METHODS OF ENERGY CONSERVATION

IN

WINNIPEG ELEMENTARY SCHOOLS

By

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A Practicum Submitted
In Partial Fulfillment of the
Requirements for the Degree,
Master of Natural Resource Management

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Abstract

Increased demands for energy, and the accompanying price increases, make it more critical now than in the past, to conserve energy. The educational institution is an appropriate place to teach about energy in modern society, and how it can be conserved.

This study identifies and evaluates factors which are responsible for excessive energy consumption in Winnipeg schools. The findings, and calculation of benefits of conservation are presented in layman's terms so that a maximum audience is reached.

An old elementary school, built in 1954, is compared to a new elementary school, built in 1976. The method of data collection includes the "energy audit," literature search, and consultation with local experts. A questionnaire was distributed to determine information about building use and user attitudes.

In this study, the older school can gain the most benefits by conservation measures involving construction and significant capital investments, while appropriate measures in the new school involve little capital investment, such as building use, and operation of school systems.

It is emphasized that people in all levels of the school division system play crucial roles in determining the success of an energy conservation program.

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GLOSSARY

A.S.H.R.A.E. — American Society of Heating, Refrigerating and Air-Conditioning Engineers.

BRITISH THERMAL UNIT (Btu) — The unit of energy or heat required to raise the temperature of one pound of water from 39F to 40F or from 60F to 61F under standard pressure, or 1/180 of the heat to raise 1 lb. from 32F to 212F.

C.F.M. — Cubic feet per minute. Volume of air movement.

CONDUCTANCE — The quantity of heat (usually Btu) transmitted per unit of time (usually 1 hour) from a unit (usually a square foot) or surface to an opposite unit of surface of material under a unit temperature (usually 1°F) differential between the surfaces.

CONDUCTION — The transmission of heat from one part of a body to another part of the same body, or from one body to another in contact with it, without appreciable displacement of the particles of the body.

CONDUCTIVITY — The quantity of heat (usually Btu) transmitted per unit of time (usually 1 hour) from a unit surface (usually 1 sq. ft.) to an opposite unit of surface of one material per unit of thickness (usually 1 inch, but occasionally 1 foot) under a unit temperature differential (usually 1°F) between the surfaces.

CONVECTION — The transfer of heat from one point to another within a fluid by the mixing of one portion of the fluid with another. When the motion is due to differences in density, from temperature differences, the convection is natural; if the motion is imparted mechanically, it is forced convection.

DEGREE-DAY — The product of one day and the number of degrees F the daily mean temperature is below 65F. Thus on a day when the mean temperature is 40F, there are 25 degree-days. The degree-day unit is used in eliminating the weather variable in determining heating load efficiency and in predicting fuel consumption.

DEMAND METERING — Manitoba Hydro bills new schools by demand metering. Payments are based on the highest 32 min. period of electrical consumption in the heating season.

F.C. — Footcandle - standard measure of illumination intensity.

H.V.A.C. — Heating, Ventilating and Air-Conditioning.

<u>INFILTRATION</u> Leaking inward. In heat transmission, applies to the air entering the space through cracks, doors, etc. The opposite of Exfiltration.

<u>kW.h</u> Kilowatt hour, one thousand watts per hr. Electrical consumption.

<u>LOAD FACTOR</u> Ratio of average output during a period to maximum output during the period. Sometimes, ratio of output to maximum capacity.

<u>RADIATION</u> The transfer of energy in wave form from a hot body to a (relatively) cold body independent of matter between the two bodies.

<u>RESISTANCE</u> In heat transfer, the reciprocal of Conductance.

<u>R-VALUE·RESISTIVITY</u> The reciprocal of Conductivity.

<u>RETURN AIR</u> Air returning to a heater or conditioner from the heated or conditioned space.

<u>SENSIBLE HEAT</u> That heat which when added or subtracted results in a change of temperature, as distinguished from Latent heat.

<u>SUN EFFECT</u> The quantity of heat from the sun tending to heat an enclosed space.

<u>U-VALUE</u> See, Conductivity.

<u>UNIT HEATER</u> Of two types: (1) an assembly of encased heating surface with fan and motor and for connection to a source of steam or hot water; (2) an assembly of the above plus a fuel burner so that the device is for connection to a source of oil or gas (or supplied with coal) and not to steam or water lines.

<u>UNIT VENTILATOR</u> A unit heater (which see) of type (1) but connected to a source of ventilation air and usually provided with an air filter.

<u>VENTILATION</u> The art or process of supplying outside (so-called fresh) air to or removing air from an enclosure.

CHAPTER I

1. The Problem Setting
1.1 Introduction

Canadians consume more energy per capita, than any other country in the world with the exception of the United States.[1] Reasons for this high consumption vary from climate to vast travelling distances to underdesigned and oversized buildings. Perhaps the most important factor is a general waste of energy stimulated by formerly low energy prices.

Traditional supplies of oil and gas are declining, increasing the role that new and distant resources play in evergy policy planning.[2] These frontier resources such as Beaufort Sea oil and the Athabasca tar sands entail increased recovery and delivery costs as well as added social and environmental impacts.

Conservation of energy is a method which can have immediate effect on the energy supply/demand situation by extending the life of known resources, allowing time for necessary research and development of both fossil fuel, and alternative, renewable energy resources. In this way, the construction of a pipeline may be delayed sufficiently to allow a decision to be made on the location of a pipeline route with minimum social and environmental impact. Conservation of energy may provide the time for a more efficient alternative to piped oil or gas to be developed. An indirect benefit of conservation would be a reduction

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1. Background Paper on the Canadian Energy Situation, prepared by the Government of Canada for the Conference of First Ministers, Paper No. 3; April 9-10, 1975, p.12.

2. An Energy Strategy for Canada, Policies for Self-Reliance, Energy, Mines and Resources Canada, Energy Policy Sector, Ottawa; 1976, p.44.

in environmental problems associated with the production and consumption of energy. A short term effect of conservation to the individual is a monetary saving in fuel bills. A long term effect of conservation could conceivably be the stabilization of the demand for additional power projects. Utilities would be able to reduce capital commitments and eventually be able to stabilize energy prices.

In the discussion of the implementation of energy conservation measures, it is logical that schools be one of the first areas considered. Energy conservation techniques, other than the most popular, are largely unknown to the average person, and thus need to be learned. Adults should be the focus of an awareness program, but so should children. It is the children of today who must cope with the conserver society of tomorrow. Also, children should adapt to an energy-aware style of living more easily than those who are already accustomed to a high energy consumption lifestyle. A sensible location for a learning program is in the educational institution. Schools offer an excellent opportunity for students to observe firsthand, the results of applied conservation methods. The benefit of such a program is that the school division (and thus the taxpayer) gains financially from the exercise, through reduced energy bills. This will be demonstrated in detail later in this study.

A study by the Government of Manitoba, (Department of Public Works, and Bureau of Statistics) has shown that among 38 Winnipeg schools, there exists a range of energy consumptions varying from 51,000 Btu. per square foot to 235,000 Btu per square foot per year.[3]

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3. An Energy survey of schools and offices in Winnipeg, Manitoba Department of Public Works and Manitoba Bureau of Statistics, Working document only - not for release, Winnipeg, 1976, p.9.

Data from this study revealed that there was no direct corelation between the size of the school, and the energy consumed, as might be expected. Factors are obviously operating to cause one school to consume more than four times that of another, on a per square foot basis.

1.2 Research Objectives

The objectives of this study can be stated as follows:

a) to identify and evaluate factors which are responsible for excessive energy consumption in Winnipeg elementary schools. Analysis is divided into six categories:*

- attitudes towards conservation,
- regulations and codes which in some way influence the amount of energy used in schools,
- building usage,
- building operation and maintenance,
- building construction,
- site characteristics.

Where possible energy conserving measures will actually be implemented at the schools.

b) to present the information in a format which is easily understandable to the lay person. In this way it is hoped the information will reach the greatest audience. To allow approximation of possible energy savings from introducing conservation measures in other situations, savings in this study are expressed in percentages of the total energy bill,as well as in units of energy, and in dollars.

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*An expansion of major areas of concern recommended by the following studies:

1) A.A. Bourassa, M.P. Graham, Variation in the Energy Consumption of School Buildings, Ottawa: Carlton Board of Education, 1976, p.1.

2) The Conservation of Energy in Housing, Central Mortgage and Housing Corporation, NHA 5149, Ottawa: 1977, p.2.

3) Manitoba Department of Public Works and Manitoba Bureau of Statistics, Working Document (not for release) 1976, p.47.

1.3 Study Area

The schools used in this study were chosen on the basis of representation of the greatest number of Winnipeg schools. St. George School, built in 1954, represents the older school population ,while William Whyte School, built in 1976, represents the newer population of Winnipeg schools. (see page 11)

Figure 1: Orientation of the Schools in Winnipeg

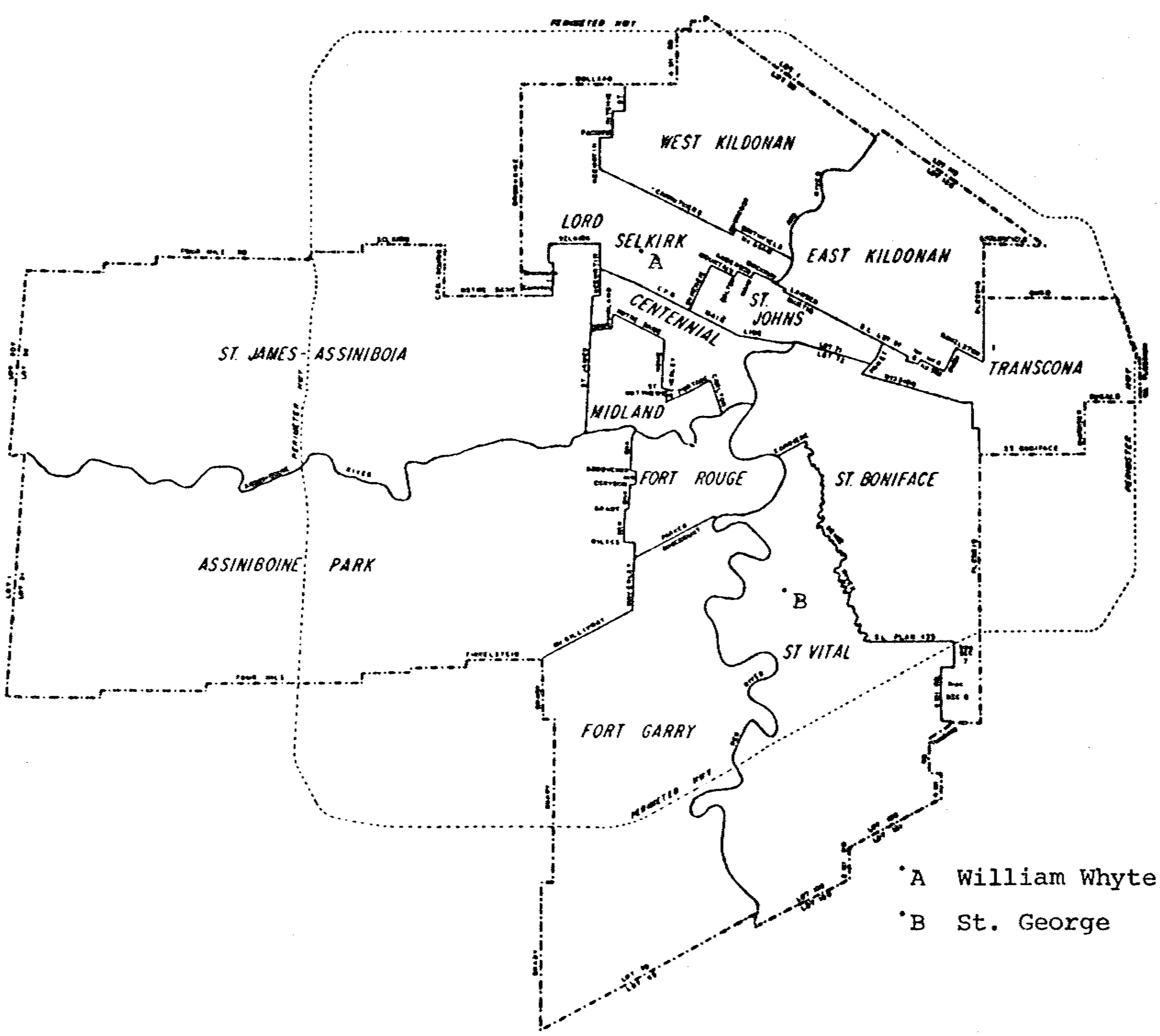


Figure 2: Site Plan of William Whyte School

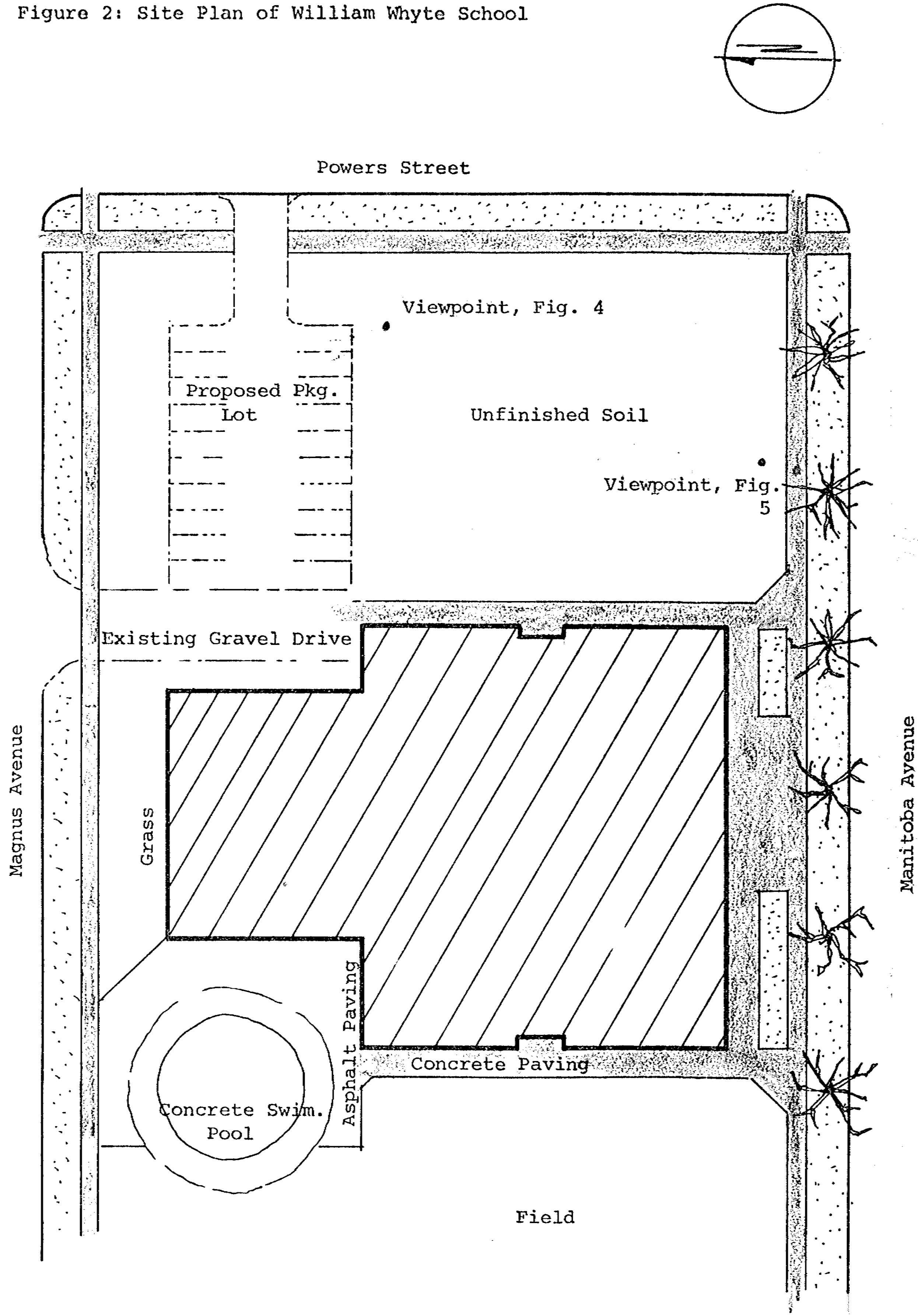
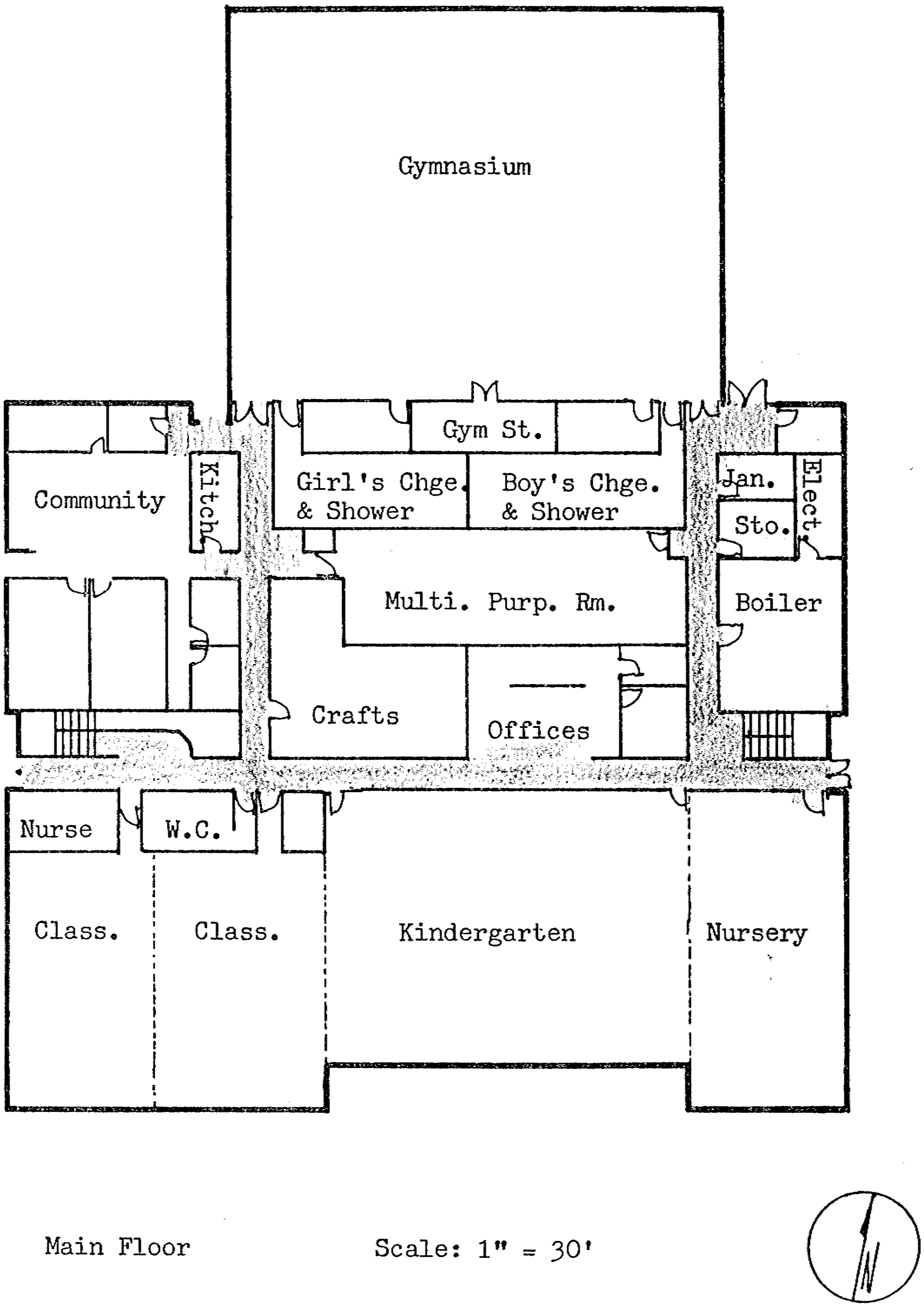


Figure 3: Sketch Plan of William Whyte School



Main Floor Scale: 1" = 30'

William Whyte elementary/community school was built in 1976, with 41,200 square feet, and approximately 83 square feet of floor area per pupil. The school is located in Winnipeg #1 school division.

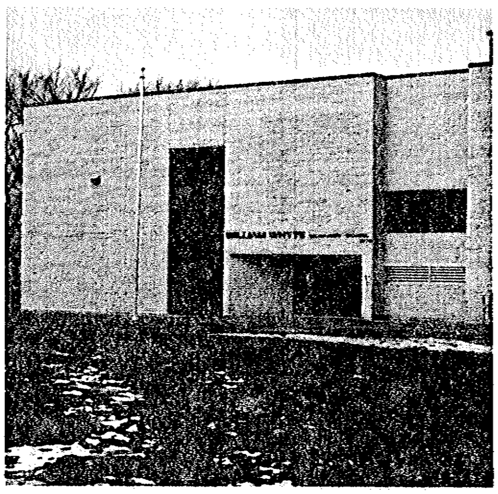


Figure 4 : William Whyte School, note the lack of landscaping in the foreground.

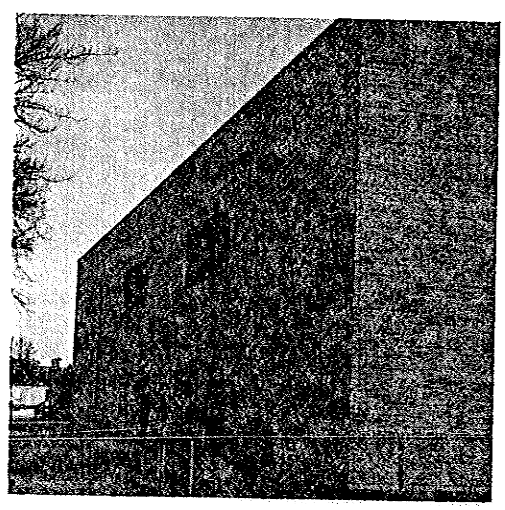


Figure 5 : William Whyte School, note the small window areas.

