DOCUMENT RESUME

ED 096 733 EA 006 407

TITLE	Case Studies of Energy Use: Elementary and Secondary Schools. BSIC/EFL Energy Workbook No. 1.
INSTITUTION	Building Systems Information Clearinghouse, Menlo Park, Calif.
PUB DATE	Oct 74
NOTE	24p.; A related document is EA 006 323
AVAILABLE FROM	BSIC/EFL, 3000 Sand Hill Road, Menlo Park, California 94025 ($2.00, postpaid)
EDRS PRICE	MF-$0.75 HC-$1.50 PLUS POSTAGE
DESCRIPTORS	Building Design; *Building Operation; Case Studies; *Climate Control; *Comparative Analysis; Computer Programs; Design Build Approach; Elementary Schools; *Energy Conservation; *Fuel Consumption; School Maintenance; Secondary Schools; Simulation; Tables (Data)
IDENTIFIERS	Life Cycle Cost Analysis

ABSTRACT

This report is the first in a series of energy use studies intended to provide real life examples of the implication of energy conservation practices. Research reports from five public school districts describing their methods of measuring and conserving energy are summarized. While investigating the responses of various school districts to the energy crisis, BSIC arrived at some conclusions regarding the current energy situation and the possibility of coping with it by rational procedures. These conclusions, discussed in the final section, relate to (1) the problems of analysis using existing tools, (2) the need for design and operation energy use guidelines, and (3) the need for more complete energy use studies. (Author/MLF)

ED 096733

BSIC/EFL ENERGY WORKBOOK

CASE STUDIES OF ENERGY USE

ELEMENTARY AND SECONDARY SCHOOLS

Published by

Building Systems Information Clearinghouse
Educational Facilities Laboratories, Inc.
3000 Sand Hill Road
Menlo Park, California 94025

October 1974

BSIC/EFL

Building Systems Information Clearinghouse was established by Educational Facilities Laboratories to undertake research on matters pertaining to the development and use of building systems; accumulate and distribute information about systems projects to architects, educators, and manufacturers, and to serve as a medium to encourage communication among those interested in building systems.

EFL OFFICERS

BSIC STAFF

Printed in the United States of America

Library of Congress Catalog Number: 74-20284

Copies of this publication, as well as other publications dealing with building systems, are available from BSIC/EFL, 3000 Sand Hill Road, Menlo Park, California 94025.

$2.00, post paid

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INTRODUCTION TO WORKBOOK SERIES

The winter of 1974 brought the realities of what scarce fuel supplies and rapidly increasing energy costs are likely to mean to the school districts of the nation. With a return to warmer weather and "normal" gasoline supplies it remains to be seen whether or not school districts got the message and, if they did, whether they will face up to their responsibility to exert the leadership required to set an example of energy conservation for the nation.

Because the facilities they plan and operate are high consumers of energy and because they are most directly answerable to the public, planners, designers, manufacturers and owners must take the lead in developing and using energy conservative practices in the design, building, equipping and use of school buildings.

EFL and BSIC have undertaken a number of activities designed to provide decision makers with the information necessary to make intelligent decisions with respect to energy conservation practices. This effort began in 1973 with the publication of EFL's *Economy of Energy Conservation in Educational Facilities.* This document provides a basic introduction to energy conservation problems and life-cycle cost analysis. It forms the basis for more detailed studies of various energy consuming systems.

In order to provide specific data on the effect of various design and operating decisions on both cost and energy consumption, BSIC undertook the development of an energy conservation workbook. This workbook is designed to make clear the energy consumption and cost implications of various building design and operating decisions in terms that both the layman and the design professional can understand.

While recognizing that energy conscious design must consider the entire building as one system, BSIC has, for reasons of manpower, time and money, decided to release the Workbook in sections. The first section of this work is *Energy Conservation and the Building Shell.* This will be followed by Section 2 which deals with mechanical systems and Section 3 which explores the problems of school lighting and energy conservation.

The intent of this series is to provide a simple means for determining the consequences of the various possible decision options open to designers and school officials. The methods used to achieve this end are of necessity imprecise and are not intended to replace detailed architectural and engineering studies by the district's professionals. They will, however, when properly used, provide the degree of accuracy necessary to make comparisons between alternatives and to make decisions that will set the course of the design process.

To provide real life examples of the implication of energy conservation practices, BSIC will also publish a series of energy use studies. This report, case studies of energy use analyses in five public school jurisdictions, is the first title in this series. The next report in the case study series will present a number of case studies of energy use in higher educational facilities.

FAIRFAX COUNTY, VIRGINIA

The Fairfax County, Virginia, School District has been one of the leaders in investigating and attempting to implement energy conservation measures in school buildings. This large, suburban Washington, D.C., district operates more than 165 school plants and serves an area of rapid population growth—factors which encourage a concern with both economical operation of existing buildings and planning for maximum energy economy in new facilities.

In the following articles, two of the district's recent projects, both undertaken with EFL assistance, will be reported. The first of these is a study of means of reducing energy consumption in existing school buildings and of methods of estimating the energy and cost effects of various energy saving strategies. The second reports on the energy evaluation aspect of a recent design/build program in which energy consumption was a major criterion in selecting from among the proposed schemes.

FAIRFAX COUNTY ENERGY STUDY, 1973

This article was prepared from material contained in the 1973 Fairfax County Public Schools Report to EFL on the Fairfax County Energy Study.

In late 1972, EFL made a $20,000 grant to the Fairfax County District to assist in financing a study of energy conservation in existing schools. The purpose of the program was to determine by studying three typical plants what can, and should, be done to reduce the energy consumption of schools without compromising their educational effectiveness.

The project was directed by Edward Stephan, then the district's Assistant Superintendent for Building. Stephan had developed the idea for the study while reviewing the manuscript of the EFL publication, *The Economy of Energy Conservation in Educational Facilities*. Goodwin H. Taylor, Ltd., Consulting Engineers, of Arlington, Virginia, was chosen chief technical consultant to the project.

PROCESS AND PROCEDURES

The process followed in the program was to select three typical school plants and to estimate for each the effects of a number of energy saving operational and physical modifications. The effects of these modifications were estimated by a combination of hand calculation and computer simulation to determine:

1. How much energy the modification would save.
2. The fuel and utility implications of these energy savings.
3. The capital cost, if any, of making the modification.
4. The time required to recoup the capital investment through the savings in fuel and utility costs.

The basic tool used in the study was a package of computer simulation programs developed by Ross F. Meriwether and Associates of San Antonio, Texas. These programs are capable of simulating the energy consumption of a building with reasonable accuracy. Later, when the Trace package of programs became available from The Trane Company, one of the schools was run through this package for testing purposes.

Selection of Representative School Plants

The first and one of the most difficult steps in the program was to select schools that were representative of the district's stock in terms of size, use pattern, types of mechanical systems and energy consumption. An energy consumption audit of the district's plants performed by the project staff for School Year (SY) 1970-71 and partial SY 1972-73 disclosed great variations in the amount of energy consumed. For example, two nearly identical fully air-conditioned elementary schools had total energy costs of $0.402 and $0.175 per square foot in SY 1970-71 and of $0.420 and $0.176 in SY 1972-73. Clearly, these plants could not be considered typical.

In spite of these and other selection difficulties, the staff was able to identify four schools—one more than originally intended—for use in the study. Two older, noncooled schools were selected—Quander Road Elementary and Lee High School—as well as two newer, fully air-conditioned plants—Laurel Ridge Elementary and West Springfield High School. Tables I-IV give some of the physical and mechanical system characteristics of these plants.

TABLE I
QUANDER ROAD ELEMENTARY SCHOOL

Built: 1965
School Size:
40,055 sq. ft. to accommodate 410 persons
Mechanical Systems:
HEATING: oil-fired boilers
VENTILATING: gravity roof ventilators
COOLING: none
DISTRIBUTION: two-pipe
TERMINALS: fin-tube radiators
HOT WATER: generated by boiler
Building Shell:
ROOF: 24,600 sq. ft., U = 0.21
WALLS: 9,728 sq. ft., U = 0.33
GLASS: 5,125 sq. ft., U = 1.13
Block Loads:
HEATING: 51 BtuH/sq. ft.
COOLING: N/A

TABLE II
LAUREL RIDGE ELEMENTARY SCHOOL

Built: 1969
School Size:
80,929 sq. ft. to accommodate 1,100 persons
Mechanical Systems:
Rooftop single- and multizone units
HEATING: electric coil
VENTILATION: through units
COOLING: electric DX
DISTRIBUTION: duct
TERMINALS: ceiling diffusers
HOT WATER: electric water heater
Building Shell:
ROOF: 52,000 sq. ft., U = 0.21
WALLS: 19,018 sq. ft., U = 0.33
GLASS: 1,058 sq. ft., U = 1.13 (winter), 1.06 (summer)
Block Loads:
HEATING: 33 BtuH/sq. ft.
COOLING: 32 BtuH/sq. ft.

