications relating to energy conservation. However, from the data collected, no significant differences were found at the .05 level between group means of the heating
Table 12c. Capacity of the heating system in relation to the exposed exterior surface area for buildings in the sample

<table>
<thead>
<tr>
<th>Building classification</th>
<th>n(^a)</th>
<th>(\bar{X}) (BTU/hr)</th>
<th>(\bar{X}(\text{Ft}^2))</th>
<th>BTU/hr-(\text{Ft}^2)</th>
<th>(s_{\text{BTU/hr}}^2)</th>
<th>(s_{\text{Ft}^2}^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy superior buildings</td>
<td>8</td>
<td>(4.06 \times 10^6)</td>
<td>87062</td>
<td>54.7</td>
<td>(2.13 \times 10^{13})</td>
<td>(4.08 \times 10^9)</td>
</tr>
<tr>
<td>Energy excessive buildings</td>
<td>8</td>
<td>(4.62 \times 10^6)</td>
<td>85861</td>
<td>53.8</td>
<td>(9.86 \times 10^{12})</td>
<td>(7.24 \times 10^9)</td>
</tr>
</tbody>
</table>

\(^a\)Sixteen (16) of the thirty-six (36) buildings reported the capacity of the heating system (44.4 percent). The capacity of the heating system was not listed in twenty (20) of the sample buildings (55.6 percent).
system capacity (BTU/hr), group means of the total exposed exterior area (Ft²), or the respective sample variances (s²_BTU/hr and s²_Ft²) for the two types of building classification.

Data obtained for the dependent and independent variable

Table 13a reveals the data obtained in this study for both the dependent and independent variables previously cited in Chapter III. It should be re-emphasized that the independent variables (with the exception of those variables dealing with the physical factors of the sample building) were deduced from two or more responses in the maintenance and administrator surveys. Precaution was taken utilizing a Pearson Product-Moment Correlation matrix to insure the summed raw data making up each independent variable were not negatively correlated.

A second correlation matrix was constructed which shows the correlation between all variables involved in the study. Table 13b illustrates the relationships found between the dependent and independent variables.

Discussion: Significantly correlated variables

The variable USEPATRN was found to be significantly correlated with several of the other independent variables. These included PRINRESP, MAINTPRO, MSYSTEMS, PROBLEM, and ACTELEM with correlation values of -0.509, 0.465, 0.706, 0.342, and 0.429, respectively. Each of these relationships is discussed in some detail.
Table 13a. Data obtained for independent variables

<table>
<thead>
<tr>
<th>Building Code</th>
<th>SUPRESP</th>
<th>PRINRESP</th>
<th>ACTELEM</th>
<th>PROLEM</th>
<th>MSYSTEMS</th>
<th>USEPATRN</th>
<th>AGE</th>
<th>RVALUE</th>
<th>INFLEST</th>
<th>MAINTPRO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 111</td>
<td>7.6</td>
<td>7.9</td>
<td>4</td>
<td>2</td>
<td>16.3</td>
<td>4.0</td>
<td>20</td>
<td>6.54</td>
<td>5</td>
<td>2.6</td>
</tr>
<tr>
<td>2. 112</td>
<td>6.5</td>
<td>6.5</td>
<td>5</td>
<td>5</td>
<td>16.1</td>
<td>3.8</td>
<td>19</td>
<td>4.03</td>
<td>1</td>
<td>3.1</td>
</tr>
<tr>
<td>3. 121</td>
<td>9.7</td>
<td>8.3</td>
<td>9</td>
<td>8</td>
<td>17.8</td>
<td>4.3</td>
<td>42</td>
<td>4.00</td>
<td>5</td>
<td>3.7</td>
</tr>
<tr>
<td>4. 122</td>
<td>9.4</td>
<td>7.6</td>
<td>12</td>
<td>6</td>
<td>15.2</td>
<td>4.2</td>
<td>40</td>
<td>3.53</td>
<td>3</td>
<td>3.3</td>
</tr>
<tr>
<td>5. 131</td>
<td>9.6</td>
<td>11.2</td>
<td>8</td>
<td>2</td>
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Table 13b. A product-moment correlation matrix for the dependent and independent variables

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(CORRELATION COEFFICIENTS / PROB > |R| UNDER H0: RHO=0 / NUMBER OF OBSERVATIONS)
The positive relationships between USEPATRN and the last four independent variables listed above are not unreasonable in relation to common energy conservation techniques. That is, the significant and positive correlation between the variable USEPATRN and each of the variables MAINTPRO, MSYSTEMS, ACTELEM, and PROELEM may reflect the degree to which an active energy conservation program had been established within the sample building. It is easy to envision a school building in which an energy conservation program has been initiated with some degree of success in relation to the five areas mentioned above. The staff is cognizant of energy waste and high energy costs of the building and therefore reacts appropriately by shutting off unnecessary lights, lowering the thermostat, etc., in their individual classrooms. Maintenance personnel are aware of energy waste and are careful to inspect energy systems on a regular basis and conduct the required maintenance of these systems. (This particular idea in itself is supported by the positive relationship between MSYSTEMS and MAINTPRO—rho = 0.526.) The significant correlation of USEPATRN with ACTELEM and PROELEM indicates the above situation does not happen in isolation without some form of interaction with management at the district level. Generally speaking, the significant and positive correlation between the variable USEPATRN and the independent variables MAINTPRO, MSYSTEMS, PROELEM, and ACTELEM indicates the patterns of energy use within the building fluctuate according to the degree to which energy conservation
techniques are being applied by building maintenance personnel and the administration at the district level. Buildings in the sample which received low scores for the variable USEPATRN had accomplished little in terms of the variables MAINTPRO, MSYSTEMS, ACTELEM, and PROELEM. Buildings in the sample which received high scores for the variable USEPATRN had established a relatively successful energy conservation program in terms of effort and innovation as witnessed by the high scores for the variables MAINTPRO, MSYSTEMS, ACTELEM, and PROELEM.

However, buildings which received high scores for the variable USEPATRN were not necessarily more energy efficient than their lower scoring counterparts. In fact, of the variables mentioned above, only the variable MSYSTEMS was significantly correlated with the dependent variables EUI and BEC. That is to say, an active energy conservation program within a sample building did not automatically insure the school was more energy efficient than a similar building in the sample without an energy conservation program.

The correlation found between USEPATRN and PRINRESP was a negative relationship where rho = -0.509. Although this relationship seemed surprising initially, it supported what had been suggested above. By assuming the building receiving a high score for the variable USEPATRN had an active energy conservation program, the negative correlation could be justified. That is, principals of buildings with visibly active energy
conservation programs did not feel the need to initiate many of the policies and activities suggested on the administrator survey form, at least not to a high degree. Perhaps they had already experienced frustrations in attempting to achieve the theoretical goals expressed by the various "response levels" for some of the items on the administrator survey and were more realistic in their choices. On the other hand, principals in buildings without an active energy conservation program were enthusiastic about the possibility of initiating a good energy conservation (management) program to reduce energy costs, and were more unrealistic in their choices. In retrospect, the "response levels" in Section II of the administrator survey form were written with the intent of having increasing involvement for response levels "a" through "e." The "e" response level was the "best" theoretically, but perhaps not the most realistic in terms of achievement.

MSYSTEMS appeared to be the key variable relating an active energy conservation program with the achievement of energy efficiency in the sample building. The variable MSYSTEMS was correlated with both the independent variable USEPATRN and the dependent variables (EUI and BEC). However, caution must be taken not to assume that a causal relationship exists. The most that can be said at this point is that energy efficient buildings in the study generally received higher scores for the variable MSYSTEMS. This situation implied that
within the group of energy superior buildings there was a higher probability of finding a "successful" energy conservation program than within the group of energy excessive buildings.

However, the essential element providing the motivation and organization needed to link the conservation effort with greater energy efficiency of the building is still unknown. Judging from the findings for the variables PRINRESP and SUPTRESP, the administrators of the sample buildings did not appear to be the essential element which contributed to energy conservation. That is, for whatever the reason, administrators of the sample buildings did not appear to be providing any significant leadership in relation to the energy conservation process. (This leadership role and top level commitment by the administration was denoted in the review of the literature as "energy management.") As indicated by the relationship between MSYSTEMS and standardized energy consumption of the sample buildings, the head custodian seemed to be an important element in the link between applied energy conservation measures and the energy efficiency of the selected building.

Essentially then, the variables INFILEST and MSYSTEMS appeared to be very important in relation to the actual energy efficiency of the sample building. These variables will be discussed in more detail in relation to Hypothesis V.

The significant relationship between the variables RVALUE and AGE was not surprising. The negative correlation between
these variables for buildings in the sample implied that the greater the relative age of the building, the lower the RVALUE. It is likely that this correlation was at least partially due to the more recent emphasis on energy conservation in school buildings and the advances in the field of construction engineering during the time period in which the sample buildings were constructed.

Hypotheses and Findings of the Study

The format used in reporting the findings for this part of the study included:

(1) A re-statement of each of the five hypotheses described in Chapter III.

(2) A presentation of the appropriate tables revealing the data utilized and results of the statistical analyses.

(3) The inclusion of any necessary explanation or discussion relevant to the findings.

Table 14 shows the mean for the building energy characteristic (BEC) and the energy utilization index (EUI) values obtained for the thirty-six sample buildings (determined from fuel and occupancy data on the preliminary energy audit (PEA) forms). Units for the BEC are BTU/day-°F-ft² while those for EUI are BTU/ft²-yr. Buildings are displayed in the table using a three digit code. The first number in the code indicates the size category of the school district in which the building was located. The second digit is the "matching" code number. Equal second digits within each size category represent
Table 14. Energy Utilization Index (EUI) and Building Energy Characteristic (BEC) values determined for sample buildings

<table>
<thead>
<tr>
<th>Building Code</th>
<th>EUI BTU/yr-ft²</th>
<th>BEC BTU/dy-°F-Ft²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy superior buildings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. 111</td>
<td>22103</td>
<td>0.883</td>
</tr>
<tr>
<td>2. 121</td>
<td>20451</td>
<td>0.998</td>
</tr>
<tr>
<td>3. 131</td>
<td>42358</td>
<td>1.679</td>
</tr>
<tr>
<td>4. 141</td>
<td>76227</td>
<td>2.355</td>
</tr>
<tr>
<td>5. 151</td>
<td>69569</td>
<td>3.060</td>
</tr>
<tr>
<td>6. 161</td>
<td>77441</td>
<td>3.156</td>
</tr>
<tr>
<td>7. 211</td>
<td>21173</td>
<td>0.780</td>
</tr>
<tr>
<td>8. 221</td>
<td>40654</td>
<td>1.718</td>
</tr>
<tr>
<td>9. 231</td>
<td>50722</td>
<td>2.156</td>
</tr>
<tr>
<td>10. 241</td>
<td>58043</td>
<td>2.462</td>
</tr>
<tr>
<td>11. 251</td>
<td>70315</td>
<td>2.955</td>
</tr>
<tr>
<td>12. 261</td>
<td>74637</td>
<td>3.157</td>
</tr>
<tr>
<td>13. 311</td>
<td>46305</td>
<td>2.074</td>
</tr>
<tr>
<td>14. 321</td>
<td>68992</td>
<td>2.808</td>
</tr>
<tr>
<td>15. 331</td>
<td>70124</td>
<td>2.941</td>
</tr>
<tr>
<td>16. 341</td>
<td>72138</td>
<td>3.050</td>
</tr>
<tr>
<td>17. 351</td>
<td>78635</td>
<td>3.481</td>
</tr>
<tr>
<td>18. 361</td>
<td>92820</td>
<td>3.996</td>
</tr>
<tr>
<td>Energy excessive buildings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. 112</td>
<td>199259</td>
<td>8.102</td>
</tr>
<tr>
<td>2. 122</td>
<td>156709</td>
<td>6.880</td>
</tr>
<tr>
<td>3. 132</td>
<td>163794</td>
<td>7.393</td>
</tr>
<tr>
<td>4. 142</td>
<td>262160</td>
<td>11.400</td>
</tr>
<tr>
<td>5. 152</td>
<td>176395</td>
<td>8.630</td>
</tr>
<tr>
<td>6. 162</td>
<td>256939</td>
<td>11.010</td>
</tr>
<tr>
<td>7. 212</td>
<td>279522</td>
<td>12.085</td>
</tr>
<tr>
<td>8. 222</td>
<td>198478</td>
<td>8.730</td>
</tr>
<tr>
<td>9. 232</td>
<td>175927</td>
<td>7.333</td>
</tr>
<tr>
<td>10. 242</td>
<td>193533</td>
<td>7.940</td>
</tr>
<tr>
<td>11. 252</td>
<td>162640</td>
<td>6.683</td>
</tr>
<tr>
<td>12. 262</td>
<td>234575</td>
<td>9.116</td>
</tr>
<tr>
<td>13. 312</td>
<td>182237</td>
<td>7.540</td>
</tr>
<tr>
<td>14. 322</td>
<td>160131</td>
<td>7.033</td>
</tr>
<tr>
<td>15. 332</td>
<td>230160</td>
<td>10.356</td>
</tr>
<tr>
<td>16. 342</td>
<td>218784</td>
<td>10.190</td>
</tr>
<tr>
<td>17. 352</td>
<td>563265</td>
<td>22.042</td>
</tr>
<tr>
<td>18. 362</td>
<td>214169</td>
<td>9.825</td>
</tr>
</tbody>
</table>
"matched" or "paired" buildings. Lastly, the third digit indicates the building classification. The number one as the third digit represents an energy superior building. The number two as the third digit represents an energy excessive building. A pictorial representation of the entire code is shown below:

When using the code, building 132 is the match of building 131, building 212 is the match of building 211, etc.

**Research Hypothesis I**

It was hypothesized that the mean building energy characteristic (BEC) of school buildings designated as energy excessive does not differ from the mean BEC of buildings designated as energy superior beyond that suspected due to random sampling error.

