Analysis of Energy Conservation Options

prepared for

Canada Mortgage and Housing Corporation

by
Anne Beamish

May 1981

TABLE OF CONTENTS

INTRODUCTION

The purpose of this report is to review the state-of-the-art and background technical information for a variety of energy gain and conservation equipment and in particular the equipment or devices for which information has been collected in the "Energy Conservation Equipment Information File". For each device or piece of equipment, the report looks at what is available for the homeowner, the costs, and the potential savings, and a life-cycle analysis to assess the long term economic viability.

This report is not intended to be a definitive treatment on the economics of the energy conservation devices considered. Rather, it is intended to serve as a preliminary assessment of viability; the figures presented should only be considered as an order of magnitude since in all calculations, many assumptions both technical and economic have to be made and these may not hold true in all situations.

The information used in this report was obtained from a wide variety of sources ranging from books, reports and documents, to contacts with informed officials from the private and public sector, however, most of the information came from the "Energy Conservation Equipment Information File". The calculations therefore can be considered only as accurate as the information available from these sources.

This report was produced under a small contract ($3,325) funded by Part V for the Demonstration and Analysis

Division. The objective of the contract was to collect, organize and present in a written report format, information on state-of-the-art of energy conservation products and to outline how these products may be applied toward improving residential energy conservation as well as an estimation of the likely range of energy savings. The information was to come from the Energy Conservation Equipment Information and Resource Inventory which is a collection of general and product information relating to energy conservation equipment. This inventory was produced under a prior contract.

All figures in this report are in metric units with imperial equivalents given in brackets.

SUMMARY

The objective of this report is to review information on the state-of-the-art of energy conservation and gain products and equipment relating to those categories for which information was collected in the "Energy Conservation Equipment Information File", and to outline how theseproducts and equipment may be applied toward improving residential energy conservation.

Due to the time and budget constraints on the project, the extent of this analysis was restricted to twenty-one of the most common energy conserving products or techniques available to the homeowner.

The approach to this study consisted of collecting manufacturers' information, analyzing the product information and relevant literature to project the likely range of energy savings, and estimating the life-cycle cost of each device when implemented in a sample "typical" house.

Each product or device presented is discussed noting operating characteristics, current costs, expected energy savings, projected changes in the fuel consumption when applied to the example house, life-cycle savings and the life-cycle benefit/cost ratio. Detailed calculations for each feature are to be found in the appendices following the text.

The following is a summary chart of annual fuel savings and life-cycle benefits and costs, resulting in a life-cycle savings and benefit/cost ratio. The twenty-one features or techniques have been ranked according to their benefit/cost ratio.

OPTION	Savings per Year $	Unit Cost $	Total Cost $	Life-Cycle Expenses (present value) $	Life-Cycle Benefits (present value) $	Life-Cycle Savings (present value) $	B/C Ratio
Thermostat Set Back (manual)	170	0	0	0	1751	1751	1751
Hot Water Tank Thermostat	150	0	0	0	1545	1545	1545
Shower Restrictor	75	20	20	21.60	773	751	38.55
Hot Water Tank Insulation	40	-	15	17.50	412	394	27.30
Faucet Restrictor	5.50	3	3	3	57	54	19.00
Toilet Tank Dam	18.25	10	10	10	188	178	18.80
Thermostat Set Back (programmable)	170	100	100	100	1751	1651	17.51
Furnace Improvements /Maintenance	151	-	100	343	1555	1212	13.12
Weatherstripping	120	.82/m	51	102	1236	1134	12.57
Weatherstripping and Caulking	238	7/tube	156	215	2451	2236	12.01