TABLE III
WEST SPRINGFIELD HIGH SCHOOL

Built: 1964
School Size:
279,085 sq. ft. to accommodate 2,800 persons
Mechanical Systems:
HEATING: oil-fired boiler
VENTILATION: power roof ventilators
COOLING: electric centrifugal chiller
DISTRIBUTION: two-pipe water
TERMINALS: fan-coil and air-handling units
HOT WATER: generated by boiler
Building Shell:
ROOF: 141,068 sq. ft., U = 0.15
WALLS: 62,114 sq. ft., U = 0.33
GLASS: 14,417 sq. ft., U = 1.13 (winter), 1.06 (summer)
Block Loads:
HEATING: 38 BtuH/sq. ft.
COOLING: 28 BtuH/sq. ft.

TABLE IV
LEE HIGH SCHOOL

Built: 1957, addition 1965
School Size:
250,463 sq. ft. to accommodate 1,800 persons
Mechanical Systems:
HEATING: oil-fired boiler
VENTILATING: power and gravity root ventilators
COOLING: none
DISTRIBUTION: two-pipe steam
TERMINALS: convectors and radiators
HOT WATER: generated by boiler
Building Shell:
ROOF: 178,354 sq. ft., U = 0.17
WALLS: 67,088 sq. ft., U = 0.33
GLASS: 26,056 sq. ft., U = 1.13
Block Loads:
HEATING: 46 BtuH/sq. ft.
COOLING: N/A

Simulating Energy Consumption with the Computer

Preparing Input Data. The computer analysis technique requires that a great deal of data on building characteristics and performance be determined as accurately as possible before submitting it to the machine. This required data includes not only information on building and mechanical system characteristics, but also information on operating procedures, use patterns and such detailed data as demand patterns for electricity and domestic hot water.

From the building plans of the four selected plants, the project consultants were able to prepare the computer input data on building and general mechanical system performance. Obtaining accurate operating and use profiles proved to be a more difficult problem. The computer input schedule required the preparation of three use profiles: building occupancy, electrical load demand and domestic hot water usage.

Identifying the actual occupancy profile—important because of the large amount of heat given off by the human body even at rest—forced the project staff to rely on the memories of school officials. Unfortunately, these officials proved to have less than perfect knowledge of how the buildings had been and were being used.

This problem had two aspects. In the first case, because the staff wished to correlate data collected for two years prior to the undertaking of the study with past plant use patterns, it was necessary to rely on the officials' *recall* of past operations. In the second case, the staff was often informed that a certain plant was currently operating in a certain way, when, in fact, field checking proved otherwise. For example, the staff was informed that at one school the exhaust fans were shut off from 4 p.m. to 7 a.m. when they actually ran continuously. One outcome of these difficulties was that each major contributing factor had to be examined in the field.

Electrical load demand had to be measured by installing recording meters at the four schools. This was done for a period of one week during May 1973—a week that was assumed to be typical of year-round weekly demand. At one of the schools, Laurel Ridge Elementary, metering problems contributed to the ultimate elimination of the plant from the program. The demand profile for domestic hot water, a small but significant portion of a school's energy requirement, was also determined.

With this data in hand, the engineers were able to program all of the building's mechanical equipment—heating, cooling, airhandling, hot water heating, etc. —for both full and part load efficiencies. The data was then ready to be fed to the computer.

Making the Computer Runs. The Meriwether package, like all currently available energy consumption simulation packages, is what is known as a "single pass" program, that is, it runs one single set of data without variation to completion. Each variation of the building must be run through the entire package as if it were an entirely new, discrete building. As a result, in the Fairfax program the existing base model and each of the modifications to each of the four plants in the study had to be run at least once through the computer.

This also means that in order to "debug" the data about each building, it may take several runs of each option in order to obtain what appears to be accurate and reliable output.

"Calibrating" the Computer Simulations. In order to insure the accuracy of the simulations of the various modifications, the first step was to obtain computer simulations of actual conditions which were reasonably close to actual fuel and utility consumptions—a seven per cent variation was accepted by the staff. This necessitated the collection of data about actual operating consumptions and then several computer runs of the base model of each school to adjust it to this reality.

The actual energy consumptions of the study schools were compiled using the cost invoices provided to the Board for each school. For electrical power consumption, the district was fortunate in having, at the time of the study, a flat "no demand" rate which simplified calculations. Measurement of oil consumption was not as simple, however. A number of complications, including the simple one of whether the supplier topped off the tank at each filling, prevented accurate determination in some cases and led to the need to average consumption over time periods for comparison.

Once actual consumptions were known, however, there remained the problem of correlating computer estimates and actual figures. Several factors worked against the credibility of the computer simulations, and, in the case of one school, led to its elimination from the program. As has been mentioned previously in this article, the source of data about operating profiles and use patterns was the none-too-reliable information of school officials.

A second problem was the difference between supposed and actual operation of the systems themselves. In one school, faulty control valves put full heat into one classroom, regardless of the control's setting, forcing the teacher to open the windows even on the coldest days. In another school, clogged filters made calculation of outside air intake impossible. The project staff found that it was virtually impossible to accurately determine the actual amount of outside air being introduced into the schools. Engineering judgments based on field measurements proved to be more accurate than amounts specified on plans.

Although satisfactory correlation was obtained for three of the schools, one, Laurel Ridge Elementary, was eliminated from the program because a correlation could not be achieved. The staff blamed two factors for this situation: (1) a malfunction of the recording electric meter and (2) inability to accurately measure the amount of outside air introduced by the HVC system. This was doubly unfortunate as the plant was all-electric and had the highest energy cost of those in the study.

Comparative Analysis of the Computer Output

The final step in the evaluation of energy saving modifications was to study the capital and life-cycle costs associated with each. This was done by hand calculation using the results of the correlated computer runs and estimates of the first costs of each modification prepared by the staff and its consultants. Although initial calculations used 1972 fuel and utility costs, a rise in the price of oil during the study led to the use of 1973 costs in the final calculations.*

In order to show the life-cycle cost effects of each

* See also pages 19, 20 (BSIC Conclusions).

modification, an estimate was prepared of the time required to recoup the first cost investment using the annual energy cost savings as the annual repayment. The following formula was used:

$$n = \frac{\log \frac{S/rC}{S/rC-1}}{\log (1+r)}$$

where n = number of years to repay capital investment
C = total investment cost
S = annual savings in operating costs
r = interest rate (here assumed to be 6%).

FINDINGS

Tables V-VII present the results of the computer simulations and the investment cost recovery calculations. The project staff divided modifications into three categories, reflecting the effort required to make each change to the building in question. These categories are:

1. Modifications to existing buildings which require little if any additional capital investment; primarily changes in operating techniques and usage, e.g. making more effective use of the night set back control at West Springfield High School.
2. Major maintenance items plus all modifications involving capital investment which can be made to the plant and which result in energy savings, e.g. installing better controls on the exhaust fans at Quander Road Elementary School.
3. Major architectural and mechanical changes which might not be practical to make in the existing building, but which could be easily incorporated into a new design, e.g., installation of heat recovery systems at all schools.

CONCLUSIONS

The project staff concluded that, if the energy crisis were to become any worse, a major reevaluation of laws and standards related to the building industry in general and to schools in particular will have to be made. Many requirements are excessive and are often based on out-dated situations and problems which no longer exist.

The staff found that the two most obvious errors of energy usage identified by the project are:

1. The energy wasted in heating and cooling the amounts of outside air introduced into most buildings in excess of code and legal requirements.
2. The wastage of energy through improper operating techniques.

To quote from the project report:

While educational programs may vary within the county and within the nation, it would appear evident from our investigation that great quantities of energy can be conserved by taking a close look at both of these areas.

TABLE V
QUANDER ROAD ELEMENTARY SCHOOL COMPUTER SIMULATIONS

Modification	*Effect on Heating Energy*	*Effect on Cooling Energy*	*Effect on Elec. Energy*	*Annual Energy Cost (1973)*	*Investment Required (1973)*	*Time to Recoup*
Base—Existing				$7,808		
#1—Increase insulation	−19.7%	0.0	0.0	−$1,039	N/A	N/A
#2—Shut off exhaust fans between 3 p.m. and 7 a.m.	−40.6%	0.0	− 2.0%	−$2,192	$ 1,600	9.3 mos.
#3—Hold maximum air intake to 5,000 CFM during operational hours (plus fan shut off in #2)	−53.0%	0.0	− 2.7%	−$2,842	N/A	N/A
#4—Reduce glass area from 35% to 17%	− 4.0%	0.0	0.0	−$ 265	$ 4,500	**
#5—Cut lighting wattage by 15%	+ 2.4%	0.0	−14.5%	−$ 209	N/A	N/A
#6—Use a heat recovery system 80% efficient	−18.2%	0.0	+ 3.3%	−$ 885	$16,000	**
#7—Install double glazing on all windows	−12.7%	0.0	0.0	−$ 672	$10,200	41.5 yrs.

N/A = not applicable to this school.

** = annual energy savings do not equal annual interest payments on investment at 6%, see Table II, page 19, for pay-off period with increased fuel and energy costs.