The analysis of data using the BECs for the matched buildings is summarized in Table 15. All three categories are shown. The calculated values using the matching student t-test were 14.06, 6.02, and 3.80 for size categories one, two, and three, respectively. These values indicated a significant difference between the mean BEC of the energy superior buildings and the "matched" energy excessive buildings. Therefore,
Table 15. A comparison of average monthly Building Energy Characteristic (BEC) values between matched buildings in the sample

<table>
<thead>
<tr>
<th>Size</th>
<th>$\overline{d}$</th>
<th>$s_d^2$</th>
<th>$s_d$</th>
<th>t value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6.75</td>
<td>1.38</td>
<td>0.48</td>
<td>14.06*</td>
</tr>
<tr>
<td>2</td>
<td>6.44</td>
<td>6.82</td>
<td>1.07</td>
<td>6.02**</td>
</tr>
<tr>
<td>3</td>
<td>8.13</td>
<td>27.53</td>
<td>2.14</td>
<td>3.08***</td>
</tr>
</tbody>
</table>

* $p < .001$.
** $p < .01$.
*** $p < .001$.

the null hypothesis is rejected at the .05 level for all three size categories referred to in Research Hypothesis I.

Research Hypothesis II

It was hypothesized that the mean Energy Utilization Index (EUI) of school buildings designated as energy excessive does not differ from the mean EUI of buildings designated as energy superior beyond that suspected due to random sampling error.
The analysis of data using EUI is summarized in Table 16 for all three size categories in the study. The matched t-test values in this instance were 10.95, 6.73, and 3.18 for size categories one, two, and three, respectively. These values indicated a significant difference between the mean EUI of the energy superior buildings and the "matched" energy excessive buildings. The null hypothesis is therefore rejected at the .05 level of significance for all three size categories referred to in Research Hypothesis II. The results of the above statistical tests for EUI and BEC indicated the building energy management index (BEMI) method does discriminate between energy efficiency of school buildings.

Table 16. A comparison of Energy Utilization Index (EUI) values between matched buildings in the sample

<table>
<thead>
<tr>
<th>Size</th>
<th>( \bar{d} )</th>
<th>( s_d^2 )</th>
<th>( s_d^2 )</th>
<th>t value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>151184</td>
<td>1.15 x 10^9</td>
<td>1.38 x 10^4</td>
<td>10.95*</td>
</tr>
<tr>
<td>2</td>
<td>154855</td>
<td>3.18 x 10^9</td>
<td>2.30 x 10^4</td>
<td>6.73**</td>
</tr>
<tr>
<td>3</td>
<td>189995</td>
<td>2.14 x 10^10</td>
<td>5.97 x 10^4</td>
<td>3.18***</td>
</tr>
</tbody>
</table>

* \( p < .001. \)
** \( p < .01. \)
*** \( p < .05. \)
Discussion: Hypotheses I and II

The results of Hypotheses I and II confirmed that, within size categories, the mean difference in the BEC values and the EUI values between the matched buildings is significant. Therefore, utilizing the Building Energy Management Index (BEMI) method for identifying "energy superior" and "energy excessive" buildings appeared to be a satisfactory procedure. It is important to note that the EUI unit does not include a value for "outside temperature" in the evaluation of energy consumption as does the unit for BEC. Energy excessive buildings were significantly different in mean energy usage from the matched energy superior buildings without considering the temperature differences due to the various locations of the sample buildings within the state of Iowa. Such results gave added confidence in the BEMI method since the monthly BEC values were used when converting to EUI values. Average monthly temperatures for the specific building locations were used in converting the monthly BEC values to EUI values for the sample buildings.

Research Hypothesis III and IV

It was hypothesized that classification of buildings by (A) energy superior versus energy excessive, (B) size of district, and (C) the combination of efficiency and size will not affect the mean building energy characteristic (BEC) value.

It was hypothesized that classification of buildings by (A) energy superior versus energy excessive, (B) size of
district, and (C) the combination of efficiency and size will not affect the mean building energy utilization index (EUI) value.

Tables 17a and 17b illustrate the results of the analysis of variance (ANOVA) utilizing a "mixed" design for both the BEC and EUI values obtained for buildings in the sample. Calculated F values for the "A effect" in both cases (EUI and BEC) indicate a significant difference in energy efficiency between energy superior buildings and energy excessive buildings. These F values for the variables BEC and EUI were 75.81 and 57.36, respectively. Based on these results, the null hypothesis for "repeated measures" is rejected at the .05 level of significance.

Calculated F values for the B Group effect (size) and interaction effect for both EUI and BEC suggested these areas are not significant at the .05 level. That is, neither size of the district in which the building is located nor the combination of energy efficiency and size had an effect on the mean EUI and BEC values for the two building classification types. Therefore, the null hypotheses for "between unit measures" and "interaction measures" is accepted at the .05 level of significance.

Discussion: Hypotheses III and IV

These results have important implications for smaller school districts. They indicate that, on the average, size of
Table 17a. Analysis of variance (mixed design) of the mean Building Energy Characteristic (BEC) by (A) energy superior versus energy excessive, (B) size of district, and (C) the combination of efficiency and size

<table>
<thead>
<tr>
<th>Source</th>
<th>D.F.</th>
<th>SS</th>
<th>MS</th>
<th>F value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Among subjects</td>
<td>17</td>
<td>129.9764</td>
<td>7.6457</td>
<td></td>
</tr>
<tr>
<td>(B) Groups</td>
<td>2</td>
<td>22.2422</td>
<td>11.1211</td>
<td>1.55</td>
</tr>
<tr>
<td>(B) Error</td>
<td>15</td>
<td>107.7342</td>
<td>7.1823</td>
<td></td>
</tr>
<tr>
<td>Within subjects</td>
<td>18</td>
<td>554.6252</td>
<td>30.8125</td>
<td></td>
</tr>
<tr>
<td>(A) Effect</td>
<td>1</td>
<td>459.2378</td>
<td>459.2378</td>
<td>75.76</td>
</tr>
<tr>
<td>(C) = A X B</td>
<td>2</td>
<td>4.4578</td>
<td>2.2269</td>
<td>0.37</td>
</tr>
<tr>
<td>Cell error</td>
<td>15</td>
<td>90.9296</td>
<td>6.0619</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>35</td>
<td>684.6016</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 17b. Analysis of variance (mixed design) of the mean Energy Utilization Index (EUI) by (A) energy superior versus energy excessive, (B) size of district, and (C) the combination of efficiency and size

<table>
<thead>
<tr>
<th>Source</th>
<th>D.F.</th>
<th>SS</th>
<th>MS</th>
<th>F value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Among subjects</td>
<td>17</td>
<td>8.659 x 10^10</td>
<td>5.094 x 10^9</td>
<td></td>
</tr>
<tr>
<td>(B) Groups</td>
<td>2</td>
<td>1.161 x 10^10</td>
<td>5.803 x 10^9</td>
<td>1.16</td>
</tr>
<tr>
<td>(B) Error</td>
<td>15</td>
<td>7.499 x 10^10</td>
<td>4.999 x 10^9</td>
<td></td>
</tr>
<tr>
<td>Within subjects</td>
<td>18</td>
<td>3.131 x 10^11</td>
<td>1.739 x 10^10</td>
<td></td>
</tr>
<tr>
<td>(A) Effect</td>
<td>1</td>
<td>2.460 x 10^11</td>
<td>2.460 x 10^11</td>
<td>57.36</td>
</tr>
<tr>
<td>(C) = A X B</td>
<td>2</td>
<td>2.749 x 10^9</td>
<td>1.374 x 10^9</td>
<td>0.32</td>
</tr>
<tr>
<td>Cell error</td>
<td>15</td>
<td>6.433 x 10^10</td>
<td>4.289 x 10^9</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>35</td>
<td>3.997 x 10^11</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
the district by itself had little or no effect on the energy efficiency of the school building. In addition, the interaction of the relative energy efficiency of the building in relation to the school district size had little or no effect on the actual energy consumption of the building. This finding seems to discredit the idea of an optimum school district size in relation to building energy efficiency. From these findings, consolidation of several small school districts into one large centralized system does not appear to be beneficial from the standpoint of building energy efficiency.

Research Hypothesis V

It was hypothesized that the standardized partial regression coefficient between standardized energy usage of a school building and the independent variables listed below does not differ significantly from zero beyond that expected by chance alone. Standardized energy use was measured by the EUI and the average of the monthly BEC. Both standardized units were used separately as the dependent variable.

Independent Variables:

1. Average weighted response to energy management, conservation, and cost reduction statements made by the superintendent—coded SUPTRESP

2. Average weighted response to energy management, conservation, and cost reduction statements made by the principal—coded PRINRESP

3. Adoption practices of energy conservation guideline elements as reported by the superintendent (these guideline elements were reported in an earlier study conducted by Hicks (1978)—coded ACTELEM and PROELEM
4. Frequency of maintenance procedures for the building as reported by the head custodian (or maintenance director)—coded MAINTPRO

5. Degree to which energy conservation practices have been implemented for the building's envelope and energy systems as rated by the head custodian (or maintenance director)—coded MSYSTEMS

6. Patterns of energy use by occupants of the building as rated by the head custodian (or maintenance director)—coded USEPATRN

7. Physical characteristics of the building:
   a. Age—coded AGE
   b. Reciprocal of the overall U factor—coded RVALUE
   c. Estimation of the overall air infiltration for the building as reported by the head custodian or maintenance director—coded INFILEST

(Note: Size of the district was also entered into the regression analysis using a "dummy variable")

Discussion: Hypothesis V

Tables 18a, 18b, 19a, and 19b illustrate the "best" single and multivariate models generated by the "stepwise" regression analysis model using EUI and BEC as dependent variables (Helwig and Council, 1979). The stepwise statistical analysis "selects" the best one variate model, the best two variate model, etc., considering all the independent variables under examination.

Analysis of the dependent variable EUI (Energy Utilization Index)

Table 18a shows the best single predictor (independent) variable (among all the independent variables) for the dependent variable EUI. INFILEST is the code for the estimation of air infiltration for the sample building as reported by the head
Table 18a. Stepwise regression analysis results for dependent variable EUI ("Best" single variable model)

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>Sum of squares</th>
<th>Mean square</th>
<th>F value</th>
<th>Prob &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>1</td>
<td>47351898569.</td>
<td>47351898569.</td>
<td>9.21</td>
<td>0.0051</td>
</tr>
<tr>
<td>Error</td>
<td>29</td>
<td>149182618286.</td>
<td>5144228216.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>30</td>
<td>196544516866.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>B value</th>
<th>Std. error</th>
<th>Type II SS</th>
<th>F value</th>
<th>Prob &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>226318.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INFILEST</td>
<td>-18742.</td>
<td>6176.</td>
<td>9.21</td>
<td>0.0051</td>
</tr>
</tbody>
</table>

Table 18b. Stepwise regression analysis results for dependent variable EUX ("Best" multivariate model)

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>Sum of squares</th>
<th>Mean square</th>
<th>F value</th>
<th>Prob &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>2</td>
<td>67256138056.</td>
<td>33628069028.</td>
<td>7.28</td>
<td>0.0028</td>
</tr>
<tr>
<td>Error</td>
<td>28</td>
<td>129288378799.</td>
<td>4617442099.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>30</td>
<td>196544516855.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>B value</th>
<th>Std. error</th>
<th>Type II SS</th>
<th>F value</th>
<th>Prob &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>401366.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MSYSTEMS</td>
<td>-11811.</td>
<td>4186.</td>
<td>36761824532</td>
<td>7.96</td>
</tr>
<tr>
<td>RVALUE</td>
<td>-18780.</td>
<td>6140.</td>
<td>43195780171</td>
<td>9.35</td>
</tr>
</tbody>
</table>
custodian. The "R square" for the above relationship indicates 24 percent of the variability in EUI can be predicted by this one factor. The calculated F value associated with the analysis was 9.21. The probability of the calculated F value being greater than the critical F values was 0.0051. Therefore, the null hypothesis stated using the standardized partial regression coefficient for the variable INFILBEST in relation to the dependent variable EUI is rejected at the .05 level of significance. (Note: Five observations were deleted in all stepwise regression analyses due to missing values--i.e. N = 31.)

Table 18b shows two variables which make up the "best" multivariate regression model under the .05 level of significance specified in Hypothesis V. The variables MSYSTEMS and RVALUE (in combination) predict 34 percent of the variability in EUI between sample buildings. MSYSTEMS is the code for the degree to which energy conservation practices have been implemented for the building's envelope and energy systems. RVALUE is the reciprocal of the overall U factor for the sample building. The calculated F value associated with the full model was 7.28. The probability of this value being greater than the critical F value was 0.0028. The probability of the calculated F values for MSYSTEMS and RVALUE being greater than the corresponding critical F values were 0.0087 and 0.0049, respectively. (Note: The value for the "Type II SS" used in calculating the F values for the restricted models, is the sum
of squares for the regression model when that specific variable was withheld from the full model.) Therefore, the null hypothesis stated for the standardized partial regression coefficients for the combined variables MSYSTEMS and RVALUE is rejected at the .05 level of significance.

It should be noted that both regression models, stated above, form an inverse relationship with the dependent variable EUI. This inverse relationship is indicated by the negative "B values" listed for the specific variables in each regression model.

Analysis of the dependent variable BEC (Building Energy Characteristic)

Table 19a shows the best single predictor variable of the dependent variable BEC. INFILEST was again found to describe the best linear relationship with energy efficiency of the sample buildings. In this instance, the R square value was 0.2313—slightly smaller than the corresponding value between INFILEST and EUI (0.2410). The calculated F value was 8.73. The probability of this value being greater than the critical F value was 0.0062. Therefore, the null hypothesis stated using the standardized partial regression coefficient for the variable INFILEST in relation to the dependent variable BEC is rejected at the .05 level of significance.