Figure 6: Site Plan -- St. George

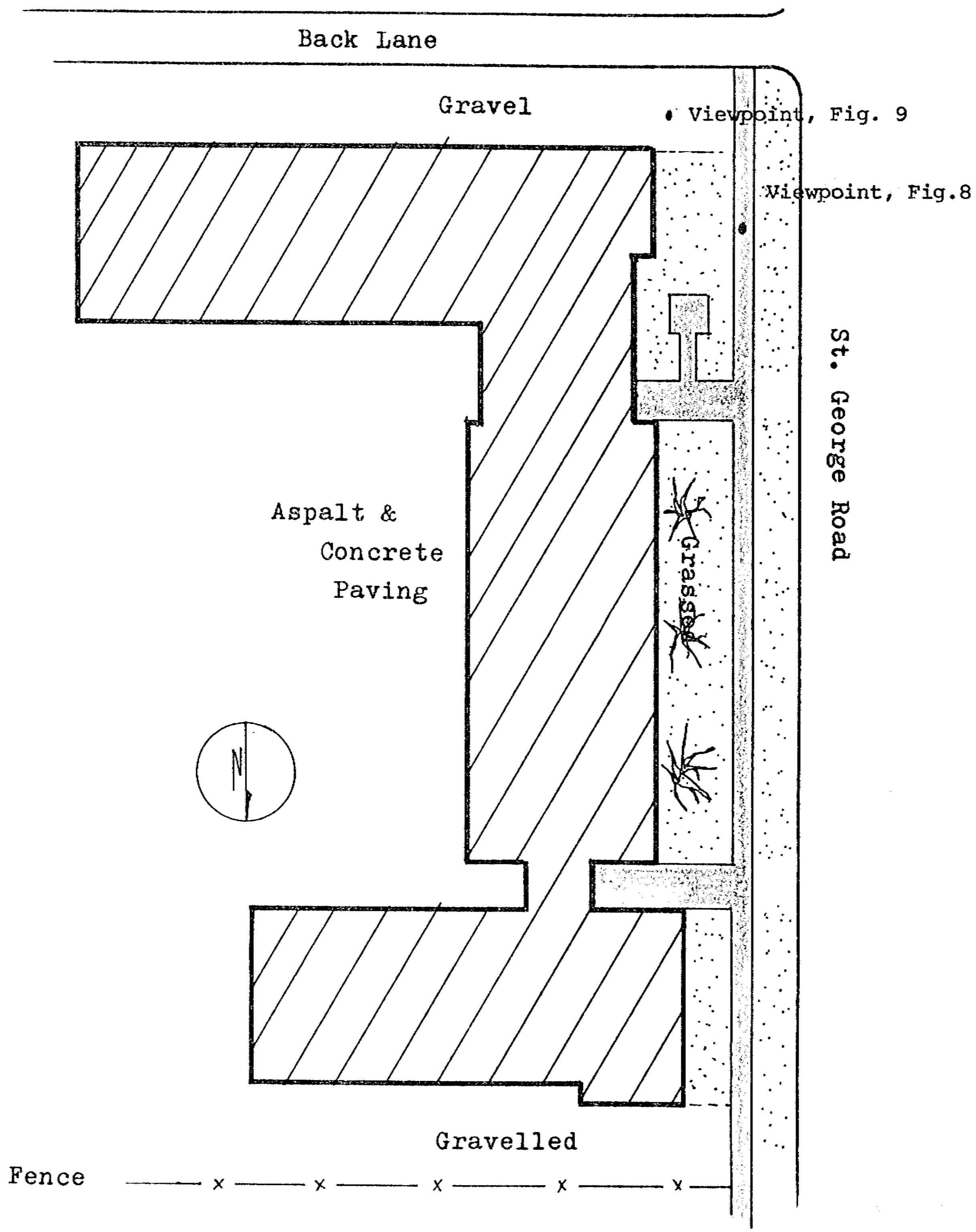
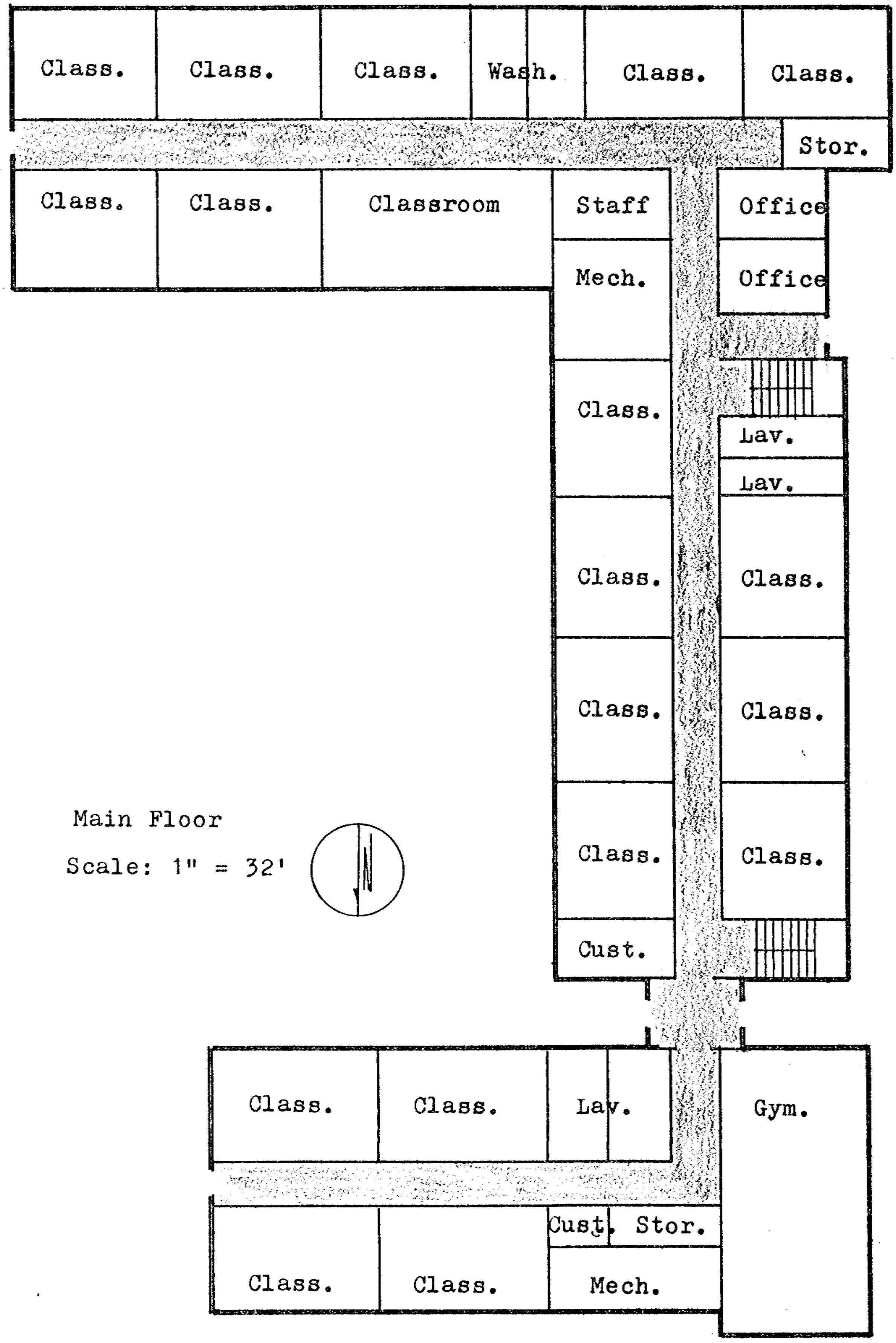


Figure 7: Sketch Plans of St. George School



St. George elementary school was built in 1954; additions were made in 1955, 1961, and 1967, for a total of 39,800 square feet of floor area or approximately 79 square feet per student. The school, is situated in St. Vital school division #9.

Figure 8 : St. George School, note the large areas of glazing.

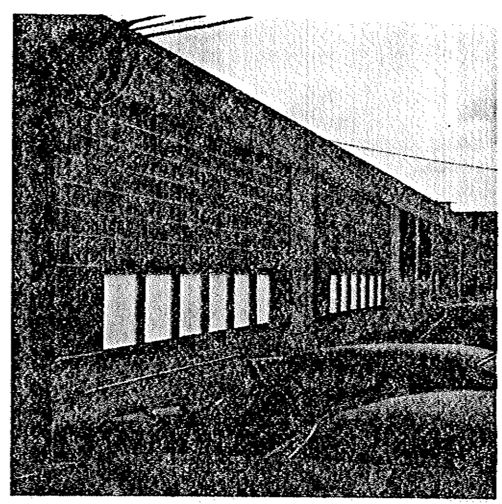


Figure 9 : St. George School, an attempt has been made to reduce the glazed area.

1.4 Delimitations

The Government of Manitoba energy study indicated that the total number of schools in Winnipeg as of 1974 was 233, of which 26% (60) were built in the prewar period, 8% (19) in the immediate post war period (to 1951), and the remaining 66% (154) in the period 1951 - 1974.[4]

Due to time and resource constraints, two schools were studied in detail. In order to maximize the relevance of the research to the population of Winnipeg schools and to reveal the effect of different construction types on energy use as well as the effect of age on building energy consumption, a school built in the beginning of the period 1951 to 1978 was chosen for study; the second choice was a school recently constructed. Both schools are two storey, and approximately the same size.

This study is concerned with conservation techniques which can be applied to existing buildings.

One overiding constraint on the effort to conserve energy, is that the quality of the teaching program in the schools must be maintained. Measures which cause discomfort will be amended, or discontinued. (ie. class becomes too dark, or ventilation inadequate.) In future years, if the energy situation becomes critical, some sacrifice in comfort may be necessary.

1.5 Assumptions

In order to make a decision about a particular conservation measure, it is necessary to know the cost and benefits associated with

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4. Ibid, p.3.

each measure. Wherever possible, discussion of each measure in this study includes a detailed benefit cost analysis. In this analysis, dollars saved over future years (for the life of the school) are discounted to present day 1978 dollars. This allows fair comparison of benefits and costs in 1978. The examples included in this study are based on an annual fuel price increase of 10% above inflation, and an interest rate of 10%. A chart has been included in Appendix B to allow analysis of various combinations of interest and fuel price growth rates. The chart also includes divisions into time periods of 10, 20, 30, 40 and 50 years, in order to reflect the number of years remaining in the expected life of the building.

It is assumed that, due to differences in building age, construction and design, one conservation measure will have more relevance to one school than to another. Where possible these differences between the two study schools will be identified and analyzed.

To calculate the dollar value of the energy savings, the energy rates as of April 1, 1978 were used.

It is assumed that labour required to implement conservation measures in this study, is provided from the school division resources, and not the private sector. School division labour is expected to be less expensive than 'outside' contractors.

1.6 Methodology

1.6.1 Data Collection

The first step in the data collection process is to conduct an energy audit. The purpose of this is to gather a comprehensive picture of building use, operation and maintenance, building construction, and site characteristics, as they affect energy consumption. This was accomplished by field inspection of the building, as well as by examination of architectural, mechanical and electrical drawings and specifications for the building. Published literature was also examined. To provide a supplement to the field inspection, a questionnaire was distributed among the teaching staff of both schools. This demonstrated the teacher perceptions of the school and how they used it.

1.6.2 Criteria for the Admissibility of Data

To be useful in this study, data which was extracted from the literature had to be appropriate to the cold climate experienced in Winnipeg. Some techniques to conserve energy in warmer climates are not compatible in this climate. Whereas a boiler could be switched off for extended periods in warmer climates, pipes would freeze in Winnipeg, with potentially disastrous results. The requirements of schools change with variation in size. Larger schools may have sophisticated eating arrangements (ie. cafeteria), swimming pool facilities, and diverse curricular activities. A smaller school may have only basic requirements. For this reason information which was gathered had to be applicable to average schools in the area of 35,000 to 45,000 square feet.

1.6.3 Research Methodology

Acceptable data was categorized according to its relation to building use, construction, operation and maintenance, site characteristics, and attitudes towards energy conservation. An assessment of the situation at each school was made through analysis of usable data, consultation with experts, and by using a set of questions such as the following:

- Is the operation of this equipment absolutely necessary? (ie. can lights be disconnected?)
- Can the time required to perform this function be shortened?
- Can the operation be adjusted to consume less energy?
- Can two operations be combined to reduce overall energy consumption?

When a proposed set of adjustments had been compiled, school division authorities, building users, and the building custodian were consulted. Approval was sought for official recognition of the proposed measures; this also allowed the researcher to obtain feedback on the possible effects of the adjustments on the people involved. With final approval and acceptance by all involved, the program could be successfully implemented in whole or in part.

A school division operating under severe economic constraints, may wish to implement those measures which require only labour expenses. One option for such schools would be to implement measures requiring no capital investment, and wait until the earnings from these measures yield sufficient returns to finance the implementation of measures which do require capital investment.

CHAPTER II

2. Literature Review
2.1 Overview

Energy conservation is not a new concept. It is only today, however, that the advantages of energy efficiency are being widely recognized. Rising fuel prices are making small changes in energy consumption very noticeable.

Bruce McCallum, in Environmentally Appropriate Technology,[1] believes energy conservation has two merits. First, through decreased consumption, the existing resource life is extended, allowing time to develop alternate, renewable sources of energy. Second, decreasing energy demand is a transitional step to the necessary efficient, low consumption lifestyle where resources are used only at permanently sustainable levels.

Residential and commercial energy consumption accounts for about one-third of total Canadian energy consumption.[2] Through conservation in buildings, major reductions in total energy use can be attained. Transportation industry and utilities form the remaining categories of high energy consumption.

A.G. Stone cites the present fuel pricing system as a major deterrent to energy conservation.[3] Utilities commonly practise second degree price discrimination, where different rates are charged to different residential users. An initial amount of energy costs the

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1. McCallum, Bruce, Environmentally Appropriate Technology, 4th ed.; Ottawa: Fisheries and Environment Canada, 1977, p.6.

2. Energy Conservation in Schools, Ottawa; Ministry of Education, 1976, p.2.

3. Stone, A.G., "New Thinking and the Future," Energy Conservation in Buildings, London: conference proceedings March 12, 1975.

consumer a fixed price per unit. (ie. 3.6¢ /kWh) If enough energy is used to place the consumer in the next rate block, cost per unit energy will decrease. (ie. 2.2¢/kWh) (see Appendix B) Stone recommends a reversal of this system, whereby the less energy that is used, the cheaper it becomes. A major organized effort is required to effect changes in this area.

At this point it may be useful to divert from a discussion of the overall picture, and discuss energy conservation as it pertains to institutional buildings. Later, literature will be reviewed which relates specifically to the categories outlined in Objective "a". (pg. 3)

2.2 Institutional Buildings

One of the most significant documents dealing with standards of energy conservation in the last few years, is the American Society of Heating, Refrigerating and Air Conditioning Engineers (A.S.H.R.A.E.) ASHRAE standard 90-75, Energy Conservation in New Building Design.[4] Although it is oriented towards new building design, many of the recommendations have application to existing buildings. Temperature and air volume settings, as well as performance standards for most of the energy consuming equipment in institutional buildings are recommended. The document also encompasses efficient operation and maintenance. With regards to building shell construction, high thermal resistance and reduced air leakage are emphasized.

The guidelines in ASHRAE 90-75 are drawn in some cases from

4. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., A.S.H.R.A.E. Standard 90-75, Energy Conservation in New Building Design, New York: 1975.

ASHRAE 62-73 Standards for Natural and Mechanical Ventilation.[5] The study contains both minumum and recommended levels of ventilation, (ASHRAE 90-75 uses the former) for a wide range of building types, from private residences to prisons. By comparing existing ventilation levels in buildings to these standards, one can objectively determine whether or not the existing ventilation levels are excessive. If fan systems are moving too much air, equipment is either oversized, or running longer than necessary, therby consuming more energy than necessary. The excessive flow of air through the building means that more air is heated or cooled than necessary.

Energy Conservation Control (EC^2)[6] is a technical manual which deals with many new and innovative energy conservation methods in institutional buildings. Criteria for the efficient design of new buildings are presented. It is recommended that heating and cooling needs of interior zones be assessed separately from exterior zones, since the same temperature losses do not occur in each space. It is also mentioned that intermittently or seldom used zones should be accorded different consideration than high density zones. This would result in a more efficient heating, ventilating and air conditioning (H.V.A.C.) system. Technical information such as heat loss through uninsulated and insulated piping is provided. Recommendations include the application of such tests as flue gas analysis, which indicate efficient fuel combustion. Psychological aspects of temperature,

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5. The American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., A.S.H.R.A.E. Standard 62-73, Standards for Natural and Mechanical Ventilation, New York: 1973.

6. Johnson Controls, Ltd., Energy Conservation Controls (EC2), Toronto; 1974.

ventilation and lighting changes are considered. It is suggested that temperature indicators be removed to prevent users from being 'told' that they are cold.

The Guide on Interior Lighting[7] is a technical paper encompassing many aspects of lighting in buildings. It deals with such topics as the efficiencies of luminaires (light fixtures), increased efficiency through regular cleaning, and a variety of lighting systems from general ceiling lighting to specialized task lighting. Technologies such as amalgamating the lighting and air conditioning systems to increase lamp efficiency are discussed.(temperature of the lamps is reduced by drawing cool air over them, thus increasing efficiency.)

A number of energy conservation techniques are presented in Energy Management for Commercial Buildings.[8] This article is somewhat different from those previously mentioned in that recommendations are conveniently divided into those which do require capital investment, and those which do not. A further distinction has been made as to whether the saving is electrical energy or mechanical energy. The article recommends and briefly outlines the procedure for an "energy audit." Although the recommendations are not exhaustive, they do cover the more significant areas of energy loading.

2.3 School Buildings

2.3.1 Building Operation and Maintenance

The area of building operation and maintenance is one which has received much attention in energy conservation programs. This is

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7. International Commission on Illumination, Guide on Interior Lighting, Paris: 1975.

8. Minnesota Energy Agency, Division of Energy Conservation and Planning, Energy Management in Commercial Buildings, St. Paul, Minnesota: 1976.

due mainly to the fact that no significant amounts of capital outlay are required to effect energy conservation measures. A study by the Metropolitan Toronto School Board[9] estimated that school building operation and maintenance (O.&M.) accounted for one-third or more of total building life costs. An Educational Facilities Laboratories report pointed out that one of the most obvious errors in schools was inefficient operating techniques which resulted in wasted energy.[10] Reductions in O.&M. costs can thus significantly reduce total building costs.

Energy Usage Guidelines - Educational Institutions by the University of the State of New York,[11] outlines a large checklist of O.+M. conservation measures. A convenient distinction is drawn between O.&M. in winter season heating and ventilating, and summer season air conditioning and ventilation. A plumbing, electric and general checklist are also included. All the suggestions cannot be applied to one building, but enough could be relevant that if followed, a significant saving could be obtained.

In the Educational Facilities Laboratories report,[12] it was noted that a school in Colorado saved 23.9% of its annual heating costs by shutting down and draining the hot water heating system during

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9. The Metropolitan Toronto School Board, Study of Educational Facilities, High Rise and Mixed-Use Study, Toronto: 1970, p.62.

10. Building Systems Information Clearinghouse, Educational Facilities Laboratories, Elementary and Secondary Schools: Case Studies of of Energy Use, California: 1974, p.4.

11. The University of the State of New York, The State Education Department, Energy Usage Guidelines - Educational Institutions Heating and Cooling Seasons, New York: Sept., 1974.

12. Educational Facilities Laboratories, The Economy of Energy Conservation in Educational Facilities, New York, 1973: p.25.

Christmas and January. This method is not feasible in Winnipeg, since the water lines within the school would freeze and rupture pipes.

One of the most important people to convince of the importance of energy conservation is the school custodian. He is the person who makes many of the adjustments to school equipment and carries out routine inspections. He needs to fully understand the system he is working with. In the Economy of Energy Conservation in Educational Facilities it is recommended that these personnel should be regularly upgraded on building processes.[13] Promotions should be based on the number of courses taken. This would increase self-esteem, as well as competence. One building operator in Carleton school division in Ontario, saved $3,000 in fuel costs in one year in one school.[14] He was publically recognized for it, and others will probably follow his example.

2.3.2 Building Use

Bourassa and Graham, in Variation in Energy Consumption in School Buildings, cite building use as one of the major factors of high energy consumption.[15] They maintain that building superintendents, staff and students all need to play a role in a successful energy conservation campaign. The Economy of Energy Conservation in Educational Facilities substantiates this, accrediting energy waste to lethargy and

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13. Ibid, p.25.

14. M.P. Graham, A.A. Bourassa, Variation in the Energy Consumption of School Buildings, Ottawa: Carleton Board of Education, 1976, p.10.

15. Ibid, p.1.

ignorance.[16] In one case study, 30% of a school's total energy was used between 4 p.m. and midnight. Investigation revealed that the three custodians had habits of leaving lights on in all areas, and furnaces heating the entire school while they worked in one localized area.[17] It was estimated that half of the energy used in cleaning was needlessly lost.

A study in New Jersey revealed that fuel consumption in two identical buildings varied by as much as 50%.[18] This was attributed to the building users' habits of leaving windows open, and doors ajar. In schools, the amount the doors are open is related to the traffic patterns within the school. Some scheduling would ensure the doors be open the minimum time possible.

The scheduling of extra-curricular activities should be of concern when considering energy reductions. In Energy Usage Guidelines,[19] it is recommended that extra hour use of the facilities be reduced to the most important activities. If possible they should be scheduled in the afternoon, allowing the building to be closed at night. Those activities which must be held at night should be confined to as few HVAC zones as possible, so the temperatures in the other zones may be reduced. Energy Usage Guidelines[20] lists a number of procedures which the users of a school could follow to improve the energy efficiency of the school.

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16. The Economy of Energy Conservation in Educational Facilities, p.13.

17. Ibid, p.13.

18. Steadman, Philip, Energy, Environment and Building, Cambridge: Cambridge University Press, 1975, p.31.

19. Energy Usage Guidelines - Educational Institution, p.8.

20. Ibid, p.11.

2.3.3 Building Construction

Building construction, in the context of this project, refers to the building structure as well as to the mechanical and electrical services within. Methods of conservation which require the alteration of construction generally require significant amounts of capital investment. The best application of conservation techniques in construction is in the design of new buildings. However, in this paper, concerned mainly with existing buildings, the emphasis is placed on retrofitting buildings.

Bourassa and Graham attribute excessive energy consumption to four major factors, three of which lie in the realm of building construction: infiltration, lighting, and heating systems. (the fourth is building use.)[21]

Energy Conservation Controls shows that in a room with windows and doors on only one wall, air infiltrates through cracks at a rate of one room air change per hour.[22] A 'poorly fitting' building could cost much more than necessary to heat and cool. This could be partially remedied with a good operations and maintenance program with regular inspections and recaulking.

An over lit building can be extremely wasteful. The Economy of Energy Conservation in Educational Facilities proves that with fluorescent lighting, 80% of electrical energy ends up as waste heat.[23] A reduction in illumination level from 150 footcandles (fc.) to 50 fc.,

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21. A.A. Bourassa, M.P. Graham, p.1.

22. Energy Conservation Control, section VII (pages not numbered)

23. The Economy of Energy Conservation in Educational Facilities, p.39.

reduces electrical energy consumption by 90%.[24] The reduction in lighting could be arranged by delamping, but greater davings could be had by not installing too many fixtures during construction, thereby saving on the initial cost of the hardware. Task lighting would be even more efficient, since the workspace, and not the entire room, is lighted to a high level.

Many people are becoming aware of insulation as a conservation method. Generally, the more insulation, the better (to an optimum amount). High thermal resistance will reduce energy loss, as well as reduce the required size of the HVAC equipment. According to The Economy of Energy Conservation, insulation is the best investment in terms of speed of recovering costs.[25]

Insulating materials are usually sandwiched within the wall for protection from the elements. If the insulation is weather resistant and vandal resistant, it can be placed on the outside of the structure. This would allow the interior warmth (or coolness) to be retained in the structural elements, before being released to the outside air. Installation of insulation on the outside of the school would reduce the costs of the retrofit, as well as not reduce the interior floor space (as would interior construction). Care must be taken when adding insulation, so as not to violate fire codes.

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24. The Economy of Energy Conservation in Educational Facilities, p.13.

25. Ibid, p.38.

2.3.4 Codes and Regulations

Presently, there are no codes which are enforced to encourage energy conservation in Manitoba schools. National and provincial building codes must be adhered to, but they remain very lax with respect to energy conservation. The Manitoba Building Code, for example, stipulates that mechanical ventilating systems must be capable of providing at least one air change per hour.[26] No upper limit is recommended.

Building designers refer to handbooks such as the ASHRAE Handbook of Fundamentals[27] for more accurate guidelines. Design recommendations of everything from hot water to ventilation requirements can be located in this book.

The ASHRAE Standards for Natural and Mechanical Ventilation[28] provides quick reference to designers regarding ventilation requirements. In some instances the recommended levels of ventilation are more than twice as high as the minimum requirements. The newer document, ASHRAE 90-75,[29] recommends the use of the minimum requirements guidelines. It is not a mandatory code, so unless school divisions stipulate that its guidelines be met, most architects and engineers will be inclined to follow the traditional, less efficient guidelines.

Although the ASHRAE Standard 90-75 represents a major step towards energy conservation, it lacks in the area of lighting. The

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26. Department of Labour, Province of Manitoba, The Manitoba Building Code, Winnipeg: 1976, p.9-115.

27. The American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., A.S.H.R.A.E. Handbook of Fundamentals, New York: 1974.

28. ASHRAE Standard 62-73, Standards for Natural and Mechanical Ventilation.

29. ASHRAE Standard 90-75, Energy Conservation in New Building Design.

standard recommends that the Illuminating Engineers Society (I.E.S.) Handbook be followed with regards to lighting levels.[30] These levels are generally far in excess of British Lighting Council standards. The British classroom lighting standard is 30fc. at desk level,[31] while the American standard ranges up to 100 fc.[32] In The Energy Usage Guidelines, it is recommended that a level of 30 fc. be maintained in classrooms.[33]

Fire regulations have a significant effect on the amount of insulation used in buildings. In one type of common roof constuction, fire codes restrict the thickness of rigid insulation to 2 inches.[34] This could be increased only if 1/2 inch gyproc were added to the construction. The negative aspect of the situation is that in order to increase insulation thicknesses, the school division must not only pay for more insulation, but also for a more complicated roof construction.

A significant document for Canadian buildings is the National Research Council's, Canadian Code for Energy Conservation in New Buildings.[35] It is modelled after the ASHRAE Standard 90-75, with

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30. Illuminating Engineering Society, L.E.S. Lighting Handbook 5th ed.; New York: 1972.

