RELATIVE HEATING COSTS FOR VIRGINIA DEPARTMENT OF HIGHWAYS AND TRANSPORTATION BUILDINGS

by

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ABSTRACT

This report presents the results of a survey of the energy used to heat various buildings owned and operated by the Virginia Department of Highways and Transportation. Energy intensity and cost intensity indices (EII and CII) for buildings were calculated. These can be used to indicate possible deficiencies in the heating and cooling systems of the buildings. Selected buildings were inspected in depth to determine possible causes for relatively high energy use and costs as compared with buildings of similar size and construction. It was concluded that much of the difference in energy and cost efficiency of buildings with similar uses could be attributed to the age and design of the buildings or to the type of heating system, rather than to differences relating to thermostat settings or the use of lights. Inefficient building design was exhibited by inadequate insulation in roofs and ceilings; no insulation on heating, ventilating, and air conditioning distribution (HVAC) systems; ineffective controls on the HVAC systems; and the use of metal-casement windows poorly sealed against infiltration of cold air.

The report recommends that immediate efforts be made to train maintenance personnel to adjust HVAC equipment for optimum efficiency and to establish a preventive maintenance schedule for each component of the HVAC system. It is also recommended that the energy efficiency of expendable items be considered in addition to first costs. Energy-efficient fluorescent lighting should be installed in place of incandescent lighting as soon as possible. Centralized purchase of energy-conserving materials such as insulation should be instituted to assure minimum costs.

Other longer range actions requiring policy or planning changes that should be acted upon as soon as possible include reorganization of the budget structure to identify funds for energy-related capital improvements. Further evaluations of the energy conservation potential should be conducted for existing buildings that were shown by the study to have high EII and CII values. The standard building design proposed for new structures should be evaluated from the standpoint of energy efficiency.

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INTRODUCTION

In 1978 a brief survey was made of conservation practices and the potential for reduced energy use in the buildings owned and operated by the Virginia Department of Highways and Transportation.(1) The report on that survey reviewed the policy within the Department and made recommendations for a number of measures that could be implemented immediately to reduce energy use.

The survey revealed that the Department owned and operated about 1,750 buildings ranging from large complex administrative buildings to unheated storage sheds. However, the existing records were insufficient to indicate the relative energy consumption or costs of heating and cooling of similar buildings using different fuel types and different heating or cooling systems. Accordingly, the present study was undertaken to provide data needed for several purposes, such as:

1. to identify deficiencies of the heating and cooling systems in the buildings;
2. to recommend corrective action when use of energy and costs are relatively high; and
3. to indicate potential savings from changes in heating and cooling procedures.

SCOPE

The study involved an initial survey of the size, type of fuel used, and method of heat distribution for all heated buildings owned by the Department. This was followed by the collection of data to show the consumption of energy by a number of selected buildings of several types. The actual consumption of fuel during a heating season and its cost were compared for buildings selected on the basis of size and data availability. Indices based on both energy use and cost were derived to take into account variations in building size and location and to identify the more energy- and cost-intensive buildings operated by the Department.

METHODS AND PROCEDURES

Much of the information for this study was collected on questionnaire forms submitted to designated representatives of the district engineers. Each representative worked closely with the principal investigator of the project in completing forms and providing the necessary information. The locations of the Department's districts and residencies by number are shown in Appendix A.

The project was conducted in three phases: (1) a preliminary survey to identify all the heated and cooled buildings at each district and residency; (2) the collection of cost and energy-use data for a designated heating period; and (3) the development of indices for costs and quantities of energy used so as to establish the relative energy- and cost-intensity of the principal buildings operated by the Department.

Data Collection

The first phase of the study was necessary because existing records did not show which of the buildings were heated, the size of the buildings, or the method of heating. To obtain the necessary information, a form was developed and copies were distributed to each district and residency administrative location. An example of the form developed for this phase of the project is shown in Appendix B. The data obtained were tabulated to provide an inventory of the heated and cooled buildings. These data were then used to select the buildings to be included in the second phase of the project, which was the collection of data on the actual energy consumed over a heating period. The form developed and used for this purpose is reproduced in Appendix C.

The general purpose of this form was to gather energy consumption and cost information. No attempt was made to have field workers convert the consumption values to Btu's or to record degree day data. To provide independent checks on the accuracy of the data for electricity and natural gas, both billing data and individual meter readings were collected. For the remaining energy sources, the records of both storage amounts and delivery amounts served this purpose.

Calculations of Energy-Intensity and Cost-Intensity Indices

From the data collected, an energy-intensity index (EII) and a cost-intensity index (CII) were calculated. The derivations and discussions of the significance of each of these indices are given in reference 2. Basically the EII is the amount of energy expressed as Btu/ft.^{2} that would be consumed for heating a building for a 3-month period if the number of degree days during that period equalled 2,500. Degree days are relative measurements of the outdoor air temperature, heating degree days are deviations of the mean daily temperature below 65°F, and cooling degree days are deviations of the mean daily temperature above 65°F. For example, if a weather station reported a mean daily temperature of 50°F, the heating degree days for that 24-hour period would be 15. In deriving the EII used in this report the energy required for heating is estimated by subtracting from the total energy consumed for the 3-month period an amount estimated to be the base load for non-heating purposes (lights, hot water, etc.). The base load is assumed to be equal to the energy use during a month in which the heating degree days most nearly equal the cooling degree days. The 3-month period selected in this study was from January 1 through March 31, 1980. The number of heating degree days, 2,500, was arbitrarily selected as representative of an average number of degree days for the selected 3 months in Virginia. The cost intensity index is similarly derived, except that the cost of heating per 1,000 ft.^{2} corrected to 2,500 heating degree days during the 3-month period is estimated.

As will be discussed later, other factors such as size, design, use of buildings, and type of fuel used can have a significant effect on both the EII and the CII. However, the indices provide good information based on unit areas heated for approximately the same climatic conditions.

In this study it was found that two or more buildings at the same site often shared a common energy supply, thus it was necessary to base the index calculations on the total group rather than individual buildings. Most frequently, groups were defined because a single electric meter served all of the buildings. The EII and CII were calculated for the total group by combining the energy consumed, cost, and floor area data.

The buildings for which individual records were obtained were classified either as offices or shops. Offices are those buildings with individually supplied energy in which sedentary work is performed. These buildings are not expected to have any large special equipment or abnormal ventilation. Shops are buildings in which more physical labor is conducted and these buildings are expected to have special energy-consuming or high-ventilation requirements.

The total-electric buildings within each group were identified for special data analysis.

The calculated indices for offices and shops were inspected individually to identify trends, and then comparisons were made between types of buildings. These comparisons made it possible to identify those buildings within each type that were more energy- or cost-intensive than normal.

Finally, a detailed inspection was made of five of the buildings to determine the reasons for high index values. Each inspection included a review of available blueprints, discussions with occupants and maintenance personnel, and a tour of the building to observe the type and manner of heat distribution and the physical condition of the system. Problems were identified and recommendations for improvement were made.

PRELIMINARY SURVEY RESULTS

The survey forms were sent to 61 sites and those returned identified 221 heated buildings. Appendix D is a summary of the information provided for each of the buildings. It includes:

1. sites and building names
2. energy supply codes (see Table 1)
3. total floor spaces
4. heated floor areas
5. cooled floor areas
6. types of energy used

Table 1 summarizes the findings concerning energy supplied to these buildings. As indicated, only 98 of the 221 heated buildings (44.3%) were supplied energy independently of other buildings. Table 2 summarizes the type of energy used to heat the buildings and the floor space involved in each.

Table 1

Preliminary Survey Results — Breakdown by Energy Supply Code

Energy Supply Code*	Number of Buildings	Total Heated Floor Area (ft.^{2})	Percentage of Buildings	Average Floor Area (ft.^{2})
B	98	728,114	44.3	7,430
C	114	301,319	51.6	2,643
A,C	7	16,235	3 .2	2,319
No response	2	—	0.9	—

*Energy Supply Codes:

A — A heated asphalt tank is on the electric circuit.

B — The point of delivery of all energy types is the building; consumption data would apply to only one conditioned (heated/cooled) building.

C — The point of delivery for at least one of the energy types is at a central location; consumption data would apply to a group of conditioned buildings.

Table 2

Preliminary Survey Results — Breakdown by Heating Energy Type

Energy Type	Number of Buildings	Total Heated Floor Area (ft.^{2})	Percentage of Buildings	Average Floor Area (ft.^{2})
Electricity*	42	106,754	19.2	2,542
#2 Fuel Oil*	119	666,233	54.3	5,599
Residual Fuel Oil	2	9,012	0.9	4,506
Natural Gas	8	16,540	3.7	2,068
Propane/LPG	6	8,392	2.7	1,399
Kerosene	26	26,082	11.9	1,003
Wood/Coal	7	4,824	3.2	689
Combination	9	207,831	4.1	23,092
All Types*	219	1,045,668	100.0	4,775

*Two buildings did not report heated floor area and are omitted from this table; one was electrically heated and the other was heated with #2 fuel oil.

These tables show that generally it is the larger buildings that are individually metered, the average size of this group being 7,430 $ft.^2$ compared to an overall average of 4,775 $ft.^2$. Seven types of fuel are used; namely, electricity, No. 2 fuel oil, residual fuel oil (No. 5 or No. 6), natural gas, propane/LPG, kerosene, and wood/coal. Number 2 fuel oil is the most frequently used fuel and electricity is the second most frequently used. Together these two fuels supply heat to 73.5% of the buildings. Propane/LPG, kerosene, and wood/coal are used most often for the smaller buildings.

The data provided in the survey (Appendix D) was used to examine the relative energy-and cost-intensities for various functional categories of buildings. The categories are:

1. district offices
2. residency offices
3. survey offices
4. design offices
5. materials labs
6. district maintenance shops
7. residency maintenance shops
8. sign shops.

In order that the comparisons made would reflect similar conditions for different geographical locations, some of the data provided in Appendix D were eliminated from consideration in calculating the energy intensity and cost intensity indices. The exclusions were:

1. All buildings in the Salem District, because only 4 of the 43 buildings were individually metered.
2. The buildings at the Chesterfield and Petersburg residencies (Richmond District), because renovation work was under way.
3. All buildings on electric meters with heated asphalt tanks.
4. The transportation engineer's office in the Culpeper District, because it was on an electric meter with non-Department buildings.
5. All Richmond/Petersburg Turnpike facilities, because of the late arrival of survey responses.

By this process, 145 of the 221 buildings listed in Appendix D were selected for further study; 86 individually supplied buildings and 59 buildings in groups.

ENERGY USE AND COST DATA SUMMARY

The statewide collection of energy data was initiated in October 1979 and continued through June 1980. The data were received quarterly and screened for accuracy. The period from October to December 1979 was used as a training period for data gatherers in an attempt to minimize mistakes that would be made because of unfamiliarity with the new data collection forms and procedures. However, screening of the data for the period January through June 1980 revealed erroneous or incomplete data for 73 buildings. It was, therefore, necessary to also eliminate those from the calculations of the cost and energy indices. The numbers and types of buildings eliminated and the reasons for the elimination are given in Table 3.