Table 19b reveals the best multivariate model between the independent variables and the dependent variable BEC at the
Table 19a. Stepwise regression analysis results for the dependent variable BEC ("Best" single variable model)

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>Sum of squares</th>
<th>Mean square</th>
<th>F value</th>
<th>Prob &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>1</td>
<td>87.6251</td>
<td>87.6251</td>
<td>8.73</td>
<td>0.0062</td>
</tr>
<tr>
<td>Error</td>
<td>29</td>
<td>291.1401</td>
<td>10.0393</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>30</td>
<td>378.7652</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

B value  Std. error Type II SS F value Prob > F

Intercept  9.7005
INFILEST   -0.8061  0.2728  87.6251  8.73  0.0062

Table 19b. Stepwise regression analysis results for the dependent variable BEC ("Best" multivariate model)

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>Sum of squares</th>
<th>Mean square</th>
<th>F value</th>
<th>Prob &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>2</td>
<td>131.7173</td>
<td>65.8586</td>
<td>7.46</td>
<td>0.0025</td>
</tr>
<tr>
<td>Error</td>
<td>28</td>
<td>247.0480</td>
<td>8.8231</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>30</td>
<td>378.7652</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

B value  Std. error Type II SS F value Prob > F

Intercept  17.5691
MSYSTEMS   -0.5228  0.1830  72.0346  8.16  0.0080
RVALUE     -0.8309  0.2684  84.5591  9.58  0.0044
pre-determined level of significance set at alpha = .05. Again, MSYSTEMS and RVALUE were found to be the best combination of independent variables predicting variability of energy efficiency among sample buildings. The R square for this situation was 0.3477 (slightly higher than the corresponding relationship with EUI). The calculated F value associated with the full model was 7.46 while specific F values for MSYSTEMS and RVALUE (restricted models) were 8.16 and 9.58, respectively. Therefore, the null hypothesis stated for the standardized partial regression coefficients for the combined variables MSYSTEMS and RVALUE was rejected at the .05 level of significance.

Although not shown in table form, the variable MSYSTEMS was also found to be a significant single variate predictor of the dependent variables EUI and BEC. The R square relationships for the general linear regression model (GLM) between the predictor variable and the dependent variables EUI and BEC were 0.128502 and 0.128484, respectively. The significant B value obtained for the GLM using EUI as the dependent variable was -9778. When BEC was used as the dependent variable, the corresponding B value was -0.4311. The calculated F values were identical for both dependent variables (i.e. 4.72). The probability of this value being greater than the critical F value was 0.0374, thus indicating the rejection of the null hypothesis using the standardized partial regression coefficients for the variable MSYSTEMS. Although these results are
somewhat overshadowed by the findings for the variable INFILEST, they should not be dismissed as irrelevant.

No other variables (either single or multivariate) used in the regression analysis met the .05 level of significance necessary for entry into the models. All independent variables found significant under Research Hypothesis V formed an inverse relationship with the dependent variables. It should also be noted that all the regression analyses were checked for the possibility of a curvilinear relationship between variables by plotting a graph of "residual" values versus predicted values. No apparent relationships were discovered.

Summary

The findings of this chapter suggested significant factors related to energy efficiency of the selected buildings. The two single variables found to be correlated with the dependent variables were MSYSTEMS and INFILEST. The variable MSYSTEMS measured the degree to which energy conservation practices had been implemented for the building's envelope and energy systems. INFILEST was an estimate of the air infiltration through the building envelope. These results indicated that the physical characteristics of the sample building may be more important than the patterns of energy use by occupants within the building. In addition, such evidence suggested that the expertise with which the school building envelope was constructed (and
maintained) as well as the quality of materials used are more important than the overall U factor of the building. There is little doubt that the latter concept has been generally accepted for some time. However, the significance of the finding of this study is that INFILEST was the predominant variable indicating the relative energy consumption patterns of the sample buildings based on standardized energy units (BEC and EUI). That is, this one variable was the single most important factor predicting energy efficiency of a sample building. However, caution must be taken since a high correlation does not imply a causal relationship exists.

Although the single variate MSYSTEMS was found to be significant in predicting energy efficiency of the sample buildings, a more important relationship with the dependent variables was found when the variables MSYSTEMS and RVALUE were combined in a multivariate regression model. This regression model predicted energy efficiency of the sample building better than any other single or multivariate regression model in the study. That is, the combination of these two factors formed a significant linear relationship relative to building energy efficiency which predicted more than one-third (1/3) of the variance in the dependent variables. Considering the complexity involved in the many facets of energy conservation dealing with school buildings, this result seemed that much more significant.
Other important findings of this chapter were:

1. Size of the school district was not a significant factor in relation to energy efficiency of the sample building.

2. Energy consumption (as measured by the BEC and EUI) was significantly different between the two types of building classifications. The correlation between the two dependent variables was found to be rho = 0.994.
CHAPTER V. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

This research included a study of factors relating to energy conservation, energy management and energy cost reduction of public school buildings in Iowa. The previous chapters have included:

1. An introduction to the importance of energy conservation in schools and a delineation of the basic questions to be investigated in this research study.
2. A review of the literature pertaining to the current advancements and knowledge relating to energy conservation, energy management, and energy cost reduction in schools.
3. The methodology involved in conducting this research study and the procedures for analysis of the data.
4. A presentation of the findings of this study utilizing tables to illustrate the results obtained with descriptive and parametric statistics.

The purpose of this chapter is to summarize the findings of this research study and draw basic conclusions implied by the findings reported in Chapter IV. Lastly, several recommendations will be presented based on the implications and conclusions of this research study.
Restatement of the problem

The problem of this study was to investigate the differences in energy efficiency of public elementary and secondary schools in Iowa and to determine factors which are correlated to energy efficiency of school buildings.

Restatement of the purpose

The purpose of the study was to provide information which will help to reduce the current impact of energy costs on the budgets of Iowa school districts. Specifically, this information will serve two functions:

1. Help administrators of public schools become more knowledgeable in the areas of energy management, energy conservation, and energy cost reduction methods, thereby assisting them in coping with the energy related problems of the school, and

2. Identify those areas which are significantly correlated to the energy efficiency of school buildings, thus serving the best interests of administrator time management and the school district budget.

Conclusions

This section presents a summary and the conclusions of the study pertaining to the research hypotheses. Each hypothesis was restated and followed by a conclusion based on the findings.
of Chapter IV. A discussion of the implications drawn from related hypotheses was included where appropriate.

Research Hypothesis I

It was hypothesized that the mean building energy characteristic (BEC) of school buildings designated as energy excessive does not differ from the mean BEC of buildings designated as energy superior beyond that suspected due to random sampling error.

The above hypothesis was made for energy superior and energy excessive school buildings grouped in three size categories. Superior and excessive buildings were matched on the basis of five factors commonly accepted as being related to energy use.

Conclusion I

It was concluded that, based on the findings of the previous chapter and Table 15, the average of the monthly building energy characteristic (BEC) is a suitable measure when discriminating between "energy superior" and "energy excessive" buildings. Therefore, it appears that this method may be used to measure the difference in energy efficiency of Iowa public school buildings and classify them accordingly.
Research Hypothesis II

It was hypothesized that the mean energy utilization index (EUI) of school buildings designated as energy excessive does not differ from the mean EUI of buildings designated as energy superior beyond that suspected due to random sampling error.

The above hypothesis was made for energy superior and energy excessive school buildings grouped in three size categories. Superior and excessive buildings were matched on the basis of five factors commonly accepted as being related to energy use.

Conclusion II

It was concluded that, based on the findings of the previous chapter and Table 16, the energy utilization index (EUI) derived from the building energy management index (BEMI) is a suitable measure when discriminating between "energy excessive" and "energy superior" buildings. Therefore, it is possible to measure the difference in energy efficiency of Iowa public school buildings and to classify them accordingly.

Discussion related to Hypotheses I and II

From the conclusions of Hypotheses I and II, it appears that the BEMI method is a satisfactory procedure when identifying energy excessive and energy efficient school buildings. The fact that the more popular EUI unit was found to give equivalent results in all the areas tested supports the validity of the
BEMI method since the former unit was derived from monthly BEC values in this study. Secondly, by utilizing the BEMI method, individual school buildings within a given category are chosen with respect to monthly temperature data pertaining to the specific school building location. Therefore, classification of the structure in relation to energy efficiency should be more sensitive to the variance in energy consumption due to the geographical location of the building within the state than the alternate EUI method (derived only by the energy consumption data for the building).

Research Hypothesis III

It was hypothesized that classification of buildings by (a) energy superior versus energy excessive, (b) size of district, and (c) the combination of efficiency and size will not affect the mean building energy characteristic (BEC) value.

Conclusion III

It was concluded that, based on the findings of the previous chapter and Table 17a, neither the size of the school district in which the building was located nor the interaction of efficiency and size have an influence on the actual energy consumption of the building when measured by the BEC.

Research Hypothesis IV

It was hypothesized that classification of buildings by (a) energy superior versus energy excessive, (b) size of
district, and (c) the combination of efficiency and size will not affect the mean energy utilization index (EUI) value.

**Conclusion IV**

It was concluded that, based on the findings of the previous chapter and Table 17b, neither the size of the school district in which the building was located nor the interaction of efficiency and size have an influence on the actual energy consumption of the building when measured by the EUI.

**Discussion related to Hypotheses III and IV**

The above conclusions have important implications pertaining to the energy efficiency of the individual school buildings in relation to an optimum school district size. It could easily be proposed that some optimum district size existed whereby the individual school buildings within the district were more energy efficient as a result of inter-relating factors inherent to district size (such as a centralized organizational structure or ability of the district to employ specialists in a given area). However, the evidence presented in this study seems to discredit that idea. It appears from the findings in Chapter IV that no immediate benefits relating to individual building efficiency would be realized through either consolidation of districts into larger sized units or decentralization of a large district into smaller school systems.
Research Hypothesis V

It was hypothesized that the standardized partial regression coefficient between standardized energy usage of a school building and the independent variables listed below do not differ significantly from zero beyond that expected by chance alone. Standardized energy use will be measured by the EUI and the average of the monthly BEC. Both standardized units will be used separately as the dependent variable.

Independent variables:

1. Average weighted response to energy management, energy conservation, and energy cost reduction statements made by the superintendent—coded SUPTRESP

2. Average weighted response to energy management, energy conservation, and energy cost reduction statements made by the principal—coded PRINRESP

3. Adoption practices of energy conservation guideline elements as reported by the superintendent (these guideline elements were reported in an earlier study conducted by Hicks (1978)—coded ACTELEM and PROBLEM

4. Frequency of maintenance procedures for the building as reported by the head custodian or maintenance director—coded MAINTPRO

5. Degree to which energy conservation practices have been implemented for the building's envelope and energy systems as rated by the head custodian or maintenance director—coded MSYSTEMS

6. Patterns of energy use by occupants of the building as rated by the head custodian or maintenance director—coded USEPATRN
7. Physical characteristics of the building:
   
a. Age—coded AGE
   
b. Reciprocal of the overall U factor—coded RVALUE
   
c. Estimation of the overall air infiltration for the building as reported by the head custodian or maintenance director—coded INFILEST
   
(Note: Size of the district was also entered into the regression analysis using a "dummy variable")

Conclusion V

It was concluded that, based on the findings reported in the previous chapter and Tables 18a and 19a, the degree of air infiltration through the building envelope as estimated by the head custodian is the best predictor of the overall building energy efficiency.

It was also concluded that, based on the findings reported in Table 13b, the only other single factor correlated with energy efficiency of the building is the degree to which energy conservation practices have been implemented for the building's envelope and energy systems.

In addition, it was concluded that, based on the findings reported in the previous chapter and Tables 18b and 19b, the combined effects of the reciprocal of the overall U factor (overall thermal resistance) of the building and the degree to which energy conservation practices have been implemented for the building's envelope and energy systems is the best overall indicator of the building energy efficiency.
No other factors or combinations of factors were found to be significant in the study.

Discussion related to Hypothesis V

These results indicated that physical characteristics of the school building and implemented energy conservation practices for the building's energy systems were more important than any other factors in relation to energy efficiency of the structure. Moreover, the relationship of these significant factors with maintenance practices of the building indicated the director of maintenance or head custodian may have had more of an effect on the energy efficiency of the building than the energy management provided by the principal and superintendent. This is not to say involvement by administrators is unimportant to the optimum energy efficiency of a building. However, evidence from this study suggests that, in general, the feelings of superintendents and principals about energy management do not appear to have a significant effect on energy efficiency of school buildings. Perhaps as more knowledge about successful energy management practices is acquired by administrators, the benefits of an energy management program will become more evident.

Recommendations

This section presents the recommendations of the study. These recommendations were divided into two categories, major
recommendations and supporting recommendations. The major recommendations were made in reference to the significant findings of the hypotheses for the study. The supporting recommendations were in reference to other important implications of the present study and suggestions for further study. Finally, this writer's opinion was included in closing remarks.

Major recommendations

1. It is recommended that the BEMI method of discriminating between energy efficient and energy excessive buildings be used as an equivalent approach to the EUI method. The BEMI method should be given strong consideration in situations where the differential in environmental temperature between the locations of the school buildings is significant.

2. It is recommended that the size of a school district not be included as a criterion by any funding agency or other organization when ranking school buildings in terms of energy efficiency.

3. It is recommended that the boards of education, with all other energy conservation opportunities (ECO) being equal, give highest priority to those ECOs dealing with the building's envelope and energy systems.
Supporting recommendations

1. It is recommended that the State Department of Public Instruction, in conjunction with the Iowa Energy Policy Council, continue to investigate all possible avenues to aid school districts in financing needed energy conservation measures.

2. It is recommended that the State Department of Public Instruction, in conjunction with the Iowa Energy Policy Council, undertake a public relations campaign to help educate community leaders and school administrators on the importance of energy conservation in schools for the benefit of energy cost reduction.

3. It is recommended that an instrument be developed to investigate the need for in-service training for the maintenance personnel of school districts in relation to (1) effective energy conservation techniques and practices which can be applied to the energy systems of a school building, and (2) procedures which improve the physical characteristics of the school building envelope in terms of energy conservation.

4. It is recommended that further studies be conducted in the area of energy management by utilizing controlled experimentation techniques. For example, energy conservation measures dealing with the energy
systems of a building might be examined. Effects of each of the energy conservation practices could be assessed by systematically varying one variable while controlling other variables.