31. British Lighting Council, Interior Lighting Design, London: 1962, p.58.

32. Westinghouse Lighting Handbook, Bloomfield, New Jersey: 1964, p.5-6.

33. Energy Usage Guidelines, p.7.

34. A.A. Bourassa, M.P. Graham, p.8.

35. Associate Committee on the National Building Code, National Research Council Canada, Canadian Code for Energy Conservation in New Buildings, (draft for public comment): June, 1977.

some modifications to reflect the climatic differences. It also shares some of the weaknesses of the ASHRAE document. Nonetheless, if the recommendations were incorporated into the building code, it would be a dynamic step forward on the part of the government.

2.3.5 Site Characteristics

The environment of buildings has been sadly neglected in recent years by designers. Due to high construction costs, siting and landscaping are often neglected. The designer is generally preoccupied with other criteria such as orientation to the street, and parking lots. Windbreaks are seldom planted, and windows are seldom shaded. McCallum speculates that the practice now is simply to increase the size of the heating and air-conditioning systems. He believes that in many cases, natural ventilation, perhaps supplemented by fans, would be more appropriate than air-conditioning, and at a significantly lower cost.[36]

Prevailing winter winds are usually from a different direction than prevailing summer breezes. Richard Speers suggests in Building Form Siting and Orientation, that with some careful planning, trees can be effective blocks against winter winds, yet let summer breezes pass by to cool the building.[37] Philip Steadman notes that a 20 mph. wind can double the heat loss of a building normally exposed to 5 mph. winds.[38]

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36. McCallum, Bruce, p.104.

37. Speers, Richard C., Preliminary Work Toward Building Form Siting and Orientation in SubArctic Climates, Centre for Settlement Studies, Series 2: Research Report 26, University of Manitoba, 1976.

38. Steadman, Philip, p.30.

The sun is a major factor in thermal loading of a building. The albedo (reflectance) of the surfaces adjacent to the building can have significant effect on the light and heat radiated into the building. A grassed lawn, having a lower albedo, in front of a window would produce a more pleasant condition in a classroom than a light concrete playing surface. The site conditions farther away are also significant. A breeze which passes through treed and grassy areas will be cooler than the same breeze passing over an asphalt parking lot.

The amount of sun striking a window can have significant heating effects. In the winter, solar heating is generally desirable, (provided overheating does not occur) and in the summer, undesirable. A convenient solution to the problem is proposed by Bruce McCallum.[39] He recommends that deciduous trees be planted along the southern exposure of buildings. In the summer, the trees have a full foliage of leaves, providing an effective shading mechanism. In the winter, the leaves fall to the ground, allowing the sun to pass through the branches to warm the building.

Building orientation is an important factor, since the amount of sun warming depends on the area of the surface facing the sun. McCallum believes the best orientation is along an east-west axis.[40] This ensures heating in winter, and makes shading easier in summer. (since the sun passes over at a high position in the sky.) Steadman agrees that by minimizing east and west wall areas cooling problems are minimized.[41]

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39. McCallum, Bruce, p.100.

40. Ibid, p.102.

41. Steadman, Philip, p.38.

The answer to the problem of siting lies in dealing with winds and sun with a combination of topography, vegetation and orientation. McCallum concludes that a well landscaped lot, incorporating the above ideas, could reduce heating and cooling needs by 10 to 20%.[42]

2.4 Conclusion

This literature review has demonstrated that there is a wealth of information available regarding energy conservation. It is significant to note, however, that a large number of the references deal with specialized topics. (ie. lighting, and heating) Further, the material does not necessarily apply to Winnipeg elementary schools. Data in the literature must be carefully selected to ensure applicability to the schools and climate in this study.

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42. McCallum, Bruce p.103.

CHAPTER III

Attitudes Towards Energy Conservation

Throughout the course of this study, the researcher has encountered an array of attitudes of people whose cooperation was necessary to make a school energy conservation program a success. At the outset, individuals were apprehensive about the idea of doing more than talking about energy conservation. As program strategies were discussed, and the ease of program implementation realized, people became more enthusiastic.

School division officials were the first to be approached, since personnel such as operations and maintenance supervisors, and school architects have the necessary power to authorize adjustments to school equipment. In addition, such persons can generate interest in other sectors of the school administrativa hierarchy. A unified energy conservation program, organized at the division level, would be far more effective than a series of independent, uncoordinated efforts. A conservation program approved and supported by the division would add credibility to any requests for financial or technical assistance from provincial education officials.

The first person to be contacted, at the school level, was the principal. As a matter of courtesy, an introductory letter was sent, explaining the future presence of an energy resource person at the school. Following a preliminary study, a group of resource people and division officials met with the principal and discussed the implications of the measures with him. With new information provided by the principal, and staff, changes may be in order. Other measures for saving energy may become evident at this stage.

Armed with a thorough knowledge of the proposed adjustments, reasons for the adjustments, and savings which would accrue from them, the principal can approach the teaching staff, who represent a key component of the program. It is important that the building users know what the program entails--what obvious changes will occur. This will ensure that they are psychologically prepared for the changes. In addition, users may be able to contribute ideas for the best implementation of the measures. Custodians in both schools have indicated that, previous to the energy program, a burnt-out fluorescent tube was followed by an immediate outcry of complaint, completely different from the reaction after the program.

A majority of the teachers at both schools expressed satisfaction with the prevailing lighting levels. This is significant, since it was found that lighting levels at St. George were on the order of 50 fc., while William Whyte registered an average level of from 75-100 fc. It was apparent that most people quickly adjust to differing light levels. In the course of the program at William Whyte, up to 42 tubes were removed from a single classroom. Personal communication with the teachers after the delamping program, revealed no objections.

A unique aspect of this study is the integration of energy conservation into the teaching curriculum of these two schools. Teachers are particulary important to this part of the program, which teaches students to appreciate the large role which energy plays in today's world. Resource material was provided by the researcher. Methods of conservation, sources of energy, and uses of energy were among the topics for discussion. In William Whyte, the construction of a large mural is underway, on which will be a chart which compares energy used in past years, to energy used after the start of the program. This allows students to see some of the "real life" results of what they are learning about. "Switch-off lights" posters, designed by the students, were affixed over light switches throughout the schools.

A majority of the teachers of both schools agreed that the school is the proper place to teach energy conservation, but many of these same teachers felt that the home is an equally appropriate place to learn about energy. It is anticipated that the students will carry this knowledge home with them, and benefit the community through increased awareness of the importance of energy in today's society.

The attitude of the students is important, since it is essentially for them that the teaching component of the energy program is designed. Children are usually quite optimistic about most things, so instilling a knowledge and appreciation of energy should not be too difficult.

The school custodian is an important component of the conservation program. He is responsible for such tasks as daily switching of fans and lights, cleaning equipment such as lights and filters, and monitoring systems and general building condition. His role is so essential that consideration should be given to special training for the additional tasks required in an energy conservation program. Barring union complications, personnel who have this additional valuable training could be awarded higher salaries than "untrained" personnel.

Building designers exercise a large degree of control over building energy consumption patterns. They determine the type of building construction, selection and sizing of building systems, and the mode of operation of these systems. To date in Manitoba, St. Vital School

Division is one of the only divisions which has contributed actively throughout the design process.

The attitude of the finance committee, which is responsible for the allocation of money for new school construction, is gradually improving. In the past, school construction costs were tightly restricted in an attempt to economize on taxpayer money. This was generally false economy, since important components such as thicker insulation, extra layers of glazing, and quality of materials were often omitted from otherwise expensive buildings. Thus, a dollar saved in construction could be spent ten times over in operation and maintenance costs. Evidence of a better attitude lies in the financing of more energy conscious (and expensive) designs such as the proposed Brandon underground school, and the proposed waste fuelled school in St. Vital School Division.

Last mentioned, but not least important, is the attitude of energy utilities personnel who determine the energy pricing structure, and develop power sources in anticipation of future demand. One of the reasons that rates increase is to defray the huge amount of capital cost required to develop a new energy source. Reductions in consumption would reduce pressure on the utility to increase supply. The short term result for Manitoba Hydro would be excess capacity (given low export demand), and great financial discomfort. The long term effect would be to stabilize demand, and the price would also be stabilized.

Utilities use a pricing structure which discriminates among users. High consumption rates are indirectly encouraged by lower rates. Manitoba Hydro is gradually removing these rate blocks. The eventual result will be a horizontal price line--equal rates for all users.

It is evident from this review that no unilateral attempt at energy conservation will be totally successful. It is not until people on all levels have a positive attitude towards conservation, that maximum savings can be realized.

CHAPTER IV

Methods of Energy Conservation

Important to the analysis of potential for energy conservation in a school, is an awareness of the heat loss through the building itself. This provides the groundwork for analysis of the systems within the building, the energy audit. The assessment of a large number of schools could lead to some sort of energy "guideline" which would serve as an ideal with which to compare study schools. For the purposes of this study, a comparison of the two schools will suffice. Conservation measures were applied to the school in which need of the measure is most evident.

4.1 Building Heat Loss

To determine the extent to which building construction contributes to energy consumption, a detailed heat loss analysis of both schools was carried out. The methodology is similar to that used in the Chapter on 'Construction'. Since the difference that construction type made was of immediate interest, the buildings were treated as if newly built. (An analysis of present condition would necessitate the use of a building condition depreciation factor.) Examination of walls, roof and floor for heat conductivity revealed significant differences between the schools.

4.2 Roof Heat Loss

St. George was built in several stages, the last two of which were single storey. William Whyte, being two storey with no additions, has significantly less roof area than St. George school. This factor, combined with the thinner insulation on the older school results in a total conducted heat loss of more than double that of the new school. The effects of building proportion and construction materials are reflected in Table I

TABLE I: TOTAL CONDUCTED HEAT LOSS (B.T.U. PER HOUR)*

Exposure / School	ROOF	NORTH	EAST	SOUTH	WEST	FLOOR	TOTAL
St. George	150,480	58,380	91,310	61,740	81,550	55,630	499,090
William Whyte	70,820	14,320	22,100	19,280	22,460	60,810	209,790

The effect on heatloss, of the construction materials only is readily seen in Table II. This represents an average of the total heat losses, on a per square foot basis.

TABLE II: AVERAGE CONDUCTED HEAT LOSS PER SQ. FT. (B.T.U./HR./SQ./ FT.)

Exposure / School	ROOF	NORTH	EAST	SOUTH	WEST	FLOOR	TOTAL
St. George	5.2	12.7	12.5	11.1	12.1	2.0	55.6
William Whyte	3.0	4.0	3.9	3.5	3.9	2.6	20.9

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*Total conducted heat loss was calculated by multiplying total surface areas (ie. glazing, brick wall, doors) by the u-value of those areas, multiplied by the temperature difference between outside and inside air. ie. Btu/hr = (ΔT UA)

Floor heat loss is based on an average of 10°C. (50°F.) ground temp.

TABLE III: BUILDING COMPONENT AREAS (SQ. FT.)

SCHOOL / COMPONENT	ST. GEORGE	W. WHYTE
ROOF	28,900	23,400
FLOOR	39,800	41,200
WALLS	25,700	20,300

The effect on component areas, of having several building additions, can readily be seen in Table III. St. George has a higher wall area, as well as roof area, than William Whyte, even though floor area is less.

The roof insulation in William Whyte, although only ½" thicker than the 2" fibrous board used on St. George, is of an expanded polyurethane type, which has a much greater R-value.

4.3 Wall Heat Loss

Table II shows that the wall construction of William Whyte has a smaller heat transfer rate than the older school. The lower heat loss is also attributed to reduced window area, as indicated by the architectural drawing.* It is interesting to note from Table I, that in both schools, heat loss through the North exposure (the coolest) is smaller than any other exposure. This is due mainly to reduced window area, and the fact that the gymnasium, in both schools, is on the North side.

The large areas of glazing which cause excessive heat loss,

*The architectural drawings should always be substantiated by field inspection. The original drawings may not contain revisions made during construction.

such as in the case of St. George, may not be so bad as they look. With southern exposures, a heat gain is obtained during sunny daylight hours, balancing off the conducted heat loss through the glass. Although heat gain values were not calculated, they should be kept in mind.

4.4 Floor Heat Loss

Total conducted heat loss for the two schools is approximately the same, due to similar crawlspace design. (Table II) William Whyte has a slightly higher average floor heat loss because of the large gym area which incorporates 6" void forms instead of crawlspace.

4.5 Energy Consumption

For a one year period in 1976-77, energy consumption has been analysed. Readings for this period can be compared to consumption in other years (which may be warmer or cooler) by using the "degree-day" method. Degree-days are periods of time for which the outdoor temperature falls below 18.3°C. (65°F). All other factors remaining equal, the consumption in one period can be compared to the consumption in another period by multiplying the number of degree days by the consumption for that period. [ie. (D.D. 1976 x consumption 1976) (D.D. 1977 x consumption 1977)].

Using the 76/77 period in this study, the same number of degree days were experienced by both schools, facilitating comparisons. The degree day method was unnecessary in this case.

One could assume that the heat loss in St. George, being more than double that of William Whyte, would result in a similarly increased heating fuel consumption. Examination of fuel bills proves this assumption false. In fact, both schools consume about the same amount of gas, on a per square foot basis.

St. George - 99,810 BTU/SQ. FT./YR.
William Whyte - 93,994 BTU/SQ. FT./YR.*

Obviously, factors other than building shell heat loss are operating. These factors will be discussed later in this chapter.

The difference between the two schools, in electrical consumption, is astounding. William Whyte consumes nearly four times (4x) that of St. George, on a per square foot basis.

St. George - 8,119 BTU/SQ.FT./YR.

William Whyte - 32,204 BTU/SQ.FT./YR.

Given the same activities occurring within the school, factors must be operating to cause such a large differential in electrical energy consumption. These factors were identified in the energy audit of the two schools. All energy consuming equipment was investigated according to the methodology outlined earlier.

4.6 The Energy Audit

4.6.1 Building Use

William Whyte is an elementary and community school. Portions of the building are used summer days, and until 10:00 p.m. on winter nights and weekends. St. George is also used some nights, and for community recreation in the summer. This extra-hour use results in slightly increased energy consumption in both schools, because lighting, heating and ventilating systems must be maintained at "occupancy" status

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*Values were calculated by dividing the heating value of the energy consumed in one year, by the number of square feet floor area.
1 cu. ft. gas = 1,031 Btu.
1 kWh electricity = 3,400 Btu.

during non-school hours.

A nutrition program is in effect at William Whyte, and hot meals are occassionally prepared. A potters wheel and kiln are used intermittently.

According to the custodian, few teachers switched classroom lights off when the space was unoccupied.

Students were allowed inside over a twenty minute period prior to the first morning class. Egress at noon, and 4:00 p.m. was considerably quicker. (from 5 to 10 minutes.)

Neither school had staff vehicle plug-ins in winter. There was no extra equipment such as soft drink and hot food machines.

4.6.2 Construction

4.6.2.1 Lighting

Lighting in William Whyte was overdesigned. Preliminary light meter recordings indicated light levels far in excess of minimum levels recommended by the literature. In most classroom areas, lighting ranged from 75 to 100 f.c. Corridor levels were about 20 f.c.

St. George lighting levels in classrooms ranges from about 50 to 60 f.c. in classrooms with curtains drawn, and as high as 180 f.c. with sunlight. Corridor levels are about 5 f.c.

In both schools, the greatest proportion of lighting is fluorescent. Only one section of corridors in St. George is lighted by incandescent lamps.

4.6.2.2 Air Conditioning

Air conditioning in William Whyte is in operation from May to September, despite the fact that classes are dismissed for July and

August. The machinery creates a maximum electrical load of 74 kilowatts.

4.6.2.3 Heating

In St. George and William Whyte, heating is accomplished by both radiators and forced warm air. Heating and ventilation in four classrooms in St. George are provided by unit ventilators. The central and south sections of St. George are heated by hot water which has been heated by steam. The boiler originally burned coal, but was converted to gas combustion, and is larger than that of a normal gas fired boiler.

4.6.2.4 Hot Water

The domestic hot water system in William Whyte incorporates a 245 gal. fully insulated water tank, and sidearm heater. The tank and heater, located in the boiler room, at times must supply hot water, out of regular class time, to community users located at the opposite end of the school. The tank thermostat is set at 59°C. (138°F.)

St. George has two water tanks with immersion heating elements, at opposite ends of the school. The smaller 40 gallon tank is insulated, with a thermostat setting of 72°C. (162°F.). The other, 90 gallon tank is uninsulated, with a temperature setting of 57°C. (135°F.).

4.6.2.5 Thermostats

Special keys are required to adjust temperature settings at William Whyte. The caretakers stated that they had no knowledge of how to adjust the temperature, and had not done so since the school was built. There is no provision for day/night adjustments of the thermostats (ie. reducing temperature in the school during unoccupied periods.) The setting for William Whyte was 22°C. (72°F.) year round.

A crude variable control of temperature is used at St. George. A temperature sensor in the water line maintains the set temperature by stopping or starting the hot water circulation pumps. Temperature is adjusted by the custodian daily at St. George, with daytime temperatures maintained at around 20°C. (68°F.) and unoccupied temperatures several degrees lower.

4.6.2.6 Switching

At William Whyte the lighting in all corridors, washrooms and changerooms is controlled by two switches in the boiler room. The result of this arrangement is that in order to provide light for cleaning purposes in one isolated area, the lights in half the corridors, washrooms and changerooms must also be on. Only classroom and office lighting could be controlled individually.

Alternate hallway lights could be extinguished with switches at St. George. Classrooms, washrooms, storage rooms and office could be switched off individually.

In both schools, banks of lights were arranged at right angles to the window wall. Two switches controlled the lighting in each room.

Exterior security lights at William Whyte are switched automatically by a 7-day timer. Manual switches control the exterior lights at St. George.

4.6.2.7 Vestibules

Vestibule entrances are designed into both schools. Entrances at William Whyte are intelligently designed: the inside and outside set of doors are about 8.5 m. (28 ft.) apart. This ensures that, with several people entering at once, the outside door still has time to close before the inside door is opened. This reduces the amount of heat loss.

The doors at St. George are typically spaced approximately $2\frac{1}{2}$ m. (8 ft.) apart. The inside doors at St. George, however, were propped open and the vestibule area used for extra storage.

4.6.2.8 Pipe and Duct Insulation

Insulation on hot water and steam pipes in the crawlspace of St. George was either badly decomposed or nonexistent. All pipes were in need of new insulation. Insulation on hot air ducts, with the exception of the boiler room, was not evident.

Insulation in good condition was evident on all hot water pipes and air ducts in William Whyte.

4.6.2.9 Flooring Materials

Most of the floor area at William Whyte is carpetted. (including corridors) Terrazzo is the flooring material throughout St. George.

It should be noted that for cleaning purposes, William Whyte uses relatively more electricity for vacuuming, and St. George uses more gas for hot water mopping.

4.6.2.10 Exterior Shading Devices

There are no exterior sunshades in either school. Drapes and interior shades were used in most rooms at St. George, while none were used in William Whyte.

4.6.2.11 Colour

Darker colours absorb more solar radiation than lighter ones. The exterior wall surface of William Whyte is rough-cut, facing stone of a light sandy sandy colour. Yellow facing brick is used extensively at St. George. Darker colours would cause beneficial warming in the winter, and annoying heating in the hot summer, subject to factors such as thermal capacity of the wall, and exterior shading devices.

4.6.3 Building Operation

4.6.3.1 Fans

Air supply fans at William Whyte operate 24 hours a day, year round, to provide heating, cooling, and ventilation air to the building. A "night-cycle" setting allows closure of outside air and exhaust air dampers (to a minimum of 10-15% opening) during unoccupied hours. This recirculates inside air, reducing substantially the amount of outside air which must be heated or cooled. The "night-cycle" is regulated by a 7-day timer which was set for recirculation from 6:00 p.m. to 7:00 a.m., and during weekends. Washroom and change-room exhaust fans were in operation 24 hours a day, throughout the year.

The St. George custodian switches off fan operation during unoccupied hours in milder winter periods, heating the school only with hot water radiators. Washroom exhaust fans are switched off in extremely cold weather. (The inferior arrangement of exterior-mounting causes the fans to cut off in cold weather.)

4.6.3.2 Custodians

The school custodians at William Whyte were unsure of the nature of operation of several of the building systems. This could be attributed to a failure to provide them with a summarized operating and maintenance manual. The St. George custodian displayed a thorough knowledge of his school and an obvious interest in energy conservation.

4.6.3.3 Switching

Field observations revealed that in both schools, many teachers forget to switch off lights when leaving areas for more than seven minutes. (see pg.59) St. George, has local washroom light switching, and washroom lights were left on for the duration of the day.

4.6.3.4 Cleaning

At both schools, the official timetable for cleaning light fixture reflectors and diffusers is three times a year: Christmas, Easter, and the summer holidays. Examination of the dust accumulation in light fixtures at William Whyte indicated that they had not been cleaned for a considerable period of time. This causes a significant reduction in lighting efficiency.

4.6.4 Site Characteristics
4.6.4.1 William Whyte

South side - Concrete paving stretches to the public sidewalk about 6 M. (20 Ft.) away from the wall. Two storey houses on the opposite side of the street provide a marginal wind barrier. Large deciduous trees in the neighbourhood offer no wind protection in the winter.

West side - Concrete paving extends to about 3 M. (10 Ft.) from the wall. Black earth extends from the concrete outwards to the street. A large field enables wind to gather speed and sweep across the school.

North side - The ground surface is grassed to the walk about 6 M. (20 Ft.) away. The two storey neighbourhood provides a marginal wind barrier.

East side - Asphalt paving extends to about 12 M. (40 Ft.) from the wall, with black earth from there to the public sidewalk about 45 M. (150 Ft.) from the wall. An asphalt paved parking lot is proposed for construction on the north side of this lot.

4.6.4.2 St. George

South side - Gravel parking lot to lane 25 Ft. away. Housing in the neighbourhood is predominately single-storey. The few existing trees are deciduous.

West side - From the wall to the walk, 15 ft. away, is a grassed lawn. Single storey houses face the school from across the street.

North side - The yard is gravel from the wall to a distance about 30 ft. away. A grassed field extends beyond the gravel. The adjacent neighbourhood is single-storey.

East side - The school additions partially enclose a courtyard area, consisting of asphalt paving and gravel. (see sketch plans) A field extends to a lane about 200 yds. away. The adjacent neighbourhood is predominately single storey.

Both schools display inefficiencies in each of the categories mentioned--O.&M., construction, use, and site characteristics. Although several areas of inefficiency were the same in both schools, a significant number differed between the schools. It was not evident from the audit, exactly how much energy and money cost each area of inefficiency incurred.

Using the preliminary observations from the audit, the effects of potential adjustments to building systems and use can be identified. Before completing any research into other aspects of conservation, it was deemed necessary to inquire into the codes and regulations of various government agencies, and school divisions, to determine if there existed regulatory obstacles to the implementation of changes.

4.7 Codes and Regulations

All new buildings in Manitoba must comply with the Manitoba Building Code.[1] This code parallels the National Building Code, although some amendments have been made.[2] There is no specific code by the City of Winnipeg, relating to building construction.

The Department of Education has no special code which must be observed in the construction of its buildings. Conservation guidelines for new school construction are presently being researched by the Department of Education.

Health standards such as minimum ventilation and lighting levels were monitored by the provincial government in the past. There is no evidence of a current program.

4.7.1 Ventilation

A stipulation found in the Manitoba Building Code refers to mechanical ventilation. Article 9.33.1.3 states:

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1. Department of Labour, Province of Manitoba, The Manitoba Building Code, Winnipeg, 1976.

2. Associate Committee on the National Building Code, National Building Code of Canada 1975, National Research Council of Canada, NRCC No. 13982, Ottawa, 1975.

"Ventilation of rooms and spaces in other than residential occupancies shall be in accordance with good engineering practice. (The procedures described in the A.S.H.R.A.E. Guide and Data Books and the A.S.H.R.A.E. Handbooks shall be considered as good engineering practice)[3] ".

The A.S.H.R.A.E. Standard 90-75 Energy Conservation in New Building Design, recommends that the minimum standards in A.S.H.R.A.E. Standard 62-73, Standards for Natural and Mechanical Ventilation be used.[4] This document specifies a classroom standard of 10 c.f.m. per person assuming 100% outdoor air.[5] If air is recirculated, this level may be reduced; the minimum allowable ventilation level is 5 c.f.m.[6]

In William Whyte, the minimum outside air introduction during occupied hours is 8806 c.f.m. (see Appendix D) This is equivalent to 15 c.f.m. per person. (based on 550 students and staff.) The rate of ventilation at St. George is about 12 c.f.m. Thus, ventilation rates could be reduced, and remain within the parameter established by the building code.