Indices were calculated for the remaining 72 buildings. Table 4 lists these buildings and includes the building type, size, energy use, and energy cost for the period from January 1 through March 31, 1980. These buildings represent 539,609 ft^2 of heated floor space, or 51.6% of the total floor space for all buildings listed in the preliminary survey results. They generally represent the larger buildings operated by the Department, as indicated by the average size of 7,495 $ft.^2$ compared to the overall average in the preliminary survey of 4,775 $ft.^2$ The average heated floor space in the individually supplied buildings in this group is 9,273 $ft.^2$ The cost for this group for the 3-month period involved was $216,629. Expressed in more familiar terms, the total of 30.3 billion Btu's involved is equivalent to the energy contained in approximately 220,000 gallons of number 2 fuel oil.

Table 3

Reasons for Omission of Selected Buildings from Index Calculations

Reason	Office	Shop	Group	Total
No form received	12	9	13	34
Missing entries	2	2	15	19
Data inconsistencies	2	6	10	18
Heating system down	0	1	0	1
Heating system converted	1	0	0	1
TOTAL	17	18	38	73

Table 4

Summary of Heating Energy Use and Cost for Selected VDH&T Buildings for January through March 1980

Site and Building Name	Building Category	Heated Floor Area (ft.^{2})	Energy Use (Millions of Btu's)	Energy Cost (Dollars)
BRISTOL DISTRICT				
Bristol District				
Office	Office	23,000	832	6,893
Survey Office	Office	5,400	86	924
Materials Lab	Office	6,400	367	2,569
Maintenance Shop	Shop	36,000	2,717	17,119
Sign Shop	Shop	11,500	477	3,092
Abingdon Residency				
Office	Office	3,094	169	1,090
Maintenance Shop	Shop	3,078	269	1,716
Marion Area Shop	Shop	4,000	350	2,182
Jonesville Residency				
Office	Office	2,400	111	772
Maintenance Shop	Shop	2,880	270	1,972
Lebanon Residency				
Oakwood Area Shop	Shop	4,000	326	2,079
Tazewell Residency				
Office	Office	3,600	57	646
Wise Residency				
Office	Office	2,736	85	645
Fremont Area Shop	Shop	2,880	326	2,079
Wytheville Residency				
Office	Office	2,433	108	710
Maintenance Shop	Shop	3,600	483	3,104

Table 4 (continued)

Site and Building Name	Building Category	Heated Floor Area ($ft.^2$)	Energy Use (Millions of Btu's)	Energy Cost (Dollars)
CULPEPER DISTRICT				
Culpeper District				
Office Group	Group	33,786	1,636	11,900
Maintenance Shop	Shop	36,792	2,870	16,125
Sign Shop	Shop	8,750	441	3,567
Charlottesville Residency				
Group	Group	11,400	506	3,731
Leesburg Residency				
Office	Office	3,157	81	1,121
Maintenance Shop	Shop	5,680	486	3,100
Louisa Residency				
Group	Group	7,582	512	4,060
Warrenton Residency				
Office	Office	4,566	101	477
FREDERICKSBURG DISTRICT				
Fredericksburg District				
Office	Office	11,340	655	4,706
Materials Lab	Office	6,400	408	2,932
Maintenance Shop	Shop	38,000	1,931	12,129
Sign Shop	Shop	11,400	373	5,104
Fredericksburg Residency				
Office	Office	2,833	71	983
Warsaw Residency				
Office	Office	1,850	117	761

Table 4 (continued)

Site and Building Name	Building Category	Heated Floor Area ($ft.^2$)	Energy Use (Millions of Btu's)	Energy Cost (Dollars)
RICHMOND DISTRICT				
Richmond District				
Office (original)	Office	11,872	539	4,053
Office (1979 addition)	Office	5,632	165	2,266
Survey Office	Office	2,345	132	948
Design Office	Office	4,800	137	1,507
Materials Group	Group	3,561	376	2,965
Maintenance Shop	Shop	29,104	1,040	6,839
Amelia Residency				
Office	Office	3,157	54	746
Shop Group	Group	6,936	255	1,694
Maintenance Headquarters	Office	480	44	620
Ashland Residency				
Office Group	Group	4,362	187	2,024
Survey Office	Office	480	42	401
Shop Group	Group	5,770	517	3,236
Sandston Residency				
Office	Office	3,885	114	1,565
Survey Group	Group	2,696	150	2,061
STAUNTON DISTRICT				
Staunton District				
Office	Office	20,770	691	6,949
Survey Office	Office	1,350	27	393
Materials Lab	Office	4,730	278	2,011
Maintenance Shop	Shop	25,100	3,051	19,296
Edinburg Residency				
Group	Group	11,576	719	5,385
Harrisonburg Residency				
Office	Office	3,480	91	1,372

Table 4 (continued)

Site and Building Name	Building Category	Heated Floor Area ($ft.^2$)	Energy Use (Millions of Btu's)	Energy Cost (Dollars)
Luray Residency				
Office	Office	2,600	63	849
Verona Residency				
Office	Office	2,878	65	942
SUFFOLK DISTRICT				
Suffolk District				
Office	Office	24,000	1,031	9,272
Survey Office	Office	3,200	78	1,080
Maintenance Shop	Shop	36,000	2,133	11,742
Accomac Residency				
Office	Office	2,604	59	1,334
Williamsburg Residency				
Maintenance Shop	Shop	4,436	415	2,648
Hampton Roads				
Bridge-Tunnel Office	Office	11,268	605	4,143
TOTAL		539,609	30,282	$216,629

Indices were calculated for the 49 buildings individually supplied energy, and the remaining 22 buildings were combined into nine groups for calculating the indices. Table 5 lists the groups and the individual buildings involved. Table 6 shows the costs of energy by type for each district for the January through March 1980 period and Table 7 lists the consumption in terms of the purchasing unit for each type of energy.

As indicated in Table 7, only two fuels were used by all districts; electricity and No. 2 fuel oil. No. 2 fuel oil was purchased statewide at a uniform price of $0.83 per gallon and thus no differences based on geographical location can be shown for these data. However, the average cost of electricity for each district was computed and is shown in Table 8. Costs per kilowatt hour are fairly uniform statewide except for the Bristol District, which has a significantly lower unit cost (about 10% less).

Table 5

Building Groupings for Index Calculations

Name	Size (ft.^{2})
Culpeper District Office Group	
-Culpeper District Office	26,313
-Culpeper Residency Office	7,473
Charlottesville Residency Group	
-Charlottesville Residency Office	3,800
-Charlottesville Residency Maintenance Shop	7,600
Louisa Residency Group	
-Louisa Residency Office	2,902
-Louisa Residency Maintenance Shop	4,000
-Louisa Area Headquarters	680
Richmond District Materials Group	
-Richmond District Materials Office	3,321
-Richmond District Materials Shed	2,440
Amelia Residency Shop Group	
-Amelia Residency Maintenance Shop	2,960
-Amelia Residency Wash & Storage	3,976
Ashland Residency Office Group	
-Ashland Residency Office	3,662
-Ashland Residency Warming House	700
Ashland Residency Shop Group	
-Ashland Residency Maintenance Shop	700
-Ashland Residency Truck & Storage	2,370
-Ashland Residency Sign Shed	600
Sandston Residency Survey Group	
-Sandston Residency Survey Office	896
-Sandston Residency Warming House	600
-Sandston Residency Sign Shop	1,200
Edinburg Residency Group	
-Edinburg Residency Office	3,600
-Edinburg Residency Maintenance Shop	5,600
-Edinburg Residency Warming House	576
-Edinburg Residency Sign and Bridge	1,800

Table 6

Cost of Various Energy Types by District, January — March 1980

Energy Type	Bristol	Culpeper	Fredericksburg	Richmond	Staunton	Suffolk
Electricity	10,339	12,864	9,418	15,474	12,872	11,625
Natural Gas	0	282	0	0	0	0
Fuel Oil #2	37,195	19,869	17,198	9,991	24,324	10,721
Fuel Oil #5	0	10,455	0	4,071	0	7,689
Residual Fuel Oil (Gallons)						
Kerosene (Gallons)	0	493	0	1,389	0	0
Propane/LPG (Pounds)	0	119	0	0	0	184

Table 7

Consumption of Various Energy Types by District, January — March 1980

Energy Type	Bristol	Culpeper	Fredericksburg	Richmond	Staunton	Suffolk
Electricity (KWH)	239,374	269,140	199,880	326,550	269,680	236,377
Natural Gas (MCF)	0	86	0	0	0	0
Fuel Oil #2 (Gallons)	44,813	23,939	20,720	12,037	29,306	12,917
Residual Fuel Oil (Gallons)	0	14,724	0	4,906	0	11,335
Kerosene (Gallons)	0	594	0	1,673	0	0
Propane/LPG (Pounds)	0	838	0	0	0	1,144

Table 8

Average Cost of Electricity

District	Average Cost ($/KWH)*
Suffolk District**	0.0470
Culpeper District	0.0478
Staunton District	0.0477
Richmond District	0.0474
Fredericksburg District	0.0471
Bristol District	0.0434

*Averaged over the period of January — March 1980.

**Average cost shown omits Accomac Residency data, which were abnormally high because of remote location. If the Accomac Residency data are included, the district average becomes 0.0492.

COMPARISON OF ENERGY INTENSITY AND COST INTENSITY INDICES

Energy Intensity Indices for Offices

The calculated EII values for offices, shown in Table 9, range from 95,485 to 15,906. This wide range emphasizes the extreme differences in the amounts of energy required for different sizes and designs of buildings and the different efficiencies of various fuels for heating.

To provide a better understanding of the significance of these differences, the equivalent gallons of No. 2 fuel oil that would be needed to heat an average size office of 150 $ft.^2$ for the 3-month period after correction to 2,500 heating degree days is given in the second column of Table 9. These results are depicted graphically in Figure 1. In this figure a distinction is made between those buildings heated by electricity and those heated by other means.

Table 9

Energy Use for Office Buildings Operated by the Department

Building Name	Energy Intensity Index Btu/ft.^{2}*	Equivalent Energy Requirement**
+ Amelia Residency Maintenance Headquarters	95,485	105.0
Ashland Residency Survey Office	88,586	97.4
Fredericksburg District Materials Lab	67,119	73.8
Warsaw Residency Office	64,897	71.4
Fredericksburg District Office	60,160	66.2
Hampton Roads Bridge-Tunnel Cffice	59,768	65.7
Bristol District Materials Lab	57,547	63.3
Abingdon Residency Office	55,682	61.2
Staunton District Materials Lab	55,190	60.7
Richmond District Survey Office	53,876	59.3
Richmond District Office (original)	49,767	54.7
Jonesville Residency Office	48,437	53.3
Suffolk District Office	45,497	50.0
Wytheville Residency Office	42,407	46.6
Bristol District Office	36,262	39.9
+ Sandston Residency Office	31,695	34.9
Staunton District Office	30,535	33.6
Wise Residency Office	29,921	32.9
+ Richmond District Office (1979 edition)	29,605	32.6
Richmond District Design	29,441	32.4
+ Tazewell Residency Office	26,806	29.5
+ Suffolk District Survey Office	25,786	28.4
+ Fredericksburg Residency Office	25,247	27.7
+ Leesburg Residency Office	25,182	27.7
+ Harrisonburg Residency Office	23,801	26.1
+ Accomac Residency Office	23,221	25.5
+ Luray Residency Office	21,567	23.7
+ Verona Residency Office	20,666	22.7
Warrenton Residency Office	20,532	22.6
+ Staunton District Survey Office	18,141	20.0
+ Amelia Residency Office	17,795	19.6
+ Bristol District Survey Office	15,906	17.5

+Denotes a total electric facility

*Based on 2,500 heating degree days

**EII expressed as the equivalent gallons of No. 2 fuel oil required to heat a space 150 ft.^{2} in area for a 3-month period assuming 2,500 heating degree days.