Closing remarks

From the results of this research study, it appears evident that energy management and an organized approach to energy conservation within school districts is in an embryonic stage of development. Support for this speculation comes from the lack of any significant correlation between administrators' feelings toward realistic levels of attainment of energy management procedures and standardized energy consumption of the selected buildings in the study. There appears to be a lack of top level commitment on the part of superintendents and principals in establishing an energy management program. Since a review of the literature exposed specific examples where top administrative commitment was critical to energy cost reduction in schools, it is unlikely that a substantial number of energy management programs existent in either type of building classification had reached optimum effectiveness.

The correlation between the variable INFILEST and energy efficiency of the sample buildings provides valuable insight in relation to energy conservation within the selected build-
ings. That is, in general, head maintenance personnel have a reasonably good idea of the condition of the building envelope in relation to a "well constructed" building of the same age and function. From their apparent judgment indicated on the maintenance survey form, they recognize when a problem exists in relation to the building (or at least they recognize the building envelope is not the same "calibre" as some buildings). If it can be assumed that this information has been shared with other personnel responsible for the management of the building, it is likely that information about the status of the building envelope has been reported to the School Board. Coupling this conjecture with the correlation found between the variable INFILEST and the standardized energy consumption in the study, it seems highly probable that basic differences between matched school buildings are attributable to the following possibilities: (1) the original energy superior building was constructed to a higher degree of quality than the energy excessive counterpart and/or (2) the superior building envelope was maintained to a higher degree of integrity than the matched energy excessive building. From the experience of a personal visit to each of the sample buildings, it is this investigator's impression that the latter option reflects the real situation. This condition is essentially equivalent to saying there is more
condition is essentially equivalent to saying there is more of a "willingness" on the part of the School Board of energy superior buildings to "invest" in energy conservation opportunities for the purpose of reducing energy costs in the future. (Note: A "willingness" to appropriate money is not necessarily coterminous with the establishment of an energy management program.)

A closer examination of the variable RVALUE gives merit to the above observation. From the evidence gathered by this investigator in determining the overall U factor for each of the sample buildings, it appears that the typical school is composed of quite similar materials from a thermal transmission standpoint. A good example is the similarity in school building wall construction. The exterior wall of most of the buildings in the sample was four inch face brick. This followed by a one inch "dead air space" and, lastly, the eight inch concrete block usually serves as the interior wall. Floor, ceiling, and roof materials were also quite similar for the typical school. If the data for RVALUE were plotted on a graph of RVALUE versus energy consumption, the consistency or similarity in thermal resistance of the building materials could be pictorially represented by a horizontal line with no slope. This result is substantiated by the lack of a significant correlation between RVALUE and the dependent variables. The point representing the RVALUE for most schools would fall near this
horizontal line. Hence, when a particular building had special insulating properties due to the materials used in construction, the point representing the RVALUE of the building would deviate from the norm and fall above the line. (Note: The horizontal line could be imagined as a "base line." Very few points representing the RVALUE of the buildings would be found substantially "below" this prescribed standard.) A good example of a building where the RVALUE point would fall above the base line is in the case of an "all electric" heating system. (Four such cases were found in the energy superior classification of buildings. Only the "mobile" building in the energy excessive building classification was equipped with an electric heating system.) For those buildings with installed electric heating systems, anticipation of higher utility costs for electricity apparently lead to installation of above average insulating materials in the building envelope. Thus, a larger value for the variable RVALUE was the result.

The above mental construct gives credence to the combined relationship found with the variables RVALUE and MSYSTEMS. The fact that the two variables are inter-related--in terms of simple payback period and the financial impact on the school district budget--is also important in explaining the relationship between RVALUE and MSYSTEMS.

In the case of energy superior buildings, it can be assumed that the integrity of the building envelope is substantial, i.e. a high rating for the variable INFILEST was obtained. If the
value for RVALUE is also large, the tendency for relatively long payback periods for energy conservation opportunities relating to MSYSTEMS is very probable. Thus, the relative value for RVALUE in this case would be large while the value for MSYSTEMS would be relatively small. Conversely, if the RVALUE is only moderate, the same energy conservation opportunities considered in the above situation would tend to have shorter payback periods. In general, this would produce a greater financial motivation for installation of the energy conservation opportunities than in the previous case where the value for RVALUE was large. Hence, in the latter situation described, the value for RVALUE would be relatively low while the value for MSYSTEMS would be comparably high. The magnitude of this combined interaction between RVALUE and MSYSTEMS becomes more and more pronounced as the relative energy consumption of the building decreases. That is, in general, the greater the energy efficiency of the building, the larger the combined value associated with RVALUE and MSYSTEMS. The correlation found between the variable MSYSTEMS and standardized energy consumption of the sample buildings adds support to this observed interaction. Generally speaking, as the integrity of the building envelope declines within the superior building classification, the relative payback periods decrease for the energy conservation opportunities in relation to the variable MSYSTEMS. Thus, even though the variability of RVALUE is small
in comparison to MSYSTEMS, the inverse proportion found with the combined variables (MSYSTEMS and RVALUE) and the standardized energy consumption of the sample buildings seem that much more probable.

To continue with the same correlation, in the energy excessive classification of buildings, the relative integrity of the building envelope has substantially deteriorated in comparison to the energy superior building classification (as indicated by the findings for the variable INFILEST). Although the value for the variable RVALUE may be relatively high in some cases, the exorbitant energy consumption due to the excessive air infiltration diminishes the effect the variable MSYSTEMS has on the overall energy consumption of the building. This situation would tend to result in relatively long payback periods for installation of energy conservation opportunities to improve the effectiveness of energy systems within the building (MSYSTEMS). To recapitulate the general situation for this case, as the infiltration of air through the building envelope becomes more excessive, the relative energy consumption of the building becomes higher. The corresponding payback periods associated with the installation of energy conservation opportunities to the energy systems of the building become longer and longer—i.e. the implemented energy conservation measures to the energy systems would be less and less effective. Consequently, in the extremely energy excessive buildings, the
effectiveness of implemented energy conservation measures to the energy systems of the building would be greatly reduced due to the overriding effect of excessive air infiltration through the building envelope. In situations such as these, it becomes more and more important to address the problem of excessive air infiltration rather than improving the efficiency of the energy systems.

The above speculation only encourages the initiation of an effective energy management program with a firm commitment by the top administrators of the school to reduce energy costs. However, this commitment presupposes that administrators are knowledgeable in the areas dealing with energy conservation of schools. It is this researcher's observation that school administrators in the state of Iowa are insufficiently equipped in the skills and knowledge necessary to achieve optimum energy efficiency within a school building/district. It is therefore suggested that courses dealing with successful energy management/conservation practices pertaining to school systems be initiated at institutions of higher learning which prepare students for degrees in educational administration.
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ACKNOWLEDGEMENTS

I wish to express gratitude to my graduate committee for guidance throughout this research study. Special appreciation is extended to my major professor, Dr. William Wolansky, for his patience and words of encouragement during the completion of this work. A special word of thanks is also given to Dr. William Miller, professor of Industrial Education, for the many hours of assistance with the statistical methods used in this research study. In addition, I wish to thank Dr. Walter Hart, associate professor of Professional Studies in Education, who has been a great inspiration and very supportive of this research.

Finally, I dedicate this paper to my wife and our two children. First, to my wife Andrea, for her unending patience, hard work, and expression of love. Secondly, to our children Clinton and Kara, for their acceptance of the many inconveniences thrust upon them during the completion of this project.
APPENDIX A. COMPLETE BUDGET BREAKDOWN FOR A
TYPICAL WISCONSIN SCHOOL (Olsen, 1978)

One Year's Operating Budget for a Typical
Elementary School in Madison, WI

<table>
<thead>
<tr>
<th>Budgetary item</th>
<th>% of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Energy</td>
<td>4</td>
</tr>
<tr>
<td>2. Instructional resources</td>
<td>7</td>
</tr>
<tr>
<td>3. Plant improvements and additions</td>
<td>1</td>
</tr>
<tr>
<td>4. Plant maintenance</td>
<td>8</td>
</tr>
<tr>
<td>5. Salaries</td>
<td>80</td>
</tr>
</tbody>
</table>

One Year's Operating Budget for a Typical
High School in Madison, WI

<table>
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<th>Budgetary item</th>
<th>% of total</th>
</tr>
</thead>
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<td>9</td>
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<tr>
<td>2. Instructional resources</td>
<td>6</td>
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<tr>
<td>3. Plant improvements and additions</td>
<td>1</td>
</tr>
<tr>
<td>4. Plant maintenance</td>
<td>10</td>
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<td>5. Salaries</td>
<td>67</td>
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<tr>
<td>6. Special programs</td>
<td>7</td>
</tr>
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</table>
## APPENDIX B. COMMON ENERGY CONVERSION FACTORS

(Gatts, Massey, and Robertson, 1974)

<table>
<thead>
<tr>
<th>Conversion Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 U.S. barrel</td>
</tr>
<tr>
<td>1 atmosphere</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>1 atmosphere</td>
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<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>1 pound per square inch</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>1 inch head of water</td>
</tr>
<tr>
<td>1 British thermal unit (Btu)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>1 therm</td>
</tr>
<tr>
<td>1 kilowatt (kW)</td>
</tr>
<tr>
<td>1 kilowatt-hour</td>
</tr>
<tr>
<td>1 horsepower (hp)</td>
</tr>
<tr>
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<tr>
<td>1 horsepower-hour</td>
</tr>
<tr>
<td>1 kilowatt-hour (kWh)</td>
</tr>
<tr>
<td>1 ton refrigeration</td>
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<tr>
<td>1 degree day</td>
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<tr>
<td></td>
</tr>
<tr>
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</tr>
<tr>
<td>1 year</td>
</tr>
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<td>1 MBtu</td>
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</table>
APPENDIX C. THE TOP TWENTY ENERGY CONSERVATION MEASURES
FOR WISCONSIN SCHOOLS (Olsen, 1978)

1. Heading the list of energy conservation opportunities is lowering the thermostats to 68°F during the heating season and raising the thermostats to 78°F during the cooling season.

2. Examine the entire building for air leaks. Seal all leaks.

3. Check the efficiency of the boiler(s).

4. Make monthly energy consumption and cost data available to top administration and the chief operating engineer.

5. Set back the heating season thermostats 10° during the night.

6. Turn off the cooling system during the night. Use ventilation air to cool the building at night.

7. Insulate hot, bare heating pipes.

8. Check steam traps to insure proper functioning.

9. Close off unoccupied areas.


11. Replace inefficient air conditioners. Newer units may save as much as 25% of the energy normally consumed.

12. Replace old, inefficient burners with new, efficient ones.

13. Install storm windows and/or double glaze windows where appropriate.

14. Correct the power factor on electrical devices as needed. Capacitors can be installed to correct for a low power factor.

15. Appeal for authorization to disregard codes and standards where they are a deterrent to energy conservation.

16. Lower domestic hot water heaters to 110°F.
17. Reduce fresh air to legal limits.

18. Check the boiler control system for proper functioning.

19. Remove excess lamps or fixtures. If only lamps are removed, disconnect ballasts. The ballast accounts for ten to thirty percent of the lamp's power drain.

20. Control exterior lighting. Use photocells and timers.
APPENDIX D. ENERGY CONSERVATION MEASURES
LISTED BY GENERIC TYPE
("Minnesota Mini Energy Audit Program," 1975)

Types 1 and 1A - Prewar Low Energy Schools

Type 1A has mechanical cooling
Dates of completion: 1920-1940
Plan type: double-loaded corridor
Construction: heavy frame and heavy walls
Mechanical systems: hot water or steam boiler, radiation type system
Lighting: originally incandescent, now largely high level fluorescent (2.0 or more watts/sq. ft.)
Classroom glass: 40 to 60 percent of exposed wall

Types 2 and 2A - Postwar Low Energy Schools

Type 2A has mechanical cooling
Date of completion: 1945 to present
Plan types: double or single-loaded corridors
Construction: light frame and light walls
Mechanical systems: hot water or steam boilers, unit ventilators or similar type systems
Lighting: incandescent or low fluorescent, high level fluorescent if modernized
Classroom glass: 70 to 90 percent of exposed wall
Types 3 and 3A - Artificial Environment Schools

Type 3A has mechanical cooling

Dates of completion: ca. 1965 to present

Plan types: compact

Construction: as Type 2

Mechanical systems: sophisticated air handling, as single- or double-duct, variable air volume, multi-zone, etc.

Lighting: high level fluorescent

Classroom glass: less than 40 percent, 5 to 15 percent typical

Type 1 and 1A Schools

Space heating conservation measures

1) Consider having a competent combustion engineer make a flue gas analysis at least once each year to properly adjust the fuel input and to check combustion.

2) Consider making the energy consumption and cost data available to the school principal and chief operating engineer so that they can evaluate and compare against previous months, normal budget, and perhaps against other schools.

3) Consider changing the spring, fall and winter day-night control settings to operate heating equipment fewer hours on the day cycle.

4) Consider connecting all of the manual day-night control switches to time clocks so that night setback temperatures can be achieved even if inadvertently left on "day."

5) Consider installing modulating oil burners to eliminate continuous cycling.

6) Consider derating the boiler(s) (decrease gas or oil input) so that the boiler(s) will operate over longer periods of time, decreasing off cycle losses.
7) Consider converting to a low pressure system to improve the heating system annual operating efficiency. The installation of small steam electric boilers near the termination of some steam lines may reduce the need for piping modifications.

8) Consider reinsulating the outer surface of the boilers to reduce heat loss.

9) Consider installing turbulators in boiler tubes to increase the heat transfer from the hot gases to the water side.

10) Consider insulating the exposed steam and condensate lines in classrooms.

11) Consider increasing the steam differential to increase the length of time the boiler stays on the line to reduce the energy loss during re- and post-purge cycles.