OPTION	Savings per Year $	Unit Cost $	Total Cost $	Life-Cycle Expenses (present value) $	Life-Cycle Benefits (present value) $	Life-Cycle Savings (present value) $	B/C Ratio
Pipe Insulation	19	1/m	50	54	196	142	3.82
Wood Stove	567	-	1000	4562	6050	1488	2.88
Insulation	396		2500	2702	4614	1912	1.96
Interior Storm Windows	201	$70/m^2$	1050	1135	2070	935	1.89
Foil Thermal Blinds	111	$43/m^2$	645	697	1143	446	1.69
Bubble Film	69	$16/m^2$	240	479	650	171	1.37
Reflective Film	56	$27/m^2$	400	432	577	145	1.36
Thermal Shutters	103	$50/m^2$	750	811	1061	250	1.33
Air to Air Heat Exchanger	104	-	700	858	1071	213	1.30
Fibrefill Thermal Blinds	94	$75/m^2$	1125	1216	968	0	.78
Windows	228	500	7500	7784	3919	0	.35
Heat Pump	1135	-	3000	14,933	12,319	0	.10

ECONOMIC ANALYSIS

There are two methods which will be used for the financial analysis in this report; Life-Cycle Savings and Benefit/Cost Analyses. The total life cycle costing technique is effective for determining if a conservation feature will save more than it costs over the years and for finding the most economically efficient size of an investment. However, it is not dependable for allocating a limited budget among competing conservation investments to obtain the highest net savings for the entire budget, because it does not distinguish between a costly project with a given net savings and a less costly project with the same net savings. The Benefit/Cost Ratio technique offers an advantage by providing a measure that can be used to rank alternative projects to determine the most profitable group of investments for the investor with a limited budget.

The principal feature of life-cycle analysis is that all costs and benefits are weighed to their present value in today's dollars. The weighting function is a compound interest formula based on the rate of return or discount rate (d%), the interest rate (i%) or price escalation of energy (e%), and the life-cycle period (N years). The choice of these variables plays an important role in the analysis and must be based on reasonable expectations.

In this report, it is assumed that over a ten year life-cycle period (N=10), the average rate of inflation, price escalation rate for non-renewable energy (oil, gas and electricity) and the discount rate will be: i=12%, e=18% and d=14% respectively. The present value multipliers are found in specially formulated charts with the corresponding figures. (See A-02)

The following is a general formula for finding the total life-cycle savings where all costs are in present value or annual value dollars:

TLCS	=	LCB	-	LCE
Total Life - Cycle Savings		Life-Cycle Benefits		Life-Cycle Expenses

where life-cycle benefits consist of fuel savings plus the estimated resale or salvage value at the end of the life-cycle period, and life-cycle expenses include initial cost, operating cost, maintenance and repair costs and replacement cost where applicable.

The following is a general formula for computing the ratio of savings to costs where all costs are in life-cycle present value or annual value dollars:

$$\text{Benefit/Cost Ratio (B/C)} = \frac{\text{(fuel savings)} - \text{(operating costs)} - \text{(maintenance costs)}}{\text{(initial cost)} - \text{(salvage value)} + \text{(replacement cost)}}$$

The life-cycle analysis for each conservation feature, device or piece of equipment can be found in the appendices (A-07 to A-28)

References

(1) Beach, R.K. National Research Council. Life Cycle Cost Equations. Building Research Note No. 150. Ottawa: NRC.

(2) U.S. Department of Commerce. Energy Conservation in Buildings: An Economic Guidebook for Investment Decisions. NBS Handbook 132. Washington, D.C.: GPO, 1980.

THE EXAMPLE HOUSE

The house that has been chosen to note the changes in the fuel bill following the addition of various energy conservation devices and features is a 110 m^2 (1200 ft^2) house built between 1950 and 1960 and is situated in a 4400°C (8000°F) degree day climate. The windows are single glazed with storms, the walls and roof are insulated to R 1.76 (R 10) and R 1.9 (R 11) respectively; the basement is uninsulated and the furnace has an efficiency of 65%.