TABLE VI

LEE HIGH SCHOOL COMPUTER SIMULATIONS

Modification	Effect on Heating Energy	Effect on Cooling Energy	Effect on Elec. Energy	Annual Energy Cost (1973)	Invest-ment Required (1973)	Time to Re-coup
Base—Existing				$47,713		
#1—Reduce glass area from 28% to 10%	− 9.8%	0.0	0.0	−$ 3,351	$84,405	**
#2—Reduce lighting wattage by 15%	+ 2.4%	0.0	−15.0%	−$ 1,050	N/A	N/A
#3—Reduce outside air intake by 50%	−14.5%	0.0	− 2.0%	−$12 020	N/A	N/A
#4—Use a heat recovery system 80% efficient	−49.1%	0.0	+ 5.0%	−$16,387	$79,000	5.9 yrs.
#5—Install double glazing on all windows	−10.3%	0.0	0.0	−$ 3,501	$53,312	42.1 yrs.
#6—Set back to 60° between 3 p.m. and 7 a.m.	−50.6%	0.0	0.0	−$17,267	none	immediate

N/A = not applicable to this school (Category 3 item).
** = annual energy savings does not equal interest payments at 6% at this fuel rate, see Table II, page 19, for pay-off period with increased energy costs.

TABLE VII

WEST SPRINGFIELD HIGH SCHOOL COMPUTER SIMULATIONS

Modification	Effect on Heating Energy	Effect on Cooling Energy	Effect on Elec. Energy	Annual Energy Cost (1973)	Invest-ment Required (1973)	Time to Re-coup
Base—Existing				$52,638		
#1—Reduce glass area from 18.5% to 10%	− 0.8%	−12.9%	0.0	−$ 695	$33,820	**
#2—Reduce lighting wattage by 15%	+ 8.2%	− 9.8%	−15.0%	−$ 3,331	none	immediate
#3—Reduce outside air intake by 50%	−31.8%	− 1.5%	− 1.0%	−$ 5,949	none	immediate
#4—Use a heat recovery system 80% efficient	−50.4%	0.0	+ 2.0%	−$ 9,170	$50,000	6.8 yrs.
#5—Shut off exhaust fans between 3 p.m. and 7 a.m.	− 6.5%	+ 1.9%	− 2.0%	−$ 1,642	none	immediate
#6—Install double glazing on all windows	− 8.7%	− 5.9%	0.0	−$ 1,778	$28,834	62.4 yrs.
#7—Set back to 60° between 3 p.m. and 7 a.m.	−43.4%	−43.2%	− 2.0%	−$10,076	none	immediate
#8—Night set back (#7) plus reduced outside air (#3)	−52.4%	−42.8%	0.0	−$11,059	none	immediate

** = annual energy savings do not equal interest payments at 6% at this fuel rate, see Table II, page 19, for pay-off period with increased energy costs.

HERNDON/FLORIS DESIGN/BUILD PROGRAM, 1973-74

This article is prepared from material submitted by Michel Berline of Berline and Associates, San Francisco, California. Mr. Berline served as a technical consultant to the Herndon/Floris project.

In fall 1973, the Fairfax County School District issued a request for proposals (RFP) for two elementary schools—one new construction, the other a major remodeling/addition to an existing plant—using a single-contract, fixed-price design/build procedure. In March 1974, the School Board signed contracts with the successful design/build team to place the two plants in service by the fall of 1975.

Several features of this program were unique, including the fixing of the price to be paid for the schools by the Board prior to issuing the RFP and the use of energy consumption as a major element in the evaluation of the proposed schemes. As the price was already fixed, competition was based upon quality, educational usefulness, architectural excellence and energy consumption. Table I outlines the various evaluation categories established by the district and gives their relative weights.

A number of the ideas generated during the earlier Fairfax Energy Study described in the preceding article were carried over into this program. Key among these ideas was the use of the Meriwether package of computer simulation programs to estimate the probable energy consumption of each scheme.

PROCESS AND PROCEDURES

The district and its consultants followed a five-step procedure to evaluate the energy aspects of the proposals and to assign them points on the basis of relative energy efficiency. These five steps were: establishing a fuel type for the schools, establishing the basis of comparison, preparing the computer input, running each scheme through the computer, and assigning points to each. It should be noted that these procedures were outlined and described to the proponents in an addendum to the RFP issued by the Board prior to taking proposals.

Establishing the Fuel Type. The first step in the development of the evaluation process was the selection of electricity as the fuel type to be used at both schools. By selecting a single fuel type, the district was able to evaluate energy consumption solely on the basis of the quantity of fuel consumed during the year. If proponents had been allowed to name their own fuel types, the district would have been in the impractical position of having to base their evaluations on projected future costs of different fuels.

Electricity was selected as the fuel type because of its availability and its relatively low rate of cost escalation. Natural gas was simply not available to the district. Oil, the only other alternative, had problems of unpredictable supply and a faster rate of cost increase than electricity. At the time of the study, price of oil was already over $0.25 per gallon (about 3360 useable Btu per $0.01) compared with electricity's price of $0.01 per kilowatt-hour (about 3414 useable Btu per $0.01).

Establishing a Basis for Comparison. The comparison of schemes was limited to comparing the energy required to operate the heating ventilating and cooling (HVC) and lighting systems of each plant. Two items —the power required to heat domestic hot water and that needed to run equipment plugged into electric outlets—were not included primarily because the demand for these services was likely to be the same in all schemes. In addition, the amount of energy required to provide hot water in an elementary school is relatively minor.

Preparing the Computer Input. The RFP required that the design/build teams submit data about building and system performance and that they perform the calculations of heat gains and losses associated with their schemes. The district assumed that the data on the submittal forms could be fed into the computer. Upon receipt of the submittals, however, the technical consultant team found it necessary to recalculate virtually all of the input data provided by the proponents. Other necessary inputs—weather data and the use pattern and operating profiles—were provided in the RFP.

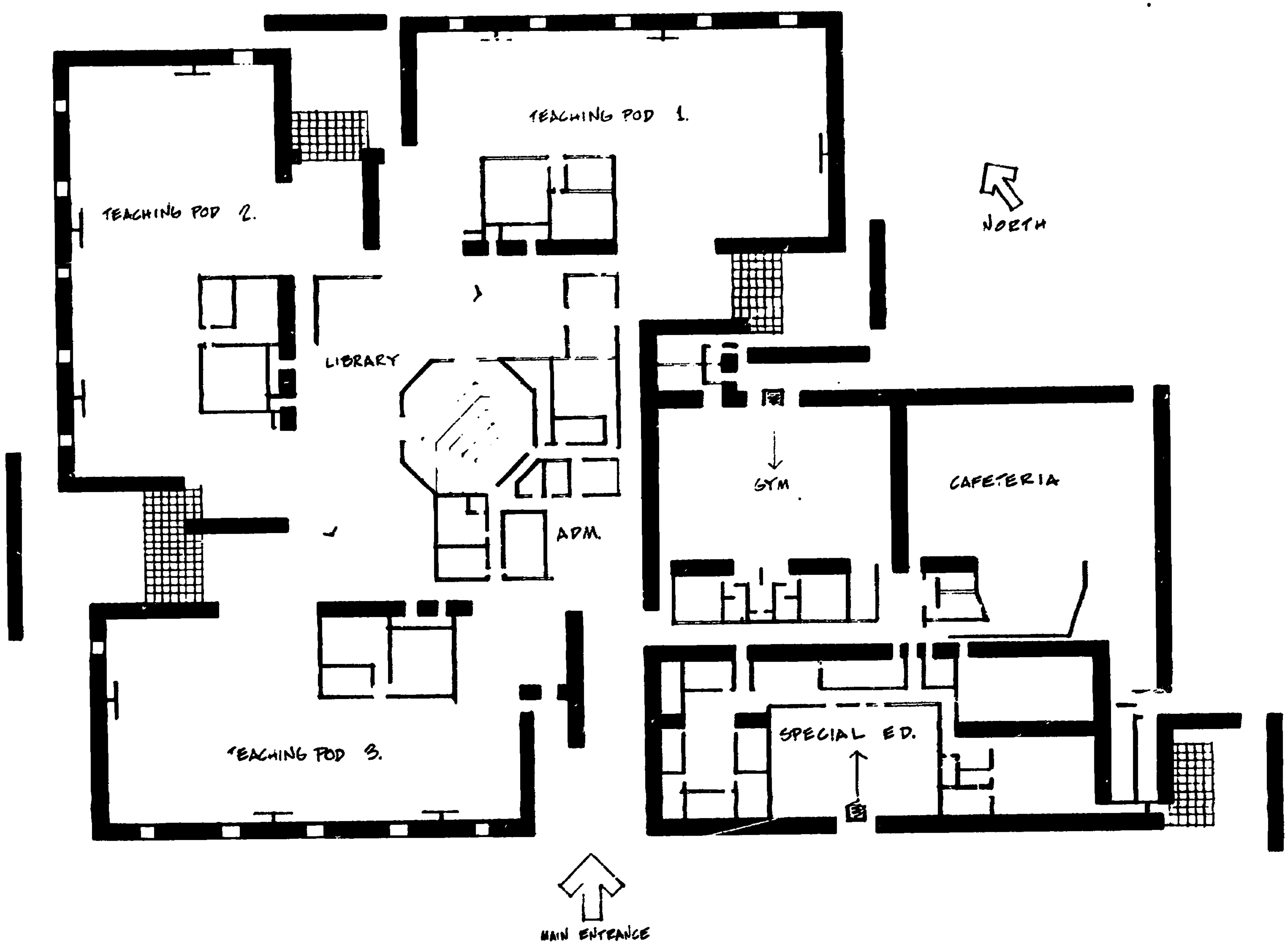
After completion of the required calculations and obtaining of missing data, each scheme was run through the Meriwether simulation package to arrive at an estimate of its annual operating energy usage in kilowatt-hours (KWh).