4.7.2 Lighting

The only regulation concerning lighting in the Manitoba Building Code is found in Section 9, and deals with housing and small

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3. The Manitoba Building Code; 1976: p.9-114.

4. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., A.S.H.R.A.E. Standard 90-75, Energy Conservation in New Building Design, New York: 1975, p.23.

5. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., A.S.H.R.A.E. Standard 62-73, Standards for Natural and Mechanical Ventilation, New York: 1973, p.15.

6. Ibid, p.5.

buildings. Minimum lighting for public corridors and stairways is 5 fc.[7] As evidenced by the energy audit, levels at William Whyte are four times (4x) this level. The lighting level in St. George corridors is about 5 fc.

St. George meets code requirements for lighting and William Whyte far exceeds them. The benefits of reducing lighting levels are discussed in section 4.10., Building Construction. (pg.83)

4.7.3 Insulation

The fire code directly affects the maximum amount of insulation on the roof of a building. In the provincial building code, roof assemblies of schools in this size range are required to have a one hour fire resistance rating.[8] Up until now, Underwriters Laboratories had recommended a maximum of 2" rigid or 3" foamed plastic insulation to meet these requirements.[9] (3"rigid insulation may be used if ½" gyproc is incorporated into the construction.) A recent supplement to this (September supplement, 1977, U.L.C.) specifies a minimum of one inch insulation; the maximum thickness is unrestricted. (with Roofmate insulation) This is timely since more than 3" of insulation is required to fulfill the requirements of the proposed building code supplement, Canadian Code for Energy Conservation in New Buildings.[10]

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7. Manitoba Building Code; 1976, p.9-122.

8. Ibid, p.3-33.

9. Underwriters' Laboratories of Canada, Fire Resistance Rating Design No. R202; March 1976, p.290.

10. Associate Committee on the National Building Code, National Research Council Canada, Canadian Code for Energy Conservation in New Buildings, (draft for public comment): June, 1977, p.12.

4.7.4 Proposed Code for Energy Conservation in New Buildings

Some key points presented in the proposed code are discussed below.

4.7.4.1 Insulation

Minimum heat resistance values for various components of the building shell are established in the proposed code. (see Table IV) Higher resistance values are required for colder climates. Winnipeg, with 10679 fahrenheit degree days, is indicated on the table.

TABLE IV: Proposed Minimum Building R-Values

Minimum Thermal Resistance (R value) $m^2 \cdot {}^oC/W$ (1) (R values in Imperial units shown in brackets, hr·sq ft·°F/Btu)				
Enclosing Construction	Maximum Number of Celsius Degree Days (Fahrenheit Degree Days in Brackets.			
	3500 (6300)	Winnipeg 5000 (9000)	6500 (11,700)	8000 and over (14,400)
Walls separating heated space from unheated space or the outside air. (2)	2.5 (14.2)	3.0 (17.0)	8.4 (19.3)	3.7 (21.0)
Exterior foundation walls (2) cellars and crawl spaces that separate heated space from the exterior or adjacent earth.	1.6 (9.0)	1.6 (9.0)	1.6 (9.0)	1.6 (9.0)
Roof or ceiling assemblies separating heated space from unheated space or the exterior				
(a) if combustible construction is permitted (4)	4.9 (27.8)	5.7 (32.3)	6.4 (36.3)	7.0 (39.7)
(b) if noncombustible construction is required	2.4 (13.6)	2.8 (15.9)	8.2 (18.2)	3.5 (19.9)
Floor assemblies separating heated space from unheated space or the exterior				
(a) if combustible construction is permitted	4.7 (26.7)	4.7 (26.7)	4.7 (26.7)	4.7 (26.7)
(b) if noncombustible construction is required	2.4 (13.6)	2.8 (15.9)	8.2 (18.2)	3.5 (19.9)
Perimeter insulation for slab -on-ground floors that are less than 2 ft below adjacent ground level				
(a) heated slabs	1.3 (7.4)	1.7 (9.6)	2.1 (11.9)	2.5 (14.2)
(b) unheated slabs	0.8 (4.5)	1.3 (7.4)	1.7 (9.6)	2.1 (11.9)

Source: Associate Committee on the National Building Code, National Research Council Canada, Canadian Code for Energy Conservation in New Buildings, (draft for public comment): June, 1977, p.12.

Notes (1) Values shown are for the insulated portion of the assembly and do not include the affect of framing or furring. In making heat loss calculations to determine the design of the heating or cooling system, such affects have to be taken into account.

(2) The portion of a foundation wall more than 1.2 m (4 ft) above adjacent ground level shall be insulated in conformance with the requirements for exterior walls above the foundation walls.

(3) Where the number of degree days for a particular area is different from those listed, interpolation between the values shown in the Table may be made to obtain the minimum required thermal resistance values for that area.

(4) Thermal resistance may be reduced near the eaves to the extent made necessary by the roof slope and required ventilation clearances but the R value at a point directly above the inner surface of the exterior wall shall not be less than 2.1 $m^2 \cdot {}^oC/W$ (11.9·hr·sq ft · ^oF/Btu).

TABLE V: Average R-Values of Study Schools (^{O}F per BTU) Hr.) (Sq. Ft.)

	FLOOR	NORTH WALL	EAST WALL	SOUTH WALL	WEST WALL	ROOF
St. George	10.0	4.5	4.4	3.9	4.0	9.6
William Whyte	7.7	14.0	13.0	12.4	12.8	16.5

Table IV shows that both schools under consideration fail to meet the standards for new buildings in the proposed code. It is noteworthy that such a code would leave finance committees with no choice but to increase funding for the construction of more efficient buildings.

4.7.4.2 Glazing

The proposed code stipulates that in a Winnipeg climate, window areas must be at least double glazed. Maximum areas of glazing are specified, the exact quantities depending on orientation to the sun. A south-facing wall is generally permitted more glass than a north-facing wall, although certain conditions must be met. The window must not be shaded from the sun in winter. This disqualifies all buildings using solar film on windows. Air-conditioned buildings are also disqualified from using larger glazing areas because of southern orientation. Most new schools in Manitoba today are partially air-conditioned.*

*personal communication, Des. St. Lawrence, Manitoba Department of Education, June 23, 1977.

4.7.4.3 Infiltration

The proposed code specifies maximum permissible infiltration rates for various building components such as windows, doors, and walls.

4.7.4.4 Heating, Ventilating and Air-Conditioning

Efficient H.V.A.C. system design and operation is designated, as is ducting and piping of air and water. For example, in buildings with a warm air exhaust equivalent of 1,024,000 Btu./hr.* or more, heat recovery systems are required which reclaim a minimum of 40% of the sensible heat.

4.7.4.5 Electrical Systems

Maximum lighting load is specified, according to the nature of the use of the space. The limit for schools is 2.05 W./sq.ft. In William Whyte, this limit would work out to be 84.5 kW. of lighting. The school now has a peak load of 121 kW, a full 43% higher than the proposed code specifies.

Switching of lighting for custodial work is outlined in the document.

Given standards such as these in the building code, little is left to the whim of the building designer and financier. Despite the fact that, by code, the building will be efficiently constructed, it could still use more energy than necessary, because of inefficient use.

4.8 Building Use

The effectiveness of energy conservation measures are significantly increased, if the people using the building are in favour of

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*William Whyte achieves this level of exhaust.

the changes, and make an effort to conserve energy. This study shows that over five hundred dollars a year could be saved by merely switching lights. (pg. 60) In many instances, the only initiative required is to inform users of the significance of their role in conservation. In other cases, a firm directive must be issued: "you must reduce consumption."

To impress upon the numerous people involved, the amounts of savings which can be accomplished by conservation, various units of measurement are used. For the money conscious, dollars are used. For the energy conscious, quantities of energy are stated. Percentage of the total annual school energy bill is also expressed.

In St. George, respondents to the staff questionnaire indicated that most teachers would conserve energy to extend the life of present resources, leaving some for future users. The second reason chosen was to increase efficiency of energy use. The third reason selected was savings of money. Teachers at William Whyte seemed to be equally divided among all three motivations. Teachers in the schools indicated that the children would probably identify with monetary units as easily as any other units.

4.8.1 Temperature

Those accustomed to an energy-rich lifestyle will probably have the most difficulty adjusting to reduced energy use. It is generally the teachers who expect the building temperature to be warmer in winter, and cooler in summer. The young students, for whom the school is supposedly designed, rearely complain. The questionnaire showed that children seldom complained in winter about the cold, but found the summer heat slightly more offensive. (in both the air-conditioned and non-air-conditioned school)

When a staff member is uncomfortable, the custodian is duly informed. The teachers at St. George presently operate in an environment of 20°C. (68°F.) mainly because of the efforts of the custodian. Occasionally, he is approached with a request for an increase in temperature. If he decides that it is warm enough, he will not adjust the central thermostat, but will disappear into the boiler room. On most of these occasions , he has returned to the teacher, and been thanked for increasing the temperature. This suggests a certain amount of psychological manipulation involved in coping with reduced temperatures.

A very effective technique for adjusting to temperature change is clothing change. It has been shown that type of clothing can alter sensible temperature by about 3°C. (5°F.) in winter, and about 1½°C. (3°F.) in summer.[1] Calculations indicate that reducing temperature by 4°F. in William Whyte results in annual savings of $550 (242,500 cu. ft. gas) (3% of total energy use) (see Appendix C). For the benefit the measure provides, it is desirable to encourage the teachers to wear sweaters.

At St. George, where one thermostat controls the heat in several rooms, the habits of one teacher can contribute significantly to excessive energy consumption. The occupants of the non-thermostat rooms are quite dependent on the actions of the teacher in the thermostat room. If the teacher is not in the habit of wearing extra

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1. <u>Energy Conservation Controls</u>, (EC^2), Section 2, (pages not numbered).

clothing, or is susceptible to cold, and accordingly increases the demand for heat, the other rooms become overheated. The only way to compensate for the heat is to open windows. Clearly, this is not very efficient. A discussion with the thermostat-room teacher might convince her to wear extra clothing, and keep the thermostat lower. Failing this, a rearrangement of teachers to classrooms may lessen the problem.

4.8.2 Hours of Use

The actual hours of building use are significant in terms of energy consumption. During unoccupied periods, temperature can be reduced, exhaust fans switched off, outside air intake reduced, and lights extinguished. Heat loss through open doors ceases.

For the greater part of the year, a minimum of outside air introduction is desirable. In winter, heating systems must heat the cold air; in summer, systems must cool the hot air. The infrequent time where this does not hold true is when outside air is cooler than inside air and cooling is desirable. In this situation it is more economical to introduce outside air than to air-condition.

To reduce energy use, it is best to schedule extra-curricular and community activities during regular classroom hours or as soon after as possible. Some balance needs to be established between committment to the community needs on one hand, and energy conservation on the other. The final decision rests with the school division.

Being a community school, one section of William Whyte is used regularly, after school hours. This definitely adds to the cost of heating, ventilating and lighting the building.

If the extra-hour activity is relatively passive, of small size, and short duration perhaps the school fan systems could remain at "night cycle" position with a minimum amount of outside air introduced into the building and exhaust systems switched off, leaving only lighting on. For periods of extended extra-hour usage, or for situations involving large crowds, a timer located in the administrative office of William Whyte will extend the "normal" system operation to a period of 12 hours.

As indicated in the Energy Audit, the 7 day timer controlling the hours of "night cycle" is set for recirculation from 6:00 p.m. to 7:00 a.m. These hours can easily be extended. Given regular school hours from 8:30 a.m. to 4:00 p.m. the hours could at least coincide with these. Owing to the large volume of air in the school, a time lag is experienced between the time the system is switched to "recirculate", and the time that the effects become noticeable. This enables the system to be switched to "night-cycle" while the school is still occupied. In this study, the timer was readjusted for operation on "night cycle" from 3:30 p.m. to 8:30 a.m., an extra four (4) hours per weekday. The estimated savings, by reducing the introduction of outside air by 20 hours a week during one heating season, was calculated as $1066. (469,081 cu. ft. gas) (5.4% of total energy bill) (see Appendix D).

If extra-hour activities are such that outdoor air ventilation and lighting are required, the costs should be made known, if not charged to the users. This would be one incentive to use the facilities during regular hours, when no additional costs are incurred.

4.8.3 Type of Activity

The degree of activity which occurs in a section of the school can affect the heat requirement in that section. Heat generated by the occupants can vary by as much as $3\frac{1}{2}$ times, depending on the activity. A location where children are active requires less energy for heating than a passive class in the same location. The opposite may be true in summer: active children require more energy for cooling (in air-conditioned spaces) than a nonactive student. Table VI shows that a class of 25 active children and a teacher would emit about 600 BTU/HR/person; a total of about 16,000 BTU/HR. A class of 25 passive students would produce about 7000 BTU/HR less.

It may be desirable, when a class begins in the morning, to exercise the children, in an attempt to raise room temperature. It is conceivable that a building, if constructed for high thermal resistance, could be heated with little more than the heat emitted by the occupants.

TABLE VI: Heat Gain from Occupants of Conditioned School Spaces

	Children*	Adult Male
	BTU/HOUR	
Seated, Very Light Work	340	450
Moderately Active Office Work	360	475
Walking Slowly	415	550
Light Work	600	800
Heavy Work	1125	1500

Source: Johnson Controls Ltd., Energy Conservation Controls (EC^2), Section VII (pages not numbered)

*based on 75% of adult male

4.8.4 Traffic

One aspect of building use which could be considered is traffic through the building entrances. Every time a door is opened, cold air enters the building. With vestibule construction, the problem is reduced, the extent depending on the nature of traffic flow.

In-out traffic in elementary schools is such that children enter the building over a period of about 20 minutes, in both schools. Leaving the school takes about 5 minutes. It was revealed in the audit that both schools have vestibules. Since the vestibules in St. George are representative of most schools, analysis is based on that school.

Entrance heat loss is a function of the number of doors used by a given number of people, the time period in which all personnel entered or left the building, and whether or not the entrance incorporates a vestibule. It was found that to conserve energy, buildings with no vestibules should minimize the period of time in which personnel enter and exit the building. In schools, this can be accomplished by encouraging parents to wait until a certain time before sending their children to school. At the school, students could be retained outdoors and allowed in during one brief time interval (as is currently practiced for recess, in some schools). If the number of entrances used are too great, reduction in time may not accomplish any savings. (see Table VII.)

Vestibule entrances require a different method of conservation. The purpose of the doors is defeated if traffic is so heavy that both doors remain open at the same time. In this case, the use of all entrances over as long a period a time as possible should be encouraged.

(see Table VII.) This may be accomplished by staggering admission and dismissal times and requiring certain classes to use certain entrances.

TABLE VII: Maximum Air Loss Through Entrances* (cu. ft.)
(based on school population of 480)

No. of doors	Entry Time(Min.)	W. Vestibule	W/O Vestibule
8	20	10900	28000
(4 double)	10	10900	28000
2	20	20000	28000
	15	15000	21000
	10	10000	14000

*compiled in Appendix E. (2 to 4 Storey buildings)

4.8.5 Switching of Interior Lights

User habits determine the degree of savings that switching of interior lights produce as a conservation measure. If teachers and students switch off lights in unused rooms, a significant saving can be accomplished.

Many people encountered in this study were unsure as to the period of time the lights must be off to make it economically worthwhile to turn them off. The life of a fluorescent tube is reduced, the more often it is switched on and off. This cost can be offset by the energy savings of the light being off for those times when light is not required. The minimum period of time required for fluorescent lights to be off in order to effect an energy saving in Winnipeg is 7 minutes.* There is no minimum period for incandescent

*Personal communication, Paul Wasney, Westinghouse,Winnipeg, May 16, 1977 lights,which should be switched off whenever possible.

In William Whyte, over 71 KW of lighting can be switched off during an average day. Lights can be switched off for morning and afternoon recess, and lunch break. Over a ten month school term, the savings of switching lights by users could amount to $507. (51744kWh) (2% of total energy bill) (see Appendix F).

The questionnaire revealed that the majority of teachers in both schools believed the minimum economic switch-off time to be ten minutes or more. The majority of those indicating ten minutes also indicated that they switched off lights accordingly. Field observations revealed that many did not switch off lights. It is expected that the student "switch off lights" posters would remind teachers to switch off lights.

A classification of energy conservation measures which is closely related to building use, is building operation and maintenance. To a large extent, it is the users who influence the way in which a building is operated and to a certain extent the amount of maintenance required.

4.9 Building Operation and Maintenance

Energy conservation measures in the realm of building operation and maintenance easily provide the most savings per dollar input of any other category. In many cases energy can be saved by making only minor adjustments to building systems and providing operators and custodians with daily routines to follow.

It is important to note that the age of the building is a key factor in determining the extent to which capital intensive measures should be implemented. Installing insulation on the steam pipes of a twenty year old school may be worthwhile economically, but installation in a fifty-five year old school may not. The number of years remaining in the life of a building is critical since benefits and some costs are relative to this number.

An important difference was found in the types of measures which should be used in each school. William Whyte, not lacking (relatively) in regards to quality of construction, was in need of improved operational procedures. The older school, with outdated building materials and deteriorated systems, was in need of more maintenance-oriented measures. If the custodian in St. George had been less energy-minded,that school would probably have also been in need of operating adjustments.

When planning operations and maintenance adjustments, it is absolutely essential to consider the building custodian. Any planned changes should be endorsed by him to be totally successful. He is the one who will be requested to carry the extra burden of switching lights, fans and pumps, of continuously monitoring building condition, (ie. for cracks in need of caulking) and of adjusting timers and thermostats.

4.9.1 Switching

One of the easiest and cheapest conservation measures to implement is switching of energy consuming equipment. Field observations and close examination of mechanical and electrical drawings and specifications revealed the location of energy using equipment. There may be an independent switch panel to control equipment which is switched frequently. Circuit breakers are the next-best controls. Electrical specifications were necessary to decipher an inadequately labelled switch panel at William Whyte.

Equipment which is specially switched at William Whyte includes:

- main supply and return air fans
- washroom and changeroom exhaust fans
- small exhaust fans (ie. boiler room, range hood exhaust)
- hot water circulating pumps (domestic and heating)
- unit heaters (in crawlspace)
- lighting

Equipment which requires control by circuit breaker included:

- car plug receptacles
- interior receptacles
- some exhaust fans
- unit heaters (vestibule)
- exterior lights

4.9.2 Exhaust Fans

It was learned at the time of the energy audit that washroom/changeroom exhaust fans operated 24 hours a day, year round in William Whyte school. During unoccupied periods this operation is unnecessary. Fans could be switched off from 4 p.m. to 8:30 a.m. and during weekends and holidays. Since this schedule roughly coincides with that of the custodian, he can switch the fans at the beginning and end of each work day.

To determine benefits of switching, two calculations are necessary:

1) the amount of electricity consumed by the electric motors.
2) the energy required to heat or cool the outside air which

is introduced to compensate for the exhausted warm air.

Calculations for William Whyte School:

1) Electricity consumption...

4:00 p.m. - 8:30 a.m. = 16.5 hrs. X 5 = 82.5

weekend = 48 hrs. 48

130.5 hrs.

(130.5 hrs/wk. X 10 mos. X 4 wks/mo.) + (24 hrs/day X 2 mos. X 30 days)

= 6660 hrs/yr.

kWh = (H.P. of motors) X (.746 kW per H.P.) X (reduction in number of hours of operation)

= (2 X .5 hp) X (.746) X (6660 hrs/yr)

= 4970 kWh.

4970 kWh. @ $.0098 kWh = $49.00

2) Heating...

$$\text{C.F.M. gas} = \frac{\Delta T^{\circ}F \times .018 \times \text{C.F.M. outside air}}{824.8}$$

$\Delta T^{\circ}F.$ = T inside - T outside

.018 = (density of air) X (specific heat of air)

824.8 = (1031 B.t.u. per cu. ft. nat'l. gas) X (80% efficiency)

C.F.M. gas per heating season = (C.F.M. gas) X (# of min. in season)

Because the change in temperature between outside air temperature and indoor air temperature varies throughout the year, calculations have been based on monthly averages over the heating season. An example is done for the month of January.

$$\text{C.F.M. gas} = \frac{(72^{\circ}\text{F} - -2.4^{\circ}\text{F}) \times (.018) \times (4370^{*}\ \text{c.f.m.})}{824.8}$$

$$= \underline{7.09}$$

*Total exhaust from the two exhaust fans is 4370 c.f.m.

No. of min. per month = 33670 + holidays

January - assume 1 day holiday @ 24 hrs. x 60 min/hr = 1440
33670 + 1440 = 35110 min.

7.09 c.f.m. x 35110 min. = 248,930 cu. ft. gas

\$ = (248,930 cu.ft. gas) x (\$.2272/00 cu.ft.)

= \$<u>566.00</u>

This procedure is repeated for each heating season month. (based on ave. temperatures presented in Appendix B) (see Appendix G)

The savings over one heating season of merely switching off the two exhaust fans when not required, amounts to \$3280 (1420350 cu.ft. gas, 4970 kWh electricity) (16% of total energy bill).

4.9.3 Switching of Exterior Lighting

Exterior lighting includes floodlighting, security lighting, and parking lot lighting. Exterior lighting can be operated more efficiently, if hours of excessive operation can be reduced; lighting which accomplishes no useful function can be disconnected.

Exterior lighting can be controlled by several mechanisms: photo-electric switch, timer switch, or manual switch. When the intensity of sunlight decreases below a set threshold level, the photo-electric cell triggers a relay which switches on the lights. Sensitivity can be adjusted by covering or uncovering the cell, which has the effect of diminishing or increasing the cells ability to "see". The less it "sees" the sooner it switches on the lighting. After initial adjustment the only further adjustment required is regular cleaning of the cell. Exterior lighting at William Whyte is controlled by a 7 day timer, while manual switches control lighting at St. George.

The seven day time switch is set to switch lighting on and off at determined intervals. As hours of sunlight grow longer the timer should be adjusted to switch on later. Without a schedule for adjusting times, and knowledge of how to adjust the timer, the custodian at William Whyte avoided changing it. A schedule has been compiled, based on times of sunrise and sunset in Winnipeg, in Appendix B.

In William Whyte school: the timer was set for operation from 5:00 p.m. to 8:00 a.m. This is an appropriate adjustment for November and December but the interval could be shortened for the remainder of the year. The yearly saving from reducing exterior lighting at William Whyte is calculated by the following:

kWh/month = [(connected load) x (no. of hours per day reduced lighting) x (no. of days/month)] / 1000

Using the month of June as an example...

30 days

recommended time 9:45 p.m. - 5:30 a.m.

existing time 5:00 p.m. - 8:00 a.m.

hour difference = $7\frac{1}{4}$ hours

$$\text{kWh June} - \frac{(3775W) \times (30\ \text{days}) \times (7\frac{1}{4}\ \text{hours/day})}{1000}$$

= 821

821 kWh @ $.0098 kWh = $8.04

Repeating this exercise for each month, it is found that a yearly electrical energy saving of $42.00 can be achieved. (4250 kWh). (.2% of annual energy bill.)

4.9.4 Domestic Hot Water

Domestic hot water in schools of the size range considered in this study is used primarily in washbasins, custodial activity, kitchen (staff) activities, and showers. The amount used varies, depending on such factors as the physical education instructor's policy on student showering, amount of floor area requiring mopping, home economics programs, and staff use. The maximum water temperature needed for all these activities is around 46°C (115°F). Temperature is generally set between 52°C (125°F) and 66°C. (150°F.) in schools.

Energy can be conserved by reducing temperatures to around 46°C (115°F). Less heat loss occurs at lower temperature, so loading on the water heater is reduced. Excessive pipe lengths can be avoided with "point-of-use" water heating systems. This system includes several water heaters, each servicing local hot water demands. In this way hot water needed at one end of the school need not be piped from the opposite end.

In William Whyte, water temperature was set at 59°C (138°F). Reduction to 46°C (115°F) would produce annual savings of $75.00 per year. (33,000 cu. ft. gas, or 3% of total energy bill):

New gas consumption = (Previous gas consumption) -

$$\left(\frac{\text{New temp. x previous gas consumption}}{\text{previous temp.}}\right)$$

$$= (16500 \text{ c.f./month*}) - \frac{115^{\circ}F \times 16500}{138^{\circ}F}$$

$$= 16500 - 13750$$

$$= 2750 \text{ cu. ft. gas/month}$$

2750 x 12 months - 33,000 cu. ft./yr.