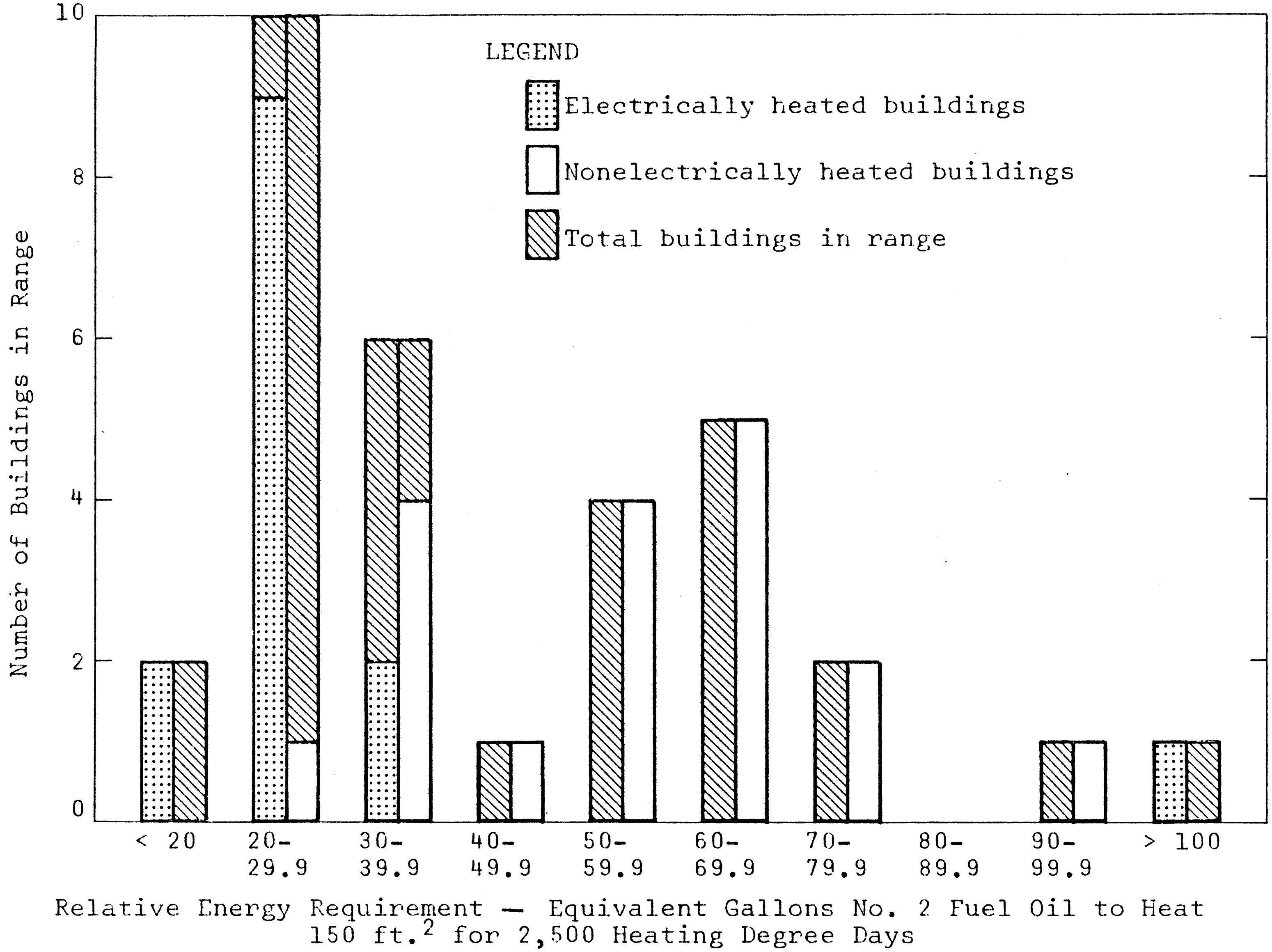

Figure 1. Energy intensity ranges for office buildings.

The unusually high values for the Amelia residency maintenance headquarters (95,485) and the Ashland residency survey office (88,586) are attributed chiefly to the size of these buildings. Each of these buildings has only 480 $ft.^2$ of heated floor space. The EII calculations are based on heated floor areas and no consideration is given to a varying ratio of exposed surface area to heated floor area. It is known that transmission heat losses from a building are directly proportional to the area of exposed surfaces.[3] Thus, for small buildings such as these two, the ratio of outside wall surface area to heated floor area is much larger than that for larger buildings with a number of interior walls. This results in higher transmission heat losses and, consequently, higher fuel demands per square foot of heated floor area in smaller buildings. Whether or not other factors also affected the EII for these buildings could not be determined from the data collected.

Another factor affecting the EII is the relative efficiencies of the heating systems by different types of fuels. After eliminating the two small buildings from consideration, it is noted in Table 9 and in Figure 1 that the total-electric buildings have generally lower EII values than others. These range from 15,906 to 31,695, which represents a range of 17.5 to 34.9 equivalent gallons of No. 2 fuel oil for a 150-$ft.^2$ office. The range for nonelectric buildings is 20,532 to 67,119. This range represents the equivalent of 22.6 to 73.8 gallons of fuel oil. A significant difference in the EII for electrically heated buildings compared to those heated by other means is expected since the conversion of electricity to heat is essentially 100% efficient on the basis of the factors used in this report—that is, 1 kw is equal to 3,412 Btu—while the conversion factors for other fuels is much lower. However, the electrical factor does not account for the energy losses in generating electricity from a primary fuel and transmitting it to the point of use. The Monthly Energy Review published by the Department of Energy states that in generating electricity with nuclear or fossil fuel approximately 65% of the energy is lost in the form of heat. Transmission and distribution losses consume about an additional 3% of the energy input. Thus, even though the conversion of the electricity to heat is 100% efficient, the overall efficiency of using electricity with respect to the demands for basic fuel resources is only 32%.

This fact is significant only if comparisons are needed of the total resources required to accomplish the desired heating by different procedures. For the purposes of this report the EII based on the output energy (1 kw = 3,412 Btu) provides the best estimate of direct energy requirements. For the conversion of volumes or masses of other fuels used for heating in Virginia, factors based on the energy content of the fuels are used. The efficiency of conversion of these fuels to useable heat depends greatly on the design and operation of the heating system used. These generally are on the order of 70% or less. It is also expected that the design and age of buildings will have a significant effect on the energy intensity index. The Department's buildings were built over a span of years and utilize different building materials and heating equipment and systems, and they vary significantly in the amount of insulation used.

Figure 1 shows that the 13 offices other than the Amelia residency headquarters heated with electricity have relative energy requirements in the lower portion of the total range. Nine of the 13 electrically heated buildings have energy requirements equivalent to from 20 to 30 gallons of No. 2 fuel oil. Two are lower (17.5 and 19.6) and two are higher. These are the Richmond district office (1979 addition), with a relative energy requirement of 32.6 equivalent gallons of fuel, and the Sandston residency office, with a requirement of 34.9 gallons. Reasons for these higher values will be discussed later.

The remaining offices heated by means other than electricity vary widely in relative energy requirements, with the lowest being 22.6 for the Warrenton residency office and the highest, other than the Ashland residency survey office, being 73.8, more than a 3-fold difference for the same space and heating degree days. This spread most likely reflects in part the type of fuel used and differences in building designs. The lowest value, 22.6, is for the Warrenton residency office, which is the only building heated by natural gas. Natural gas generally is more efficient than fuel oil. Four buildings fall into the 30.0-39.9 gallon range for the relative energy requirements. Nine of the 17 buildings involved have energy requirements in the 50.0 to 59.9 gallon range. One of the 2 buildings having a relative energy requirement in excess of 70 gallons is the Fredericksburg district materials laboratory. The other materials laboratories are also relatively high, being in the 60.0 - 69.9 range. The use of ovens, exhaust fans, and special equipment in such laboratories accounts for the higher values. Overall, the wide spread in energy requirements for the various buildings heated by either electricity or other means indicates that conservation measures applied to the higher energy users should prove fruitful, but a case-by-case investigation of each building is necessary to determine what action is needed.

Cost Intensity Indices for Offices

Although the energy-intensity index and the relative energy requirements for the various buildings provide some insight into how efficiently the energy is being used, the costs for heating are the items of immediate concern to the Department. These are shown by the cost-intensity indices. Table 10 lists these indices for office buildings. For ease of comparison the cost of heating an office of 150 $ft.^2$ (10 ft. x 15 ft.) for the 3-month period assuming 2,500 heating degree days is shown in the table, as are the relative costs for heating the same area for the same number of heating degree days. The relative costs were based on the Bristol district survey office taken as 1.0 instead of the Warrenton residency office, since the latter building was the only one heated with gas.

Figure 2 depicts the distribution of costs over the total cost range expressed as cost for heating 150 $ft.^2$ (an average size office) for 2,500 heating degree days. The two small buildings, the Amelia residency maintenance headquarters and Ashland survey office, show the highest costs, because of the very high energy consumption previously discussed. These values — \$1,349/1,000 $ft.^2$ and \$847/1,000 $ft.^2$ — will not be considered further and are not shown in Figure 2. After discounting these values, Table 10 shows that the costs for heating a 150-$ft.^2$ office in all other buildings range from \$14.85 for the lowest (Warrenton residency office) to \$78.45 for the highest (Accomac residency office). As depicted in Figure 2, the costs for electrically heated buildings are spread over the full range of costs reflecting the variable costs for electricity in different areas of the state.

Two special cases in Table 10 are exemplified by the Accomac residency office and the Warrenton residency office. The Accomac residency is a total-electric building that is charged the extremely high rate of \$0.077/kwh. This rate is almost twice the statewide average and probably results from the remote location of Accomac. Thus, even though, as shown in Table 9, the energy requirement for this building was in the lower bracket, the unit costs are the highest (except for the two small buildings eliminated from the discussion). The Warrenton residency office uses natural gas for heating. The present price regulations on this fuel cause it to be inexpensive as compared to the other fuels, the costs being only 57% of those for the next lowest.