Assigning Points to the Schemes. Using the output of the computer runs, the technical consultants assigned points to each scheme on the basis of its relative energy

TABLE I
EVALUATION CATEGORIES AND POINTS

1. Energy Consuming Subsystems		50 points
a. Energy Conservation	35 points	
b. General Sub-System Characteristics	15 points	
2. Design		50 points
a. Base Points	40 points	
b. Bonus Points	10 points	
3. General		10 points
Maximum possible points		110 points

HERNDON ELEMENTARY SCHOOL



consumption. A formula was used which weighed each scheme against the submittal with the lowest annual KWh consumption. This scheme received 35 points, the full amount available in this category. Other schemes were assigned points using this formula:

$$\text{Scheme points} = \frac{\text{KWh of lowest scheme}}{\text{KWh of this scheme}} \times 35.$$

For example, using the data provided in Table II, Submittal X received 35 points, while Submittal Z received

$$\frac{691{,}337 \text{ KWh}}{1{,}063{,}226 \text{ KWh}} \times 35 = 22.76 \text{ points.}$$

FINDINGS

Table II presents the computer predicted annual energy consumptions for the three schemes submitted for the Herndon new construction project. In order to provide a comparison which shows the effect of the concern with energy conservation built into the program, the actual consumptions for three existing all-electric elementary schools in the district are also presented. The reader should bear in mind that the Herndon figures are theoretical while those of the three existing plants represent the actual amounts of energy used during school year 1970-71.

CONCLUSIONS

The apparent better energy performance of the proposed schools illustrated in Table II should be attributed to the concern with energy conservation indicated by the RFP and the emphasis accorded it by the evaluation procedure and not to the design/build process itself. Similar or even greater efficiencies could be obtained with other building delivery processes if the same importance were assigned to energy conservation.

Interestingly enough, concern with energy conservation did not result in any apparent changes to the basic building design, except that fewer windows were provided than is typical of other Fairfax designs. Because all schemes had the same first cost for the entire building, possible additional expenditures in energy using systems to achieve fuel savings were not apparent to the owner.

Until actual energy usage data can be obtained from the buildings, it is not possible to know with certainty whether the energy consuming systems—HVC and lighting—used in the evaluation process will perform as described in the proposals and by the Meriwether programs.

The total cost of the energy consumption evaluation process to the district works out at about $0.13 per square foot of facility built or modernized. Depending on the consumption base used, it will take the buildings selected by the total evaluation process between 12 and 18 months to repay this investment. If the cost of electricity rises, this repayment period will be shortened.

In conclusion, it appears that the incorporation of energy conservation criteria into the program had no major inhibiting impact on either the design or cost of the facilities and will result in substantial energy and energy cost savings in the future.

TABLE II
RESULTS OF ENERGY EVALUATION, HERNDON/FLORIS PROJECT

	Annual Energy Consumption	
	Annual Total	*Per Sq. Ft.*
Proposed Schemes		
Submittal X	691,337 KWh	11.52 KWh[a]
Submittal Y	854,570 KWh	14.24 KWh[a]
Submittal Z	1,063,226 KWh	17.72 KWh[a]
Existing All-Electric Elementary Schools[b]		
Hunters Woods	—	31.5 KWh
Laurel Ridge	—	32.3 KWh
London Towne	--	41.1 KWh

[a] These figures do *not* include the electricity required to heat domestic hot water or to serve equipment plugged into outlets.
[b] Source: Fairfax County Public Schools, *Energy Study*, Draft, Exhibit I.

SIX MODULAR LEARNING CENTERS, DALLAS, TEXAS

The material from which this article was prepared was supplied by Ted Gilles of Lennox Industries, and has been used with permission of the Dallas School District.

In late 1973, the Dallas, Texas School District and Lennox Industries, Inc., completed a study of energy consumption at the district's six modular learning centers. Except for mechanical systems, these six plants completed in 1970 and 1971 are essentially similar, having been built to the same 40,360 square foot plan.

The major difference in the six plants is that four of the schools have central plant HVC systems while the other two have modular rooftop single-zone equipment. The two schools with rooftop systems differ in that one, Darrell, is all-electric while the other, Marshall, has natural gas heating as do the four centers with central systems.

The objectives of the energy study were threefold:

1. To measure the energy consumption of the six centers.
2. To study the difference in energy consumption between the central and the rooftop HVC systems.
3. To compare the costs of owning predicted by the Lennox Total Cost of Ownership Nomograph with actual costs.

PROCESS AND FINDINGS

Since the schools were placed in service in 1970 and 1971, 1972—the first representative year of their operation—was selected as the period to be studied. Because of variations in the summer programs, emphasis was placed on the nine non-summer months.

Gathering Data. Two sources of information—district fuel and utilities billings and recording electrical meters—were used in the preparation of the study. The base data on energy consumption at the six plants were taken from the billing to the district by their fuel and utilities suppliers. These billings indicated both the amounts and cost of energy provided to each plant.

In order to determine in detail the energy usage of the rooftop system plants, the Dallas Light and Power Company installed recording meters at Darrell and Marshall Schools to monitor:

1. Refrigeration and blower power.
2. Electric space and water heating at Darrell School, the all-electric plant.
3. Total building power consumption.

The meters at the Darrell School did not function properly and produced only partial data. As a result, much of the detailed energy breakdown data was based on Marshall only. However, the similarity of the buildings allows the assumption of similar base loads at both facilities.

Tables I, II, and III present the findings of this phase of the study. The wide variety in amounts of energy used at the six plants should be noted, especially the significantly larger usage at the Seguin Center, probably due to greater nighttime use of this facility. Note also the higher demand for power (simultaneous electrical load) at the four system plants with central HVC systems.

Because the natural gas consumption figures for 1972 are somewhat ambiguous, the study included the gas consumption of the five gas heated schools during

TABLE I
1972 ENERGY USAGE, SIX DALLAS LEARNING CENTERS

	Rooftop HVC Systems			*Central HVC Systems*							
	Darrell[a]	*Marshall*		*Buckner*		*Navarro*		*Seguin*		*Tyler*	
	KWH	KWH	MCF	KWH	MCF	KWH	MCF	KWH	MCF	KWH	MCF
January	130,675	41,203	454	60,480	347	35,712	334	67,680	679	38,304	—
February	111,206	49,612	530	76,608	585	42,048	425	77,472	698	48,672	367
March	59,827	48,960	445	88,128	414	42,288	72	91,584	588	55,296	147
April	64,627	66,585	206	80,640	142	49,536	38	115,776	585	71,712	79
May	67,392	65,932	49	85,536	80	57,024	33	123,264	341	72,576	76
June	43,584	68,390	22	84,960	63	61,632	18	116,352	351	65,664	9
July	31,795	64,473	6	72,288	0	44,064	0	113,472	62	60,480	0
August	62,016	82,252	3	73,728	0	59,040	5	117,792	0	63,648	7
September	77,145	78,412	9	105,984	26	85,536	8	111,168	0	87,264	13
October	63,628	56,448	19	76,032	49	62,496	10	92,736	6	78,912	43
November	82,252	36,480	162	71,136	151	36,576	136	66,240	341	54,144	189
December	110,400	32,832	372	46,656	419	32,832	—	55,872	595	44,928	—
TOTAL	904,547	694,228	2,277	922,176	2,276	608,784	1,079	1,149,408	4,246	741,600	930

[a] All-electric school.

TABLE II
1972 FUEL AND UTILITY COSTS
SIX DALLAS LEARNING CENTERS

	Electric	*Gas*	*Total*
Rooftop HVC Systems:			
Darrell[a]	$14,413	——	$14,413
Marshall	12,454	$ 814	13,268
Central HVC Systems			
Buckner	$15,109	$ 811	$15,920
Navarro	11,938	385	12,323
Seguin	16,564	1,474	18,038
Tyler	13,320	320	13,640

[a] All-electric plant.

the first five months of 1973. During this period, the consumption of natural gas is similar for all of the plants except Navarro School.

Comparing Cooling Energy Usage. An examination of the data in Table I indicates considerable variation in the amount of energy consumed by the six centers, a greater variation than could be explained by the differences in power demands. The magnitude of the differences suggest that they can only be explained as the result of substantial differences in the operating and use patterns of the centers.

In order to compare the cooling energy consumptions, therefore, it was necessary to eliminate the effect of these operating differences. This was done by using the observed data to estimate the consumptions had all plants been operated on the same schedule as the rooftop system plants. The probable additional consumption of the larger central system plants (160 tons versus 152.9 tons) was estimated by using the difference in total electrical demand among the plants. In this case, the difference in demand of the total building is an accurate measure of the different efficiencies of the cooling systems as all six schools have similar lighting, air-handling and miscellaneous equipment.