12) Consider measuring with the gas meter the fuel consumption of the boiler on manual versus automatic firing. During moderate temperature periods, the manual low fire setting should result in the boiler operating longer periods of time at a higher efficiency.

13) Consider installing automated damper controls to provide positive draft shutoff when the boiler is not operating.

14) Consider readjustment of damper control to maintain proper draft both high and low fire.

15) Consider informing teachers and building operators of possible savings by closing shades at night.

16) Consider automating boilers to start automatically when space temperature drops below a preset night temperature.

17) Consider installing a night thermostat to automatically control steam pressure during night hours to maintain the night setback temperature.

18) Consider the installation of an outside temperature reset controller to control steam pressure based on ambient temperatures.

19) Consider installing automatic steam control valves on some radiators to reduce the need for opening windows in rooms that overheat.
20) Consider adding some type of a key switch to hallway radiation valves so that the students cannot change the setting of the steam valves.

21) Consider adjustable vent air valves on radiators to aid in balancing system.

22) Consider operating the boilers off a timeclock during the spring and fall seasons and not permitting them to come on line during the night cycle.

23) Consider leaving one of the two boilers off during most of the winter heating season and perhaps during the entire season if the other boiler is capable of carrying the entire load under design conditions. A single boiler carrying the building space heating load will operate at a higher annual efficiency than two boilers dividing the load.

24) Consider setting all thermostats at 68°F for winter space heating.

25) Consider reducing the space heating hot water temperature to the lowest temperature that will satisfy heating needs.

26) Consider lowering steam pressure to minimum pressure that will heat the building.

27) Consider turning off the boiler natural gas standing pilot during the summer months when the boiler is off.

28) Consider revising the boiler control system so that the exhaust damper will be closed instead of open when the boiler operating control is satisfied.

Domestic hot water conservation measures

1) Consider reducing the domestic hot water temperature to 110°F or less.

2) Consider shutting off the hot water heater(s) during the summer when the school is unoccupied.

3) Consider installing a small domestic hot water heater to maintain the desired temperature in the water storage tank to eliminate the need for running one of the large space heating boilers at a very low efficiency during the summer months.
4) Consider insulating pool heat exchangers and adjacent steam piping.

5) Consider replacing the existing shower heads with units that will allow no more than 2 gpm water flow.

6) Consider shutting off circulating lines when possible to reduce radiation losses.

Ventilation system conservation measures

1) Consider adjusting the timeclock day-night settings to operate ventilation units fewer hours during the day cycle.

2) Consider operating the ventilation system only when the school is occupied. Also, consider shutting off the air handling units on normal heating days before school is out. If the steam radiators are located properly, they should be able to maintain space temperatures above freezing.

3) Consider adjusting the manual fresh air dampers to reduce the quantity of outside air heated by the ventilation system. Also, consider modifying the ventilation system to permit more return air to be recirculated. If this is done the fresh air-return air should be controlled with motorized dampers.

4) Consider operating the gym 100% outside air ventilation unit on a reduced operating schedule that coincides with occupancy of the gym. Also, consider the possibility of changing the outside air damper setting to reduce the amount of outside air brought into the gym and should be turned off immediately after the class leaves the gym in the afternoon.

5) Consider reinsulating some of the steam piping, especially near the air handling units.

6) Consider valving off steam headers in the boiler room to individual air handling units when off to reduce steam piping heat losses.

7) Consider not operating the ventilation units at all during the spring and fall because many of the windows in the classrooms are open during this time of the year.

8) Consider not operating the ventilation system at all except for pickup on cold mornings.
9) Consider operating the ventilation units with no outside air whenever the outside temperature is 25°F or below. There should be sufficient fresh air leakage through the dampers to provide adequate ventilation.

10) Consider installing an automation system to operate the ventilation units so that supply air temperature and return air-fresh air dampers can be adjusted to maintain the desired space temperature in the rooms.

**Lighting system conservation measures**

1) Consider acquiring energy conservation reminders such as posters and individual decals that can be located next to the light switches and on bulletin boards to alert both teachers and building staff that turning off lights is their responsibility.

2) Consider new high efficient light sources and fixtures when remodeling.

3) Consider using light colored reflective paint when redecorating.

4) Consider leaving the classroom exterior (window side) light switch off on sunny days to take advantage of outside natural lighting.

5) Consider raising the blinds and turning off the lights in those classrooms that have one full wall of windows.

6) Consider photo-cell control rather than timeclock on security lights.

7) Consider replacing the gym incandescent lighting systems with mercury vapor or other high efficiency source.

8) Consider initiating a training program to orient the gym instructors and the students in the proper operation of gym lighting so that no more than 50% to 75% of the lights are on at any one time when the gym is occupied, provided switching is available.

9) Consider the possibility of installing a desk lamp for the instructors so that they can occupy the classroom without all of the lights being on.
10) Consider leaving the hallway lighting off on those hall­
ways facing the interior courtyards during daylight hours, 
assuming a light meter reading indicates the lighting 
level is satisfactory.

11) Consider cleaning fixture lenses more often to improve 
lighting efficiency.

Building structural conservation measures

1) Consider weatherstripping all of the windows to reduce the 
infiltration. If this is done the school may be maintained 
at a positive pressure with the addition of very little 
outside air.

2) Consider weatherstripping the outside doors to reduce air 
infiltration.

3) Consider recaulking around all of the windows if existing 
caulking has cracked.

4) Consider reinsulating the ceiling with some type of spray 
on insulation. It might also be possible to consider 
blowing a mineral wool insulation on the top of the 
ceiling plenum or batt type between ceiling joists.

5) Consider covering and insulating the upper half of the 
exterior windows to reduce heat loss.

6) Consider adding storm windows to every other window of the 
building. Storms on 50% of the windows would still leave 
enough windows for ventilation during spring and fall 
schedules.

7) Consider adding another set of doors on the main entrance 
so that this area will serve as a vestibule.

Type 2 and 2A Schools

Space heating conservation measures

1) Consider having a competent combustion engineer make a flue 
gas analysis at least once each year to properly adjust the 
fuel input and to check combustion.
2) Consider making the energy consumption and cost data available to the school principal and chief operating engineer so that they can evaluate and compare against previous months, normal budget, and perhaps against other schools.

3) Consider changing the spring, fall and winter day-night time-clock settings to operate heating equipment fewer hours on the day cycle.

4) Consider connecting all of the manual day-night control switches to timeclocks so that night setback temperatures can be achieved even if inadvertently left on "day."

5) Consider starting the furnace ventilation fans later in the morning and shutting off earlier in the evening. Consider operating furnace fans on continuous "day" or "occupied" setting only while rooms are normally scheduled to be occupied. In mild weather, operating time can be much shorter due to the fact "pick-up" is faster. Classrooms should be up to temperature setting when class starts.

6) Consider operating the boiler off a timeclock during the spring and fall seasons and not permitting them to come on line during the night cycle.

7) Consider operating only one of the space heating water pumps during spring and fall and possibly during the entire year. Consider adjusting the timeclock to permit heating pumps to operate fewer hours on the day cycle.

8) Consider leaving one of the two boilers off during most of the winter heating season and perhaps during the entire season if the other boiler is capable of carrying the entire load under design conditions. A single boiler carrying the building space heating load will operate at a higher annual efficiency than two boilers dividing the load.

9) Consider installing night thermostats to operate the ventilation fans on nights and weekends instead of the on-off cycle with timeclocks. Night setting or "unoccupied" should start fan and burner with outside air "closed" to maintain minimum room temperature.

10) Consider connecting the space heating hot water pumps to the timeclock so that they will only operate when the boiler is on.
11) Consider setting all thermostats at 68°F for winter space heating.

12) Consider reducing the space heating hot water temperatures to the lowest temperature that will satisfy heating needs.

13) Consider installing turbulators in the boiler tubes to improve the heat transfer within the boilers.

14) Consider installing an outdoor temperature sensor that will adjust the boiler water temperature or steam pressure based on outside ambient temperatures.

15) Consider turning off the boiler natural gas standing pilot during the summer months when the boiler is off.

16) Consider building penthouse type enclosures around rooftop units to reduce radiation and wind losses from exposed ducts.

17) Consider informing teachers and building operators of possible savings by closing drapes and shades at night.

18) Consider lowering steam pressure to minimum pressure that will heat the building.

19) Consider revising the boiler control system so that the exhaust damper will be closed instead of open when the boiler operating control is satisfied.

**Domestic hot water conservation measures**

1) Consider reducing the domestic hot water temperature to 110°F or less.

2) Consider operating only one of the domestic hot water heaters. If one unit carries the load, leave the other off for standby.

3) Consider shutting off the hot water heater(s) during the summer when the school is unoccupied.

4) Consider replacing the shower heads with units that will allow less than 2 gpm water flow.
### Ventilation system conservation measures

1) Consider a temperature control training program for the operating engineers that will give them a thorough understanding of how the heating and ventilating system was designed to operate. Include optimization of energy via temperature control.

2) Consider acquiring the services of a temperature control expert to check and adjust all system controls and to recommend modifications.

3) Consider adjusting the timeclock day-night settings to operate ventilation units (unit ventilators) fewer hours during the day cycle.

4) Consider turning off all electricity to classrooms during unoccupied hours during spring and fall to keep ventilators from running 24 hours per day if remote electric power panels are conveniently located.

5) Consider leaving the multi-purpose room (gyms and auditoriums) ventilation unit in the night position all times except when the room is occupied.

6) Consider increasing the mixed air temperature setting on unit ventilators to 65°F to 68°F. If this is not practical, consider adjusting the fresh air linkage so that the mixed air temperature cannot go below.

7) Consider reducing the minimum outside setting on all unit ventilators and rooftop units to permit less fresh air under design winter conditions.

8) Consider changing all fresh air limit control settings to make them consistent.

9) Consider increasing the multi-purpose room (gyms and auditoriums) ventilation units mixed air temperature from 55°F to 65°F-68°F to reduce the heating requirements during the winter.

10) Consider readjusting fresh air limit controllers from winter to summer earlier than the middle of May.

11) Consider modernizing unit ventilator systems to economizer type control so room thermostats sense and control mixed air temperature for free-cooling but close outside air when heat is needed.
12) Consider cleaning the filters more often to increase the overall efficiency of the air handling units.

13) Consider shutting off the secondary hot water pumps located in the air handling units during the spring, fall and summer when heating is not required.

14) Consider reducing the temperature of the hot deck in each multi-zone unit.

**Lighting system conservation measures**

1) Consider acquiring energy conservation reminders such as posters and individual decals that can be located next to the light switches and on bulletin boards to alert both teachers and building staff that turning off the lights is their responsibility.

2) Consider new high efficient light sources and fixtures when remodeling.

3) Consider using light colored reflective paint when redecorating.

4) Consider leaving the classroom exterior (window side) light switch off on sunny days to take advantage of outside natural lighting.

5) Consider raising the blinds and turning off the lights in those classrooms that have one full wall of windows.

6) Consider phot-cell control rather than timeclock on security lights.

7) Consider replacing the gym incandescent lighting systems with mercury vapor or other high efficiency source.

8) Consider initiating a training program to orient the gym instructors and the students in the proper operation of gym lighting so that no more than 50% to 75% of the lights are on at any one time when the gym is occupied, provided switching is available.

**Building structural conservation measures**

1) Consider weatherstripping the existing operable awning type windows with a thin rubber gasket strip.
2) Consider weatherstripping the outside doors to reduce air infiltration.

3) Consider covering and insulating a portion of the window covered with blinds with rigid insulation and a metal panel.

4) Consider installing rigid insulation between metal panels located below windows.

5) Consider increasing roof insulation when reroofing.

6) Consider recaulking around all of the windows if existing caulking has cracked.

Type 3 and 3A Schools

Space heating conservation measures

1) Consider having a competent combustion engineer make a flue gas analysis at least once each year to properly adjust the fuel input and to check combustion.

2) Consider making the energy consumption and cost data available to the school principal and chief operating engineer so that they can evaluate and compare against previous months, normal budget, and perhaps against other schools.

3) Consider hiring an engineering consultant to review and develop heating system standard operating procedures.

4) Consider changing the spring, fall and winter day-night timeclocks settings to operate heating equipment fewer hours on the day cycle.

5) Consider connecting all of the manual day-night control switches to timeclocks so that night setback temperatures can be achieved even if inadvertently left on "day."

6) Consider operating the boilers off of a timeclock during the spring and fall seasons and not permitting them to come on line during the night cycle.

7) Consider operating only one of the space heating water pumps during spring and fall and possibly during the entire year. Consider adjusting the timeclock to permit heating pumps to operate fewer hours on the day cycle.
8) Consider connecting the space heating hot water pumps to the timeclock so that they will only operate when the boiler is on.

9) Consider leaving one of the two boilers off during most of the winter heating season and perhaps during the entire season if the other boiler is capable of carrying the entire load under design conditions. A single boiler carrying the building space heating load will operate at a higher annual efficiency than two boilers dividing the load.

10) Consider shutting off boilers during the spring and fall when the air conditioning machine is off and temperature control is not needed.

11) Consider setting all thermostats at 68°F for winter space heating.

12) Consider reducing the space heating hot water temperature to the lowest temperature that will satisfy heating needs.

13) Consider reducing the steam pressure to the lowest pressure that will satisfy heating needs.

14) Consider installing a small gas or electric steam boiler near the pool heat exchanger to satisfy this heating requirement and also a small gas fired domestic hot water heater in the boiler room to eliminate the need for operating the large steam boilers during peak season.

15) Consider adjusting the boiler so that during the spring, summer and fall the boiler will come on line at low fire and stay on low fire until the heating requirement is satisfied. We feel that the boiler will cycle less often and maintain a higher overall annual efficiency with this operating procedure.

16) If the hot water boilers must be operated during the spring, summer and fall, consider shutting off one or more of the hot water into the air handling hot water coils, increasing the heating requirement.

17) Consider changing the night setback temperatures from 60°F to 55°F, especially in spring and fall when mild weather exists.

18) Consider not preheating the combustion air that is brought into the boiler room.
19) Consider installing turbulators in the boiler tubes to improve the heat transfer within the boilers.