The CII values for the remaining 28 office buildings range from 476 to 172 and average 345.5. These values are continuous, which suggests that the CII is a good comparison tool. Nine offices have indices between 400 and 476; 13 are between 300 and 399; and 6 are less than 300. The relative values shown in Table 10 are the ratios of the CII for the building compared to 172, the lowest for this group of 28 buildings. As indicated, the relative cost range for this group is 1.0 to 2.8.

Table 10

Cost Intensity Indices for Office Buildings

Building Name	Cost Intensity Index*	Heating Cost for 150 ft.^{2}**	Relative Cost Index***
+ Amelia Residency Maintenance Headquarters	$1,349	$202.35	7.8
Ashland Residency Survey Office	847	127.05	4.9
+ Accomac Residency Office	523	78.45	3.0
Fredericksburg District Materials Lab	476	71.40	2.8
+ Sandston Residency Office	437	65.55	2.5
Fredericksburg District Office	429	64.35	2.5
Warsaw Residency Office	420	63.00	2.4
Staunton District Materials Labs	411	61.65	2.4
+ Richmond District Office (1979 addition)	407	61.05	2.4
Suffolk District Office	406	60.90	2.4
Hampton Roads Bridge-Tunnel Office	405	60.75	2.4
Bristol District Materials Lab	402	60.30	2.3
Richmond District Survey Office	383	57.45	2.2
Richmond District Office (original)	366	54.90	2.1
+ Harrisonburg Residency Office	359	53.85	2.1
Suffolk District Survey Office	358	53.70	2.1
Abingdon Residency Office	358	53.70	2.1
+ Fredericksburg Residency Office	351	52.65	2.0
+ Leesburg Residency Office	350	52.50	2.0
Jonesville Residency Office	336	50.40	2.0
Richmond District Design	316	47.40	1.8
Staunton District Office	311	46.65	1.8
+ Tazewell Residency Office	308	46.20	1.8
+ Verona Residency Office	302	45.30	1.8
Bristol District Office	300	45.00	1.7
+ Luray Residency Office	291	43.65	1.7
Wytheville Residency Office	280	42.00	1.6
+ Staunton District Survey Office	263	39.45	1.5
+ Amelia Residency Office	247	37.05	1.4
Wise Residency Office	230	34.50	1.3
+ Bristol District Survey Office	172	25.80	1.0
Warrenton Residency Office	99	14.85	0.6

+Denotes a total electric facility

*Dollars per 1,000 ft.^{2} for 2,500 heating degree days

**Costs for a 3-month period of 2,500 heating days

***Ratio of cost for indicated building and lowest cost exclusive of the Warrenton residency office, which was the only building heated with natural gas. (Bristol district survey office taken as 1.)

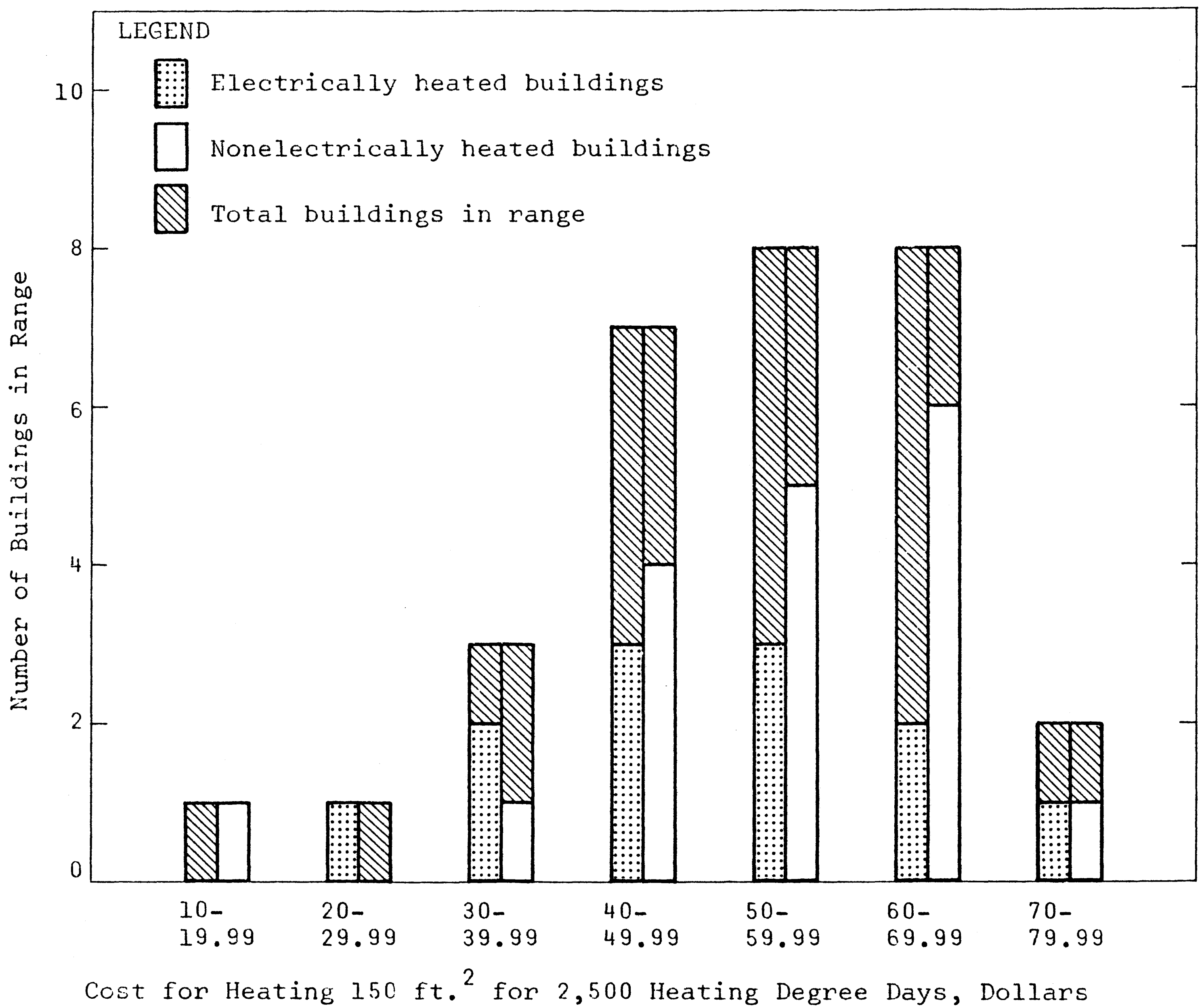

Figure 2. Relative unit costs of heating office buildings.

Energy Intensity Indices for Shop Buildings

The EII values for 17 shop buildings are presented in Table 11. They range from 127,982 to 34,761. Three types of shops are included in this tabulation and each seems to have distinguishing characteristics. Sign shops generally have the lowest energy use, district maintenance shops are mid-range energy users, and residency/area shops are high energy users.

Of the three sign shops listed in Table 11, one is total-electric. The EII values range from 34,761 to 50,234, with the total-electric facility being the lowest, as expected. Insufficient data are available to draw conclusions concerning any significant difference among these 3 shops, but it can be seen that they are the lowest energy users of the three shop types. The special pieces of equipment in sign shops are the electric sign heaters, which have rows of light bulbs to heat sign surfaces. Since the equipment is primarily electric, the energy conversion losses are low and the EII values are also low. The heat from such equipment also is useful in reducing the demand from the heaters.

District maintenance shops have EII values ranging from 77,893 at Staunton to 39,919 at Richmond.

Table 11

Energy Intensity Indices for Shop Buildings

Building Name	Energy Intensity Index Btu/ft.^{2}*
Wytheville Residency Maintenance Shop	127,982
Fremont Area Shop	111,509
Williamsburg Residency Maintenance Shop	100,907
Jonesville Residency Maintenance Shop	98,621
Abingdon Residency Maintenance Shop	88,588
Marion Area Shop	86,119
Leesburg Residency Maintenance Shop	84,010
Oakwood Area Shop	80,247
Staunton District Maintenance Shop	77,893
Culpeper District Maintenance Shop	77,623
Bristol District Maintenance Shop	75,698
Suffolk District Maintenance Shop	63,552
Fredericksburg District Maintenance Shop	53,935
Culpeper District Sign Shop	50,234
Bristol District Sign Shop	41,597
Richmond District Maintenance Shop	39,919
+ Fredericksburg District Sign Shop	34,761

+ Denotes a total-electric facility.

*Based on 2,500 heating degree days.

Residency and area maintenance shops have high values, with 3 exceeding 100,000 and 5 being between 80,000 and 100,000. All values are high compared to those for the district maintenance shops. The normal values for this group range from 80,000 to 90,000.

In summary, the shops vary greatly in their EII values, depending on the type of shop. Sign shops are low energy users with EII values near 40,000. District maintenance shops have a normal value of nearly 65,000, and residency/area shops have normal values between 80,000 and 90,000. Three shop buildings seem to have excessively high EII values: the Wytheville residency maintenance shop (127,982), the Fremont area shop (111,509), and the Williamsburg residency maintenance shop (100,907). The data originally reported for the Staunton district maintenance shop also indicated it to be abnormally high, but upon investigation it was found that the floor area for this building had been incorrectly reported. The corrected value, 77,893, although still the highest of those for the district maintenance shops is not significantly different from the EIIs of the Culpeper and Bristol district shops.

Cost Intensity Indices for Shop Buildings

CII values for shop buildings range from \$823/1,000 ft.^{2} to \$260/1,000 ft.^{2}, as shown in Table 12. As would be expected, they generally follow the same pattern established for the EIIs. District maintenance shops and district sign shops have the lower values and residency/area shops the higher.

The district sign shops are not represented well enough to determine how efficiently they are run, but the three values (475, 406, and 270) are similar.

The six district shops appear in the lower half of Table 12 with values between 495 and 260. The Staunton district shop was the most expensive of this group to heat, having a CII of 495.

The residency/area shops had eight CII values from 823 to 512, and four less than 600. The three highest values seem extreme.

Three shops had unusually high CII values. These are:

1. Wytheville residency maintenance shop (823)
2. Jonesville residency maintenance shop (718)
3. Fremont area shop (712)

The CII values for the remaining shop buildings fall into a normal range, with the cost indices for the residency/area shops being generally higher.

Table 12

Cost Intensity Indices for Shop Buildings

Building Name	Cost Intensity Index*
Wytheville Residency Maintenance Shop	$823
Jonesville Residency Maintenance Shop	718
Fremont Area Shop	712
Williamsburg Residency Maintenance Shop	642
Abingdon Residency Maintenance Shop	565
Leesburg Residency Maintenance Shop	537
Marion Area Shop	536
Oakwood Area Shop	512
Staunton District Maintenance Shop	495
Bristol District Maintenance Shop	477
+ Fredericksburg District Sign Shop	475
Culpeper District Maintenance Shop	436
Culpeper District Sign Shop	406
Suffolk District Maintenance Shop	348
Fredericksburg District Maintenance Shop	337
Bristol District Sign Shop	270
Richmond District Maintenance Shop	260

+ Denotes a total electric facility.