This process resulted in an estimate of about twenty per cent greater energy consumption by the central HVC systems in cooling, assuming all six plants were run on the same operating schedule. The excess consumption was estimated at 21,643 KWh per central system school during the hot Dallas summer months and about 21,505 KWh each for the rest of the year.

Validating the Nomograph. The two types of systems were then run through the Lennox Industries Total Cost of Ownership Nomograph to test its results. Although prepared with computer assistance, this device allows a graphical solution of owning costs for the various types of HVC system using local values for key variables, such as fuel costs, weather, etc.

Using the monograph to estimate the costs of ownership at the Marshall School resulted in a very close correlation with the actual annual ownership costs. The monograph estimated annual cooling operating costs at $28 per ton against actual costs of $27.58 per ton. The heating energy cost estimate of $5 per ton per year compares favorably with the observed $5.41 per ton per year.

The projection of annual ownership costs for the two types of systems is $94 per ton for the rooftop system and $134 per ton for the central. The higher costs associated with the central plants are the result of the increased cooling operation costs plus the amortization of a considerable higher first cost for the HVC plant ($880 per ton against $500 per ton). Both owning cost calculations include an $18 per ton annual cost for a five-year maintenance contract.

TABLE III
1972 MAXIMUM KW DEMANDS
SIX DALLAS LEARNING CENTERS

	Rooftop HVC		*Central HVC*			
	Darrell	*Marshall*	*Buckner*	*Navarro*	*Seguin*	*Tyler*
January	156[a]	156	229	155	254	129
February	211	193	228	207	254	259
March	244	239	279	222	311	311
April	261	295	347	290	264	331
May	255	262	290	274	321	331
June	238	290	342	300	316	331
July	192	262	342	300	279	238
August	285	299	285	285	331	300
September	303	304	336	342	321	308
October	331	285	326	305	290	311
November	201	198	269	290	274	238
December	119	119	207	124	202	155

[a] For Darrell School, the all-electric plant, demand figures are derived and do not include electric heating demand. For all other schools, demand figures are from utilities billings.

HUNTINGTON BEACH, CALIFORNIA, UNION HIGH SCHOOL DISTRICT

The material from which this article was prepared was submitted by Ted Gilles of Lennox Industries, and was used with the permission of the Huntington Beach Union High School District.

In 1968, Lennox Industries, acting in response to requests from the staff of the Huntington Beach Union High School District, undertook a study of electric power and natural gas use at two of the district's plants —Marina and Fountain Valley High Schools. One of the major objectives of the study was to identify the causes of greater energy consumption at the newer Fountain Valley plant and to suggest methods of reducing this usage. When another school, Edison High School, was completed in 1969, the study was extended to cover its energy usage.

Although the three plants are similar in size, plan, enrollment and educational usage, significant differences exist in the lighting and HVC systems, particularly between the two newer plants and Marina (see Table I). Both Fountain Valley and Edison were constructed with building systems, Fountain Valley under the SCSD program and Edison as one of the first "post-SCSD" schools.

PROCESS AND PROCEDURES

After studying utility billings for the Marina and Fountain Valley plants, in 1968 the architect issued a new schedule for the operation of the clock-timers on the 41 rooftop HVC units at Fountain Valley in an effort to reduce the school's energy consumption. In spite of these efforts, significant differences in consumption between the two plants continued to exist.

To find the causes of these differences, special recording kilowatt-hour meters, capable of providing *hourly* determination of electric use, were installed at the two plants by the Southern California Edison Company. Using data from these meters, plus utility billings and information on operating profile at the schools, the study team was able to identify causes of excess energy usage and suggest possible means of reducing consumption.

At the time of this writing, the meters are still in use at the two plants. Current plans call for an annual evaluation of energy usage at the three schools by the district, Lennox, Southern California Edison and the Southern California Gas Company.

FINDINGS

The results to date of the study can be grouped under five headings:

1. Energy Use at Fountain Valley and Marina, 1970-1971.
2. Comparison of Daytime Classroom Hours Power Use.
3. Improvement in Energy Use at Fountain Valley High School.
4. Unnecessary Operating Costs at Edison High School.
5. Comparative 1972-1973 Energy Cost for the Three Schools.

Energy Use Analysis, School Year 1970-71. Table II compares the use of electricity and natural gas at Fountain Valley and Marina schools during School Year (SY) 1970-71. An examination of this table indicates that there are differences in usage in all three time periods, with the major difference occurring in the weekend and holiday usage category. The greater power use at Marina during the midnight to 7:00 a.m. period

TABLE I
CHARACTERISTICS OF STUDY SCHOOLS

	Marina	*Fountain Valley*	*Edison*
Building Area:	216,372 sq. ft.	220,640 sq. ft.	220,640 sq. ft.
Construction Completed:	1963	1966	1969
Installed Lighting:	450,000 watts	650,000 watts*	650,000 watts
Air Conditioning System:	Central energy source—modular air handlers	41 rooftop modular units	41 rooftop modular units
Air Conditioning Units and Cooling Tonnage:	1—386 ton 1—100 ton 2— 10 ton	23—16 ton 9—22 ton 9—heat & vent only	23—16 ton 9—22 ton 9—heat & vent only
Installed Tonnage:	506 tons	566 tons	566 tons
Outside Air Control:	Fixed minimum	Full range automatic (economizer)	

* Requires about 30 tons more cooling than Marina lighting.

TABLE II
1970-71 FOUNTAIN VALLEY AND MARINA ENERGY USE

	Fountain Valley	*Marina*	*Difference*
School Days—Midnight to 7:00 a.m.	278,053 KWh	310,545 KWh	−32,492 KWh
	695 Mcf*	506 Mcf*	189 Mcf*
School Days—7:00 a.m. to 4:00 p.m.	1,214,356 KWh	1,117,178 KWh	97,178 KWh
	886 Mcf*	825 Mcf*	61 Mcf*
School Days—4:00 p.m. to Midnight	676,733 KWh	658,309 KWh	18,424 KWh
	536 Mcf*	547 Mcf*	−11 Mcf*
Weekends and Holidays	638,088 KWh	371,766 KWh	266,322 KWh
	1,190 Mcf*	533 Mcf*	637 Mcf*
TOTALS	2,807,230 KWh	2,457,798 KWh	349,432 KWh
	3,307 Mcf*	2,431 Mcf*	876 Mcf*

* Gas consumption measured during November 5-23, 1971, and April 27-May 15, 1972, only.

can be attributed to the less efficient start-up procedure required by its older HVC system.

During the school hours from 7:00 a.m. to 4:00 p.m., Fountain Valley shows a 9 per cent greater energy use than Marina. One of the objectives of this study was to determine whether the additional 200 KW of lighting at Fountain Valley or the differences in methods of air-conditioning was the principal cause of this greater consumption.

Daytime Classroom Hours Power Use. After subtracting the estimated base power usage—lighting, fans and miscellaneous equipment—from the average daily power usage observed on the recording meters, the study concluded that the rooftop cooling system at Fountain Valley consumed about 18.5 per cent less electricity annually than the older, central plant system at Marina. A considerable portion of this difference can be attributed to the economizer cycles of the HVC units at Fountain Valley, which lock out all refrigeration equipment when the outside air is suitable for cooling (roughly when the air temperature is below 60°). The older Marina system uses a fixed minimum amount of outside air and therefore must operate refrigeration of cool recycled air at times when the Fountain Valley units are using outside air without cooling.

Fountain Valley Energy Savings. The excessive energy consumption at Fountain Valley during the weekend and holiday periods suggested improperly set or inoperative clock-timers. In late 1971 and early 1972, all 41 HVC units at the school were checked by Lennox factory service consultants. All clock-timers were placed in proper operating condition, improved design gas-fired heat exchangers as used in the newer units at Edison were installed and all units at Fountain Valley fine "tuned" to provide similar operating characteristics at both schools to get the most realistic comparison for the 1972-73 SY.

Using two comparative measures—KWh/average daily attendance unit (ADA) for electricity and cubic feet/degree day of heating/ADA for natural gas consumption—Table III presents an estimate of the savings in energy achieved at Fountain Valley between SY 1970-71 and SY 1972-73 as a result of this major maintenance program and other steps suggested by the study.

Avoidable Excess Usage at Edison High School. A similar analysis of energy usage at Edison suggests that $4,064 in energy costs could have been saved by more efficient operations. This analysis indicates that, while energy consumption has remained essentially the same at Marina and has been reduced significantly at Fountain Valley, it has increased considerably at Edison High School during the same period. A 1973 investigation of Edison's 41 rooftop HVC units found the variation from previous years energy use to also be due to improper operation and settings of the individual unit clock-timers. These problems have been corrected with revised maintenance instructions and procedures.

Comparative 1972-1973 Energy Costs. Using a comparative basis of the cost of energy per student per day, the three plants studied have the following energy costs for SY 1972-73:

Fountain Valley:	$0.0911/ADA/day
Marina:	$0.0931/ADA/day
Edison:	$0.1015/ADA/day

If the "avoidable excess" usage at Edison is eliminated the school's energy cost is reduced to $0.0944/ADA/day.