20) Consider installing an outdoor temperature sensor that will adjust the boiler water temperature or steam pressure based on outside ambient temperatures.

21) Consider turning off the boiler natural gas standing pilot during the summer months when the boiler is off.

22) Consider building penthouse type enclosures around rooftop units to reduce radiation and wind losses from exposed ducts.

23) Consider informing teachers and building operators of possible savings by closing drapes and shades at night.

24) Consider revising the boiler control system so that the exhaust damper will be closed instead of open when the boiler operating control is satisfied.

Domestic hot water conservation measures

1) Consider reducing the domestic hot water temperature to 110°F or less. If the kitchen does not have a hot water booster unit, it may be worthwhile installing a separate booster heater and then reducing the domestic hot water storage tank temperature to 110°F or less.

2) Consider operating only one of the domestic hot water heaters. If one unit carries the load, leave the other off for standby.

3) Consider shutting off the hot water heaters(s) during the summer when the school is unoccupied.

4) Consider having a competent combustion engineer make a flue gas analysis at least once each year to properly adjust the fuel input and to check combustion.

5) Consider connecting the domestic circulating line water pumps to a timeclock.

6) Consider changing the shower heads from the existing gpm rating to 2 gpm. Also consider the possibility of adding a timer on each shower so that they cannot be left on longer than a predetermined period.

7) Check for internal scale deposits on coil-type tank heaters and delime when necessary.
Ventilation system conservation measures

1) Consider a temperature control training program for the operating engineers that will give them a thorough understanding of how the heating and ventilating system was designed to operate. Include optimization of energy via temperature control.

2) Consider acquiring the services of a temperature control expert to check and adjust all control systems and to recommend modifications.

3) Consider sending the chief engineer to visit other buildings that have obtained significant energy savings with their HVAC automation systems.

4) Consider adjusting the timeclock day-night settings to operate ventilation units fewer hours during the day cycle. Operate ventilation units the shortest period that is acceptable.

5) Consider operating systems on "warm-up" cycle: (no outside air) until classes are in session.

6) Consider operating exhaust fans only when needed. Consider separate timeclocks for these cycles. Some pressurized buildings may not require all of the exhaust fans to operate for proper ventilation.

7) Consider using minimum amounts of outside air when either heating or cooling is required and make maximum use of outside air when conditions are correct for "free" cooling.

8) Consider enthalpy controls on outside air use.

9) Consider separate controls and schedules for office and kitchen areas.

10) Consider operating air systems in gym, auditorium, cafeteria and shop areas only when areas are occupied. Consider a "start-stop" station in the area so that the authorized persons may cooperate with energy conservation recommendations.

11) Consider heat recovery or exchange between make-up and exhaust air.

12) Consider reducing the volume of air circulated by adjusting the inlet valves on the supply air fans. This should decrease the horsepower requirements of these units.
13) Consider increasing the ventilation units summer mixed air temperature to minimize the air conditioning and reheat requirements.

14) Consider raising cold deck temperatures to highest temperature that will still give acceptable humidity control.

15) Consider lowering hot deck temperatures to point that will just satisfy system.

16) Consider increasing the supply air temperatures on all air handling units to the point where at least one space served by each unit is warmer than desired.

17) Consider turning off electric reheat coils during the summer. With increased supply air temperatures, reheat may not be needed.

18) Consider sealing ducts in equipment rooms to minimize short circulating of hot and cold air.

19) Consider maintaining filters preferably by pressure drop readings. Consider installing differential gauges.

20) Consider valving off steam or hot water lines seasonally when not needed. Do this preferably on the boiler room heater.

21) Consider higher room temperature of 78°F in summer.

22) Consider periodically logging temperature and pressure readings of operating systems. By comparing these readings, subtle changes can be noted and corrections made to bring back to optimum conditions.

23) Consider adjusting or replacing all supply air temperature gauges so that accurate ventilation temperatures can be read and maintained.

24) Consider combining class activities into one section of the building in the summer to eliminate the need for running all of the air handling units.

**Air conditioning system conservation measures**

1) Consider operating only those water pumps needed to maintain flow volume where multiple pumps are installed in parallel. This would apply to chilled water pumps and condenser water pumps.
2) Consider setting the demand limiter on the chiller at lowest setting that will maintain the building temperature.

3) Consider installing a second timeclock for the chiller equipment so that it can be started later and shut off earlier on those days when minimum air conditioning is required, making use of the building "fly wheel" effect.

4) Consider shutting off chilling equipment when the building has no real need for cooling (nights and weekends). Valve leakage can waste energy.

5) Consider supplying chilled water at highest temperature possible as lower than necessary temperatures require larger energy inputs.

6) Consider raising room temperatures seasonally be steps to match increase in outside temperatures.

7) Consider raising setting of electric drinking water coolers to reduce energy consumption.

Lighting system conservation measures

1) Consider acquiring energy conservation measures such as posters and individual decals that can be located next to the light switches and on bulletin boards to alert both teachers and building staff that turning off the lights is their responsibility.

2) Consider new high efficient light sources and fixtures when remodeling.

3) Consider disconnecting ballasts from fixtures where tubes have been removed. Ballasts consume a small amount of energy and will eventually burn out.

4) Consider using light colored reflective paint when redecorating.

5) Consider leaving the classroom exterior (window side) light switch off on sunny days to take advantage of outside natural lighting.

6) Consider raising the blinds and turning off the lights in those classrooms that have one full wall of windows.
7) Consider photo-cell control rather than timeclock on security lights.

8) Consider replacing the gym incandescent and/or fluorescent lighting systems with mercury vapor or other high efficiency source.

9) Consider initiating a training program to orient the gym instructors and the students in the proper operation of gym lighting so that no more than 50% to 75% of the lights are on at any one time when the gym is occupied, provided switching is available.

10) Consider installing timers on gym and field house lighting systems that will automatically shut off lights after each class.

11) Consider the installation of photo-cell and timeclock to operate some of the swimming pool lights during occupied hours.

12) Consider turning off all of the cafeteria-lunchroom lights when unoccupied and switching on by sections when cleaning.

13) Consider installation of switching capability in classrooms so certain rows of lights can be used as needed.

Building structure conservation measures

1) Consider insulating penthouse room metal walls to reduce heat loss and heat gain.
APPENDIX E. EXAMPLE OF WEIGHT FACTORS AND
A PRELIMINARY ENERGY AUDIT FORM (Sullivan, 1978)

Examples of Weight Factors

Heat recovery

If percent outside air to total air is high and heat recovery is feasible, considerable energy can be recovered.

<table>
<thead>
<tr>
<th>Range</th>
<th>Weight factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>100% outside air with recovery feasible</td>
<td>90</td>
</tr>
<tr>
<td>75% outside air with recovery feasible</td>
<td>80</td>
</tr>
<tr>
<td>50% outside air with recovery feasible</td>
<td>70</td>
</tr>
<tr>
<td>100% outside air with recovery difficult</td>
<td>60</td>
</tr>
<tr>
<td>Heat recovery not feasible</td>
<td>50</td>
</tr>
</tbody>
</table>

User inconvenience

The building user may or may not be able to tolerate the disruption caused by installation of major retrofits. This factor should be addressed as follows:

<table>
<thead>
<tr>
<th>Range</th>
<th>Weight factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>User can tolerate major retrofit</td>
<td>90</td>
</tr>
<tr>
<td>User can tolerate minor retrofit</td>
<td>70</td>
</tr>
<tr>
<td>User cannot tolerate any disruptions</td>
<td>50</td>
</tr>
</tbody>
</table>
## Preliminary Audit Evaluation Form

<table>
<thead>
<tr>
<th>Item</th>
<th>Relative importance factor</th>
<th>X Weight factor</th>
<th>Eval.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Annual energy use Btu source plus square feet</td>
<td>.10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Ratio occupancy hours to operating hours</td>
<td>.16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Rated capacity of heating plus cooling equipment</td>
<td>.10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Modification potentials</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Building age and life expectancy</td>
<td>.04</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. Building envelope—percent glass and infiltration</td>
<td>.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. Lighting levels</td>
<td>.07</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. HVAC system type</td>
<td>.14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. Ratio outside air to total air</td>
<td>.09</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F. Fan energy</td>
<td>.06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G. Controls maintenance and performance</td>
<td>.06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H. Base load—process, DHW, etc.</td>
<td>.03</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I. Heat recovery</td>
<td>.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>J. User inconvenience</td>
<td>.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td><strong>1.00</strong></td>
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<td></td>
</tr>
</tbody>
</table>
APPENDIX F. A DIAGRAM OF THE PUBLIC SCHOOLS

ENERGY CONSERVATION SURVEY (PSECS) PROCESS (Boice, 1976)
Outside groups

District

PSECS

District requests PSECS assistance

PSECS sends Data Base Guidelines (PS2) and Data Forms (PS4)

District sets up data base and returns Data Forms (PS4)

PSECS classifies schools; prepares and sends Energy Report (PS5, PS6)

District selects course(s) of action

PSECS prepares and sends Self-Audit (PS8)

Utility Mini-Audit Consulting A/E Services

District performs Self-Audit

PSECS sends Capital Audit Form (PS9)

District fills out and returns Capital Audit Form (PS9)

PSECS prepares and sends Capital Modifications Survey (PS10)

District takes appropriate action

PSECS uses feedback to revise system
APPENDIX G. ENERGY AUDITING INSTRUMENTS

Temperature Measurement
Thermometers: Thermometer type used is determined by cost, durability, and application. Temperature range is the major consideration.
Surface pyrometer: A surface pyrometer measures the temperatures of surfaces. Pyrometers measure heat loss through walls and test steam traps.
Psychrometer: The psychrometer measures relative humidity.
Suction pyrometer: The suction pyrometer is especially useful in measuring high gas temperatures. Sensitivity of measurement is accomplished with a thermocouple.

Electrical System Measurements
Ammeter: The ammeter is used to measure electrical current through a conductor.
Voltmeter: A voltmeter measures the difference in electric potential between two points in a circuit.
Wattmeter: The wattmeter is used to make a direct measurement of the wattage through an electrical circuit.
Power factor meter: The power factor meter is a three-phased instrument which is used to measure sources of poor power factor within energy using systems.
Footcandle meter: The footcandle meter measures the level of illumination through the use of photosensitive cells.

Combustion System Measurements

Combustion tester: The combustion tester measures the amount of excess oxygen as well as the concentration of combustion products in the stack gas. The Orsat apparatus is normally used in this test.

Boiler test kit: This test kit measures the concentrations of carbon monoxide, carbon dioxide, and oxygen.

Draft gauge: The draft gauge is used to measure pressure.

Smoke tester: The smoke tester measures the extent to which combustion has taken place. A probe with a filtering mechanism is inserted in the stack gas. The resulting smoke residue is then compared with a standard scale.
APPENDIX H. DEMONSTRATION SITES FOR THE
'SAVING SCHOOLHOUSE ENERGY PROJECT'

DEMONSTRATION SITES

UNITED STATES - CLIMATE ZONES

HEATING DEGREE DAYS
ZONE 1 - OVER 9,000 DEGREE DAYS
ZONE 2 - 6,000 - 9,000 DEGREE DAYS
ZONE 3 - 3,000 - 6,000 DEGREE DAYS
ZONE 4 - UNDER 3,000 DEGREE DAYS
APPENDIX I. ENERGY CONSERVATION GUIDELINE
ELEMENTS AND CORRESPONDING EXPLANATIONS (Hicks, 1978)

<table>
<thead>
<tr>
<th>Guideline element</th>
<th>Explanation of guideline</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Insulation</td>
<td>1. Adequate insulation for facility that meets specifications for temperate zone</td>
</tr>
<tr>
<td>2. Roof and ceiling (R-19)</td>
<td>2. Minimum R-value for roof and ceiling areas should be R-19</td>
</tr>
<tr>
<td>3. Walls (R-11)</td>
<td>3. Minimum R-value for outside wall areas should be R-11</td>
</tr>
<tr>
<td>4. Floors (R-7-11)</td>
<td>4. Minimum R-value for floor areas should be R-7</td>
</tr>
<tr>
<td>5. Air infiltration</td>
<td>5. Correction of unwanted air infiltration</td>
</tr>
<tr>
<td>6. Storm doors, windows or plastic window kits</td>
<td>6. Elements used for correction of unwanted air infiltration</td>
</tr>
<tr>
<td>7. Double windows</td>
<td>7. Use of double windows (thermo-pane) rather than single pane</td>
</tr>
<tr>
<td>8. Triple windows</td>
<td>8. Use of triple windows rather than double or single pane windows</td>
</tr>
<tr>
<td>9. Weatherstripping and caulking</td>
<td>9. Use of sealants for correction of unwanted air infiltration</td>
</tr>
<tr>
<td>10. Ventilation</td>
<td>10. Adequate ventilation to maintain proper moisture control and to meet exhaust requirements</td>
</tr>
<tr>
<td>11. Heating/cooling</td>
<td>11. Heating/cooling plan that makes efficient use of units without sacrificing thermal comfort</td>
</tr>
<tr>
<td>12. Non air conditioned zones</td>
<td>12. Turning off heating/cooling in zones such as garages, docks, loading platforms and unused areas</td>
</tr>
<tr>
<td>Guideline element</td>
<td>Explanation of guideline</td>
</tr>
<tr>
<td>--------------------------------------</td>
<td>----------------------------------------------------------------</td>
</tr>
<tr>
<td>13. Automatic timers and photocells</td>
<td>13. Use of timers to activate or deactivate heating/cooling and lighting units</td>
</tr>
<tr>
<td>14. Night/holiday setback</td>
<td>14. Use of night/holiday setback controls to conserve heating/cooling and lighting energy use during unoccupied intervals</td>
</tr>
<tr>
<td>15. Lighting</td>
<td>15. Reducing lighting levels to meet recommended standards</td>
</tr>
<tr>
<td>16. Room decor</td>
<td>16. Use of room decor to enhance or improve lighting efficiency</td>
</tr>
<tr>
<td>17. Maintenance</td>
<td>17. Proper maintenance of all appliances and equipment</td>
</tr>
<tr>
<td>18. Water conservation</td>
<td>18. Use of flow restrictors for showerheads, toilets, and faucets</td>
</tr>
<tr>
<td>19. Lower thermostat temperature level on water heaters</td>
<td>19. 150°F temperature is adequate for general water usage (most water heater thermostats are set much higher)</td>
</tr>
<tr>
<td>20. Landscaping</td>
<td>20. Use of deciduous trees for providing shade in summer, sun in winter; use of evergreens as windbreaks; use of trees and shrubs to provide cooling effect near facility perimeter</td>
</tr>
<tr>
<td>21. Training</td>
<td>21. Training programs in energy conservation for all staff members</td>
</tr>
<tr>
<td>22. Goals and objectives</td>
<td>22. Setting goals and objectives for energy conservation in the facility</td>
</tr>
<tr>
<td>23. Enlightenment</td>
<td>23. Informing system population of goals and objectives</td>
</tr>
<tr>
<td>24. Administrative policy</td>
<td>24. Written policy of energy conservation philosophy of the system</td>
</tr>
<tr>
<td>Guideline element</td>
<td>Explanation of guideline</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>--------------------------------------------------------------</td>
</tr>
<tr>
<td>25. Administrative commitment</td>
<td>25. Total commitment to energy conservation by top level</td>
</tr>
<tr>
<td></td>
<td>administrators in the system</td>
</tr>
<tr>
<td></td>
<td>opportunities</td>
</tr>
<tr>
<td>27. Energy conservation committee</td>
<td>27. Committee appointed to determine energy conservation</td>
</tr>
<tr>
<td></td>
<td>opportunities and to develop goals and objectives for efficient energy use</td>
</tr>
</tbody>
</table>
APPENDIX J. LETTER TO SUPERINTENDENTS