33,000 cu. ft. @ $.2272/00 cu. ft. = $75

In St. George school, conserving domestic hot water does not yield any dollar savings to the division. The school is billed by the utility, on a flat rate basis. If the school were billed for hot water on a consumption basis, electrical savings would be 15% for the 90 gallons tank (previously 57°C) and 29% for the 40 gallon tank (previously 72°C). With the consumption previous to temperature reduction not known, percentages must suffice. (It should be noted that in a more sophisticated experiment, electrical and gas metering equipment could be installed at the water heater to determine exact consumption.)

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* 18000 cu. ft. mo. gas consumption during off-heating' season. Subtract 2 boiler pilot lights @ 1 cu. ft. hr. each = 1,440 cu. ft./mo. 18000 - 1440 = 16500 cu. ft. gas

Caution must be exercised when reducing hot water temperature, to ensure that the tank has sufficient capacity, or heater a fast enough recovery, to satisfy peak hot water demands. With reduced temperature, less mixing with cold water is necessary to yield a given mixed water temperature. It is useful to know how much hot water is required at peak periods.

William Whyte, for example, has a 245 gal. capacity tank. It has a sidearm heater with recovery of 6.4 gallons per minute at 46°C (115°F). The school has two sets of five showers. The showerheads have 2 gpm. flow, resulting in a maximum flow of (10 x 2) 20 gpm.

Tank capacity alone would provide 12 mins. of hot water. (A diffuser is incorporated at the water inlet to minimize cold water mixing). The sidearm heater, over a 10 min. period would provide (10 x 6.4) 64 gal. of 46°C. water, adding (64 ÷ 20) three minutes to the showering time. Showering time at maximum use is 15 minutes, sufficient for most uses.

4.9.5 Maintenance of Insulation

Insulation is the method probably most closely identified with energy conservation. The thicker the insulation the more heat transfer is prevented. This applies to hot water and steam piping, as well as to air-ducting, wall, roof, and floor components.

It is essential that insulating materials be kept dry. Wet insulation has a lower R-value, and a shorter life than does dry insulation. Dryness can be maintained through the use of adequate venting and vapour barriers.

The original insulation on hot water and steam pipes at St. George school had decomposed into shreds of hanging cloth and paper.

An obvious reason for this would be age, but upon closer examination it was found that ventilation in the crawlspace was perhaps the causal factor. For reasons unknown, the crawlspace vents under the entire school had been bricked in with the exception of two square foot vents, causing humidity to accumulate. This moisture was probably a major factor in the rapid deterioration of the insulation.

Moisture contributes to excess heat loss through condensation on the ground and exterior walls. Condensation results in heat loss of 1100 Btu. per 16 oz. of water condensed on walls.[1] (releasing heat to the cold surface).

It was proposed by the researcher that the pipes be insulated, and the vents re-opened. The reduced heat loss along pipes, and the elimination of condensation, would reduce the workload on the boiler, decreasing the amount of energy required to heat the school.

Some may argue that since heat from the pipes was lost into the unvented crawlspace, actual losses are not great. However, heating the ground, walls and floor above by pipe heat loss (temp. 93°C (200°F)) is very inefficient. This may explain why, in the past, classrooms closest to the boiler are excessively warm, while those towards the outlying ends of the school are cool, in the winter. Insulated pipes will help deliver 'hot' water to farthest sections of the school.

It was decided by St. Vital school division authorities to insulate all hot water and steam pipes in the crawlspace, with 1½" fibre-glass pipe insulation. This product incorporated a metallic moisture shield to resist deterioration. Savings were calculated by comparing heat loss through bare pipe, to heat loss through newly insulated pipe.

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1. Welch, John D., Basic Heat Transfer, Faculty of Architecture, University of Manitoba, Winnipeg: 1977, p.11.

A heat loss chart for 1" and 1½" insulation has been compiled. (Table VIII.)

Table VIII: Heat Loss Through Heating Pipes (Btu./hr./lin. ft.)*

PIPE SIZE	HOT WATER			STEAM		
(inches)	BARE	1" INSUL.	1½" INSUL.	BARE	1" INSUL.	1½" INSUL.
3/4	58	12	9.4	113	18	14.2
1	84	13	10.6	139	20	15.8
1¼	104	15	11.8	172	23	18.2
1½	117	17	13	195	25	19.8
2	144	19	15.2	239	30	23.7
2½	172	22	17.4	285	34	26.9
3	206	26	20.6	342	39	30.8
3½	233	29	22.8	387	44	34.8

INSUL. means INSULATION

*Values for the 1" insulation and bare pipes, were obtained from EC[2]., Section VII.

Values for 1½" insulation on steam pipes were extrapolated from the values for 1".

1½" insulation reduces heat loss of 1" insulation by 21%

Values for 1½" insulation on hot water pipes were calculated by the following formula. . .

$$\text{Btu./hr./lineal ft.} = \frac{\pi k \Delta t \, r2}{6\left(r2 \ln \frac{r1}{r2} + r_s k\right)}$$

k = thermal conductivity $\frac{\text{Btu/inch}}{\text{hr.ft.}^2 \, {}^{\circ}\text{F}}$ (John Manville Microlok 650 = .26)

T = °F temperature difference between pipe and still air (102°F)

r2 = outer radius of insulation (inches)

r1 = inner radius of insulation (inches)

$R_s K$ = outside surface resistance in $\frac{{}^{\circ}\text{F hr. ft.}^2}{\text{Btu.}}$ = .67

π = pye

ln = natural logarithm

In the calculation of energy savings from insulating hot water and steam pipes, the first step is to carry out a complete inventory of pipe sizes, lengths, and the medium transported. The easiest way to accomplish this is to study the heating system drawings, and confirm findings with field checks. It is important to distinguish the different pipes, both for calculations of heat loss, and in the event of budget restraints, in which case the largest diameter, and hottest pipes should be given priority.

The best time to insulate piping is during the summer months. The obvious reason for this is that the heating system is not in operation, and pipes are cool.

An example of the methodology used to calculate savings which could be obtained from insulating heating pipes at St. George school follows:

Situation - $2\frac{1}{2}$" dia. steam pipe from boiler to south addition, 72 lineal feet.

1) Heat loss from uninsulated pipe

= 285 Btu./hr./lin. ft. (from Table VIII, steam pipes) x 72 lin. ft.
= 20520 Btu/hr.

2) Heat loss from insulated pipe ($1\frac{1}{2}$" insul.)

= 26.9 Btu./hr./lin. ft. x 72 lin. ft.
= 1937 Btu/hr.

The difference, or net heat saving is (20520 - 1937)=18,583 Btu./hr. At an efficiency of 80%, the boiler produces 824.8 Btu. per cubic foot of gas. The gas saving which would accrue from pipe insulation is (18583 ÷ 824.8)=22.53 cu. ft./hr. At an approximate rate of .2272/00 cu. ft. of gas, the saving is 5.1¢ per hour of operation. This amounts to an approximate figure of $165.00 per year, for this section of pipe.

Insulation of all hot water and steam pipes in the crawlspace results in energy savings of 352,150 Btu. per hour. This amounts to a dollar saving of $2095.00 in one year. (922216 cu. ft. gas) (19% of total energy bill) (see Appendix H).

Assuming a 30 year remaining life, at 10% interest, and 10% fuel increases above inflation, the present value of the insulation saving is 27.2 x 2095.00 = $57,000. (1978 dollars) (see Appendix B: Discounting Chart).*

The cost of materials and taxes amounts to $4400. Labour for two unskilled men working one month (at $4.00/hr.) amounts to $1300. Present day costs are thus $5700. The present value of total benefits is $57,000. The net benefit of insulation, over the life of the building is thus ($57,000 - $5700) = $51,300.00.

4.9.6 Caulking and Weatherstripping

Maintenance oriented conservation techniques which can yield savings include caulking and weatherstripping of windows, doors, and other exterior-interior passages. The amount of cool air which infiltrates through cracks can be reduced by 50% by these methods, thus reducing the load on the heating plant, and increasing interior comfort.[2]

It is estimated that in St. George school, which has older casement and sash windows, annual savings by caulking and weatherstripping would amount to $203.00 (see Appendix J).

The method by which infiltration heat loss is calculated includes calculation of the number of lineal feet of crack around both windows, and frame. This was "plugged-in" to the formula below.[3]

$$\text{Infiltration Heat Loss (Btu./hr.)} = (Lc)\ (Q)\ (\Delta T)\ (.018)$$

Lc = length of crack (in feet)
Q = volume of air per lineal foot (from Table IX)
ΔT = Temperature inside minus temperature outside (^{o}F)
.018 = constant (air density x specific heat)

*When significant capital investment is involved, it is necessary to discount benefits over the life of the building to determine the viability of the conservation measure.

2. Welch, John D., p.9.

3. Ibid, p.9.

Table IX: Infiltration Through Wall Components (Q-value)
(cu. ft./hr./lin. ft. of crack)

a) Wooden sash windows				
around frame, masonry -				
not caulked	3	8	14	
caulked	1	2	3	
wood frame construction	2	6	11	
window only, double hung or casement				
average quality, non-weather-stripped	5	15	28	reduced by 50% with storm windows.
weatherstripped	2	7	13	
poorly fitted, non-weather-stripped	25	63	100	
weatherstripped	4	13	23	
b) Door only - well fitted, non w.stripped	25	63	100	reduce by 50% if w.s
poorly fitted non w.stripped	50	126	200	
c) Wall - wood frame, plastered	.03	.07	.13	per square foot wall area
8 in. brick wall, plain	2	4	8	
plastered	.02	.04	.07	

The formula is completed for Q values without caulking and weatherstripping, and again using values with caulking and weather-stripping. The difference in heat loss under each condition is the saving in heat loss. This is divided by the heat value of the heating fuel, to obtain values for quantities of fuel saved per hour. This is then extended over the heating season to obtain a yearly benefit.
(see Appendix K)

The benefits should be calculated for the duration of time the materials can be expected to last. From this figure, should be subtracted the cost of materials and installation. The resulting sum is the value of the conservation measure. Over a 20 year advertised caulking life, net present value saving amounted to $3540.00.

4.10 Building Construction

Conservation techniques in the category of 'building construction' are most effective and economic when incorporated into the original building design. Attempts to modify an existing structure are at best, only second best. It is crucial that architects and engineers understand, and incorporate energy conservation principles into their building designs.

Many difficulties such as excessive energy consumption encountered in operations and maintenance, can be attributed to decisions at the design stage. A dilemna with most buildings, is that first cost plays a large role in determining the quantity and quality of components finally included in construction. The costs of new schools are cases in point, which must fall below tight first cost constraints. Attitudes are improving, and more emphasis is being placed on efficient design of new schools.

The objective of this section is to identify methods of energy conservation which can be applied to the construction of existing schools. The application to new school design will be implicit. It can be seen that these measures would yield larger benefits, had they been built in to the school initially.

4.10.1 Increasing the 'R - Value' of the Wall

In the original construction of St. George school, the exterior classroom wall contains a large area of glass block and glazing. This is readily apparent in Figure 10. The glass block and glazing has thermal resistance (R-Value) of 1.8. The wall construction is R7.5.

Figure 10:Elevation of Original St. George School Wall

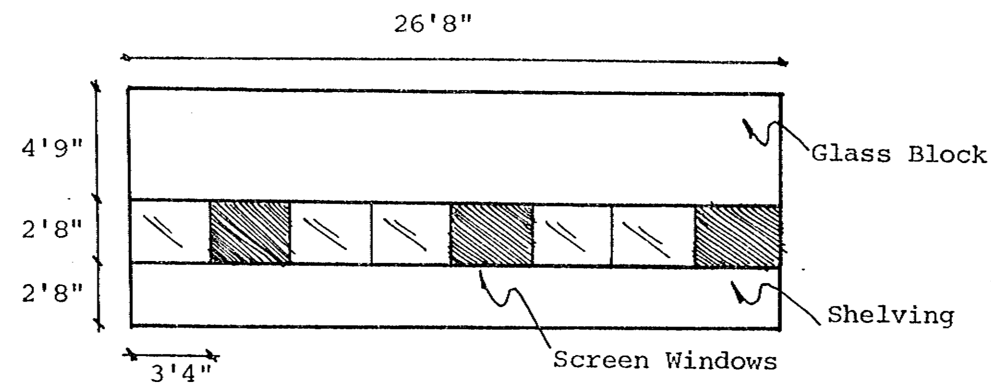


Table X: R-Values for Figure 10 (hr. ft.^{2} °F/Btu.)*

#	Material	R	Area (sq. ft)
1	8" Glass Block	1.8	127
2	Double Glazing	1.8	72
3	Outside Air Film 4" Facing Brick 3/4" Airspace 8" concrete block 3/4" insulation 1 layer paper 3/4" stucco on wire lathe Inside air film	.2 .44 1.31 1.72 3 .06 .1 .68	
		7.51	132

The construction combination of a typical exterior wall in Figure 10 loses 6783 Btu./hr. This is calculated by adding the various construction material R-Values, and 'plugging-in' to the formula shown on the next page.

*R-Values for various building materials are in Appendix A.

Conducted Heat Loss (H_c) = UA (TIN. - TOUT.)

U = 1/R
A = Area (ft^2)
T = ^oF

U wall = 1/7.51 = .133
U glass = 1/1.8 = .56

Total Wall heat loss = (wall heat loss) + (glass block heat loss) + (glazing heat loss)
= [(.133) (132) (68-20)] + [(.56) (127) (68-20)] + [(.56) (72) (68-20)
= 842.7 + 3413.8 + 1935.4
= 6191.9 Btu./hr. + 591.3 Btu./hr. infiltration (Appendix J - with w/s)
= 6783 Btu./hr.

To calculate the energy savings which would result from retrofitting the wall area, it is necessary to repeat the previous exercise, using the new wall materials. The difference in heat loss between the old construction, and new construction, is the energy saving.

Figure 11: Elevation of Renovated St. George School Wall

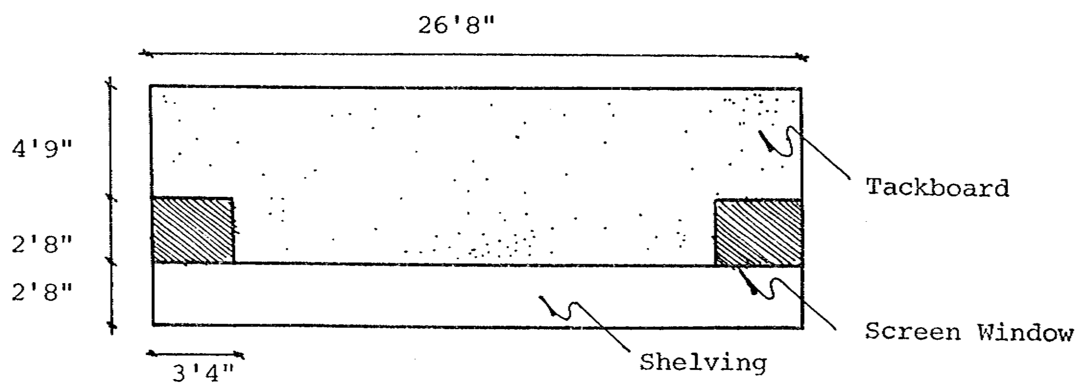


Table XI: R-Values for Figure 11 (hr.ft.^{2} ^{o}F/Btu.)

#	Material	R	Area (sq.ft.)
1	Double Glazing	1.8	17.8
2	Outside Air Film Facia ½" sheathing R-12 batt insulation ½" gypsum millboard inside air film	.2 .6 .63 12.0 .45 1.0 .68	
		15.56	313.2

Conducted Heat Loss (Hc) of renovated wall is calculated as follows:

U wall = 1/15.56 = .06
U Glazing = 1/1.8 = .56

Total Wall Heat Loss = [(.56) (17.8) (68-20)] + [(.06) (313.2) (68-20)]
= 478.5 + 902
= 1380.5 Btu./hr.

Infiltration Heat Loss = frame + window
= [(20.4') (6) (68-20) (.018)] + [(20.4') 97) (68-20) (.018)]
= 105.7 + 123.4
= 229 Btu./hr.
1380.5 + 229 = 1609.5 Btu./hr.

The difference between heat losses of the two wall constructions is (6783 - 1609.5)=5173.5 Btu./hr.

The amount of fuel conserved:

= 5173.5 Btu./hr. + (1031 Btu./cu.ft. gas @ 80% efficiency)
= 6.27 cu. ft. gas per hour.

Over a 9 month heating season this amounts to

40630 cu. ft. gas
40630 cu. ft. @ $.2272/00 cu.ft. = $92.00

Over a 30 year remaining life, @10% interest, 10% fuel price increase, the dollar benefits are:

= $92.00 x 27.2 (see Appendix B)
= $2500 per classroom.

Several rooms at St. George were actually renovated, enabling use of exact reconstruction costs. Costs were held down, since the existing windows were left in place. This reduced costs from $2,000 to $1,600 per classroom.* Compared to the present value of benefits, this represents a present value saving of $900. It is important to note that if the building had a 20 year remaining life, the benefits would only amount to $1674. New benefits would then only be $74. Under these circumstances the measure would not likely be implemented.

Two lessons have been learned from this last exercise. First, the remaining life of a building is of extreme importance in calculating the benefits of a conservation measure involving significant capital investment. Second, at some point, economics does take priority over the desire to conserve energy. No too many school divisions would implement a capital intensive measure which would yield only $75 over 20 years, unless other benefits could be achieved at the same time. Other benefits could include controlled lighting, and extra tackboard and chalkboard space.

4.10.2 Double Glazing

It can be seen from the previous analysis, that area of glazing is a key factor in determining total wall heat loss. The type of glazing is also significant. Generally, the more layers of glass, the higher the insulation value. An analysis was done to determine the savings, if any, of adding a second light of glass to an existing single-glazed area. Assuming that St. George was converted from single

*Personal communication, Gordon Edmunds , July 8, 1977.

glazing, to double glazing, net savings of $2,310 per classroom would be obtained. Twenty-three classrooms, similarly renovated, would yield a present value of $53,130. (1053699 cu. ft. gas per year). (Appendix K)

4.10.3 Decreased Glazed Area

According to Des St. Lawrence, architect for the Department of Education, there is a trend today towards decreasing window area in schools, to about 4½% of the exterior wall area.* In terms of energy conservation, for normally operated buildings, minimal glazing is desirable. Without adequate shading in the summer, sunlight penetrates into the building through glazing, resulting in overheating. In winter, the low resistance of glass to heat transmission allows valuable heat to escape to the cold environment. Glazing can be a source of discomfort when body heat is radiated to the cold surface. Under favourable conditions, south facing windows may produce a net heat gain through solar radiation.

Some may argue that large window areas can allow enough natural light into a room to reduce the demand for electric lighting. This is true. However, in the schools studied, the switching scheme did not permit lights parallel the windows to be switched off, while leaving the lights on in the farther, darker corners. The intensity of natural light varies irregularly, and as such is an unreliable light source. With natural lighting levels three times that provided by the electric lights, the switches at St. George remained "on". It can be seen that, although large glazed areas add to overall lighting

*Personal communication, Des. St. Lawrence, July 8, 1977.

levels, it has not in the past saved any electrical energy in the study schools. It has, however, caused an increase in heating energy consumption.

A balance must be struck between reducing window area for conservation, and providing the occupants with an identification with the 'outside'. In St. George, where there are extensive areas of glazing, most teachers said that they would prefer the window area to remain the same. At William Whyte, with little window area, almost 70% wanted the window area increased.*

4.10.4 Solar Film

If maintaining window area is deemed important, but protection against summer heat gain is desired, then several options are available. One alternative which has been suggested is the use of solar reflective film. This adhesive film is applied to the inside surface of glazing. The makers of one brand claim that only 19% solar heat is admitted through glass with the film, as opposed to 87.5% without the film. They also claim that R-Value is increased from .9 to 1.2.[1] The reduction in cooling load was significant in a Winnipeg building which applied the film, although no dollar savings could be provided.[2]

One problem with solar film is that heat gain is reduced in winter, as well as in summer. Any increase in R-Value will thus be more than offset by lost solar heating during daylight hours. A

*Questionnaire, Appendix N.

1. Solar-X Corporation, Newton, Mass. 02161.

2. Personal communication, Pete Giesbrecht, Customer Advisory Services, Manitoba Hydro, August 22/1977.

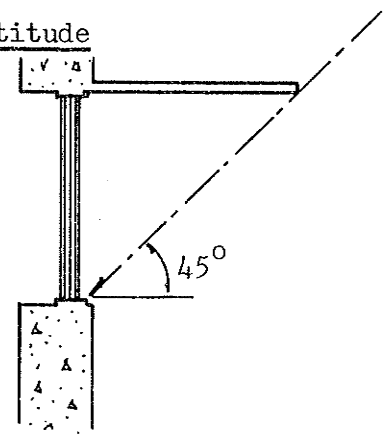
building using solar film is subject to restrictions in the proposed Code for Energy Conservation in New Buildings. (see 'Codes and Regulations')

4.10.5 Exterior Shading

Solar shading devices, or awnings, installed outside glazing, have advantages over solar film. An outside shading device prevents solar radiation from directly striking the glass. Solar film cannot offer this protection.

A properly designed overhang will stop high altitude summer sun from entering the glazing, but will allow solar heat from the low winter sun to penetrate into the building. To provide maximum shading in summer, yet let in sunlight from September through the winter months, a design altitude of 45° is optimum for south facies.

Figure 9: Design Altitude



This technique can be applied to the walls, as well as to glazing, for greater protection.

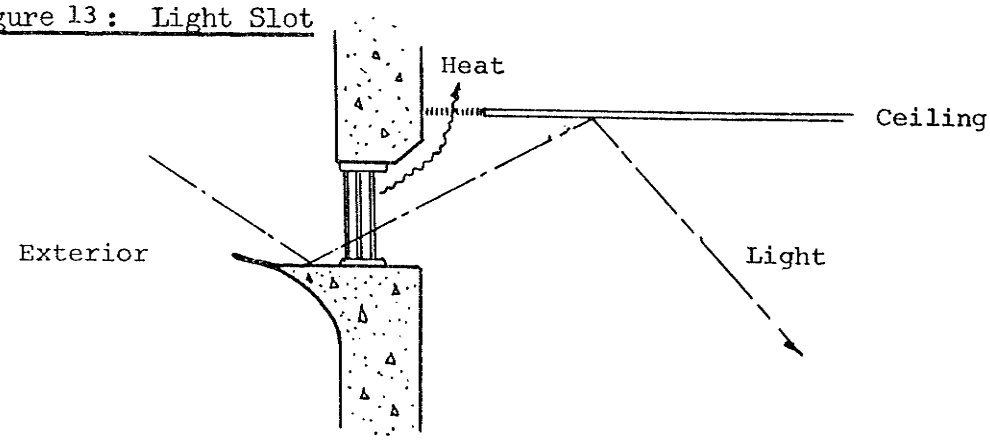
Panels of a solar shading device can be constructed of wood, which require less technology and less energy to produce than do plastic films. (Wood products probably require a greater amount of maintenance.)

As with most construction measures, the best time to incorporate these devices, is at the design stage. In this way the shading devices could operate in unison with the other building systems (ie. winter solar heating could be carried to cooler sections of the building by a properly designed air movement system; shading may make air-conditioning unnecessary).

4.10.6 Light Slots

An idea currently being developed in Europe is to utilize a horizontal strip of glazing to admit light. This slot (see Figure 13) would be built at a height close to the ceiling to allow sunlight to enter the room, deflect off the ceiling, and provide even, natural lighting in the classroom. This natural lighting would augment the electric lighting under normal working conditions. When less light is required, the natural light can be used exclusively.

Figure 13 : Light Slot



The outside ledge deflects extra sunlight into the slot. These slots, which are more efficient for lighting than large expanses of glazing, can be of much smaller area. With less glazed area, it may be economic to triple glaze, in order to reduce heat loss. Being elevated and protected somewhat by the reflective ledge, vandalism could be expected to be reduced. A difficulty which may need to be overcome is snow accumulation on the ledge.

4.10.7 Lowering Lighting Levels by Delamping

The energy audit revealed that lighting in the new school is significantly higher than the old school. This can probably be attributed to increasing standards which have been advocated over the years by North American organizations such as the Illuminating Engineering Society, and A.S.H.R.A.E.[3] It is interesting to note that British standards are much lower than (generally half of) American standards. (See Table XII)

The energy situation has inspired some decision-makers in the U.S. to consider a policy of reduced lighting levels. Under policy consideration are levels of 50 fc. for desk work, 30 fc. for ambient situations, and 10 fc. for corridors.[4]

Table XII: Recommended Levels of Illumination (footcandles)*

	I.E.S. Handbooks		Industrial safety Handbook (British)
	1952	1972(76)**	1969
Reading, High Contract Material	10	30	20
Reading, Good Contrast	-	70	
General Office Work, reading Good Reproductions	30	100	50
Bookkeeping	50	150	
Drafting	-	200	75
Corridors, Stairways	5	20	10

* Source: Project Independence, p.132.
** In 1976, Westinghouse Lighting Handbook, levels are the same.