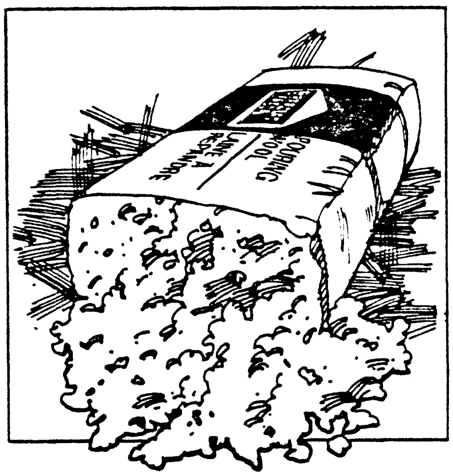
The heat loss is calculated to be about 131,000 MJ (1.24×10^8 Btu) per heating season and the fuel consumption is 5160 litres (1135 gal) of #2 fuel oil per season which was about the "average" consumption for single family homes in late 1975. (See A-06)

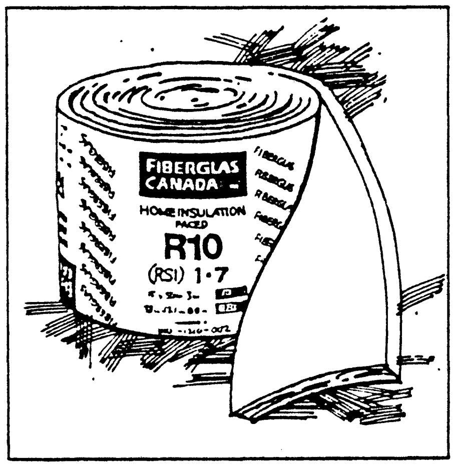
INSULATION

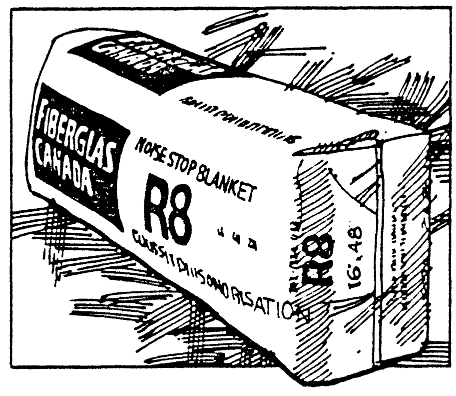
There are four broad categories of residential insulation materials available. They include:

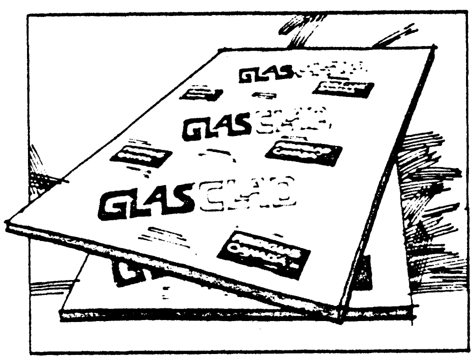
Mineral	- fiberglass
	- rock wool
	- vermiculite
	- perlite
Organic	- cellulose
	- cotton
	- cork
Plastic	- styrofoam
	- urethane
Resin	- urea foam

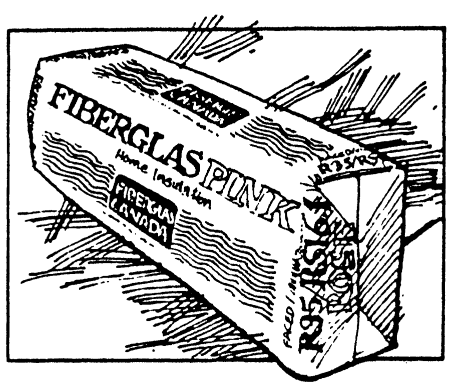
These materials come in various forms, from loose fill and batts to rigid board and foam. Mineral products are the best known and most widely used, fibreglass being the most common, but organic materials, specifically cellulose fibre, has become almost as popular because of its low cost, availability and good insulating properties. Though some of the plastics and resins have excellent insulating values, there have been concerns about both their flammability and the potential health hazards caused by the gas released as the foam cures. On 18 December 1980, Health and Welfare Canada announced a temporary ban on the use of urea formaldehyde insulation; homes insulated after this date will not be eligible for Canadian Home Insulation Programme grants. The state of technology of insulation material is well advanced and it appears