Dear Superintendent:

Thank you for your cooperation and participation in this important research. I will be visiting the ________ building on January ___. As I indicated in our telephone conversation before Christmas, I would like you, the building principal, and the head custodian (director of maintenance) to complete the enclosed survey forms. Those surveys with code numbers marked in RED ink are to be completed by administrators. The form coded in BLUE ink should be completed by the head custodian or director of maintenance.

While visiting this school building I would like to collect the following information:
1. the orientation of the building to the prevailing winds.
2. the amount of glassed area on the exterior walls*,
3. the construction materials used in walls, roof, and floor slab* (including air space and insulation),
4. record whether the building has vestibules at entrances, and
5. pick up the completed survey forms.

*These measurements are usually available from "building specifications" (blue prints) or energy audit reports.

If the building specs or an energy audit report is available, the amount of time needed for physically inspecting the building would be greatly reduced (or even eliminated since I could take the necessary information directly from these forms). If either of these items could be "on hand" during my visit, it would be greatly appreciated. (I have scheduled two hours for each school visitation and plan to visit three schools per day).

Should bad weather or other unforeseen circumstances prevent my visit on the date stated above, I will contact you as soon as possible for an alternate date.

Thanks again for all your help. Sincerely,

Consultant:  
Mr. Benjamin Guise  
Iowa Energy Policy Council  
Des Moines, Iowa  
(515)281-4075

Denis E. Zeimet  
(515)233-4087  
Major Professor:  
Dr. William Wolansky  
Iowa State University  
Ames, Iowa  
(515)294-1033
APPENDIX K. ENERGY CONSERVATION SURVEY FOR
PRINCIPALS AND SUPERINTENDENTS

Energy efficient schools are necessary to insure money budgeted for the educational program is not squandered on fuel bills which might have been avoided. School buildings must be made as energy efficient as possible within a limited budget.

This study is being conducted in an effort to improve energy efficiency of school buildings. Data pertaining to physical characteristics, maintenance procedures, administrative impact, and patterns of energy use will be collected in survey form. A composite of this information will hopefully show significant factors and trends in the area of energy conservation. Schools involved in the study have been coded. Respondents will not sign any forms to insure anonymity. Personnel chosen as respondents in the study may refuse to complete the form at any phase. The origin of the data will be kept in strictest confidence by the experimenter.

A complete explanation of the experiment and significant results will be provided upon request at the conclusion of the study.

( ) the district wishes to have a copy of the results of this study.
Building code: ___________ Building category: Elem Sec

Directions: Please check (✓) or fill in the appropriate answers below dealing with your background and respond to other questions and statements pertaining to energy conservation within your school. Confidentiality of information gathered will be held in highest regard. No reference by name will be made to any particular school or school personnel in the analysis of the data.

Section I

1. Please check your present title:
   ___ principal  ___ superintendent  ___ asst. superintendent

2. Number of years experience:
   this school: ___ yrs.  admin. career: ___ yrs.

3. B.A. degree earned in __________ (discipline).

4. Please list any energy related courses or workshops you have completed (list semester credit hours if applicable).

5. Are any of the following building modifications anticipated within the next five years for this building? (Please check one)
   ___ a. new construction (e.g. addition or wing)
   ___ b. remodeling or retrofit
   ___ c. demolition or closing of school building
   ___ d. no changes planned at this time
6. Has an energy audit been completed for this building?
   ___Yes. . . Date last energy audit was completed: ______
   ___No

7. Has an energy manager been designated for the school district?
   ___Yes. . . Please check one:
   ___a. duties were added to existing job description
   ___b. new position--full-time or part-time
   ___No

8. Assign the following in RANK ORDER (most to least) according to their importance in maintaining the present level of the educational program in this building:

    curriculum                     Most
    energy conservation            1.______________________________
    other administrative problems  2.______________________________
    salaries                      3.______________________________
    staff development             4.______________________________
    student discipline            5.______________________________
    student discipline

9. What is the greatest opposition in working towards a solution of energy related problems in this building? (Please choose one - combinations may be listed under choice e.)

   ___a. subordinates
   ___b. supervisors
   ___c. bureaucratic "red tape"
   ___d. lack of funds
   ___e. other: ________________________________
10. a. Has this school building had funds made available for upgrading the building envelope or energy system?

___Yes . . . ___ Schoolhouse tax or similar levy
(year passed____)
___ Grant from Iowa Energy Policy Council
(type and amount________)
___ General budget
(amount designated $____)
___ Other: ________________________________

___No

b. Major area(s) of applied funds:

___ insulation
___ lighting
___ windows and/or infiltration of air
___ boiler or heating system
___ other energy conservation measures (Please elaborate)

11. Are monthly fuel bills analyzed for energy use patterns of individual buildings within the school district?

___Yes . . . Who is responsible for the analysis? (title)

___No
Section II

Directions: The following statements represent actions and policies which may be important to the success of energy conservation and energy cost reduction in Iowa school buildings. FOR EACH STATEMENT, CHOOSE THE RESPONSE WRITTEN BELOW WHICH YOU FEEL COULD BE REALISTICALLY ATTAINED in consideration of your other administrative duties and responsibilities. Mark (x) your choice to the LEFT of the response. (A mark (x) to the left of the response "no action taken" indicates you feel no action is realistically possible in consideration of other administrative duties and responsibilities.)

Next, ON THE SCALE TO THE RIGHT OF EACH STATEMENT, RANK THE STATEMENT IN TERMS OF ITS IMPORTANCE TO THE SUCCESS OF ENERGY CONSERVATION AND ENERGY COST REDUCTION IN IOWA SCHOOL BUILDINGS. For example, if you feel the statement has little importance in relation to the total energy conservation effort, circle a low number on the scale. If you feel the statement is very important in relation to the total energy conservation effort, circle a high number on the scale. ONE REPRESENTS THE LOWEST MARK. FIVE REPRESENTS THE HIGHEST MARK.

<table>
<thead>
<tr>
<th>STATEMENT</th>
<th>SCALE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Little Importance</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>Very Important</td>
<td></td>
</tr>
</tbody>
</table>

1. Conducting a "walk-through audit"* on a regular basis with an energy team

Responses:

___a. no action taken
___b. semi annually
___c. annually
___d. biannually
___e. greater than biannually

* A "walk through audit" is defined here as an organized inspection of the building and its energy systems without the aid of highly technical equipment.
2. Contacting other professionals for assistance with energy conservation measures
   (1 2 3 4 5)
   a. no action taken
   b. consulting other principals and/or superintendents
   c. in addition to the above, consulting public utility personnel and/or other technicians
   d. in addition to the above, consulting state energy department employees with expertise in the given area
   e. in addition to the above, consulting a qualified engineer or engineering firm which specializes in energy conservation measures for schools

3. Employing or designating an energy manager for the school district
   (1 2 3 4 5)
   a. no action taken
   b. duties are generally assumed to be part of the superintendent's responsibilities
   c. duties are added to the job description of a presently employed person - no change in salary
   d. a person is hired to fill a part-time position
   e. a person is hired to fill a full-time position

4. Insuring energy education is an important and functional part of the school curriculum
   (1 2 3 4 5)
   a. no action taken
   b. reviewing course outlines - adding material if feasible (or at instructor's discretion)
   c. conducting a curriculum study to evaluate the extent to which energy education is presently taught - revising as needed
__d. in addition to the above, the newest concepts in energy education are implemented into the present instructional program - consultants at the university level are utilized

__e. in addition to the above, completely new courses dealing with energy education are implemented - these courses might be considered as "pilot studies" from which other schools could model

5. Providing inservice for the teaching staff to improve their background in energy education

__a. no action taken

__b. inservice meetings are scheduled within the school year but the emphasis on energy education must share time with many other topics

__c. inservice meetings and/or workshops are provided for those teachers interested in improving their energy education background

__d. department chairpersons and/or selected staff members are given inservice training to help implement energy education within the existing curriculum

__e. all staff members receive inservice training to help implement energy education within the existing curriculum

6. Establishing policies which reflect an administrative commitment to reduce energy costs

__a. no action taken

__b. unwritten policy - generally assumed as part of existing administrative duty to trim unnecessary costs from the budget

__c. verbal or written statement by the superintendent and/or principal (e.g. memos or monthly reports to the staff)

__d. in addition to the above, unofficial commitment by the Board - mentioned in minutes of board meeting - superintendent directed to act accordingly
e. official policy statement which expresses a commitment to reduce energy costs within the district - this top level commitment is voted upon, passed, and publicized by the Board of Education.

7. Providing incentives for energy conservation within the school

   a. no action taken
   b. giving special recognition to energy conservation units conducted within the classroom
   c. encouraging and promoting authorized energy conservation activities originating from individual classes within the curriculum
   d. in addition to the above, occasionally fostering contests and providing rewards via the central office (or other administrator initiative)
   e. initiating a variety of rewards and incentives on a frequent and continuing basis through the central office

8. Appointing an energy team to facilitate energy conservation measures at the building level

   a. no action taken
   b. the energy team should be comprised of the head custodian (maintenance director), and interested staff members
   c. the energy team should be comprised of maintenance personnel, director of food services, building principal, interested staff, students and community representatives
   d. all of the above plus a public utility representative or other technical consultant
   e. all of the above plus an engineer qualified in the field of energy conservation for schools
9. Establishing an Advisory Committee to assist in developing energy conservation guidelines
   a. no action taken
   b. committee should generally serve as a "pool" for ideas
   c. in addition to the above, committee should assist in determining specific areas of energy waste within the school district
   d. in addition to the above, the committee should assist in determining a viable plan of action for dealing with energy problems
   e. in addition to the above, the committee should assist in determining feasible energy conservation goals

10. Establishing energy conservation goals
    a. no action taken
    b. general goals are discussed by the administration
    c. specific goals are discussed by the administration
    d. both general and specific goals are outlined and reported to the Board in written form
    e. written general and specific goals are outlined - an organizational structure to monitor progress and measure success is included

11. Formulating contingency plans in the event of an energy crisis (shortage)
    a. no action taken
    b. basic ideas and procedures are discussed by administrators
    c. in addition to the above, written plans for other districts are collected and discussed
    d. in addition to the above, an organized, written plan catering to district needs is outlined and submitted to the Board
12. Establishing available finances for implementation of "high cost" energy conservation measures

__a. no action taken
__b. overbudget some line items - money should be available for moderate energy conservation measures, barring unforeseen circumstances
__c. apply for funding through the state energy office or other sources of aid
__d. earmark money in the general budget specifically for energy conservation opportunities
__e. in addition to the above, seek passage of a special tax levy such as the "Schoolhouse Fund" for implementation of energy conservation measures

13. Establishing a specific plan of action for confronting problems dealing with energy

__a. no action taken
__b. steps involve defining the general problem and implementing what seems to be the best available alternatives
__c. steps involve defining the general problem, collecting a consensus of opinions relative to the problem, and implementing the best of available alternatives based on the above information
__d. steps involve defining the specific problem, establishing a data base, reviewing material for discrepancies, arriving at recommendations from previously stated objectives, and implementing the best of alternatives based on this criteria
__e. in addition to the above, steps include evaluating the entire implemented measure and making changes as needed
14. Developing a "preventive maintenance" program for energy systems within the building
   ___a. no action taken
   ___b. program consists of random "spot checking" and watching for unusual performance of energy systems - service as needed
   ___c. program consists of routine annual checks of energy systems - service as needed
   ___d. program involves inspecting, repairing and testing energy systems on a frequent schedule - more frequently than annual (varies with different systems)
   ___e. program involves inspecting, repairing and testing energy systems on a frequent schedule - in addition, detailed and accurate records are kept to establish service requirements and life expectancy patterns

15. Maintaining building energy consumption records
   ___a. no action taken
   ___b. monthly fuel bills are recorded
   ___c. in addition to the above, fuel bills are analyzed for areas of excessive use
   ___d. in addition to the above, yearly graphs and/or other visual displays are constructed to show fluctuation in usage of various energy sources
   ___e. in addition to the above, a set of accurate and complete records are kept which show consumption patterns for the building based on Btu's per square foot per degree day or other standardized measure

16. Establishing an "energy management program" at the school district level
   ___a. no action taken
   ___b. top administrative commitment by superintendent and Board
c. in addition to the above, goals and objectives for the program are delineated and disseminated

d. in addition to the above, a complete and efficient record-keeping system of operations within the program is employed

e. all the above with special emphasis on accountability i.e. an organized (line-staff) structure with specific duties listed for specific people

17. Implementation of energy conservation measures from available alternatives

a. no action taken

b. list alternatives, implement as directed by Board

c. analyze energy conservation opportunities, prioritize them on a first cost basis from least to most expensive, and implement as directed by Board

d. analyze energy conservation opportunities, prioritize them according to simple payback period* and implement as directed by Board

e. analyze energy conservation opportunities, prioritize them according to life-cycle costing** procedures, and implement as directed by Board

*Simple payback period is defined here as the number of years it takes an implemented energy conservation measure to pay for itself as a result of reduced energy costs.