The reader is cautioned that larger enrollments usually result in apparently more efficient energy usages when this measure is applied, as certain base loads do not increase with enrollment. Spreading these constant consumptions and costs over a larger base results in lower average unit costs.

CONCLUSIONS

The study concludes that, as the national energy situation worsens, there are a number of steps which can

TABLE III
ENERGY SAVINGS, FOUNTAIN VALLEY HIGH SCHOOL, 1970-1973

POWER USE

	kwh	*Cost*	*Cost/kwh*	*A.D.A.*	*kwh/A.D.A.*
1970-71	2,851,200	$36,000.53	$0.0126	3,320	859
1972-73	3,045,600	$48,508.30	$0.0159	3,999	762

1972-73 with 1970-71 kwh/A.D.A.:

3,999 A.D.A. × 859 kwh/A.D.A. = 3,435,100 kwh
3,435,100 kwh @ $0.0159 = $54,618.09
Actual 1972-73 = 48,508.30
ELECTRIC POWER COST SAVINGS $6,109.79

GAS USE

	Mcf	*Cost*	*Cost/Mcf*	*Degree-days*	*Mcf/D.D.*	*cf/D.D./A.D.A.*
1970-71	25,519.2	$19,363.90	$0.759	1,448	17.62	5.31
1972-73	20,726.0	$15,637.93	0.755	1,490	13.91	3.48

1972-73 A.D.A. and degree-days with 1970-71 cf/D.D./A.D.A.:

3,999 A.D.A. × 1,490 D.D. × 5.31 cf/D.D./
A.D.A. @ $0.755 = $23,887.96
Actual 1972-73 Gas Cost = 15,637.93
GAS COST SAVINGS 8,250.03
TOTAL ENERGY COST SAVINGS FOR NINE MONTHS $14,359.82

be taken to reduce further the energy consumption of the three plants and to respond to temporary shortages in local power and fuel. The report finds that the rooftop modular units are particularly effective in this situation. To obtain these further savings from the rooftop units, some modifications could be made, including:

1. Connecting remote "operation selection" switches from a central panel to each of the 32 units equipped with refrigeration equipment to permit manual control of the operation of the two compressors in each unit when desired.
2. Locking out all second stage compressors during times of "brown outs," thereby reducing the power demand of each school by up to 300 KW. Critical areas could continue to have full cooling capacity by use of the operation selection switches.
3. Installing similar controls on the gas-fired heating sections of the units to lock out burner operation on any unit at any time such action was deemed desirable.

COLORADO DEPARTMENT OF EDUCATION

This article was prepared from material contained in the report "Energy Usage: a Computer Report on the School Day, School Calendar, Night Set-Back, and Year-Round Schools," released by the Colorado Department of Education in June 1974.

In June 1974, the Colorado Department of Education released the results of a computerized study of the probable effects of energy conservation strategies applied to a "typical" Colorado school. This study, performed by Energy Management Consultants of Colorado Springs at the request of State Commissioner of Education Calvin M. Frazier, was designed to estimate the effects on heating energy consumption of various changes in the building's operating schedule. The E CUBE Computerized Energy Analysis program was used to estimate the effects of the changes.

The Will Rogers Elementary School, located in Colorado Springs, was selected as a "typical" school building. This 39,756 square foot school, housing 497 students, was built in the late 1950's with an addition in the mid-1960's. About half of the building area is in internal spaces, including four classrooms, a learning center, a multi-purpose gym and several smaller rooms. The heating system provides hot water to unit ventilators located in each classroom.[1] Weather data for Denver in 1964 was used in the study, 1964 being the year which most closely approximates thirty-year averages.

SUMMARY OF FINDINGS

The report presents a summary of its findings in the following question and answer dialogue:

1. What heating fuel would be saved by closing school in January and extending school through June?
   a. The savings is 1.6% annually.
   b. With "special" set-back to 50°F, the savings is 3.9% annually.[2]
   c. With "special" set-back to 45°F, the savings is 5.8% annually.[2]
   d. With heating system shut-down and drained during Christmas vacation and January, the savings is 23.9% annually.
2. What heating fuel would be saved using four-day weeks in January and February?
   a. The savings is 0.7% annually. (Temperature set-back beyond 55° to 60°F is *not* recommended for short periods of three days or less.)
3. What fuel would be saved by closing school an additional seven days in January (extending Christmas vacation)?
   a. The savings is 0.7% annually.
   b. With a "special" set-back to 50°F, the savings is 3.9% annually.[2]
   c. With a "special" set-back to 45°F, the savings is 5.8% annually.[2]
4. What heating fuel would be saved using a four-day week and extending school one hour per day and one week in June?
   a. The savings is 0.7% annually.
5. What fuel would be saved if we delayed school starting time to 10:00 a.m., Daylight Savings Time in lieu of 9:00 a.m., Daylight Savings Time?
   a. The savings is 2.4% annually.
6. What fuel would be saved if we delayed school starting time to 11:00 a.m., Daylight Savings Time in lieu of 9:00 a.m., Daylight Savings Time?
   a. The savings is 5.2% annually.
7. How much fuel is actually saved with reduced daytime temperatures, using 75°F as the "base" temperature?
   a. A temperature of 70°F saves 17.1% annually (3.4% per degree reduced).
   b. A temperature of 68°F saves 23.4% annually (3.3% per degree reduced).
8. How much fuel is saved using various night set-back temperatures?
   a. A set-back of 5°F (to 65°F) saves 8.5% annually.
   b. A set-back of 10°F (to 60°F) saves 12.1% annually.[3]
   c. A set-back of 15°F (to 55°F) saves 15.2% annually.[3]

The report also made some suggest ons about energy usage with further operating chang :s. These results can be grouped under three headings: effects of fur-

[1] The data assumes that the school heating plant is on an occupied-unoccupied seven-day time clock schedule using 10° of set-back from 70°F space temperature (i.e., night set-back), unless noted otherwise. Time clock was set to bring heating system "on" two hours before school starting time (9:00 a.m. Standard Time was the "base" time), with outside air off until school actually started. The time clock went to unoccupied set-back with outside air off at 3:00 p.m. Standard Time.

[2] Most standard night thermostats cannot be set below 55°F; therefore, special s t-back methods must usually be used.

[3] Set-back temperatures or time duration of set-back should be varied with outside ambient and wind conditions. Either smaller set-backs or shorter time schedules should be used during severe weather conditions. Also, different school buildings and systems require varied "recovery" time.

ther operating changes, the probable effects of air-conditioning and year around use of the school, and the reliability of the results.

Further Operating Changes. Energy can be conserved by using the most appropriate night set-back schedule as well as by lowering the night set-back temperatures. Altering the night set-back schedule from "on" at 5:00 a.m. and "off" at 6:00 p.m. to "on" at 7:00 a.m. and "off" at 3:00 p.m. will result in an estimated heating fuel savings of 13.8 per cent annually.

If the state code requirement for minimum outside air were reduced to 12.5 per cent from its present 25 per cent, savings in heating fuel of 3.4 per cent annually could be expected. This saving is based on the assumption that outside air is controlled and is introduced into the building between 9:00 a.m. and 3:00 p.m. only. If outside air is used until 6:00 p.m., an additional 8.1 per cent in heating fuel would be required.

Air-Conditioning and Year-Round Use. The computer was used to predict changes in fuel and utility costs resulting from adding full air-conditioning, including cooling, to the plant. Adding full air-conditioning to the plant without changing its insulation or its nine-month school year adds 16.4 per cent to the annual electrical consumption of the building.

Using the air-conditioned school plant on a year-round basis would increase the annual electrical consumption by 61.2 per cent—largely the result of having to remove the heat added to the building by sunlight, by school children, and by the lighting system. The study found that the large percentage increase in electrical consumption resulting from year-round air-conditioning would be essentially the same if the plant were located in Eagle, Colorado, a high-altitude town with a cool climate.

The amount of energy that could be saved by improved thermal insulation of the building was not studied; however, other studies by Energy Management Consultants indicate that as much as 40 per cent or more of the annual heating fuel could be saved by improved insulation. Such treatment would include better insulation in the walls and roof, reducing and shading the glass area, and replacing existing glass with insulating glass. Such improvements would not only reduce the energy consumption, they would also allow the use of smaller heating and cooling plants.

Reliability of the Results. To test the reliability of the results, the computer program was run using Colorado Springs weather data and the result compared with the actual consumption of Will Rogers School. The computer results differed by only 5.9 per cent from actual consumption figures.

SEQUOIA (SAN MATEO COUNTY, CALIFORNIA) UNION HIGH SCHOOL DISTRICT

The material from which this article was prepared was submitted by Hector H. Aiken, Consulting Mechanical Engineer, and is used with permission of the Sequoia Union High School District.

In the winter of 1973, the Sequoia Union High School District initiated an energy conservation program at its six educational plants and central district office. Key elements in this conservation plan were the setting back of thermostats to 68° and reducing the temperature of heated water in the district's swimming pools. During the month of December 1973, all heating of swimming pool water was stopped.