3. Project Independence - Residential and Commercial Energy Use Patterns 1970 - 1998, Federal Energy Administration Final Task Force Report, Washington; Vol. I: November 1974, p.132.

4. Ibid, p.133.

Among the most popular studies on electric lighting were those carried out under the direction of an American, Dr. Richard Blackwell. One report states that, with reasonable lighting levels (of 35 to 40 f.c.) the limiting factor of effective lighting in classrooms may be a function of shiny desk tops, glossy book pages, low contrast reading and writing materials, noise in corridors, interest of the lecture, or inattentiveness of the students.[5]

It is noteworthy that in St. George, where lighting levels are about 50 f.c., 18% of the teachers indicated that students had complained about the quality of lighting at some time. In William Whyte, with levels of 75 to 100 f.c., complaints of the teachers from 32% were received. Examples of these complaints are: ballast noise, glare on the chalkboard, and eyestrain. (see Appendix N.)

A school division could save significant amounts of money if architects were to design for lower levels of lighting. Lighting equipment would require less energy for operation, require less maintenance, and initial cost would be substantially lower than a system with higher light levels. Figure14 gives an indication of the increased costs of providing various lighting levels. It can be seen that increasing the level from 30 to 70 f.c. doubles the installed cost of lighting equipment, while improving reading rate (ease of reading) by only 2%.

In schools with existing lighting levels which are deemed excessive, reduction can be accomplished by disconnecting lamps and ballasts.

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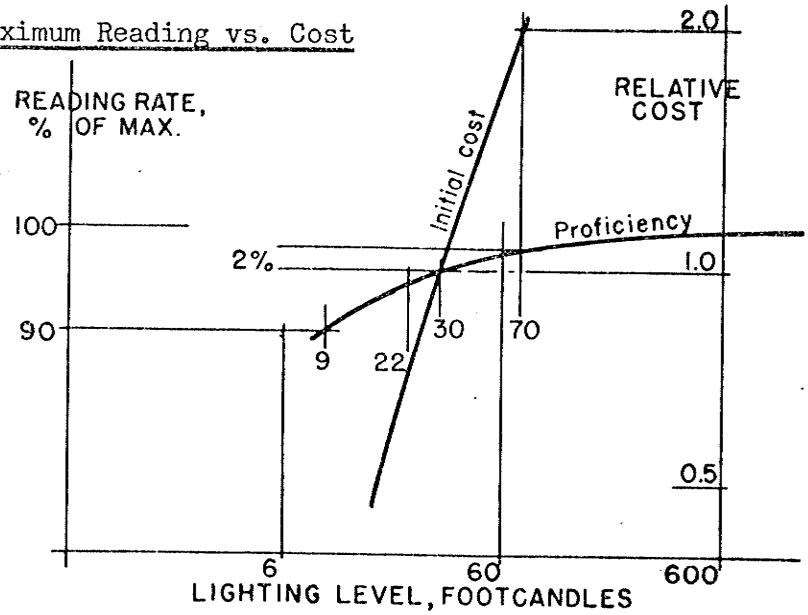
5. National Academy of Science - National Research Council, Building Illumination, The Effect of New Lighting Levels, Building Research Institute, publication 744; Washington: 1959, p.71.

Figure 14 : Maximum Reading vs. Cost



Source: Building Illumination, The Effect of New Lighting Levels, p.70.

Consider a fixture with four fluorescent tubes. The two inside tubes, generally being connected in series to one ballast, can both be removed, and the ballast for those two tubes disconnected. This would leave the two outside tubes, and ballast, intact. This method can be applied to as many fixtures as necessary to reduce overall lighting level to a desired level.

At the outset of such a program it may be wise to leave the ballast connected for an experimental period. During this time it may become evident that several fixtures should be reconnected, and others disconnected. Since the ballasts themselves consume electricity, the sooner they can be disconnected the better. The experimental period should be as short as possible.

Fixtures which are delamped must be clearly identified, to distinguish them from fixtures with burnt-out tubes. Reflected ceiling plans tend to be misplaced. A fixture can be marked with pen or crayon, self adhesive stickers, etc. In this study, squares of masking tape were used.

William Whyte had classroom lighting levels of 75 to 100 f.c.; this is typical of modern design trends. Corridor levels were 20 f.c. It was decided among a group of school division technicians, school staff, and the researcher, to reduce lighting levels, under experimental authority, to 50 - 60 f.c. in classrooms, and 10 f.c. in corridors. Lighting which could be disconnected by switching was included in this aspect of the program.

A total of 17.3 KW could be taken off stream, by removing specific tubes. Since this resulted in a reduction of peak electric load, a demand billing saving could be achieved, as well as a consumption billing saving. Total benefits amounted to $750./yr. (31500 KWH electricity)(3.6% of total energy bill)(See Appendix L.).

The costs of implementing this measure were estimated as eight man days @ $80.00/day = $640. The measure thus pays for itself in less than one year. The removed ballasts and tubes can be saved and installed as the remaining ones burn out, thus reducing future operating and maintenance costs.

4.10.8 Ceiling Height

In the past, ceilings in institutional buildings were necessarily high. Tall windows were needed to supplement the poor quality incandescent lighting. To partially compensate for poor mechanical ventilating systems, a high ceiling allowed some time lag before the room became stuffy from the occupants. Ceiling heights at William Whyte were about 9½ ft., while at St. George they were over 10 feet.

It is understood that in large spaces, a high ceiling will psychologically diminish the distance sensation. To a youngster, however, heights of over 6 feet are intimidating. A teacher at St. George school recognized this, and had a policy of hanging children's artwork from the ceiling, to a level of about 6½ feet from the floor. She noted that this created a more intimate atmosphere for the children, as well as being an effective way to demonstrate artwork.

The benefits of a low ceiling (about 8 feet) are numerous. A low ceiling creates a better environment for small children. The capital cost of materials in construction is reduced, since less wall materials are needed. Less lighting is needed if the fixtures are closer to the floor. This implies lower capital cost for fixtures, as well as decreased operating and energy costs. A reduction in ceiling height proportionately lowers the volume of air inside which requires heating and cooling. H.V.A.C. equipment can thus be smaller, and less expensive. Operating and energy costs will again be reduced.

Reduced ceiling height is a case in point where a conservation measure incorporated into the initial building construction can reduce capital costs, as well as operating costs.

4.10.9 Ventilation and Air Conditioning

An interesting discovery from the questionnaire involved ventilation. In both schools, 60% of the teachers felt ventilation was inadequate for their comfort. The fan systems in both schools moved about the same amount of mixed air. The significant difference between the schools is that William Whyte is air-conditioned, while St. George is not.

The most obvious question that arises from this situation, is if air-conditioning does not improve comfort appreciably, then why use it? One measure which would likely make a more significant difference is to increase the amount of air circulation in the school. D. Stephens agrees that fans can be more effective for cooling than air-conditioning, at a fraction of the price and energy consumption.[6]

4.11 Siting Characteristics

The effects on energy consumption of the site surrounding the building can be readily identified, but extremely difficult to quantify. For this reason, the effects have only been identified, and not assessed economically.

Vegetation is an important component of the site. Deciduous trees on southern exposures, adjacent to the building, can be more effective shading devices than man-made devices. In the summer, the foliage prevents direct sunlight from heating windows and walls, while still permitting breezes to cool the wall. In winter, the trees lose their foliage, and sunlight is allowed through the branches to warm the walls and enter windows.

Evergreens planted on the windward side of buildings can serve as effective wind barriers. If winds can be slowed from 15 mph. to 10 mph., infiltration heat loss can be reduced by nearly half. (see Table IX) Indications are that a dense tree buffer creates an air pocket downwind for a distance of thirty times the height of the

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6. Stephens, D.H., "Physical Principles of Energy Conservation in Buildings," Energy Conservation in Building, Assoc. of Industrialized Building Component Manufacturers Ltd., One day seminar, London: Mar. 12, 1975, p.26.

tree.[1]

Summer breezes which pass through trees, brush,grass and over water are generally cooler than if they passed over black, hot asphalt such as a parking lot. This is due to shade, and heat loss to evaporation of water and moisture on leaves.

The albedo of surfaces adjacent to the building is important. A grassed lawn (green) beneath a window would provide more comfort through reduced light reflection (glare) and heat absorption, than a light coloured concrete playing surface.

In winter, snow accumulation below a window reflects a great deal of sunlight. This causes more light to strike the window and wall area. The heat is beneficial in winter, but proper protection is needed against excessive glare. Overheating is possible on south exposures, unless the building has an efficient heat recovery system, to move heat to cooler sections of the building.

Building orientation can affect solar heat gain. The long side of the building should be oriented along an East-West axis if possible. This permits maximum solar heat gain through glazing in the winter, and easiest shading against direct sunlight in summer. On the East and West faces, the sun rises and sets, moving from high altitude to the horizon, making shading extremely difficult.

Bruce McCallum has suggested that a well landscaped lot in this climate, incorporating the above features, could reduce building

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1. Longwell, Flint and Sanders, Physical Geology, John Wiley and Sons, Inc., New York: 1969, p.297.

heating and cooling by 10 to 20%.[2] In William Whyte school, 10% could amount to $900/year.

2. McCallum, Bruce, Environmentally Appropriate Technology, 4th edition; Fisheries and Environment Canada, Ottawa: 1976, p.103.

CHAPTER V

Conclusions, Recommendations, and Area for Further Study

5.1 Conclusions

It was found through the course of research that information required to conserve energy in schools originates from a spectrum of disciplines. As is evidenced by the acknowledgements, the researcher obtained assistance from mechanical engineers, lighting engineers, hot water specialists, architects, building material suppliers, insulation distributors, energy utilities and their helpful customer advisory services, municipal officials, government agencies such as Underwriter Laboratories and government departments such as Public Works, and Education. The list goes on. It is expected that, with all these inputs under onecover providing valuable resource material, future energy studies can be accomplished with ease and direction.

It is evident that any one given school will not find it necessary to implement every measure mentioned in this study. It was found in this study that the older school could benefit more from measures which required capital investment, while the new school benefitted a great deal from measures requiring only labour investment. Over the remaining life of the building, William Whyte could save over one hundred and eighty (180) thousand dollars, by spending eight hundred dollars in labour costs. (See Appendix M.)

Research into codes and regulations revealed no restrictions, which would adversely affect attempts to conserve energy. The proposed Canadian Code for Energy Conservation in New Buildings would accomplish a great deal in reducing energy wastage in new buildings, if incorporated into the national building code.

People are essential in the planning of energy conservation programs. Measures in the category of "Building Use" amounted to a present value of $57,800. or 31.4% of total energy savings possible. (Appendix M).

Conservation measures involving building construction are best implemented at the design stage. In many cases, the first cost of a building would actually be reduced by including conservation measures. Retrofitting an existing building is not as economically desirable, yet still produces considerable energy savings. The longer the time left in the life of the building, the more economically desirable measures involving construction become. In William Whyte, delamping measures yielded energy savings worth $24,000 (12.3% of total energy savings). (Appendix M)

Attitudes of people involved are fundamental to the total success of conservation measures in both existing, and new buildings. Poor attitudes can generally be attributed to lack of knowledge about conservation and the ease with which measures can be accomplished. Some people are more inclined to conserve because of financial savings, while others find incentive in preserving energy for future users.

Attitudes towards a combined energy conservation and education program are favourable. Staff has indicated that they are in favour of such a program in the schools. Children appear to identify well with the objectives of the program, and response is encouraging.

5.2 Recommendations

It is recommended that school divisions establish an arm which is concerned solely with energy efficiency in division schools. This new component should be managed full-time by an experienced resource person, although a second best alternative would be to give part-time responsibilities to an existing staff member. Due to the enormous amount of work required to initiate an energy conservation program, it is recommended that a full time person be employed. The manager would be responsible to conduct research into specific ways to conserve energy in each school, obtain authorization for the implementation of the measures, inspect new construction, and provide resource material for a school energy awareness program.

It is recommended that the division have active representation in the design of new schools and additions. If knowledgable persons cannot be appointed, the division should enforce a policy to commission only those designers who are known to be energy conscious.

It is recommended that school divisions, or schools initially adopt relevant measures under an experimental authority. If a conservation measure adversely affects the quality of classroom work, it should be modified, or discontinued to halt the interference. Eventually, all the 'bugs' can be worked out, and the program can be instituted permanently.

It is recommended that energy-related bulletins be distributed to the schools regularly. These information packages should be directed to contact persons who have expressed an interest in energy conservation, and agreed to be the school representative. When possible the normal school representatives such as principals, should be avoided, since they already are burdened with other responsibilities.

5.3 Area for Further Study

Time and resource constraints restricted the scope of this study to existing schools, with little reference to new school design. An area of equal importance to growing school divisions is the incorporation of energy conservation features into the design of new schools and additions to existing schools. The proposed Canadian Code for Energy Conservation in New Buildings would make a good starting point.[1]

Another area of possible interest is the difference in energy consumption between rural schools, and urban schools. Casual observation revealed that rural schools had earlier times of dismissal, smaller populations, reduced vandalism, and extensive bussing programs, and near total dependence on electricity, with some oil heating in older buildings. Conservation methods applicable to rural schools may be significantly different to those applicable to urban schools.

1. Associate Committee on the National Building Code, National Research Council Canada, Canadian Code for Energy Conservation in New Buildings, (draft for public comment): June , 1977.

Estimated Heat Lost from Building by Infiltration[11]

The tabulated factors when multiplied by room or building volume (cu ft) will result in estimated heat loss (Btu/hr) due to infiltration and does not include the heat needed to warm ventilating air

Room or Building Type	No. of walls with windows	Temp. difference, F deg			
		25	50	75	100
A	None	0.23	0.45	0.68	0.90
A	1	0.34	0.68	1.02	1.36
A	2	0.68	1.35	2.02	2.70
A	3 or 4	0.90	1.80	2.70	3.60
B	Any	1.35	2.70	4.05	5.40
C	Any	0.90–1.35	1.80–2.70	2.70–4.05	3.60–5.40
D	Any	0.45–0.68	0.90–1.35	1.35–2.02	1.80–2.70
E	Any	0.68–1.35	1.35–2.70	2.03–4.05	2.70–5.40

A = Offices, apartments, hotels, multistory buildings in general.
B = Entrance halls or vestibules.
C = Industrial buildings.
D = Houses, all types, all rooms except vestibules.
E = Public or institutional buildings.

Coefficients of Transmission (U) for Slab Doors

Btu per (hr) (sq ft) (F Deg)

Thickness[a]	Winter			Summer, No Storm Door
	Solid Wood, No Storm Door	Storm Door[b]		
		Wood	Metal	
1 in.	0.64	0.30	0.39	0.61
1¼ in.	0.55	0.28	0.34	0.53
1½ in.	0.49	0.27	0.33	0.47
2 in.	0.43	0.24	0.29	0.42
	Steel Door[13]			
1¾ in.				
A[c]	0.59	—	—	0.58
B[d]	0.40	—	—	0.39
C[e]	0.47	—	—	0.46

[a] Nominal thickness.
[b] Values for wood storm doors are for approximately 50 percent glass; for metal storm doors values apply for any percent of glass.
[c] A = Mineral fiber core (2 lb/cu ft).
[d] B = Solid urethane foam core.
[e] C = solid polystyrene core.

Coefficients of Transmission (U) of Windows, Skylights, and Light Transmitting Partitions

These values are for heat transfer from air to air.

Btu per (hr) (sq ft) (F Deg)

PART A—VERTICAL PANELS (EXTERIOR WINDOWS, SLIDING PATIO DOORS, AND PARTITIONS)—FLAT GLASS, GLASS BLOCK, AND PLASTIC SHEET

Description	Exterior[a]		Interior
	Winter	Summer	
Flat Glass			
single glass	1.13	1.06	0.73
insulating glass—double[b]			
3/16 in. air space	0.69	0.64	0.51
¼ in. air space	0.65	0.61	0.49
½ in. air space	0.58	0.56	0.46
½ in. air space, low emissivity coating[c]			
emissivity = 0.20	0.38	0.36	0.32
emissivity = 0.40	0.45	0.44	0.38
emissivity = 0.60	0.52	0.50	0.42
insulating glass—triple[b]			
¼ in. air spaces	0.47	0.45	0.38
½ in. air spaces	0.36	0.35	0.30
storm windows			
1 in.–4 in. air space	0.56	0.54	0.44
Glass Block[d]			
6 × 6 × 4 in. thick	0.60	0.57	0.46
8 × 8 × 4 in. thick	0.56	0.54	0.44
—with cavity divider	0.48	0.46	0.38
12 × 12 × 4 in. thick	0.52	0.50	0.41
—with cavity divider	0.44	0.42	0.36
12 × 12 × 2 in. thick	0.60	0.57	0.46
Single Plastic Sheet	1.09	1.00	0.70

[a] See Part C for adjustment for various window and sliding patio door types.
[b] Double and triple refer to the number of lights of glass.
[c] Coating on either glass surface facing air space; all other glass surfaces uncoated.
[d] Dimensions are nominal.
[e] For heat flow up.
[f] For heat flow down.
[g] Based on area of opening, not total surface area.
[h] Refers to windows with negligible opaque area.
[i] Value becomes 1.00 when storm sash is spearated from prime window by a thermal break.

PART B—HORIZONTAL PANELS (SKYLIGHTS)—FLAT GLASS, GLASS BLOCK, AND PLASTIC BUBBLES

Description	Exterior[a]		Interior[a]
	Winter[e]	Summer[f]	
Flat Glass			
single glass	1.22	0.83	0.96
insulating glass—double[b]—			
3/16 in. air space	0.75	0.49	0.62
¼ in. air space	0.70	0.46	0.59
½ in. air space	0.66	0.44	0.56
½ in. air space, low emissivity coating[c]			
emissivity = 0.20	0.46	0.31	0.39
emissivity = 0.40	0.53	0.36	0.45
emissivity = 0.60	0.60	0.40	0.50
Glass Block[d]			
11 × 11 × 3 in. thick with cavity divider	0.53	0.35	0.44
12 × 12 × 4 in. thick with cavity divider	0.51	0.34	0.42
Plastic Bubbles[g]			
single walled	1.15	0.80	—
double walled	0.70	0.46	—

PART C—ADJUSTMENT FACTORS FOR VARIOUS WINDOW AND SLIDING PATIO DOOR TYPES (MULTIPLY U VALUES IN PARTS A AND B BY THESE FACTORS)

Description	Single Glass	Double or Triple Glass	Storm Windows
Windows			
All Glass[h]	1.00	1.00	1.00
Wood Sash—80% Glass	0.90	0.95	0.90
Wood Sash—60% Glass	0.80	0.85	0.80
Metal Sash—80% Glass	1.00	1.20	1.20[i]
Sliding Patio Doors			
Wood Frame	0.95	1.00	—
Metal Frame	1.00	1.10	—

Thermal Conductances and Resistances of a Plane[a,b,g] Air Space*
(3/4, 1 1/2, and 4 in. Air Space, Heat Flow Down)

Position of Air Space	Direction of Heat Flow	Air Space: Thickness, in.	Air Space: Mean Temp, F	3/4 inch Thickness[b]: Thermal Conductance — C: Value of E 0.03	0.05	0.2	0.5	0.82	Thermal Resistance — R: Value of E 0.03	0.05	0.2	0.5	0.82
Horiz.	Down[f]	3/4	90	0.28	0.31	0.48	0.82	1.19	*3.56*	*3.25*	*2.08*	*1.21*	*0.84*
			50	0.26	0.28	0.42	0.69	0.98	*3.80*	*3.55*	*2.39*	*1.44*	*1.02*
			0	0.23	0.25	0.35	0.55	0.76	*4.28*	*4.04*	*2.88*	*1.82*	*1.31*
			−50	0.21	0.22	0.29	0.43	0.58	*4.84*	*4.63*	*3.48*	*2.33*	*1.72*
		1 1/2	90	0.17	0.19	0.36	0.71	1.07	*5.96*	*5.24*	*2.76*	*1.42*	*0.93*
			50	0.16	0.17	0.31	0.59	0.88	*6.41*	*5.74*	*3.21*	*1.71*	*1.14*
			0	0.14	0.15	0.25	0.45	0.67	*7.18*	*6.59*	*3.97*	*2.21*	*1.50*
			−50	0.12	0.13	0.20	0.34	0.50	*8.23*	*7.63*	*4.95*	*2.90*	*2.02*
		4	90	0.10	0.12	0.30	0.64	1.01	*9.92*	*8.08*	*3.38*	*1.56*	*0.99*
			50	0.09	0.11	0.25	0.52	0.81	*10.7*	*8.94*	*4.02*	*1.91*	*1.23*
			0	0.08	0.09	0.19	0.39	0.61	*12.4*	*10.9*	*5.20*	*2.54*	*1.65*
			−50	0.07	0.08	0.15	0.29	0.45	*14.0*	*12.3*	*6.57*	*3.40*	*2.24*

Conductivities, Conductances, and Resistances of Building and Insulating Materials—(Design Values)[a]

These constants are expressed in Btu per (hour) (square foot) (Fahrenheit degree temperature difference). Conductivities (k) are per inch thickness, and conductances (C) are for thickness or construction stated, not per inch thickness

Material	Description	Density (Lb per Cu Ft)	Mean Temp F	Conductivity (k)	Conductance (C)	Resistance[b] (R): Per inch thickness (1/k)	Resistance[b] (R): For thickness listed (1/C)	Specific Heat, Btu per (lb) (F deg)
BUILDING BOARD[c] BOARDS, PANELS, SUBFLOORING, SHEATHING, WOODBASED PANEL PRODUCTS[h]	Asbestos-cement board	120	75	4.0	—	*0.25*	—	
	Asbestos-cement board, 1/8 in.	120	75	—	33.00	—	*0.03*	
	Asbestos-cement board, 1/4 in.	120	75	—	16.50	—	*0.06*	
	Gypsum or plaster board, 3/8 in.	50	75	—	3.10	—	*0.32*	
	Gypsum or plaster board, 1/2 in.	50	75	—	2.25	—	*0.45*	
	Plywood	34	75	0.80	—	*1.25*	—	0.29
	Plywood, 1/4 in.	34	75	—	3.20	—	*0.31*	0.29
	Plywood, 3/8 in.	34	75	—	2.13	—	*0.47*	0.29
	Plywood, 1/2 in.	34	75	—	1.60	—	*0.62*	0.29
	Plywood or wood panels, 3/4 in.	34	75	—	1.07	—	*0.93*	0.29
	Insulating board							
	Sheathing, regular density, 1/2 in.	18	75	—	0.76	—	*1.32*	0.31
	25/32 in.	18	75	—	0.49	—	*2.06*	0.31
	Sheathing intermediate density, 1/2 in.	22	75	—	0.82	—	*1.22*	0.31
	Nail-base sheathing, 1/2 in.	25	75	—	0.88	—	*1.14*	0.31
	Shingle backer, 3/8 in.	18	75	—	1.06	—	*0.94*	0.31
	Shingle backer, 5/16 in.	18	75	—	1.28	—	*0.78*	0.31
	Sound deadening board, 1/2 in.	15		—	0.74	—	*1.35*	0.30
	Tile and lay-in panels, plain or acoustic	18	75	0.40	—	*2.50*	—	0.32
	1/2 in.	18	75	—	0.80	—	*1.25*	0.32
	3/4 in.	18	75	—	0.53	—	*1.89*	0.32
	Laminated paperboard	30	75	0.50	—	*2.00*	—	
	Homogeneous board from repulped paper	30	75	0.50	—	*2.00*	—	0.28
	Hardboard							
	Medium density siding, 7/16 in.	40	75	—	1.49	—	*0.67*	0.28
	Other medium density	50	75	0.73	—	*1.37*	—	0.31
	High density, service temp. service, underlay	55	75	0.82	—	*1.22*	—	0.33
	High density, std. tempered	63	75	1.00	—	*1.00*	—	0.33
	Particleboard							
	Low density	37	75	0.54	—	*1.85*	—	0.31
	Medium density	50	75	0.94	—	*1.06*	—	0.31
	High density	62.5	75	1.18	—	*0.85*	—	0.31
	Underlayment, 5/8 in.	40	75	—	1.22	—	*0.82*	0.29
	Wood subfloor, 3/4 in.		75	—	1.06	—	*0.94*	0.34
BUILDING PAPER	Vapor—permeable felt	—	75	—	16.70	—	*0.06*	
	Vapor—seal, 2 layers of mopped 15 lb felt	—	75	—	8.35	—	*0.12*	
	Vapor—seal, plastic film	—	75	—	—	—	Negl.	
FINISH FLOORING MATERIALS	Carpet and fibrous pad	—	75	—	0.48	—	*2.08*	
	Carpet and rubber pad	—	75	—	0.81	—	*1.23*	0.34