* Dollars per 1,000 $ft.^2$ for 2,500 heating degree days.

Summary of Index Calculations — Offices and Shops

A comparison of office EII and CII values in Tables 9 and 10, respectively, to the shop EII and CII values in Tables 11 and 12 shows that shops consume more energy and cost more to heat than offices. Consequently, there is a greater potential for reducing heating costs in shops.

Energy and Cost Indices for Groups of Buildings

Tables 13 and 14, respectively, show the EII and CII for the 9 groups of buildings supplied from a common energy source. In Table 13 the range of EII is from 39,494 $Btu/ft.^2$ to 91,057 $Btu/ft.^2$, and in Table 14, costs are shown to range from $262/1,000 $ft.^2$ to $848/$ft.^2$ The variations in EII and CII values indicate significant differences in the efficiencies of energy use among the groups, but since there was relatively little uniformity in the types and sizes of buildings within each group, further analysis of the causes of these differences was not made.

Table 13

Energy Intensity Indices for Building Groups

Group Name	Energy Intensity Index Btu/ft.^{2}*
Ashland Residency Shop Group	91,057
Richmond District Materials Group	70,566
Louisa Residency Group	68,839
+ Sandston Residency Survey Group	61,757
Edinburg Residency Group	59,398
Culpeper District Office Group	48,230
Charlottesville Residency Group	45,253
Ashland Residency Office Group	43,187
Amelia Residency Shop Group	39,494

+ Denotes a total electric facility.

* Based on 2,500 heating degree days.

Table 14

Cost Intensity Indices for Building Groups

Group Name	Cost Intensity Index*
+ Sandston Residency Survey Group	$848
Ashland Residency Shop Group	569
Louisa Residency Group	546
Richmond District Materials Group	539
Ashland Residency Office Group	469
Edinburg Residency Group	446
Culpeper District Office Group	351
Charlottesville Residency Group	333
Amelia Residency Shop Group	262

+ Denotes a total-electric facility.

* Dollars per 1,000 ft.^{2} for 2,500 heating degree days.

IN-DEPTH INSPECTION OF BUILDINGS USING LARGE AMOUNTS OF ENERGY

Three shops and five offices were initially identified in this study as having higher than normal index values. These are listed below, and those marked with an asterisk were selected for conservation measures. As stated, the initial value for the Staunton district maintenance shop was shown by the investigation to be in error.

* 1. Wytheville residency maintenance shop

2. Fremont area shop

* 3. Staunton district maintenance shop

* 4. Fredericksburg district materials lab

5. Warsaw residency office

* 6. Fredericksburg district office

* 7. Sandston residency office

8. Richmond district office (1979 addition)

The five buildings inspected represent approximately 10% of the 49 individually-supplied buildings and will be discussed in the order named.

Wytheville Residency Maintenance Shop

The Wytheville residency maintenance shop was constructed in 1954. It is a rectangular building measuring 100 ft. by 36 ft. and is constructed of 8-in. cinderblock. The pitched roof is made of wood with asphalt shingles. Windows are of the metal-casement type. Seven large roll doors provide passages for vehicles and three small doors provide passages for personnel. The building is exposed to moderate winter winds. Lighting is primarily incandescent.

Steam heat is provided through an overhead distribution system. Fan coil units are controlled by a single thermostat at one end of the building. The thermostat is old and has no temperature markings. Steam is circulated continuously to prevent pipes from freezing. A heat exchanger is the only source of service hot water; there is no hot water in the summer months.

The inspection of the building showed that energy and thus money were being lost. The key problems are listed below.

1. No insulation was found in the walls or roof.

2. The steam pipes were not insulated.

3. The doors were not weatherstripped.

4. Two of the large roll doors did not seal well, having gaps where the topmost sections failed to contact the door frames.

5. There was no preventive maintenance to the heating system; service work was done by district personnel only upon request.

The conditions have been improved since the energy consumption data were collected; three of the large roll doors were replaced in the summer of 1980 (prior to the on-site visit).

This building typically loses much of its heat in three ways. First, infiltration losses are high because of the windy site and the poorly sealed entrances. Second, uninsulated pipes with a continuous flow of steam lose heat in the roof area. Third, the high temperature at the roof creates a large temperature differential across the uninsulated roof that yields excessive heat conduction losses. The lack of maintenance for the heating system probably causes increased fuel consumption through system inefficiencies.

The following low cost recommendations for improving the heating efficiency of this building were made.

1. Inspect and adjust the boilers. Perform a flue gas analysis, replace worn components (especially the nozzle), check the fuel filter, and check steam pressure to assure optimum heat distribution.

2. Repair steam pipe leaks and insulate.

3. Replace the existing thermostat with one that has a night-setback control.

4. Caulk and weatherstrip doors and windows.

5. Adjust roll doors for complete closure.

Staunton District Maintenance Shop

The Staunton district maintenance shop serves several purposes. It contains offices, a vehicle maintenance area, a vehicle painting room, a welding shop, a sign shop, and a carpentry shop. It is a T-shaped building that was constructed in 1955. The floor area was calculated to be 34,752 ft.^{2} Construction is primarily of 12-in. cinderblock with metal-casement windows. The office portion is two-story with a flat roof; the maintenance shop area is a high-bay area with a circular arched roof; and the remaining parts are single-story with flat roofs. All roofs are wooden and have no insulation. Lighting is fluorescent.

The heating in the majority of the building is by hot water circulating through elevated fan-coil units. The exception is the main office section (approximately 3,000 ft.^{2}), which is heated by electric baseboard units. Cooling is provided in the office section by an air conditioner with an efficiency probably less than desirable. Subsequent to the collection of data on the energy consumption in this building the office area's hot water heating system was removed and replaced with an electric baseboard system. At the same time, the office walls were insulated and the single-pane, metal-casement windows were replaced by metal frame, double-hung windows with storm windows. Thus, present energy efficiency should be better than that reported in the survey.

No major operating and maintenance problems were observed.

There was no insulation on the hot water pipes and the hot water boiler was not on a regular maintenance program. The same heat conduction loss problem is possible in this building as was observed in the Wytheville residency maintenance shop; the excessive heat lost from uninsulated pipes near the roof causes high temperatures at the roof that result in high heat losses through the roof. The losses would not be as large since hot water rather than steam was circulated.

The building is constructed without wall or roof insulation, and the lack of insulation on hot water pipes and the worn-out hot water heating system for the office (now replaced) all contributed to the reported high energy use. However, the originally reported floor area of 25,000 ft.^{2} for this building was the area for the maintenance shop alone. When the other parts of the building were included, the total heated area was found to be 34,752 ft.^{2} This larger area reduces the EII from the initial apparent value of

107,846 to 77,893 and the CII from 686 to 495. These corrected values are shown in Tables 11 and 12 and are close to those of other district maintenance shops, but slightly higher.

Fredericksburg District Materials Lab

The Fredericksburg district materials lab was designed in 1965. It is a two-story rectangular building, and built of 8-in. concrete block with 4-in. face brick. Lighting is provided with flucrescent fixtures. The roof is steel deck with 1½-in. of rigid insulation and built-up roofing. Additional insulation is provided by suspended acoustical ceiling tile. Windows are of the metal-casement type with single-pane glass and no storm windows.

The building is heated by hot water circulating through wall-mounted fan-coil units. An electric water heater supplies 105°F. potable water. Air conditioning is supplied by a reciprocating chiller. During winter the temperature is maintained at 68°F. and during summer at 78°F. There are no night setbacks on the thermostats.

This building has several pieces of special equipment. There are seven electric ovens with the following ratings: one at 11 kw, four at 2 kw, one at 9 kw, and 1 at 14 kw. These are used on irregular schedules with higher use in the summer. Also located in this building are eight exhaust systems that are also used intermittently.

The preponderence of special laboratory equipment explains the high index values for this building.

Fredericksburg District Office

The Fredericksburg district office was built in 1963 of 8-in. block with 4-in. face brick. The building is T-shaped and is three stories tall. The metal deck, built-up roof has 2 in. of rigid insulation and all rooms have suspended ceilings. Lighting is primarily fluorescent. Windows are of the metal-casement type.

The heat is provided by a single hot water boiler that uses both fan-coil units and convectors to distribute the heat. Cooling is provided by two 15-ton centrifugal chillers. An electric water heater supplies 105°F. potable hot water. Winter and summer thermostat settings are 68°F and 78°F, respectively. The boiler temperature is controlled by an outdoor/indoor temperature comparison device. The pipes in this building are insulated.

The apparent problem with this building's energy consumption is a combination of the boiler control mechanism and the distribution system. The changing water temperature causes problems in balancing the heat distribution. Consequently, the occupants of the building must periodically change the fan-coil unit controls.

Sandston Residency Office

This total-electric facility was built in 1977 and is representative of the recently designed buildings. Wall construction consists of a 4-in. brick exterior and a wood paneling over 6-in. block interior. One inch of styrofoam and a small air space are between the brick and the block. The roof is a pitched wood deck and rooms have suspended ceilings covered with 6 in. of fiberglass batt insulation. The windows are wood frame, double-hung with thermopane glass. The lighting is fluorescent.

The building has a central heat pump as well as individual baseboard units in each room. The air distribution system is equipped with a 20-kw heater unit, presumably to serve as a backup for the heat pump. The thermostats are normally set at 68°F. in the winter and 78°F. in the summer. The service hot water was set at 155°F.

The heating system has not performed well in this building and has been augmented by plug-in heaters. Recent service work by a heating equipment contractor uncovered a freon leak in the heat pump. Also, a Department electrician recently fixed some poorly wired baseboard units. These repairs should help alleviate the problems.

The site investigation uncovered some additional areas of concern. First, the air distribution ducts were in the attic above the batt insulation and did not appear to be insulated. Second, the damper for the fresh-air makeup was open on the air distribution system. (It was not clear how much fresh air was being introduced from the outside.) Third, the use of the electric-resistance heaters in the room that contains the heat pump thermostat could easily cause the heat pump to turn off. Since the heat pump has a better operating efficiency than the heaters, this would cause excessive energy consumption. Finally, the design of the air distribution system appears to be relatively poor. Both supply and return grills are located in the ceiling. This is a convenient layout for the designer, but it creates a poor air circulation pattern, particularly for heating.

These items were discussed with the supervisory personnel and the water heater thermostat settings were lowered to 120°F.

Overview of Building Inspections

These building inspections were performed to determine whether or not the EII and CII values provided a useful means of comparing energy consumption and heating costs in buildings. The individual cases show that the method works when accurate data are used. However, a high-energy-intensive building may not necessarily be wasting energy. As was seen in the case of the Fredericksburg district materials building, the functional use of buildings sometimes makes greater energy use and higher costs necessary.

It can be concluded from these inspections that the high energy consumption levels were attributable primarily to building construction features and designs rather than wasteful habits. Many of the low-cost measures such as lowering thermostat settings, caulking windows, and turning off lights in unoccupied areas were being performed and testified to a commitment of local personnel to energy conservation. The replacement of the three large roll doors at the Wytheville residency maintenance shop and the replacement of the hot water boiler at the Staunton district maintenance shop are typical of the measures that must be implemented to effect significant additional reductions in energy use.