Following the undertaking of this conservation program, the district employed Hector H. Aiken, Consulting Mechanical Engineer, to evaluate the results of the program. This study had three objectives:

1. To study consumption of natural gas at the district's plants.
2. To evaluate the effect of the energy conservation program.
3. To identify further areas of energy conservation.

PROCESS AND PROCEDURES

Most of the data used in the study was taken from utility billings to the district for the periods covered. It should be noted at this point that the study covers only the natural gas usage by the district and does not include electrical power.

FINDINGS

Natural Gas Usage at the District's Plants. Figure 1 plots the typical gas use by the district's educational plants against the degree-days of heating during each month from November 1971 to January 1974. As would be expected, the two curves exhibit a similar behavior. Unlike the districts in other articles in this report, natural gas is sold to Sequoia in therms, a unit equivalent to 100,000 Btu's of energy. Whereas the other districts in this report purchased gas by volume (cubic feet or 1000 cubic feet) the gas delivered to the Sequoia District is metered by calorimeter test and sold on the basis of energy content.

The area-energy relationship of the district's plants is illustrated in Table I. This table indicates that the plants are not all equally efficient in usage of natural gas. For example, Carlmont High School has only about 16.5 per cent of the district's floor area yet consumes over 23 percent of its heating energy. On the other hand, the Sequoia High School has over 23 per cent of the district's floor area and consumes only 15.7 per cent of its heating energy. The report attributes much of this difference to the physical layout of the plants (single-wing campus-plan versus compact two-story plan), but also indicates operating deficiencies at Carlmont.

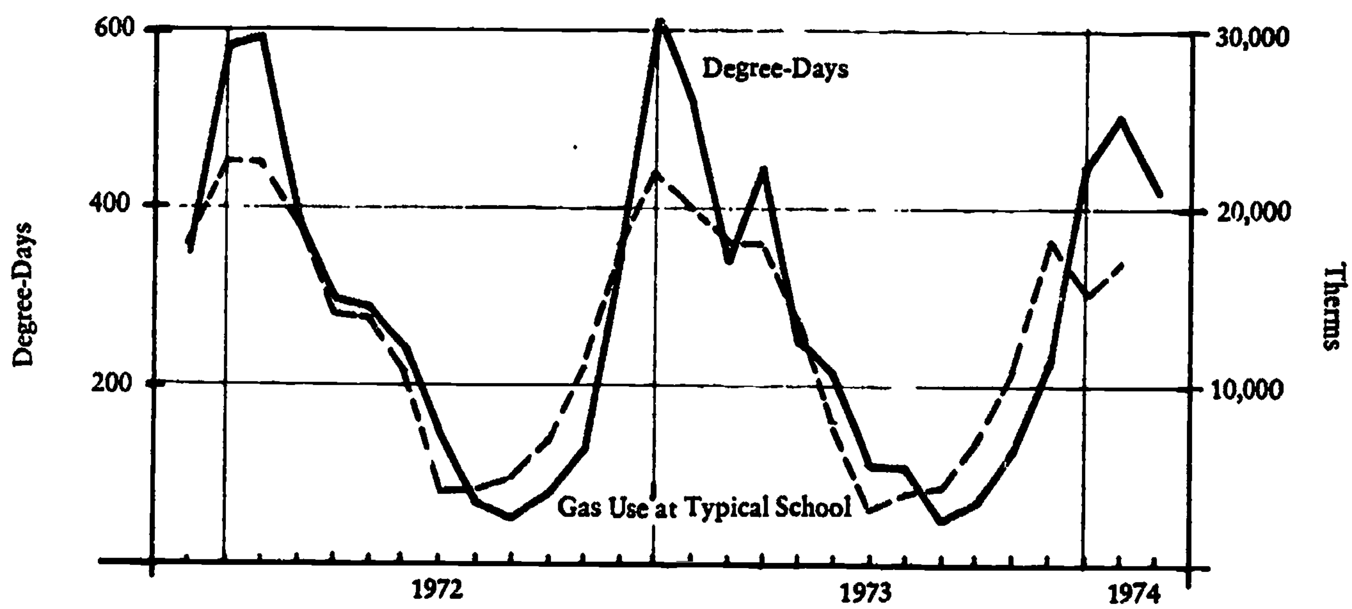


Figure 1

Gas Use and Degree Days

TABLE I
AREA-ENERGY RELATIONSHIP—SEQUOIA UNION HIGH SCHOOL DISTRICT

	Enclosed Space		*Natural Gas Consumption*		
				Therms/Sq. Ft./Year	
School	*Sq. Ft.*	*Per Cent of Total*	*Per Cent of Total*	*'71-'72*	*'72-'73*
Sequoia	197,600	23.10	15.47	0.727	0.801
Menlo-Atherton	136,700	15.98	14.71	1.102	0.996
Carlmont	141,100	16.49	23.21	1.553	1.658
Woodside	125,000	14.60	15.61	1.180	1.261
San Carlos	128,500	15.02	14.68	1.133	1.095
Ravenswood	100,400	11.73	10.17	0.962	1.016
District Office	26,400	3.08	6.15		
TOTAL	855,700	100.00	100.00		

Effect of the Energy Conservation Program. The effect of the 1973-74 energy conservation program is shown by comparing the natural gas usage in the winter months of 1972-73 and 1973-74 as shown in Figure 1 and Table II. On Figure 1, the marked drop in the typical school usage during winter 1973-74, as compared to the curve indicating degree days, indicates this saving.

Table II shows the results of the program, by school, along with the number of degree-days in each month. The report suggests that had the winter of 1973-74 not been a relatively mild winter, the energy savings from the program would have been more dramatic.

CONCLUSIONS

The report concludes that, in spite of the considerable success that the energy conservation program was able to achieve in the winter of 1973-74, there are still a number of steps which could be taken to further reduce natural gas usage at the district's plants. The report points out that the district's gas usage figure of 1.1 therms per square foot per year is still much greater than recent federal recommendations which are as low as .55 therms per square foot per year. Among the further steps recommended are:

1. Review the settings of the heating system clock-timers on a month-by-month basis.
2. Reduce teacher wastage of heating energy by encouraging them to open windows as little as possible.
3. Balance electrical use curtailment against the resulting increase in need for heating.
4. Check certain of the boiler plants, most notably the Carlmont plant, for efficiency of operation.
5. Although district plants are currently on firm (noninterruptible) gas service, continue to use oil as a back-up fuel.

TABLE II
SEQUOIA UNION HIGH SCHOOL DISTRICT
COMPARATIVE NATURAL GAS CONSUMPTION

	November			*December*			*January*		
	1972	*1973*	*Change*	*1972*	*1973*	*Change*	*1973*	*1974*	*Change*
Degree-days/month	350	327	−6.6%	613	459	−25.1%	521	501	−3.1%
COMPARATIVE THERMS PER DEGREE DAY									
Sequoia HS	57.5	59.8	+4.0%	41.5	29.3	−29.4%	38.4	33.1	−13.8%
Menlo-Atherton HS	60.5	47.1	−22.2	31.7	27.1	−14.5	33.1	31.4	−5.1
Carlmont HS	77.6	61.7	−19.9	51.6	39.0	−24.5	56.7	46.3	−18.1
Woodside HS	69.1	47.3	−31.5	36.7	29.4	−19.9	40.5	37.6	−7.2
San Carlos HS	46.1	79.5	+72.5	34.3	26.7	−22.2	38.7	28.7	−25.8
Ravenswood HS	43.0	31.6	−26.5	25.6	19.5	−23.8	23.3	22.6	−3.0
District Office	20.3	21.8	+7.4	11.5	15.9	+38.3	11.7	11.4	−2.6
TOTAL	373.2	348.9	−6.5%	232.9	186.9	−19.7%	242.3	211.1	−12.9%

BSIC CONCLUSIONS

While investigating the responses of various school districts to the energy crisis, BSIC arrived at some conclusions regarding the current energy situation and the possibility of coping with it by rational procedures. These conclusions fall under three topics, which are:

1. The problems of analysis using existing tools.
2. The need for design and operation energy use guidelines.
3. The need for more complete energy use studies.

Problems of Analysis Using Existing Tools

The science of analyzing a building's energy consumption and the related issue of life-cycle cost analysis are relatively new to the building field. As a result, many of the analytic tools available and in use are primitive. Even the conceptual foundations of these tools may be incomplete or rest on untested assumptions. If these methods are to be relied upon as universal decision-making aides, some of the problems must be identified and solved.

Problems of Computer Simulation Programs. As the need for an effective computer program to analyze building energy usage has only been widely accepted since the late 1960's, the progress made in this area by the design professions has been astounding. Today several program packages are available which have been tested and validated and which, within certain limitations, can be used to provide reliable information to decision makers.

All of these packages, however, suffer from two shortcomings. First and foremost is the difficulty of their use. Although this situation is daily improving, gathering the data required by these programs is an arduous task and requires considerable engineering expertise. Further, as the Fairfax County Energy Study shows, it may take several computer runs to obtain results which are comparable with those measured or metered on-site. On the Fairfax County Design/Build project, it was necessary for project consulting engineers to rework the data provided by the engineers for the design/build teams.