Conductivities, Conductances, and Resistances of Building and Insulating Materials—(Design Values)[a] (Continued)

Material	Description	Density (Lb per Cu Ft)	Mean Temp F	Conductivity (k)	Conductance (C)	Resistance[b] (R) Per inch thickness (1/k)	Resistance[b] (R) For thickness listed (1/C)	Specific Heat, Btu per (lb) (F deg)
FINISH FLOORING MATERIALS (*Continued*)	Cork tile............1/8 in.	—	75	—	3.60	—	0.28	
	Terrazzo............1 in.	—	75	—	12.50	—	0.08	
	Tile—asphalt, linoleum, vinyl, rubber.	—	75	—	20.00	—	0.05	0.30
	Wood, hardwood finish..........3/4 in.	—	75	—	1.47	—	0.08	
INSULATING MATERIALS	Mineral Fiber, fibrous form processed from rock, slag, or glass							
Blanket and Batt	approx.[e] 2-2¾ in..............	—	75	—	—	—	7[d]	0.18
	approx.[e] 3-3½ in..............	—	75	—	—	—	11[d]	0.18
	approx.[e] 5¼-6½ in..............	—	75	—	—	—	19[d]	0.18
Board and Slabs	Cellular glass....................	9	75	0.40	—	2.50	—	0.24
	Glass fiber, organic bonded..........	4-9	75	0.25	—	4.00	—	0.19
	Expanded rubber (rigid)............	4.5	75	0.22	—	4.55	—	
	Expanded polystyrene extruded, plain....................	1.8	75	0.25	—	4.00	—	0.29
	Expanded polystyrene extruded, (R-12 exp.)....................	2.2	75	0.20	—	5.00	—	0.29
	Expanded polystyrene extruded, (R-12 exp.) (Thickness 1 in. and greater)..	3.5	75	0.19	—	5.26	—	0.29
	Expanded polystyrene, molded beads.	1.0	75	0.28	—	3.57	—	0.29
	Expanded polyurethane[f] (R-11 exp.)	1.5	75	0.16	—	6.25	—	0.38
	(Thickness 1 in. or greater)........	2.5						0.38
	Mineral fiber with resin binder.......	15	75	0.29	—	3.45	—	0.17
	Mineral fiberboard, wet felted							
	Core or roof insulation...........	16-17	75	0.34	—	2.94	—	
	Acoustical tile..................	18	75	0.35	—	2.86	—	
	Acoustical tile..................	21	75	0.37	—	2.70	—	
	Mineral fiberboard, wet molded							
	Acoustical tile[g]................	23	75	0.42	—	2.38	—	
	Wood or cane fiberboard							
	Acoustical tile[g]..............½ in.	—	75	—	0.80	—	1.25	0.30
	Acoustical tile[g]..............¾ in.	—	75	—	0.53.	—	1.89	0.30
	Interior finish (plank, tile)	15	75	0.35	—	2.86	—	0.32
	Insulating roof deck							
	Approximately..............1½ in.	—	75	—	0.24	—	4.17	
	Approximately..............2 in.	—	75	—	0.18	—	5.56	
	Approximately..............3 in.	—	75	—	0.12	—	8.33	
	Wood shredded (cemented in preformed slabs)................	22	75	0.60	—	1.67	—	0.38
Loose Fill	Cellulose insulation (milled paper or wood pulp)....................	2.5-3	75	0.27	—	3.70	—	0.33
	Sawdust or shavings................	0.8-1.5	75	0.45	—	2.22	—	0.33
	Wood fiber, softwoods..............	2.0-3.5	75	0.30	—	3.33	—	0.33
	Perlite, expanded..................	5.0-8.0	75	0.37	—	2.70	—	
	Mineral fiber (rock, slag or glass)							
	approx.[e] 3 in....................	8-15	75	—	—	—	9[d]	0.18
	approx.[e] 4½ in..................	8-15	75	—	—	—	13[d]	0.18
	approx.[e] 6¼ in..................	8-15	75	—	—	—	19[d]	0.18
	approx.[e] 7½ in..................	8-15	75	—	—	—	24[d]	0.18
	Silica aerogel......................	7.6	75	0.17	—	5.88	—	
	Vermiculite (expanded)............	7.0-8.2	75	0.47	—	2.13	—	
		4.0-6.0	75	0.44	—	2.27	—	
Roof Insulation[h]	Preformed, for use above deck							
	Approximately..............½ in.	—	75	—	0.72	—	1.39	
	Approximately..............1 in.	—	75	—	0.36	—	2.78	
	Approximately..............1½ in.	—	75	—	0.24	—	4.17	
	Approximately..............2 in.	—	75	—	0.18	—	5.56	
	Approximately..............2½ in.	—	75	—	0.15	—	6.67	
	Approximately..............3 in.	—	75	—	0.12	—	8.33	
	Cellular glass....................	9	75	0.40	—	2.50	—	0.24
MASONRY MATERIALS Concretes	Cement mortar....................	116		5.0	—	0.20	—	
	Gypsum-fiber concrete 87½% gypsum, 12½% wood chips................	51		1.66	—	0.60	—	
	Lightweight aggregates including expanded shale, clay or slate; expanded slags; cinders; pumice; vermiculite; also cellular concretes	120		5.2	—	0.19	—	
		100		3.6	—	0.28	—	
		80		2.5	—	0.40	—	
		60		1.7	—	0.59	—	
		40		1.15	—	0.86	—	
		30		0.90	—	1.11	—	
		20		0.70		1.43		

Conductivities, Conductances, and Resistances of Building and Insulating Materials—(Design Values)[a] (Continued)

Material	Description	Density (Lb per Cu Ft)	Mean Temp F	Conductivity (k)	Conductance (C)	Resistance[a] (R) Per inch thickness (1/k)	For thickness listed (1/C)	Specific Heat, Btu per (lb)(F deg)
MASONRY MATERIALS CONCRETES (*Continued*)	Perlite	40	75	0.93	—	*1.08*	—	
		30		0.71	—	*1.41*	—	
		20		0.50	—	*2.00*	—	
	Sand and gravel or stone aggregate (oven dried)	140		9.0	—	*0.11*	—	
	Sand and gravel or stone aggregate (not dried)	140		12.0	—	*0.08*	—	
	Stucco	116		5.0	—	*0.20*	—	
MASONRY UNITS	Brick, common[i]	120	75	5.0	—	*0.20*	—	
	Brick, face[i]	130	75	9.0	—	*0.11*	—	
	Clay tile, hollow:							
	1 cell deep 3 in.	—	75	—	1.25	—	*0.80*	
	1 cell deep 4 in.	—	75	—	0.90	—	*1.11*	
	2 cells deep 6 in.	—	75	—	0.66	—	*1.52*	
	2 cells deep 8 in.	—	75	—	0.54	—	*1.85*	
	2 cells deep 10 in.	—	75	—	0.45	—	*2.22*	
	3 cells deep 12 in.	—	75	—	0.40	—	*2.50*	
	Concrete blocks, three oval core:							
	Sand and gravel aggregate 4 in.	—	75	—	1.40	—	*0.71*	
	8 in.	—	75	—	0.90	—	*1.11*	
	12 in.	—	75	—	0.78	—	*1.28*	
	Cinder aggregate 3 in.	—	75	—	1.16	—	*0.86*	
	4 in.	—	75	—	0.90	—	*1.11*	
	8 in.	—	75	—	0.58	—	*1.72*	
	12 in.	—	75	—	0.53	—	*1.89*	
	Lightweight aggregate (expanded shale, clay, slate or slag; pumice) 3 in.	—	75	—	0.79	—	*1.27*	
	4 in.	—	75	—	0.67	—	*1.50*	
	8 in.	—	75	—	0.50	—	*2.00*	
	12 in.	—	75	—	0.44	—	*2.27*	
	Concrete blocks, rectangular core.[j]							
	Sand and gravel aggregate							
	2 core, 8 in. 36 lb.[k]	—	45	—	0.96	—	*1.04*	
	Same with filled cores[l]	—	45	—	0.52	—	*1.93*	
	Lightweight aggregate (expanded shale, clay, slate or slag, pumice):							
	3 core, 6 in. 19 lb.[k]	—	45	—	0.61	—	*1.65*	
	Same with filled cores[l]	—	45	—	0.33	—	*2.99*	
	2 core, 8 in. 24 lb.[k]	—	45	—	0.46	—	*2.18*	
	Same with filled cores[l]	—	45	—	0.20	—	*5.03*	
	3 core, 12 in. 38 lb.[k]	—	45	—	0.40	—	*2.48*	
	Same with filled cores[l]	—	45	—	0.17	—	*5.82*	
	Stone, lime or sand	—	75	12.50	—	*0.08*	—	
	Gypsum partition tile:							
	3 × 12 × 30 in. solid	—	75	—	0.79	—	*1.26*	
	3 × 12 × 30 in. 4-cell	—	75	—	0.74	—	*1.35*	
	4 × 12 × 30 in. 3-cell	—	75	—	0.60	—	*1.67*	
PLASTERING MATERIALS	Cement plaster, sand aggregate	116	75	5.0	—	*0.20*	—	
	Sand aggregate 3/8 in.	—	75	—	13.3	—	*0.08*	
	Sand aggregate 3/4 in.	—	75	—	6.66	—	*0.15*	
	Gypsum plaster:							
	Lightweight aggregate 1/2 in.	45	75	—	3.12	—	*0.32*	
	Lightweight aggregate 5/8 in.	45	75	—	2.67	—	*0.39*	
	Lightweight agg. on metal lath. 3/4 in.	—	75	—	2.13	—	*0.47*	
	Perlite aggregate	45	75	1.5	—	*0.67*	—	
	Sand aggregate	105	75	5.6	—	*0.18*	—	
	Sand aggregate 1/2 in.	105	75	—	11.10	—	*0.09*	
	Sand aggregate 5/8 in.	105	75	—	9.10	—	*0.11*	
	Sand aggregate on metal lath 3/4 in.	—	75	—	7.70	—	*0.1*	
	Vermiculite aggregate	45	75	1.7	—	*0.59*	—	
ROOFING	Asbestos-cement shingles	120	75	—	4.76	—	*0.21*	
	Asphalt roll roofing	70	75	—	6.50	—	*0.15*	
	Asphalt shingles	70	75	—	2.27	—	*0.44*	
	Built-up roofing 3/8 in.	70	75	—	3.00	—	*0.33*	0.35
	Slate 1/2 in.	—	75	—	20.00	—	*0.05*	
	Wood shingles, plain a plastic film faced	—	75	—	1.06	—	*0.94*	0.31

Conductivities, Conductances, and Resistances of Building and Insulating Materials—(Design Values)[a] (*Concluded*)

Material	Description	Density (lb per Cu Ft)	Mean Temp F	Conductivity (k)	Conductance (C)	Resistance[b] (R): Per inch thickness (1/k)	Resistance[b] (R): For thickness listed (1/C)	Specific Heat Btu per (lb) (F deg)
SIDING MATERIALS (ON FLAT SURFACE)	Shingles							
	Asbestos-cement	120	75	—	4.76	—	*0.21*	
	Wood, 16 in., 7½ exposure	—	75	—	1.15	—	*0.87*	0.31
	Wood, double, 16-in., 12-in. exposure	—	75	—	0.84	—	*1.19*	0.31
	Wood, plus insul. backer board. 5/16 in.	—	75	—	0.71	—	*1.40*	0.31
	Siding							
	Asbestos-cement, ¼ in., lapped	—	75	—	4.76	—	*0.21*	
	Asphalt roll siding	—	75	—	6.50	—	*0.15*	
	Asphalt insulating siding (½ in. bd.)	—	75	—	0.69	—	*1.46*	
	Wood, drop, 1 × 8 in.	—	75	—	1.27	—	*0.79*	0.31
	Wood, bevel, ½ × 8 in., lapped	—	75	—	1.23	—	*0.81*	0.31
	Wood, bevel, ¾ × 10 in., lapped	—	75	—	0.95	—	*1.05*	0.31
	Wood, plywood, ⅜ in., lapped	—	75	—	1.59	—	*0.59*	0.29
	Aluminum or Steel[m], over sheathing							
	Hollow-backed	—	—	—	1.61	—	*0.61*	
	Insulating-board backed nominal ⅜ in.	—	—	—	0.55	—	*1.82*	
	Insulating-board backed nominal ⅜ in. foil backed	—	—	—	0.34	—	*2.96*	
	Architectural glass	—	75	—	10.00	—	*0.10*	
WOODS	Maple, oak, and similar hardwoods	45	75	1.10	—	*0.91*	—	0.30
	Fir, pine, and similar softwoods	32	75	0.80	—	*1.25*	—	0.33
	Fir, pine, and similar softwoods ... ¾ in.	32	75	—	1.06	—	*0.94*	0.33
	..1½ in.	32	75	—	0.53	—	*1.89*	0.33
	..2½ in.	32	75	—	0.32	—	*3.12*	0.33
	..3½ in.	32	75	—	0.23	—	*4.35*	0.33

Notes

[a] Representative values for dry materials is selected by the ASHRAE Committee 2.4 on Insulation. They are intended as design (not specification) values for materials of building construction in normal use. For conductivity of a particular product, the user may obtain the value supplied by the manufacturer or secure the results of unbiased tests.

[b] Resistance values are the reciprocals of *C* before rounding off *C* to two decimal places.

[c] See also Insulating Materials, Board.

[d] Includes paper backing and facing if any. In cases where the insulation forms a boundary (highly reflective or otherwise) of an air space, refer to Tables 1 and 2, to obtain the insulating value of air space for the appropriate effective emissivity and temperature conditions of the space.

[e] Conductivity varies also with fiber diameter. See also Factors Affecting Thermal Conductivity and Fig. 1, Chapter 17. Insulation is produced by different densities, therefore, there is a wide variation in thickness for the same *R*-value between various manufacturers. No effort should be made to relate any specific *R*-value to any specific thickness. The commercial thicknesses generally available range from 2 to 7 in.

[f] These are values for aged board stock. For discussion on the change in conductivity with age of Refrigerant 11 expanded urethane see Chapter 17, Factors Affecting Thermal Conductivity.

[g] Insulating values of acoustical tile vary depending on density of the board and on the type, size, and depth of the perforations. An average conductivity *k* value is 0.40.

[h] The U. S. Department of Commerce, *Simplified Practice Recommendation for Thermal Conductances Factors for Performed Above-Deck Roof Insulation*, No. R 257-55, recognizes the specification of roof insulation on the basis of the *C* values shown. Roof insulation is made in thicknesses to meet these values. Therefore, thickness supplied by different manufacturers may vary depending on the conductivity *k* value of the particular material.

[i] Face brick and common brick do not always have these specific densities. When the density is different from that shown, there will be a change in the thermal conductivity.

[j] Data on rectangular core concrete blocks differs from the above data on oval core blocks due to core configuration, different mean temperatures and possibly differences in unit weights. Weight data on the oval core blocks tested is not available.

[k] Weights of units approximately 7⅝ in. high and 15⅝ in. long. These weights are given as a means of describing the blocks tested, but conductance values are all for one square foot of area.

[l] Vermiculite, perlite or mineral wool insulation. Where insulation is used vapor barriers or other precautions must be considered to keep insulation dry.

[m] Values for metal siding applied over flat surfaces vary widely depending upon the amount of ventilation of air space beneath the siding, whether the air space is reflective or nonreflective, and on the thickness, type, and application of insulating backing-board used. Values given are averages intended for use as design guide values and were obtained from several guarded hot-box tests (ASTM C236) on hollow-backed types and on types made using backer-board of wood-fiber, foamed plastic, and glass fiber. Departures of ± 50 percent, or more, from the values given may occur.

Surface Conductances and Resistances for Air

All conductance values expressed in Btu per (hr) (sq ft) (F deg temp diff)

SECTION A. Surface Conductances and Resistances

Position of Surface	Direction of Heat Flow	Surface Emissivity: Non-reflective $\epsilon = 0.90$		Reflective $\epsilon = 0.20$		Reflective $\epsilon = 0.05$	
		f_i	R	f_i	R	f_i	R
STILL AIR							
Horizontal.....	Upward	1.63	*0.61*	0.91	*1.10*	0.76	*1.32*
Sloping—45 deg	Upward	1.60	*0.62*	0.88	*1.14*	0.73	*1.37*
Vertical.......	Horizontal	1.46	*0.68*	0.74	*1.35*	0.59	*1.70*
Sloping—45 deg	Downward	1.32	*0.76*	0.60	*1.67*	0.45	*2.22*
Horizontal.....	Downward	1.08	*0.92*	0.37	*2.70*	0.22	*4.55*
MOVING AIR (Any Position)		f_o	R	f_o	R	f_o	R
15 mph Wind (for winter)	Any	6.00	0.17				
7½ mph Wind (for summer)	Any	4.00	0.25				

SECTION B. Reflectivity and Emissivity Values of Various Surfaces[c] and Effective Emissivities of Air Spaces

Surface	Reflectivity in Percent	Average Emissivity ϵ	Effective Emissivity E of Air Space: With one surface having emissivity ϵ and other 0.90	Effective Emissivity E of Air Space: With both surfaces of emissivity ϵ
Aluminum foil, bright....	92 to 97	0.05	0.05	0.03
Aluminum sheet.........	80 to 95	0.12	0.12	0.06
Aluminum coated paper, polished..............	75 to 84	0.20	0.20	0.11
Steel, galvanized, bright..	70 to 80	0.25	0.24	0.15
Aluminum paint.........	30 to 70	0.50	0.47	0.35
Building materials: wood, paper, glass, masonry, nonmetallic paints.....	5 to 15	0.90	0.82	0.82

Conductances are for surfaces of the stated emissivity facing virtual black-body surroundings at the same temperature as the ambient air. Values are based on a surface-air temperature difference of 10 deg and for surface temperature of 70 F.

Conversion Factors to Metric (S.I.) Units

Physical Quantity	Symbol	To convert from	to	Multiply by
Length	x	inch	meter	$2.54^{*} \times 10^{-2}$
		foot	meter	$3.048^{*} \times 10^{-1}$
Area				$6.4516^{*} \times 10^{-4}$
				9.290×10^{-2}
Volume		inch	m^3	1.639×10^{-5}
		$foot^3$	m^3	2.832×10^{-2}
Temperature		Fahrenheit	Celsius	$t_C = (t_F - 32)/1.8$
Temperature difference		Fahrenheit	Kelvin	$K = (\Delta t_F)/1.8$
Pressure		inch Hg (60 F)	newton/m^2	3.377×10^{3}
Mass		lbm	kg	4.536×10^{-1}
Mass/unit area	M	lbm/ft^2	kg/m^2	4.882
Moisture content rate		lbm/ft^2 week	kg/m^2s	8.073×10^{-6}
Density	ρ	lbm/ft^3	kg/m^3	1.602×10^{1}
Thermal conductivity	k	Btu/hr ft^2 (F/inch)	W/mK	1.442×10^{-1}
U-value	U	Btu/hr ft^2 F	W/m^2 − K	5.678
Thermal resistance	R	F/(Btu/hr ft^2)	K/(W/m^2)	1.761×10^{-1}
Heat flow		Btu/hr ft^2	W/m^2	3.155
Water vapor:				
—permeability	μ	$\frac{\text{grain}}{\text{hr ft}^2 \text{ (in. Hg/in.)}}$	kgm/Ns	1.457×10^{-12}
—permeance	p, P	$\frac{\text{grain}}{\text{hr ft}^2 \text{ (in. Hg)}}$ (perm)	kg/Ns	5.738×10^{-11}

* Exact value; others are rounded to fourth place.

STANDARD ENERGY CONVERSIONS

Unit																		Abbreviation
Barrels per Day of Oil Equivalent[1]	—	—	—	—	—	—	—	—	—	—	0.003	0.013	0.02	1	2.7	18,000	470 million	BDOE
Tons of Oil Equivalent[2]	—	—	—	—	—	—	—	0.022	0.023	0.09	0.13	0.65	1	50	135	0.9 million	23 x 10^9	TOE
Metric Tons of Coal Equivalent[3]	—	—	—	—	—	—	—	0.034	0.036	0.14	0.21	1	1.5	76	209	1.3 million	36 x 10^9	MTCE
Barrels of Oil Equivalent[4]	—	—	—	—	—	0.0064	0.02	0.16	0.17	0.68	1	4.8	7.4	365	1 TBOE	6.4 million	170 x 10^9	BOE
Cubic Meters of "Average" Natural Gas[5]	—	—	—	0.027	0.09	1	2.7	25	27	106	155	745	1150	57,000	0.155 million	1 x 10^9	27 x 10^{12}	Nm^3 NG
Kilowatthours	—	—	—	0.3	1	11	29	280	293	1160	1700	8140	12,600	0.62 million	1.7 million	11 x 10^9	290 x 10^{12}	kWh
Cubic Feet of "Average" Natural Gas[5]	—	—	—	1	3.4	37.3	100	950	1000	4000	5800	27,800	43,000	2.1 million	5.8 million	37.3 x 10^9	1 x 10^{15}	ft^3 NG
Kilocalories	0.24	0.25	1	252	860	9400	25,200	0.24 million	0.25 million	1 million	1.5 million	7 million	10.8 million	530 million	1.5 x 10^9	9.4 x 10^{12}	250 x 10^{15}	kcal
British Thermal Units	0.95	1	4.0	1000	3400	37,300	1 therm	0.95 million	1 million	4 million	5.8 million	27.3 million	43 million	2.1 x 10^9	5.8 x 10^9	37.3 x 10^{12}	1 Q	Btu
Kilojoules	1	1.06	4.2	1055	3600	39,400	105,500	1 million	1.06 million	4.2 million	6.1 million	29.3 million	45.4 million	2.2 x 10^9	6.1 x 10^9	39.4 x 10^{12}	1.06 x 10^{18}	kJ

Calorific values are measured gross. Rounded equivalents only are given.

[1] Equivalents in other units are shown on a per annum basis.
[2] of 43 million Btu (~ 10,000 kcal/kg net cal. val.).
[3] of 12,000 Btu/lb = 7000 kcal/kg.
[4] of 5.8 million Btu.
[5] of 1000 Btu/ft^3 or 9400 kcal/m^3.

— = Insignificant
1 therm = 100,000 Btu
1 TBOE = 1000 BOE
1 Q = 10^{18} Btu
1 Quad = 10^{15} Btu

SOURCE: ENERGY CONVERSION EQUIVALENTS TABLE, SHELL INTERNATIONAL PETROLEUM CO. LTD.

Appendix B: Miscellaneous Data

Weather Data for Winnipeg (over a 25 yr. period)[1]

	°C.	°F.	Sunrise*	Sunset*	Recommended Settings for Outside Light Timer*	
January	-19	-2.2	8:06	5:21	8:00 am.	5:30 pm.
February	-16.5	2.3	7:15	6:09	7:00	6:00
March	- 9	15.8	6:09	6:59	6:00	7:00
April	3	37.4	6:08	8:46	6:00	9;00
May	11	51.8	5:26	9:28	5:30	9:30
June			5:23	9:42	5:30	10:00
July			5:57	8:14	6:00	8:30
August			6:42	8:16	6:30	8:30
September	12	53.6	7:27	7:10	7:30	7:00
October	6	42.8	7:17	5:08	7:30	5:00
November	- 5	23	8:05	4:31	8:00	5:00
December	-14	6.8	8:28	4:37	8:00	5:00

*Local time as of the end of each month.

Published Energy Costs in Winnipeg

Gas	As of March 1, 1978	Previous
> 200 cu. ft./mo.	$1.25 min.	$1.25
200 - 1300 cu. ft./mo.	$.2807/00 cu. ft.	$.2620
1500 - 200,000 cu. ft./mo.	$.2272/00 cu. ft.	$.2085
200,000 +	$.2128/00 cu. ft.	$.1940

Expected increases[2] January, 1979 7%

[1] Winnipeg 1977 Weather Data, Winnipeg Weather Office, Atmospheric Environment Service, International Airport, Winnipeg.