SUMMARY

This study produced two noteworthy items. First, an inventory was made of heated and cooled buildings at the district and residency administrative locations; and, second, the amounts and costs of the energy used in heating 49 buildings were established and compared.

The energy consumption and costs for many buildings were high, a situation most likely attributable to building design and inadequate heating, ventilation and air conditioning (HVAC) equipment. Inefficient building design was exhibited in the following ways:

1. inadequate insulation in roofs and ceilings

2. no insulation on HVAC distribution system components (steam pipes, hot water pipes, and air ducts)

3. ineffective HVAC system controls

4. use of metal-casement windows (sealed poorly against infiltration of cold air, and difficult to fit with storm windows)

In addition to initial design deficiencies, none of the buildings that were inspected appeared to have an adequate preventive maintenance program for the HVAC equipment.

Most of the operational changes had been implemented prior to the study and a significant expenditure of funds will be necessary to further reduce energy consumption. Herein lies the problem. Local personnel have implemented the low-and no-cost conservation measures and feel they have done as much as possible without further funding. There appears to be no mechanism within the Department budget that directly provides the funds needed for energy conservation measures, and it is not likely that significant reductions in energy consumption will be achieved until such funds are provided.

RECOMMENDATIONS

Two levels of recommendations are made. First are the recommendations for immediate implementation. These items have proven cost-effective in other studies and should be given top priority if cost-effective energy measures are to be implemented. The second level of recommendations are categorized as near-term planning changes. These items will require some study and justification prior to implementation, but should be given consideration for implementation as soon as possible.

First Level Implementation

The following recommendations should be implemented as soon as possible. Sufficient funding and attention need to be provided to assure optimum results.

1. Train maintenance personnel to adjust HVAC equipment for optimum efficiency.

2. Establish a preventive maintenance schedule, including service logs, for each component of the HVAC system.

3. Change purchasing practices so that the energy efficiency of items is considered in addition to their first-costs. (Energy efficient fluorescent lighting should be one of the first items considered.)

4. Centralize the purchase of energy conservation materials, such as insulation, to assure minimum costs.

Second Level Implementation

These items should be reviewed and acted upon subsequently or concurrently with the items listed under "First Level Implementation". Their implementation would stimulate important conservation measures and reduce the amount of energy being lost.

1. Reorganize the budget structure to identify funds for capital improvements and to provide guidelines for the selection of energy conservation measures.

2. Evaluate the energy conservation potential for existing structures. Initial candidates have been identified in this report and these should be studied as individual cases. The buildings could be evaluated with new computer programs such as DOE2 or BLAST that accurately simulate energy consumption and are capable of calculating economic comparisons of various measures.

3. Evaluate the standard building designs that are proposed for new structures. The inspection of the Sandston residency office uncovered design deficiencies that should be avoided.

4. Make an inventory survey to identify inefficient stock items and replace them with more efficient ones.

ACKNOWLEDGEMENTS

The assistance of numerous personnel of the Virginia Department of Highways and Transportation in collecting and reporting the data in this report is gratefully acknowledged. The advice and assistance from the staff of the Virginia Highway and Transportation Research Council in the preparation and editing of the report are also greatly appreciated.

REFERENCES

1. Halstead, Woodrow J., and K. H. McGhee, "Energy Conservation in Department of Highways and Transportation Buildings", VHTRC 79-R11, Virginia Highway and Transportation Research Council, Charlottesville, Virginia, September 1978.

2. Pritchard, Alan C., "A Comparison of the Heating Season Performances of Selected Buildings Operated by the Virginia Department of Highways and Transportation" — A Thesis presented to the Faculty of the School of Engineering and Applied Science, University of Virginia, Charlottesville, Virginia, May 1981.

3. American Society of Heating, Refrigeration, and Air-Conditioning Engineers, Inc., ASHRAE Handbook, 1977 Fundamentals, New York, New York.

APPENDIX A

SERVICE REGIONS FOR VIRGINIA DEPARTMENT OF HIGHWAYS AND TRANSPORTATION DISTRICTS AND RESIDENCIES: KEY TO FIGURE A-1

DISTRICT	RESIDENCY	COUNTY
Bristol	01 Wise	Dickenson & Wise
	03 Abingdon	Smyth & Washington
	04 Lebanon	Buchanan & Russell
	06 Tazewell	Bland & Tazewell
	08 Wytheville	Grayson & Wythe
	58 Jonesville	Lee & Scott
Salem	09 Hillsville	Carroll & Floyd
	11 Christiansburg	Giles, Montgomery, & Pulaski
	12 Martinsville	Henry & Patrick
	13 Rocky Mount	Franklin
	14 Salem	Botetourt, Craig, & Roanoke
	16 Bedford	Bedford
Lynchburg	17 Chatham	Pittsylvania
	18 Halifax	Charlotte & Halifax
	19 Dillwyn	Buckingham, Cumberland, & Prince Edward
	20 Appomattox	Appomattox & Campbell
	22 Amherst	Amherst & Nelson
Richmond	23 South Hill	Brunswick & Mecklenburg
	24 Amelia	Amelia, Lunenburg, & Nottoway
	25 Petersburg	Dinwiddie & Prince George
	26 Chesterfield	Chesterfield & Powhatan
	27 Sandston	Charles City, Henrico, & New Kent
	28 Ashland	Goochland & Hanover
Suffolk	31 Franklin	Greensville & Southampton
	32 Waverly	Surry & Sussex
	33 Suffolk	Isle of Wight & City of Suffolk
	34 Norfolk	Cities: Norfolk, Va. Beach, Chesapeake, & Portsmouth
	35 Williamsburg	James City & York, Cities: Poquoson, Williamsburg, Newport News, & Hampton
	36 Accomac	Accomack & Northampton
Fredericksburg	37 Saluda	Gloucester, King & Queen, Matthews & Middlesex
	39 Warsaw	Lancaster, Northumberland, Richmond, & Westmoreland
	40 Fredericksburg	King George, Spotsylvania, & Stafford
	41 Bowling Green	Caroline, Essex & King William
Culpeper	42 Louisa	Fluvanna & Louisa
	43 Charlottesville	Albemarle & Greene
	45 Culpeper	Culpeper, Madison, & Orange
	46 Warrenton	Fauquier & Rappahannock
	47 Fairfax	Fairfax & Arlington
	48 Manassas	Prince William
	49 Leesburg	Loudoun
Staunton	50 Lexington	Alleghany, Bath, & Rockbridge
	53 Staunton	Augusta & Highland
	54 Harrisonburg	Rockingham
	55 Edinburg	Frederick & Shenandoah
	56 Luray	Clarke, Page, & Warren

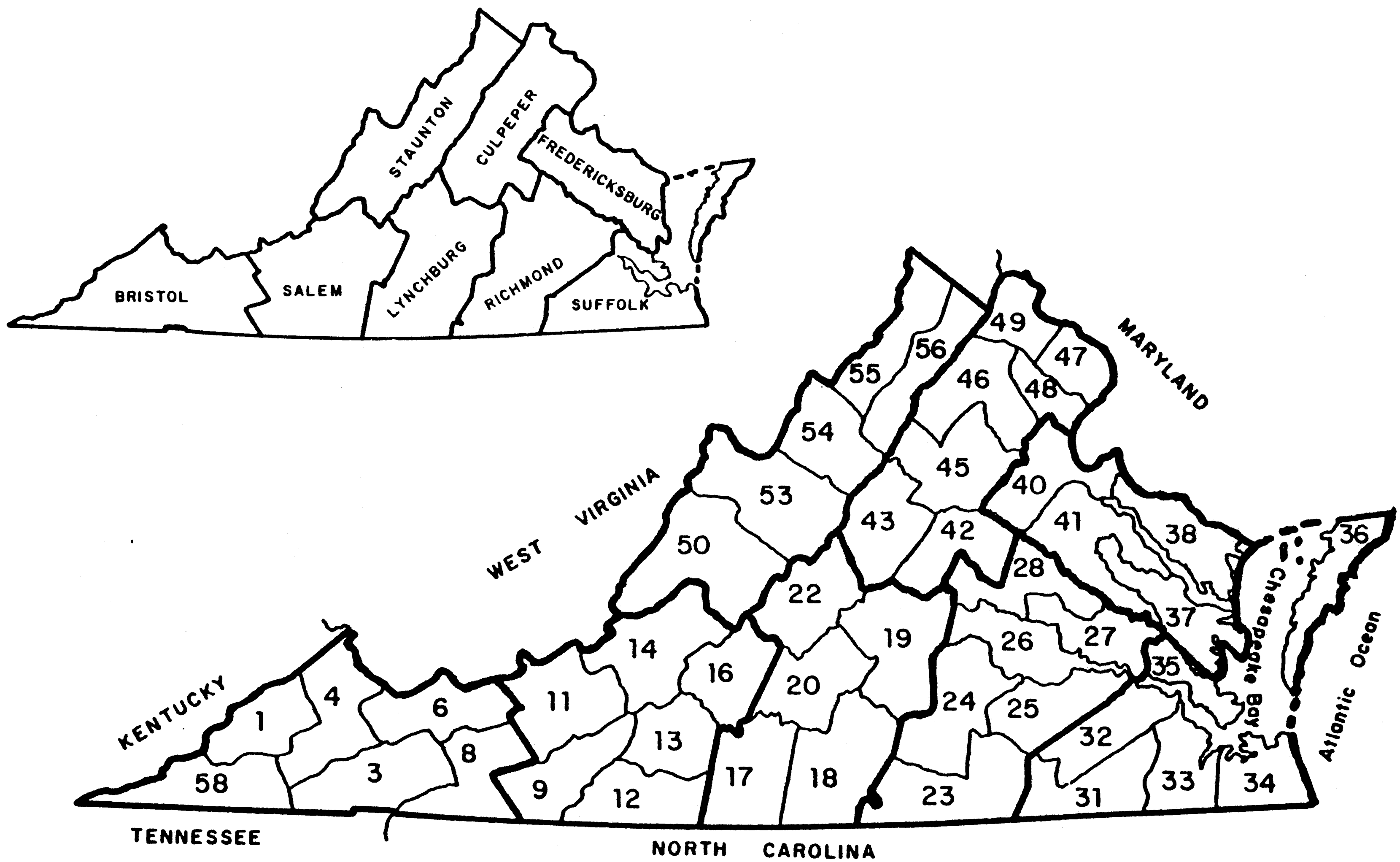

Figure A-1. Virginia Department of Highways and Transportation district and residency locations.

APPENDIX B

PRELIMINARY SURVEY FORM

SITE PLAN/BUILDING QUESTIONNAIRES

1. Please attach a drawing or sketch of the local site which shows all of the buildings and gives a name for each. Mark all buildings which are heated in winter with an "H" and all buildings which are cooled in summer with a "C". If both heated and cooled mark "H/C". (This sketch does not need to be to scale.)