The second principal problem lies in the programming currently used by energy evaluation packages. These packages are "single-pass" type programs, that is, they analyze one set of input data to conclusion without permitting different input values to be used. As a result, if several energy strategies are to be analyzed, as in the Fairfax Energy Study, a separate run of each alternative, as if it were a new building, is required.

To rectify these problems, BSIC has recently become involved with a program of the Federal Energy Administration (FEA) to develop and test a computer-aided energy use analysis center for educational buildings. At the end of this one-year program, FEA hopes to have available for school districts a center to which information about buildings and their operations can be submitted and from which suggestions, including cost implications, as to energy saving strategies can be obtained.

Unpredictable Energy Costs and Availability. Life-cost analysis is particularly sensitive to the estimates of future operating costs which must be prepared when the technique is used. Because of the short-range nature of first-cost projections, these costs are often estimated with acceptable accuracy. To project what is going to happen to fuel and utility costs, and whether these forms of energy will even be available, is much more difficult in view of the instability and the likelihood of great jumps in these costs. Few would have predicted two years ago that gasoline prices would go up by over fifty per cent in less than one year, as happened in many areas between mid-1973 and mid-1974.

To show how these cost jumps can affect rational analysis of the problem, Tables I and II show what fuel costs have done to some of the projections of costs and savings made by the Fairfax Energy Study. Table I shows how the 1973 and 1974 fuel cost hikes affected the results of the computer analysis. Table II turns this analysis around and indicates what level of fuel costs it would take to pay off the suggested capital investments in 10, 20 and 40 years. A small increase in fuel costs would justify implementing many of the suggested strategies which have seemingly unacceptable first costs at present prices.

Further information on life-cycle cost analysis and on the implications of fuel and utility costs can be found in the EFL publication *The Economy of Energy Conservation in Educational Facilities*[1] and the BSIC Energy Workbook Section *Energy Conservation and the Building Shell.*[2]

The Need for Energy Guidelines

A telling commentary on the current state-of-the-art of energy conscious design is provided by the Fairfax County Design/Build program. In a program where the energy conservative design accounted for 35 per cent of the evaluation for contract award, the three submitted proposals varied in energy consumption by

[1] Available at $2.00 per copy postpaid from EFL, 477 Madison Avenue, New York, N.Y. 10022.

[2] Available at $3.00 per copy postpaid from BSIC/EFL, 3000 Sand Hill Road, Menlo Park, CA 94025.

TABLE I
EFFECT OF ENERGY COST INCREASES ON ESTIMATED ANNUAL ENERGY COSTS & SAVINGS, WEST SPRINGFIELD HIGH SCHOOL

Alternative	Effect on Annual Energy Costs[a] 1972 Rates	1973 Rates	1974 Rates
Base—Existing	$46,630[b]	$52,638[b]	$112,547[b]
1—Reduce glass area from 18.5% to 10%	−$549	−$695	−$1,433
2—Reduce lighting wattage by 15%	−$3,669	−$3,331	−$7,985
3—Reduce outside air intake by 15%	−$4,138	−$5,949	−$11,023
4—Use a heat recovery system 80% efficient	−$6,363	−$9,170	−$16,177
5—Shut off exhaust fans between 3 p.m. and 7 a.m.	−$1,193	−$1,642	−$2,065
6—Install double glazing on all windows	−$1,217	−$1,778	−$3,468
7—Set back to 60° between 3 p.m. and 7 a.m.	−$7,639	−$10,076	−$18,560
8—Night set back plus minimum outside air	−$8,137	−$11,059	−$21,612

[a] 1972 Rates = $0.125/gallon for oil, $0.01/KWh for electricity.
1973 Rates = $0.180/gallon for oil, $0.01/KWh for electricity.
1974 Rates = $0.350/gallon for oil, $0.02/KWh for electricity.
[b] Estimated total annual energy costs.

65 per cent for the same floor area and program (see Table II, page 8).

What this seems to point to is the need for some guidelines defining what is good design and operation in energy terms. If designers know what can and should be achieved in their schemes, then there is a far greater likelihood of optimum performance within cost constraints.

To illustrate this point further, Table III presents the annual energy consumptions of the school plants discussed in this report. In order to compare their energy uses, all of the fuel and electricity consumed in the plants has been reduced to two comparative measures. These figures—Btu's of energy consumed per year and Btu's of energy consumed per square foot per year—have been suggested as means of comparative energy use analysis by the federal government's General Services Administration (GSA).

As far as BSIC can tell, the only guideline for energy consumption that has been developed to date is GSA's tentatively suggested 55,000 Btu/sq. ft./year for office buildings. Although this figure is for a different building type and operating usage, it does provide a ball-park measure of building efficiency which can be applied to schools.

The Need for More Complete Energy Use Studies

Many of the energy studies which have come to BSIC's attention are weak in direction and objectives. Few have the well defined objectives and precision of design of the Fairfax County studies. The somewhat wandering nature of most of these studies is understandable, resulting from a realistic attitude of "we must do something and we can't go too far wrong with a general approach." Unfortunately, such approaches result in pragmatic decisions about procedures and the waste of much sincere effort. Perhaps as more studies are made and published, some of this uncertainty will be cleared up.

A second problem with most current studies is that they only point toward what should be done. In many cases, districts have been able to carry out only those suggestions which do not require capital investment, if they have gone that far. As a result many of the suggestions generated by these studies have not been tested in real situations. To fully validate the methods of analysis which generated them, these suggestions must be implemented and their results analyzed.

A further point introduced by this discussion is the possibility of building into new and remodeled plants

TABLE II
FUEL COSTS REQUIRED TO RECOUP INVESTMENT IN GIVEN TIME PERIODS WEST SPRINGFIELD HIGH SCHOOL

Alternative	10-Year Payoff Oil (gal)	10-Year Payoff Elec (KWh)	20-Year Payoff Oil (gal)	20-Year Payoff Elec (KWh)	40-Year Payoff Oil (gal)	40-Year Payoff Elec (KWh)
1—Reduce glass area from 18.5% to 10%	$1.19	$0.061	$0.76	$0.042	$0.58	$0.032
2—Install double glazing on all windows	0.40	0.022	0.25	0.014	0.19	0.011

the instrumentation necessary to effectively monitor the energy usage of the plant. Each of the studies in this report is in some way affected by the generality of energy use data provided for the *building as a whole* by the energy vendors. In some districts, even this information is not available. One of the promising aspects of some of these studies is the high level of cooperation and assistance in measuring and analyzing energy use provided by the utility companies.

Even in the studies with the most complete metering and observation of energy use, vital gaps appear in the data. For example, in very few of the studies BSIC has seen is it possible to obtain the amount of electricity consumed by the lighting system of a school. Estimates can be made, but data is rare. Perhaps a new design methodology for electrical distribution, involving the routing installation of devices to monitor power flow will evolve.

Finally, large commercial buildings are routinely equipped with sophisticated control and monitor consoles for their operating systems. Examples of school plants in which all energy flow is monitored and controlled by central stations or computers are rare.

TABLE III
ANNUAL ENERGY CONSUMPTION OF SCHOOLS IN THIS REPORT

School	*Annual Use Months*	*Heating* (*Btu per year × 10^6*)	*Cooling* (*Btu per year × 10^6*)	*Other Electric* (*Btu per year × 10^6*)	*Total* (*Btu per year × 10^6*)	*Btu/sq. ft./year*
Dallas, Texas, Learning Centers, 1972						
Darrell LC	9	986	404	1,229	2,620	64,916
	12	987	648	1,454	3,089	76,536
Marshall LC	9	2,455	336	1,300	4,091	101,363
	12	2,489	735	1,636	4,860	120,416
Buckner LC	9	2,419	2,360		4,779	118,049
	12	2,488	3,149		5,637	139,668
Navarro LC	9	1,154	1,516		2,670	66,155
	12	1,179	2,079		3,258	80,723
Seguin LC	9	4,189	2,738		6,927	171,630
	12	4,641	3,925		8,566	212,240
Tyler LC	9	991	1,884		2,875	71,234
	12	1,016	2,533		3,549	87,934
Huntington Beach, California						
Fountain Valley HS						
1970-1971	9	27,663	903	8,833	37,400	169,507
1971-1972	9	26,009	10,103		36,112	163,670
1972-1973	9	22,467	10,401		32,868	148,967
Marina HS						
1970-1971	9	21,044	1,108	7,334	29,486	136,275
1971-1972	9	22,065	8,932		30,999	143,267
1972-1973	9	21,366	9,339		30,705	141,908
Edison HS						
1971-1972	9	19,099	8,232		27,331	123,871
1972-1973	9	23,166	8,983		32,149	145,708
Fairfax County, Virginia, 1971-1972						
Quander Road ES	12	3,717	000	814	4,531	113,182
West Springfield HS	12	12,628	10,930		23,558	84,412
Lee HS	9	22,792	000	3,562	26,354	105,221
	12	22,792	000	4,191	26,983	107,732
Laurel Ridge ES	9				8,039	99,338
	12				9,065	112,013