**Life-cycle costing procedures evaluate energy conservation measures by considering such things as first costs, salvage value of the equipment, maintenance costs, and the time value of money.

18. Striving to achieve a level of total involvement in the energy conservation program

a. no action taken

b. level achieved where staff and students comply with administrative directives to avoid confrontations - constant reminders of energy conservation procedures are necessary
c. level achieved where staff and students have a
general understanding that everyone's help is
needed in order to make substantial energy cost
reduction

d. level achieved where staff and students feel they
make the difference if energy cost reduction is to
be a reality - the feeling of unity is apparent
but a central office thrust is necessary to main-
tain the status quo

e. level achieved where nearly all personnel take an
active part in the energy conservation program -
most suggestions for energy conservation eminate
from the student body and teaching staff (the
involvement level is practically self-sustaining)

19. Providing training in energy systems for building
maintenance personnel*

a. no action taken

b. building maintenance personnel are allowed to go to
classes or workshops at the discretion of the Board
(the employee must initiate the request)

c. building maintenance personnel are occasionally
sent to classes and/or workshops to further develop
skills in maintaining energy systems

d. building maintenance personnel are sent to classes
and/or workshops dealing with energy systems on at
least an annual basis

e. an ongoing and highly technical training program
dealing with maintenance of energy systems is pro-
vided for maintenance personnel - technicians in
the area of energy systems frequently visit the
school to provide on-the-job training for these
employees

*Building maintenance personnel are defined here as those
people responsible for servicing energy systems equipment.
20. Providing administrative directives to limit energy waste

___a. no action taken

___b. the administrator's feelings about opening of windows, turning off unnecessary lights, adjustments of thermostats, etc. are known through day to day contact with the staff and students

___c. in addition to the above, rules and directives dealing with energy conservation procedures are outlined by the administration in staff meetings

___d. in addition to the above, written rules and directives dealing with energy conservation procedures are posted at several locations in the building

___e. in addition to the above, energy conservation procedures within the building are monitored by the central office and a monthly evaluation of compliance is conducted - the results are disseminated

Section III

Directions: Please (✓) YES to each energy conservation element already in practice in your system. Please check (✗) NO to each energy conservation element not in existence in your system

**Procedural elements**

<table>
<thead>
<tr>
<th>Procedure</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Procedure to determine that insulation of buildings meets temperate zone standards</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Procedure for correction of unwanted air infiltration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Procedure to insure adequate ventilation as determined by an authority in this field</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Written policies for efficient use of heating/cooling units</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Procedures to insure proper maintenance of all appliances and equipment</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Planned landscaping that aids energy efficiency in school buildings (Deciduous trees for shade in summer, sun in winter; evergreen wind breaks)

YES  NO

Written goals and objectives for efficient energy use in system

YES  NO

Means to disseminate information about energy conservation information

YES  NO

Written policy of energy conservation philosophy of the system

YES  NO

Top level administrative commitment to energy conservation

YES  NO

Activity elements

Annual inspection of weatherstripping and caulking

YES  NO

Routine maintenance of weatherstripping and caulking

YES  NO

Heating/cooling turned off in zones such as garages, docks, loading platforms and intermittently used areas

YES  NO

Use of automatic timers or photocells to activate or deactivate heating/cooling and lighting units

YES  NO

Use of night/weekend/holiday setback controls to conserve heating/cooling or lighting energy during unoccupied intervals

YES  NO

Use of room decor to enhance or improve lighting efficiency

YES  NO

Use of flow restrictors on showerheads, in toilets, and on faucets

YES  NO

Energy conservation training program for some staff members

YES  NO

Effective dissemination of energy conservation information

YES  NO
<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
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</thead>
<tbody>
<tr>
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<td></td>
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</tbody>
</table>

Completion of an energy audit by an energy team

Energy conservation committee has been selected or appointed

Effective administrative directives to limit energy waste by staff and students
APPENDIX L. QUESTIONNAIRE TO HEAD CUSTODIAN
OR DIRECTOR OF MAINTENANCE

Building Code: ______________ Building type: Elem. Sec.

PLEASE CHECK YOUR TITLE: ___Head Custodian ___Dir. of Maint.

Section I

Directions: Please indicate the frequency of conducting the following maintenance procedures in your building by checking (✓) the appropriate response. If the maintenance procedure is "not applicable" for this particular building, check (✓) the "NA" response. Confidentiality of information gathered will be held in highest regard. No reference by name will be made to any particular school or school personnel in the analysis of the data.

1. Boiler tubes cleaned:
   ( ) a. more than once yearly
   ( ) b. annually
   ( ) c. biannually
   ( ) d. once every three years or less
   ( ) e. NA

2. Water distribution system* balanced:
   ( ) a. more than once yearly
   ( ) b. annually
   ( ) c. biannually
   ( ) d. once every three years or less
   ( ) e. NA

*The water distribution system includes pumps and other devices to move water through the entire heating system.
3. Air distribution system balanced:
   ( ) a. more than once yearly
   ( ) b. annually
   ( ) c. biannually
   ( ) d. once every three years or less
   ( ) e. NA

4. Heating system and/or cooling system coils cleaned:
   ( ) a. more than once yearly
   ( ) b. annually
   ( ) c. biannually
   ( ) d. once every three years or less
   ( ) e. NA

5. Heating combustion system subjected to flue gas analysis:
   (i.e. proper amount of combustion air)
   ( ) a. more than once yearly
   ( ) b. annually
   ( ) c. biannually
   ( ) d. once every three years or less
   ( ) e. NA

6. Electric light covers and/or lamps cleaned:
   ( ) a. more than once yearly
   ( ) b. annually
   ( ) c. biannually
   ( ) d. once every three years or less
   ( ) e. NA
7. Filters checked or changed:
   ( ) a. monthly
   ( ) b. semi annually
   ( ) c. annually
   ( ) d. biannually or less
   ( ) e. NA

8. Fan belts checked or changed:
   ( ) a. monthly
   ( ) b. semi annually
   ( ) c. annually
   ( ) d. biannually or less
   ( ) e. NA

9. Heating systems traps and/or valves inspected for proper functioning and leaks:
   ( ) a. monthly
   ( ) b. semi annually
   ( ) c. annually
   ( ) d. biannually or less
   ( ) e. NA

10. Heating control system (e.g. thermostats) checked for proper operation:
    ( ) a. monthly
    ( ) b. semi annually
    ( ) c. annually
    ( ) d. biannually or less
    ( ) e. NA
11. Boiler water treatment:
   ( ) a. weekly
   ( ) b. monthly
   ( ) c. annually
   ( ) d. biannually or less
   ( ) e. NA

12. Frequency of water hardness test:
   ( ) a. weekly
   ( ) b. monthly
   ( ) c. annually
   ( ) d. biannually or less
   ( ) e. NA

Section II

RANK THE FOLLOWING ITEMS ON A SCALE OF 1-5 IN TERMS OF THE DEGREE TO WHICH THEY HAVE BEEN IMPLEMENTED IN THIS BUILDING. For example, if you feel the measure stated in the item has been highly implemented in the building, mark it with a high number on the scale. If you believe little implementation has occurred in the area stated, mark it with a low number on the scale. One represents the lowest score on the scale, five represents the highest mark. (If the item it "not applicable" to your building, mark the "NA" response).

Lowest implementation 1 2 3 4 5 Highest implementation

(Please Circle Your Choice)
<table>
<thead>
<tr>
<th>Patterns of use</th>
<th>Item</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Locations of all thermostats</td>
<td>provide for moderate temperature fluctuations.</td>
<td>1 2 3 4 5 NA</td>
</tr>
<tr>
<td>2. Areas which are unoccupied or</td>
<td>minimally used have modified heating/cooling temperature settings.</td>
<td>1 2 3 4 5 NA</td>
</tr>
<tr>
<td>3. Building temperatures have</td>
<td>been reduced to reflect unoccupied periods.</td>
<td>1 2 3 4 5 NA</td>
</tr>
<tr>
<td>4. Thermostats are locked to</td>
<td>eliminate unauthorized adjustment.</td>
<td>1 2 3 4 5 NA</td>
</tr>
<tr>
<td>5. Staff utilizes blinds,</td>
<td>curtains and other window covering devices to reduce energy usage.</td>
<td>1 2 3 4 5 NA</td>
</tr>
<tr>
<td>6. Occupants turn off lights in</td>
<td>unoccupied areas.</td>
<td>1 2 3 4 5 NA</td>
</tr>
</tbody>
</table>

**Section III**

**Structural systems**

7. Doors and windows remain closed while building is being heated or cooled. | 1 2 3 4 5 NA |
8. All exterior doors and windows are aligned properly, fit tightly and operate effectively. | 1 2 3 4 5 NA |
9. Penetrations in exterior walls have been properly caulked. | 1 2 3 4 5 NA |
10. Storm windows and/or combination windows are utilized to reduce energy loss. | 1 2 3 4 5 NA |

**Mechanical systems**

11. Multiple boilers or heaters have been modified to prevent simultaneous firing. | 1 2 3 4 5 NA |
12. Stack temperature is in normal range as verified by routine flue gas analysis. | 1 2 3 4 5 NA |
13. Thermostat settings accurately reflect room temperature. 1 2 3 4 5 NA

14. Heating pilot lights are scheduled to be turned off during the summer. 1 2 3 4 5 NA

15. Insulation on hot water pipes has been inspected and is not damaged or inadequate. 1 2 3 4 5 NA

16. Hot water/steam radiation units are maintained to operate efficiently. 1 2 3 4 5 NA

17. The air flow is well-balanced and consistent throughout the building. 1 2 3 4 5 NA

Special systems

18. Coils and condensers on cooling units and dehumidifiers are cleaned on at least an annual basis. 1 2 3 4 5 NA

19. Thermostats on hot water heaters have been lowered to 105°F-115°F (except for those with water intended for kitchen use). 1 2 3 4 5 NA

20. Devices which restrict hot water usage have been utilized on all showers and faucets. 1 2 3 4 5 NA

21. Heating cycles on electric water heaters are restricted to low electrical demand periods. 1 2 3 4 5 NA

Lighting systems

22. Separate switches are provided for banks of lights next to exterior windows. 1 2 3 4 5 NA

23. Lights within the classroom are connected to switches which accommodate area lighting. 1 2 3 4 5 NA

24. Lighting levels have been checked and wattage has been adjusted when appropriate. 1 2 3 4 5 NA
Section IV

Please answer the following questions:

1. HVAC System Type: Please check the proper response(s)
   _A. Through-wall unit ventilator
   _B. Cast iron radiators
   _C. Other . . . _a. Reheat or duel duct
   _b. Multizone or induction units
   _c. Rooftop units or other wall units
   _d. Fancoil, VAV or heat & vent units
   _e. Other radiation unit heaters (no fan systems)
   _f. __________________________

2. Heating System Type: Please check the appropriate response(s)
   _A. Boilers
   _B. Purchased water or steam
   _C. Unitary direct fired
   _D. Furnaces
   _E. Packaged equipment
   _F. __________________________

3. What is the output (capacity) rating of the heating system?
   (Please fill in one blank only—unless more than one heating system type is being utilized) ( ) Check (✓) here if rating is unknown.
   ___________________________ boiler horsepower
   ___________________________ pounds of steam/hour
   ___________________________ Btu's/hour
   ___________________________ But output
4. How would you rate this building in terms of amount of air infiltration (through windows and cracks in walls) in comparison to a well constructed (tight) school building of the same age? One is the POOREST rating, nine is the BEST rating. (PLEASE CIRCLE YOUR CHOICE)

<table>
<thead>
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<th>Poor condition</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
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APPENDIX M. CLASSIFICATION OF PROPOSED RECOMMENDATIONS FOR ENERGY CONSERVATION
<table>
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<tr>
<th>Source</th>
<th>Page</th>
<th>Recommended measures*</th>
<th>May be appropriate under certain conditions</th>
<th>Possible negative or deleterious effects</th>
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<td>27</td>
<td>a, b, c, d, e, f</td>
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<tr>
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<td>28</td>
<td>1, 5, 8</td>
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<td>29</td>
<td>(3, 7)^a</td>
<td>(1, 2, 3)^b, (1-6)^a, (1, 2)^c</td>
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<tr>
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<td>30</td>
<td>2^d (1, 4)^e, f</td>
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<tr>
<td>Kohler</td>
<td>31</td>
<td>(2, 3, 4, 5)^h</td>
<td>1^h (1, 2, 3, 4)^i</td>
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<tr>
<td>Woodbury</td>
<td>32</td>
<td>(2, 3)^k</td>
<td>4^k (2, 3, 4, 5)^a</td>
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<tr>
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<td>7^a</td>
<td>(8, 9)^a, (1, 2, 4, 5, 6)^l</td>
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<td>218</td>
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*The superscript letters indicate the following: a - Heating-Ventilation-Air Conditioning (HVAC); b - lighting (INVEST TO SAVE); c - HVAC (INVEST TO SAVE); d - building envelope; e - plumbing; f - vehicles; g - building envelope (INVEST TO SAVE) h - general; i - general (INVEST TO SAVE); j - vehicles (INVEST TO SAVE) k - plant and program curtailment; l - insulation; m - ventilation system conservation measures; n - lighting system conservation measures.*