[2] Personal communication, Mr. Salo, Sales, Greater Winnipeg Gas Co., November 21, 1977.

Electricity Rates, as of April 1, 1978

1) Power Standard

Demand charge	$4.15 per kV.A
Consumption charge	$.0098 per kW.h

Monthly billing demand is the greatest of:

a) The metered demand in kV.A in the month, or
b) 80% of the greatest billing demand in the previous winter months of November, December, January, and February, or
c) 55 kV.A or
d) 25% of the contract demand.

2) General Service

Service Charge	$6.60
+	
First 1000 kW.h	$ .043/ kW.h
Balance	$ .0258/kW.h

Published Water Costs as of April 1, 1978

>9600 cu. ft.	$.72 per 100 cu. ft.	+ $.40 sewer
9600 - 96000 "	$.47 per 100 cu. ft.	+ $.40 "
96000 + "	$.34 per 100 cu. ft.	+ $.40 "

Present Value Factors

10 YEAR LIFE

Energy Price Increase	Interest Rate			
	6%	8%	10%	12%
5%	9.0	8.2	7.4	6.8
10%	11.2	10.1	9.1	8.2
15%	14.0	12.5	11.2	10.1

20 YEAR LIFE

Energy Price Increase	Interest Rate			
	6%	8%	10%	12%
5%	17.3	14.4	12.1	10.4
10%	27.4	22.2	18.2	15.1
15%	45.6	35.9	28.7	23.2

30 YEAR LIFE

Energy Price Increase	Interest Rate			
	6%	8%	10%	12%
5%	24.8	19.0	15.0	12.2
10%	50.9	36.7	27.2	20.9
15%	117.0	79.7	55.9	40.3

40 YEAR LIFE

Energy Price Increase	Interest Rate			
	6%	8%	10%	12%
5%	31.6	22.5	16.9	13.2
10%	85	54.2	36.3	25.7
15%	278.2	161.9	98.4	62.6

$$P.D.V. = \left\{\frac{1}{e-i}\right\}\left\{\frac{1+e}{1+i}\right\}^n - 1$$

(accurate to within 10%)

e=Fuel price increase above inflation
i=Interest
n=Number of years

Recommended by the Can. Dept. of Public Works, & U.S. Federal Depts.

Appendix C: Benefits of Reducing Temperature from 22.2°C. (72°F.) to 20°C. (68°F.) at William Whyte School

$$\text{Cu.ft.gas} = \frac{(T^{\circ}F.)(.018)(\text{Volume of Air, cu.ft./min.})}{(\text{Btu./cu.ft. gas @ 80\% effic.})}$$

The benefit, in units of fuel, can be found by completing the formula once for each temperature, and subtracting the results to obtain the difference.

It is necessary to calculate for normal cycle, as well as night cycle fan operation, for air volumes. The volume of outside air introduced varies, depending on the outside air temperature. Volume of air at night cycle is constant, at 2895.5 cu. ft./min. (10% of max. air volume) See data sheet, Appendix B.

Btu./cu.ft. gas = 1031

.018 = Specific heat of air x density of air

The calculation for the month of January is thus ...

$$\frac{(72 - -2.2)(.018)(8806.3)}{(1031 \times .8)} = 14.2 \text{ cu.ft./hr.} \times 60 \times 11\text{hrs.} \times 22 \text{ days}$$
$$= \underline{207{,}055 \text{ cu.ft.}} \text{ of gas}$$

$$\frac{(74.2)(.018)(2895.5)}{(1031 \times .8)} = 4.7 \text{ cu.ft./hr.} \times ((13\times22) + (24\times9))$$
$$= \underline{141{,}263 \text{ cu.ft.}} \text{ of gas}$$

207.055 + 141,263 = 348,318 cu.ft. of gas

$$\frac{(68 - -2.2)(.018)(8806.3)}{(1031 \times .8)} = 13.5 \text{ cu.ft/hr.} \times 60 \times 11 \times 22$$
$$= \underline{195{,}875} \text{ cu.ft. of gas}$$

$$\frac{(70.2)(.018)(2895.5)}{(1031 \times ,8)} = 4.4 \times 60 \times ((13 \times 22) + (24 \times 9))$$
$$= \underline{133{,}432} \text{ cu.ft. of gas}$$

195,875 + 133,432 = 329,307 cu.ft. of gas

The difference in energy consumption through reduced temperature is...

= 348,318 - 329,307

= 19,011 cu. ft. gas saved

Following the same method for each remaining month yields values of ...

January	19,011
February	17,584
March	21,902
April	27,972
May	40,256
September	40,573
October	32,277
November	22,780
December	20,147
	242,502 cu. ft. gas saved

The dollar value of the savings are ...

= 242.500 cu/ ft/ gas x $.2272/00 cu. ft.

= $550.00

Over 40 years, at 10% interest, and 10% fuel price increase, the benefit is ...

= $550.00 x 36.3 (see Appendix B)

= $19,965.00

APPENDIX D: Benefits of Increasing Night Cycle (William Whyte)

In the mechanical specifications, it is noted that Outside Air, Exhaust Air, and Return Air dampers are modulated (direct acting) to maintain a Mixed Air temperature of $13^{o}C$ ($55^{o}F$). This mixed air is then heated to the supply air temperature. Given average outside air temperatures for each month, and return air temperatures of $27^{o}C$ ($80^{o}F$) it was possible to calculate the amount of outside air per minute introduced per minute, for each month. The following equation for January was followed for each of the remaining heating season months, February, March, April, May, September, October, November, and December.

(Outside air temp. X Volume of air) + (Return air temp. X Volume of Return air) = (Mixed air temp. X Volume of Mixed air ie. total capacity of supply fans).

January $(-2.2^{o}F\ X) + 0^{o}F\ Y) = (55^{o}F\ X\ 28955\ c.f.m.)$

$$(-2.2\,x) + (80y) = 1592525 \qquad Y = \text{Return Air}$$
$$x + y = 28955 \qquad X = \text{Outside Air}$$
$$2.2x + 2.2y = 63701$$
$$82.2y = 1656226$$
$$y = 20148.7\ \text{cfm}$$
$$x = 8806.3\ \text{cfm}$$

The volume of outside air normally introduced is 8806.3 cfm. The difference between this, and the volume at "night cycle," (10% of normal volume) 2895.5 cfm, is 5910.8 cfm. This represents the savings in volume of air which must be heated, each minute the fan system is set at "night cycle."

The following formula is used to determine energy consumption:

((Inside temp. - outside temp.) X (specific heat of air) X (density of air) X (volume of air)) / (heating value of heating fuel) X (efficiency of heating mechanism).

$$\text{January} = \frac{(72 - -2.2^{o}) \times (.24\ \text{Btu/lb}) \times (.075\ \text{lb./ft.}^{3}) \times (5910.8\ \text{cfm})}{(1031\ \text{Btu/cu.ft. gas}) \times (80\%\ \text{efficiency})}$$

$$= \frac{(74.2) \times (.018) \times (5910.8)}{824.8}$$

$$= 9.57\ \text{cu.ft. gas/min.}$$

In one month period, the value is ...

= 9.57 X 60 min./hr. X 88 hrs. saved in the month

= 50537 cu. ft. gas

This exercise is repeated for each month in the heating season, (varying air volumes, temperatures, and hours of operation) with the follwoing results ...

	Volume of outside air (cf).	Volume of gas. (cf).
January	8,806.3	50537
February	9,316.3	46880
March	11,275.3	54266
April	16,992.4	53648
May	25,669.3	53008
September	27,419.5	49632
October	19,459.0	55730
November	12,699.6	52839
December	9,889.0	52541
		Total 469,081 c.f.

469,081 @ $.2272/00 cubic ft.

= $1066.00 savings in one heating season (April 1978 prices).

Appendix E: Air Loss Through Entrances (St. George)

Given:
- Air loss during average vestibule door use is 6.5 c.f.m. per square foot of door area
- Air loss through a door standing open is 700 c.f.m. with no vestibule, and 500 c.f.m. with a vestibule.*
- 480 students

Assumptions:
- 36" x 84" door
- 7½ m.p.h. breeze
- door is open 5 seconds for each entry
- traffic is evenly dispersed

With Vestibule:

Volume of air lost when traffic moves through 8 doors over 10 min.

= 6.5 cfm./sq. ft. area* x 21 sq. ft. x 10 min. x 8 doors
= 10920 cu. ft.

Volume of air lost when traffic moves through 8 doors over 20 min.

= 6.5 x ½** x 21 sq. ft. x 20 min. x 8 doors
= 10920 cu. ft.

Volume of air lost when traffic moves through 2 doors over 20 min.

= (480 students ÷ 20 min.) ÷ 2 doors = 12 students/door/min.
60 sec./min. ÷ 12 students/min. = 1 student every 5 seconds, since the door (according to assumption, takes 5 seconds to open and close) is open continuously.

Thus, 500 c.f.m./door x 2 doors x 20 min. = 20,000 cu. ft.

Non-Vestibule Doors:

Volume of air lost when traffic moves through 2 doors over 15 min.

= (480 students ÷ 15 min.) ÷ 2 doors = 16 students/door/min.

60 seconds/min. ÷ 16 students/min. = 3.75 sec. cycles

At 3.75 sec. cycles, and the door taking 5 seconds to close, it is open continuously.

Thus, 700 c.f.m./door x 2 doors x 15 min. = 15,000 cu. ft.

The remaining calculations are based on the same equation.

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* Carrier Air Conditioning Manual, Carrier Air Conditioning Distributors co. Ltd., p. 1-91.

** Assume, since time is doubled, traffic would be halved.

Appendix F: Switching of Interior Lighting (William Whyte)

1) Recess = 15 min.

   Lunch = 75 min. Daily classes 8:30 am. - 4:00pm. (7½ hrs.)

   Recess = 15 min.

   One hour period after 4:00pm., until custodian turns off lights equals 60 min.

   Total time per day in which lights could be switched off = 2.75 hrs.

2) Classes in session for 10 months, with an average of 21 days/mo. equals 210 days per year in which lights could be switched off.

3) Lights which can be switched off for the 2.75 hr. period...

Nursery	18 * 4	(fixtures * no. of tubes)
Kindergarten	30 * 4	
Gr. 1 Class	24 * 4	
Crafts Room	16 * 4	
Multi purpose Room	17 * 4	
Second storey lights	190* 4	
Total:	295 * 4 * 200W. ea. = 59000 Watts	

4) Lights on only during the 2.75 hr. period (ie. off for 5.75 hrs.)...

Staff Room	8 * 4
Second storey perimeter lighting	26* 4
Total:	34 * 4 * 200W. ea. = 6800 Watts

5) Lights which can be switched off all day (one classroom is off at any one point of time in the day, due to phys. ed., etc.) (ie. off for 7.5 hrs.)

   Total: 30 * 4 * 200W. ea. = 6000 Watts

   In one year, savings are ...

   ((59000 x 2.75 hrs./day) + (6800 x 5.75 hrs./day) + (6000 x 7.5 hrs./day)) x (210 days/ year) = 51744 kW.h/yr.

   51744 kW.h * $.0098/kW.h = $507.00 per year

Appendix G: Reducing Operation of Exhaust Fans (William Whyte)

Month	Reduced Gas Consumption (cu. ft.)
January	248930
February.	223811
March	180462
April	111103
May	64863
September	59083
October	93763
November	157342
December	280993
Total:	1420350 cu.ft. @ $.2272/00 cu. ft.
	$3227.00

Total savings are...

$3230 + $49.00 (elect.consumption of motors) = $3280.00

Appendix H: Insulation of Heating Pipes (St. George)

The heat savings for each section of the school were summed to provide a total heat savings...

Section	Heat Savings (Btu. per Hour)
North	149809
Steam to South Section	25245
Central	114337
South	62760
Total:	352151 Btu./hr.

Hourly gas consumption ...

= 352151 Btu. ÷ (1031 Btu./cu.ft.gas * 80% efficiency)

= 427 cu. ft. per hr.

Total annual consumption = 427 cu.ft./hr. * 12 hrs./day * 30 days/mo. * 6 months intermittent operation

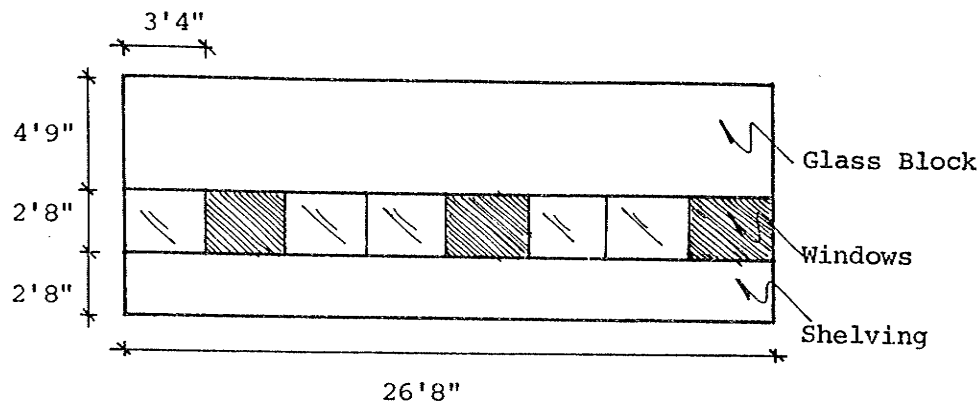
= 922,216 cu. ft. gas

Annual savings are = 922216 cu.ft. * $.2272/00 cu.ft.

= $2095.00

Appendix J: Caulking and Weatherstripping (St. George)

Assumptions: - 10 m.p.h. breeze
- Inside temp. = 20°C. (68°F.)
- Outside temp. = -7°C. (20°F. Design temp.)



Frame - 58.8 lineal ft.

Window - 85.6 lineal ft. (casement = 32.1', sash = 53.5')

Wall with no caulking = frame + casement + sash

= ((58.8)(6)(68-20)(.018)) + ((32.1)(7)(68-20)(.018)) + ((53.5)(8)(68-20)(.018))
= 1090.8 Btu./hr.

Wall with caulking

= ((58.8)(6)(68-20)(.018)) + ((32.1)(7)(68-20)(.018)) + ((53.5)(2)(68-20)(.018))
=591.3 Btu./hr.

The difference is 1090.8 - 591.3 = 499.5 Btu/hr.

Fuel consumption is

= 499.5 ÷ (1031 Btu./cu. ft. gas @ 80 % efficiency)
= .6 cu. ft. gas per hour

Over one heating season ...

= .6 cu. ft. /hr. x 24 hrs./day x 30 days/mo. x 9 mos.
= 3888 cu. ft. gas

The cost is ...

= 3888 cu. ft. @ $.2272 per hundred cu. ft. gas
= $8.83 per year, per room
= $8.83 x 23 classrooms
= $203.00 yr.

The cost of caulking is ...

= 144 lineal ft. per class x 23 classrooms

One tube of Vulkan caulking will cover 165 lineal feet with a 3/8" x 3/8" bead, and last for 20 yrs.*

= 3,312 lin. ft. ÷ 165 ft.
= 20 tubes @ $3.73 per tube
= $75.00

It is estimated that caulking would require two man days at $40.00 per day, for a sum of $80.00

= $80.00 + $75.00
= $155.00

The benefits of caulking, over 20 years, amount to ...

= $203 x 18.2 (Appendix B)
= $3695.00

Net benefits are ...

= $3695.00 - $155.00
= $3540.00

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* Gary, personal comm., Johnson Construction Materials, Wpg., Feb. 1/78

APPENDIX K: DOUBLE GLAZING

Given: Same wall as used in "Caulking and Weatherstripping," (Appendix J), and same assumptions.

Assumptions: Adding a second light of glass has same effect on heat loss as adding a storm window

1. Infiltration Losses ...

   Single glazed

   = 1090.8 Btu/hr.

   Double glazed

   = frame + casement + sash

   = ((58.8)(6)(68-20)(.018)) + ((32.1)(7.5)(68-20)(.018))
   + ((53.5)(4)(68-20)(.018))

   = 304.8 + 208 + 184.9

   = 697.7 Btu/hr.

2. Heat Transfer

   Single glazed

   = UA (Tin. - Tout.) glass + wall

   = (1.13 (199 sq.ft.) (68-20)) + ((.133)(132)(68-20))

   = 10793.8 + 842.7

   = 11,636 Btu./hr.

   Double glazed

   = (.56 (199)(68-20)) + (.133(132)(68-20))

   = 5349 + 842.7

   = 6,192 Btu/hr.

   Single glazed = Infiltration Loss + Heat Transfer
   = 1090.8 + 11,636
   = 12,727 Btu/hr.

   Double glazed = 697.7 + 6,192
   = 6890 Btu/hr.

The savings by adding a second light of glazing is (12727 - 6890) = 5,837 Btu/hr.

Fuel consumption = 5,837 Btu/hr. ÷ (1031 Btu/cu.ft. gas @ 80% eff.)

= 7.07 cu.ft. gas/hr.

Over the heating season ...

= 7.07 X 24 hrs./day X 30 days/mo. X 9 mos.

= 45,813 cu.ft. gas.

Yearly savings are thus

= 45,813 cu.ft. X $.2272/00 cu.ft.

= $104.00 per year, per classroom.

Over a thirty year period, at 10% interest, 10% fuel price increase above inflation, present value is ...

= $104.00 X 27.2 (Appendix B)

= $2830.00 per classroom.

Glass for one classroom is roughly estimated at $400. (see wall retrofit analysis) Labour for installation is estimated at 2 man days, at $7.00/hr. * This amounts to $120. Total costs are thus $520 per classroom. Net benefits are ($2830 - $520) = $2310. per classroom for adding a second light of glazing over existing single glazing.

* Personal communication, Gord Edmunds, Mar. 3, 1978.

APPENDIX L: DELAMPING

Normal operating times ...

1.	Corridors	8:00 am	-	12 midnight	= 16 hrs./day
2.	classes, etc.	8:30 am	-	4 pm.	= 7½ hrs./day
3.	staffroom	8:15 am	-	4:15 pm	= 8 hrs. /day
4.	gym	8:30 am	-	6:00 pm	= 9½ hrs./day

- 2 fluorescent tubes + ballast = 100 Watts.
- Present peak electrical load = 229 kW.

NO. OF FIXTURES DISCONNECTED X WATTAGE		FUNCTION
1.	14 X 100 = 1400 Watts	corridors
2.	3 X 100 = 300	office (2nd floor)
	22 X 100 = 2200	seminar rooms (2nd floor)
	2 X 100 = 200	office (main floor)
	19 X 100 = 1900	Grade 1
	21 X 100 = 2100	Kindergarten
	12 X 100 = 1200	Nursery
	17 X 100 = 1700	M.P.R. fluorescent (switched)
	10 X 150 = 1500	M.P.R. incan. pots (switched)
TOTAL:	11,100 Watts	
3.	8 X 100 = 800 Watts	staffroom
4.	8 X 500 = 4000 Watts	gym incandescents (switched)

1.	1400 X 16 hrs./day	= 22.4 kWh.
2.	11,100 X 7.5 hrs./day	= 83.25 "
3.	800 X 8 hrs./day	= 6.4 "
4.	4000 X 9.5 hrs./day	= 38.0 kWh

TOTAL: 17,300 W.

TOTAL: 150 kWh./day

Over the school year ...

= 150 kWh/day X 21 days/mo. X 10 mos.

= 31500 kWh/year.

Consumption billing ...

= 31500 kWh X $.0098 kWh

= $308

Demand billing ...

17300 W = 17.3 kW represents a fraction of the total peak electrical load. A crude calculation of demand is ...

$$\frac{17.3 \text{ kW}}{229 \text{ kW}} = 7.5\% \text{ of total peak electric load at the school}$$

In 1977, the "demand" portion of the electric bill was $5840. Since 7.5% of this peak is "shaved off" by disconnecting lighting, an estimation of savings is ...

= 7.5% X $5840

= $438.

Total savings are thus $438 + $308 = $750 year.

Appendix M: Present Value Savings of Combined Measures (William Whyte)

The effect of all conservation measures applied at one time is not simply the sum of the individual measures. The measures offset each other, to a small extent. The reduced benefits, determined simply be revising the inputs of the formulae previously used, are indicated below. Benefits are discounted over a building life of 40 years.

CATEGORY	MEASURE	IMPLEMENTATION	
		INDIVIDUAL	COMBINED
USE	Reducing Temperature	$19965.	$12973.
	Extending "Night Cycle"	$38696.	$31280.
	Switching Interior Lights	$18404.	$13477.
O.+M.	Switching Exhaust Fans	$1190640.	$97524.
	Switching of Exterior Lighting	$1525.	$1352.
	Reducing Domestic Hot Water Temp.	$2723.	$2444.
CONST'N.	Delamping	$27225.	$24100.
	Total:	$227,602.	$183,150

It is estimated that, to accomplish these measures, 10 man days of labour are required...

= 10 days x $80.00/day

= $800.00

Net benefits are thus ...

= $183,150 - $800.00

= $182,350

Appendix N: Energy Questionnaire
(Numbers represent no. of teachers checking that item.)

St. George (95% response from staff)

1. In class, I usually feel
   6 too cool.
   5 too warm.
   6 just right.

2. I generally wear a sweater or extra clothing.
   9 Yes
   8 No

3. I think it is worthwhile to conserve energy by turning out room lights, when leaving the room for:
   12 more than 10 minutes.
   3 more than 20 minutes.
   2 more than 1/2 hr.
   ___ the day.

4. I turn out lights accordingly.
   16 Yes
   ___ No

5. I leave lights on for the caretakers.
   3 Yes
   13 No

6. I would be more inclined to conserve energy: (rank 1,2,3, etc.)
   ___ if it would save me money.
   ___ knowing that it would increase efficiency of energy use.
   ___ knowing that more energy would be available for future users.
   ___ other (comment)

7. Students complain about lighting conditions.
   ___ often
   3 seldom
   14 never

8. Students complain about temperature,

Summer _8_ often.
_8_ seldom.
_1_ never.

Winter _4_ often.
_10_ seldom.
_3_ never.

9. If energy conservation measures became necessary at some time, they should be taught:

_16_ in schools.

_14_ in the home.

10. I think that the window area in the room(s) in which I teach should be:

_7_ increased.

_1_ decreased.

REASONS: _9_ left the same.

- save electricity
- decrease - reduce heat in summer
- feel like a mole
- living in a closed box is not pleasant
- for more ventilation
- has few windows - wants left same

11. I would like electric lighting levels: ___ increased.

REASONS: ___ decreased.

_16_ left the same.

12. Ventilation in the school is: _6_ adequate.

_9_ inadequate.

13. I sometimes find it necessary to open the windows:

_15_ in the summer.
_6_ in the winter.
_1_ never.

WILLIAM WHYTE (90% response from staff)

1. In class, I usually feel 4 too cool.
   6 too warm.
   10 just right.

2. I generally wear a sweater or extra clothing. 14 Yes
   7 No

3. I think it is worthwhile to conserve energy by turning out room lights, when leaving the room for:
   9 more than 10 minutes.
   4 more than 20 minutes.
   3 more than 1/2 hour.
   2 the day.

4. I turn out lights accordingly. 13 Yes
   5 No

5. I leave lights on for the caretakers. 5 Yes
   13 No

6. I would be more inclined to conserve energy: (rank 1,2,3, etc.).
   ___ if it would save me money.
   ___ knowing that it would increase efficiency of energy use.
   ___ knowing that more energy would be available for future users.
   ___ other (comment) - hate being cold.
   - everyone involved does his share of conservation.

7. Students complain about lighting conditions,
   ___ often.
   6 seldom.
   13 never.

8. Students complain about temperature,

Summer
- 6 often.
- 7 seldom.
- 3 never.

Winter
- 3 often.
- 9 seldom.
- 5 never.

9. If energy conservation measures became necessary at some time, they should be taught:
- 18 in schools.
- 10 in the home.

10. I think that the window area in the room(s) in which I teach should be be:
- 11 increased.
- ___ decreased.
- 5 left the same.

REASONS:
- Adequate.
- Has no windows.
- Allow using only natural lights.
- With no windows you are isolated.
- Need for natural lights.
- Less lights required.

11. I would like electric lighting levels:
- 1 increased.
- 1 decreased.
- 16 left the same.

REASONS:
- Satisfactory.
- Like to be able to reduce to 1/2 level, for certain activities is too bright.
- Very severe, hard on the eyes.

12. Ventilation in the school is:
- 7 adequate.
- 10 inadequate.

13. I sometimes find it necessary to open windows:
- 18 in the summer.
- 9 in the winter.
- ___ never.