2. Please draw a circle around each building or group of buildings which is supplied electricity through a single meter. (There should be one circle for each electric meter in use.)

3. Please complete one of the attached "Building Questionnaire" forms for each building on the sketch which has been marked "H, C, or H/C". (This information is not needed for buildings which are not heated or cooled.)

4. Please attach a short note telling what fuel and electricity records are available for the period from July 1972 to present.

BUILDING QUESTIONNAIRE

Building Name ____

1. Was the building in use in July of the following years? Check those years in which the building was used:

   _____1972 _____1973 _____1974 _____1975 _____1976 _____1977

2. What type of fuel is used to heat the building? Check those which apply to the building named above:

   _____Natural Gas _____Kerosene _____Coal

   _____Propane or LPG _____Fuel Oil #5

   _____Fuel Oil #2 _____Fuel Oil #4

   _____Fuel Oil #6 _____Other (Specify) ____________________

3. What was the gross floor area in July 1978? This information may be obtained from a building blueprint or by calculation. To calculate gross floor area, first measure the outside of the building to obtain length and width, then multiply length times width times the number of stories (length x width x number stories).

   GROSS FLOOR AREA = ______________sq.ft.

4. Has the building been modified (building additions or change in use) since June 1972? _____ Yes _____ No If yes, please describe the modification(s) on a separate sheet. Be sure to tell when modified and the amount of gross floor area added.

5. How many people work in the building? People who have offices but spend most of their time away from their offices should be included in this number. (Circle answer.)

   a. Less than 5

   b. 5-9

   c. 10-24

   d. 25-49

   e. 50-74

   f. more than 75

Name of person completing this form ______________________________

Scats No. ____________________

APPENDIX C

ENERGY USE AND COST DATA FORM

BUILDING ENERGY CONSUMPTION RECORD

Building Name ______________________________

District ______________________________

			MONTH/YEAR		
Electricity	Billed	Electricity Used (KWH)			
		Demand (KW)			
		Fuel Adjustment			
		Date Meter Read			
		Billing Period (Days)			
		Demand Adjustment ($)			
		Refund ($)			
		Total Bill ($)			
	Local	Reading (Monthly)			
		Date Meter Read			
		Electricity Used (KWH)			
Natural Gas	Billed	Gas Used (MCF)			
		Date Meter Read			
		Billing Period (Days)			
		Refund ($)			
		Total Bill ($)			
	Local	Reading (Monthly)			
		Date Meter Read			
		Gas Used (MCF)			
Fuel Oil #2	Local	Storage (Gal.)			
		Delivered (Gal.)			
		Fuel Used (Gal.)			
		Unit Price ($)			
		Cost ($)			

Name of person completing this form ______________________________
Scats No. ____________________

BUILDING NAME ______________________________

			MONTH/YEAR		
Fuel Oil #5	Local	Storage (Gal.)			
		Delivered (Gal.)			
		Fuel Used (Gal.)			
		Unit Price ($)			
		Cost ($)			

Fuel Oil #6	Local	Storage (Gal.)			
		Delivered (Gal.)			
		Fuel Used (Gal.)			
		Unit Price ($)			
		Cost ($)			

Kerosene	Local	Storage (Gal.)			
		Delivered (Gal.)			
		Fuel Used (Gal.)			
		Unit Price ($)			
		Cost ($)			

Propane/LPG*	Local	Storage (lb.)			
		Delivered (lb.)			
		Fuel Used (lb.)			
		Unit Price ($)			
		Cost ($)			

Total Energy Cost			
Cost Last Year			

*Note: For Propane/LPG One Gallon = 4.24 Pounds

Please check any of the following that have changed:

_____Building Area
_____Use of Building
_____Building Construction (modifications)
_____Heating or Cooling Equipment
_____Electricity Rates
_____Natural Gas Rates
_____Primary Heating Fuel

Explain any checked items on separate sheet, also attach copy of new fuel or electricity rates.

APPENDIX D

SUMMARY OF INFORMATION FROM PRELIMINARY SURVEY

Site and Building Name	Energy Supply*	Total Floor Area ($ft.^2$)	Heated Floor Area ($ft.^2$)	Cooled Floor Area ($ft.^2$)	Electricity	#2 Oil	#5 Oil	#6 Oil	Natural Gas	Propane/LPG	Kerosene	Wood/Coal
BRISTOL DISTRICT												
Bristol District												
Office	B	23,000	23,000	23,000	x	x						
Survey Office	B	5,400	5,400	5,400	x							
Materials Lab	B	6,400	6,400	6,400	x	x						
Maintenance Shop	B	36,000	36,000	5,500	x	x						
Sign Shop	B	11,500	11,500	0	x	x						
Abingdon Residency												
Office	B	3,094	3,094	3,094	x	x						
Maintenance Shop	B	3,078	3,078	0	x	x						
Marion Area Shop	B	4,000	4,000	0	x	x						
Jonesville Residency												
Office	B	2,400	2,400	2,400	x	x						
Maintenance Shop	B	2,880	2,880	0	x	x						
Gate City Area Shop	B	2,880	2,880	0	x	x						
Lebanon Residency												
Office	C	3,896	3,896	3,896	x							
Maintenance Shop	C	4,800	4,800	0	x	x						
Oakwood Area Shop	B	4,000	4,000	0	x	x						
Oakwood Area Headquarters	C	760	760	760	x	x						
Tazewell Residency												
Office	B	3,600	3,600	3,600	x							
Maintenance Shop	B	3,600	3,600	0	x	x						
Rocky Gap Area Shop	B	4,000	4,000	0	x	x						
Wise Residency												
Office	B	2,736	2,736	2,736	x	x						
Maintenance Shop	B	4,800	4,800	0	x	x						
Fremont Area Shop	B	2,880	2,880	0	x	x						
Wytheville Residency												
Office	B	2,433	2,433	2,433	x	x						
Maintenance Shop	B	3,600	3,600	0	x	x						
Independence Area Shop	B	2,880	2,880	0	x	x						
CULPEPER DISTRICT												
Culpeper District												
Office	C	26,313	26,313	26,313	x	x				x		
Residency Office	C	7,473	7,473	7,473	x	x						
Maintenance Shop	B	36,792	36,792	4,719	x	x	x					
Sign Shop	B	8,750	8,750	8,750	x	x						
Charlottesville Residency												
Office	C	3,800	3,800	3,800	x	x						
Maintenance Shop	C	7,600	7,600	0	x	x						
Truck Shed	B	225	225	0	x	x						

*ENERGY SUPPLY CODES:

A - A heated asphalt storage tank is on the electric circuit.

B - The point of delivery for all energy types is at the building; consumption data would apply to only one conditioned (heated/cooled) building.

C - The point of delivery for at least one of the energy types is at a central location; consumption data would apply to a group of conditioned buildings.

Site and Building Name	Energy Supply*	Total Floor Area (ft.^{2})	Heated Floor Area (ft.^{2})	Cooled Floor Area (ft.^{2})	Electricity	#2 Oil	#5 Oil	#6 Oil	Natural Gas	Propane/LPG	Kerosene	Wood/Coal
Fairfax Residency												
Office	B	8,460	8,460	8,460	x	x						
Survey Office	B	3,700	3,700	3,700	x	x						
Dormitory Office	B	3,040	3,040	3,040	x	x						
Dormitory	B	13,172	13,172	13,172	x	x						
Maintenance Shop	B	4,800	4,800	0	x	x						
Leesburg Residency												
Office	B	3,157	3,157	3,157	x							
Maintenance Shop	B	5,680	5,680	0	x	x						
Louisa Residency												
Office	C	4,353	2,902	2,902	x							
Maintenance Shop	C	4,000	4,000	0	x	x						
Area Headquarters	C	680	680	0	x						x	
Manassas Residency												
Office	C	4,200	4,200	4,200	x							
Survey Office	C	1,600	1,600	1,600	x						x	
Maintenance Shop	C	5,656	5,656	0	x	x					x	
Sign Shop	C	880	880	0	x						x	
Area Headquarters	C	800	800	800	x						x	
Warrenton Residency												
Office	B	4,566	4,566	4,566	x				x			
Maintenance Shop	B	2,916	2,916	0	x	x						
Regional Transportation Engineer's Office	C	4,650	4,650	4,650	x	x						
FREDERICKSBURG DISTRICT												
Fredericksburg District												
Office	B	11,340	11,340	11,340	x	x						
Location and Design	B	11,390	11,390	11,390	x	x						
Materials Lab	B	6,400	6,400	6,400	x	x						
Maintenance Shop	B	38,000	38,000	8,000	x	x						
Sign Shop	B	11,400	11,400	0	x							
Bowling Green Residency												
Office	B	2,361	2,361	2,361	x	x						
Inspector's Office	C	160	160	0	x	x						
Maintenance Shop	C	2,926	2,926	0	x	x						
Office Trailer	B	552	552	552	x							
Warming House	C	144	144	0	x	x						
Fredericksburg Residency												
Office	B	2,833	2,833	2,833	x							
Saluda Residency												
Office	B	2,064	2,064	2,064	x	x						
Maintenance Shop	A,C	2,400	2,400	0	x	x						
Warsaw Residency												
Office	B	1,850	1,850	1,850	x	x						
Sign Foreman's Office	A,C	750	375	0	x	x						
Maintenance Shop	A,C	2,920	2,920	0	x	x						

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B - The point of delivery for all energy types is at the building; consumption data would apply to only one conditioned (heated/cooled) building.

C - The point of delivery for at least one of the energy types is at a central location; consumption data would apply to a group of conditioned buildings.

Site and Building Name	Energy Supply*	Total Floor Area (ft.^{2})	Heated Floor Area (ft.^{2})	Cooled Floor Area (ft.^{2})	Electricity	#2 Oil	#5 Oil	#6 Oil	Natural Gas	Propane/LPG	Kerosene	Wood/Coal
<u>LYNCHBURG DISTRICT</u>												
Lynchburg District												
Office	B	18,926	18,926	18,926	x	x						
Survey Office	B	3,840	3,840	3,840	x							
Materials Lab	B	10,032	10,032	10,032	x	x						
Maintenance Shop	B	50,970	43,090	7,500	x	x	x					
Sign Shop	B	4,140	4,140	1,380	x	x						
Environmental & Skid Test	B	8,100	8,100	8,100	x							
Amherst Residency												
Office					x							
Maintenance Shop					x	x						
Appomattox Residency												
Office	B	1,838	1,838	1,838	x	x						
Maintenance Shop	B	2,880	2,880	0	x	x						
Chatham Residency												
Office	B	1,155	1,155	1,155	x	x						
Maintenance Shop	B	2,940	2,940	0	x	x						
Dillwyn Residency												
Office	C	1,800	1,800	1,800	x							
Survey Office	C	680	680	680	x							
Maintenance Shop	B	3,898	3,898	0	x	x						
Halifax Residency												
Office	C	1,430	1,430	1,430	x							
Maintenance Shop	C	3,819	3,819	0	x	x						
<u>RICHMOND DISTRICT</u>												
Richmond District												
Office (original)	B	11,872	11,872	11,872	x	x						
Office (1979 addition)	B	5,632	5,632	5,632	x							
Survey Office	B	2,745	2,345	2,345	x	x						
Design Office	B	4,800	4,800	4,800	x	x						
Materials Lab	C	3,321	3,321	3,321	x	x						
Maintenance Shop	B	29,104	29,104	2,750	x	x	x					
Carpenter Shop	B	2,400	2,400	0	x	x						
Sign Shop	C	8,064	8,064	220	x	x						
Sign & Paint Storage	C	2,251	476	476	x							
Oil House	C	166	166	0	x							
Materials Shed	C	2,440	2,440	240	x							
Amelia Residency												
Office	B	3,157	3,157	3,157	x							
Maintenance Shop	C	2,960	2,960	388	x	x						
Sign & Bridge Shop	A,C	1,792	1,792	0	x	x						
Wash & Storage	C	3,976	3,976	0	x	x						
Maintenance Headquarters	B	480	480	480	x							

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B - The point of delivery for all energy types is at the building; consumption data would apply to only one conditioned (heated/cooled) building.

C - The point of delivery for at least one of the energy types is at a central location; consumption data would apply to a group of conditioned buildings.

Site and Building Name	Energy Supply*	Total Floor Area (ft.^{2})	Heated Floor Area (ft.^{2})	Cooled Floor Area (ft.^{2})	Electricity	#2 Oil	#5 Oil	#6 Oil	Natural Gas	Propane/LPG	Kerosene	Wood/Coal
Ashland Residency												
Office	C	3,662	3,662	3,662	x							
Survey Office	B	480	480	480	x						x	
Maintenance Shop	C	2,800	2,800	140	x	x						
Warming House	C	700	700	200	x						x	
Sign Shed	C	600	600	0	x						x	
Truck & Storage Shed	C	2,370	2,370	0	x						x	
Chesterfield Residency												
Office	B	2,808	2,808	2,808	x	x						
Maintenance Shop	B	2,880	2,880	100	x	x						
Area Headquarters	C	780	780	780	x	x						
Office Trailers (2)	C	1,440	1,440	1,440	x					x		
Petersburg Residency												
Office	C	3,600	3,600	3,600	x	x						
Survey Office	C	450	450	450	x						x	
Maintenance Shop	C	2,916	2,916	150	x	x						
Sign Shop	C	2,387	764	280	x						x	
Engineer's Trailer	C	720	720	720	x					x		
Survey Office Trailer	C	256	256	256	x						x	
Wash Room	C	1,288	1,288	0	x						x	
Sandston Residency												
Office	B	3,885	3,885	3,885	x							
Survey Office	C	896	896	896	x							
Maintenance Shop	B	4,800	4,800	162	x	x						
Sign Shop	C	3,300	1,200	0	x							
Area Shop & Storage	B	1,764	1,764	0	x	x						
Warming House (Elko)	C	600	600	144	x							
South Hill Residency												
Office	C	1,096	1,096	1,096	x	x						
Maintenance Shop	B	3,076	3,076	0	x	x						
Office Trailer	C	732	732	732	x					x		
Area Headquarters	C	1,590	1,590	1,590	x						x	
<u>SALEM DISTRICT</u>												
Salem District												
Office	B	24,702	24,702	24,702	x	x						
Materials Lab	C	4,000	800	800	x				x			
Traffic & Safety Office	C	1,188	1,188	1,188	x							
Maintenance Shop	B	25,524	25,524		x	x	x					
Sign Shop	C	4,320	4,320	0	x	x						
Warming House	C	600	600	0	x						x	
Bedford Residency												
Office	B	2,500	2,500	2,500	x							
Maintenance Shop	C	4,840	4,840	0	x	x						
Area Headquarters	C	576	576	0	x						x	

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B - The point of delivery for all energy types is at the building; consumption data would apply to only one conditioned (heated/cooled) building.

C - The point of delivery for at least one of the energy types is at a central location; consumption data would apply to a group of conditioned buildings.

Site and Building Name	Energy Supply*	Total Floor Area (ft.^{2})	Heated Floor Area (ft.^{2})	Cooled Floor Area (ft.^{2})	Electricity	#2 Oil	#5 Oil	#6 Oil	Natural Gas	Propane/LPG	Kerosene	Wood/Coal
Christiansburg Residency												
Office	C	2,352	2,352	2,352	x	x				x		
Maintenance Shop	C	3,600	3,600	0	x	x						
Sign Shop	C	720	720	0	x							x
Welding Shop	C	720	720	0	x							x
Blacksmith Shop	C	800	800	0	x							x
Warming House	C	720	720	720	x						x	
Floyd Area												
Maintenance Shop	C	4,000	4,000	0	x	x						
Warming House	C	432	432	432	x						x	
Giles County Area												
Maintenance Shop	C	4,000	4,000	0	x					x		
Blacksmith Shop	C	288	288	288	x							x
Warming House	C	900	900	900	x					x		
Hillsville Residency												
Office	C	2,304	2,304	2,304	x	x						
Maintenance Shop	C	2,880	2,880	0	x	x						
Blacksmith Shop	C	624	624	0	x							x
Office Trailer	C	552	552	552	x							
Warming House	C	672	672	672	x						x	
Chemical Shed	C	1,620	756	0	x						x	
New Castle Area												
Office	C	580	580	580	x	x						
Maintenance Shop	C	3,200	3,200	3,200	x	x						
Pulaski County Area												
Maintenance Shop	C	3,600	3,600	0	x	x						
Blacksmith Shop	C	720	720	0	x							x
Soils Lab	C	580	580	580	x						x	
Warming House	C	576	576	576	x						x	
Storage Shed	C	720	720	0	x						x	
Rocky Mount Residency												
Office	B	3,600	3,600	3,600	x	x						
Maintenance Shop	C	3,312	3,312	0	x	x						
Warming House	C	392	392	392	x						x	
Salem Residency												
Office	C	2,350	2,350	2,350	x	x						
Bridge Office	C	3,000	3,000	3,000	x	x				x		
Maintenance Shop	C	11,400	11,400		x	x						
Area Headquarters	C	600	600	600	x					x		
Troutville Area												
Office	C	300	300	300	x	x						
Maintenance Shop	C	3,200	3,200	0	x	x						
Warming House	C	360	360	0	x	x						

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B - The point of delivery for all energy types is at the building; consumption data would apply to only one conditioned (heated/cooled) building.

C - The point of delivery for at least one of the energy types is at a central location; consumption data would apply to a group of conditioned buildings.

928

Site and Building Name	Energy Supply*	Total Floor Area$_2$ (ft.^{2})	Heated Floor Area$_2$ (ft.^{2})	Cooled Floor Area$_2$ (ft.^{2})	Electricity	#2 Oil	#5 Oil	#6 Oil	Natural Gas	Propane/LPG	Kerosene	Wood/Coal
STAUNTON DISTRICT												
Staunton District												
Office	B	20,770	20,770	20,770	x	x						
Survey Office	B	1,350	1,350	1,350	x							
Materials Lab	B	4,730	4,730	4,730	x	x						
Maintenance Shop	B	25,100	25,100	3,072	x	x						
Edinburg Residency												
Office	C	3,600	3,600	3,600	x							
Maintenance Shop	C	5,600	5,600	0	x	x						
Sign & Bridge Shop	C	1,800	1,800	0	x	x						
Warming House	C	576	576	576	x							
Harrisonburg Residency												
Office	B	3,480	3,480	3,480	x							
Maintenance Shop	C	6,000	6,000	0	x	x						
Sign Shop	C	1,536	1,536	0	x						x	
Warming House	C	1,024	1,024	0	x						x	
Lexington Residency												
Office	C	3,808	3,808	3,808	x				x			
Survey Office	B	990	990	990	x							
Maintenance Shop	C	2,800	2,800	150	x				x			
Warming House	C	1,059	1,059	180	x				x			
Luray Residency												
Office	B	2,600	2,600	2,600	x							
Maintenance Shop	A,C	6,268	6,268	0	x	x						
Sign & Bridge Shop	A,C	1,800	1,800	0	x							
Warming House	A,C	680	680	680	x							
Verona Residency												
Office	B	4,317	2,878	2,878	x							
Maintenance Shop	C	5,707	5,707	0	x	x						
Blacksmith Shop	C	952	952	0	x							x
Warming House	C	576	576	576	x							
Winchester Sub-Residency												
Office	C	1,135	1,135	1,135	x				x			
Survey Office	C	1,200	1,200	1,200	x				x			
Maintenance Shop	C	4,320	4,320	0	x	x						
Sign Shop	C	1,172	1,172	0	x				x			
SUFFOLK DISTRICT												
Suffolk District												
Office	B	24,000	24,000	24,000	x	x						
Survey Office	B	3,200	3,200	3,200	x							
Materials Lab	B	4,548	4,548	4,548	x	x						
Maintenance Shop	B	36,000	36,000	5,500	x	x	x			x		
Accomac Residency												
Office	B	3,504	2,604	2,604	x							
Maintenance Shop	B	4,313	4,313	0	x	x						

*ENERGY SUPPLY CODES:

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C - The point of delivery for at least one of the energy types is at a central location; consumption data would apply to a group of conditioned buildings.

Site and Building Name	Energy Supply*	Total Floor Area (ft.^{2})	Heated Floor Area (ft.^{2})	Cooled Floor Area (ft.^{2})	Electricity	#2 Oil	#5 Oil	#6 Oil	Natural Gas	Propane/LPG	Kerosene	Wood/Coal
Franklin Residency												
Office	B	3,420	3,420	3,420	x							
Survey Office	C	576	576	576	x							
Maintenance Shop	C	5,834	5,834	144	x	x						
Norfolk Residency												
Office	C	3,840	3,840	3,840	x	x						
Maintenance Shop	C	5,040	5,040	0	x						x	
Suffolk Residency												
Office	B	3,140	3,140	3,140	x			x				
Waverly Residency												
Office	B	2,321	2,321	2,321	x	x						
Maintenance Shop	C	2,880	2,880	0	x	x						
Williamsburg Residency												
Office	B	4,192	4,192	4,192	x	x						
Maintenance Shop	B	4,436	4,436	0	x	x						
Hampton Roads												
Bridge-Tunnel Office	B	11,268	11,268	11,268	x	x						
Norfolk-Virginia Beach												
Toll Road Office	C	5,872	5,872	4,256	x			x				
<u>RICHMOND-PETERSBURG TURNPIKE</u>												
Richmond-Petersburg												
Administration Office	C	12,228	12,228	12,228	x	x						
Maintenance Shop	C	10,018	10,018	806	x	x						
Belvidere Office	B	2,035	2,035	2,035	x	x						
Colonial Heights Office	B	1,550	1,550	1,550	x	x						
Dinwiddie Office	B	1,111	1,111	1,111	x	x						
Falling Creek Office	B	1,710	1,710	1,710	x	x						
Petersburg Office	B	1,111	1,111	1,111	x	x						

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