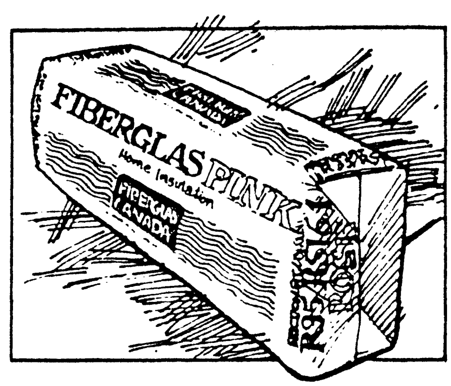



FIBERGLAS CANADA
HOME INSULATION
FACED
R10
(RSI) 1·7


FIBERGLAS CANADA
NOISE STOP BLANKET
R8




FIBERGLAS PINK
Home Insulation
FIBERGLAS CANADA


FIBERGLAS PINK
Home Insulation
FIBERGLAS CANADA

unlikely that the insulating properties will be substantially increased in the near future. (1, 2, 12)

The insulating ability varies with the type of material. Fiberglass batt has an approximate R value of 0.022/mm (R 3.2/in) and loose cellulose fibre has an R value of 0.025/mm (R 3.6/in) depending on the paper, chemical mix and applied density. The plastics and resins usually have higher R values, usually about 0.032/mm (R 4.6/in) and sometimes as high as 0.042/mm (R 6/in). (3, 4, 13)

When upgrading an existing house, the amount of insulation that can be added is often limited by its construction, especially in the case of exterior walls. New buildings can be designed to incorporate virtually any level of insulation. Building walls constructed today are often made with 50 mm x 150 mm (2" x 6") studs and some even have staggered studs in order to provide additional space for very high levels of insulation. (6)

Throughout Canada, considerable research has been undertaken and much information has been published concerning the energy savings with improved insulation. It is very difficult to make accurate predictions regarding the expected savings because of the number of variables involved. The savings will depend on the age, size and design of the house, the construction materials, the level of insulation "before" and "after", the internal temperature, the area of exposed walls, the presence of a basement and the climatic zone in which the building is located. But in spite of the variables, some approximate "rules of thumb" exist for expected savings of a "typical" Canadian house brought up to federal standards. They are: 10% to 20% fuel savings for an insulated attic, 15% to 30% for upgraded walls and savings of 15% to 25% for insulating a basement, giving a total annual fuel saving of 30% to 50%. (3, 4, 9, 11)

Costs also vary from house to house, depending on the amount of work done, the materials used and who it is done by; the homeowner or a contractor. An estimate for completely insulating an average, poorly insulated Canadian home should be between $1500 and $3000 (not including any federal insulation grant). (11)

In the case of the example house, upgrading the insulation will save a considerable amount on the annual fuel bill. If the basement, attic and exterior walls are insulated and the air infiltration is consequently reduced, the homeowner will save 1800 litres (396 gal) or $396 each year. Assuming the total job costs $2500 (no federal home insulation grant taken into account), the life-cycle savings will amount to $1900 over ten years and the benefit/cost ratio will be 1.96. (See A-07)

OPTION	Savings per Year $	Unit Cost $	Total Cost $	Life-Cycle Expenses (present value) $	Life-Cycle Benefits (present value) $	Life-Cycle Savings (present value) $	B/C Ratio
Insulation	396		2500	2702	4614	1912	1.96

References

(1) Canada Energy Mines and Resources. Enersave Advisory Service. Insulation Summary. Ottawa: EMR.

(2) Canada Energy Mines and Resources. Enersave Advisory Service. Urea Formaldehyde Foam Insulation Update. Ottawa: EMR, January 1981.

(3) Canada Energy Mines and Resources. Office of Energy Conservation. Keeping the Heat In. Ottawa: EMR, 1976.

(4) Canada Mortgage and Housing Corporation. The Conservation of Energy in Housing. Ottawa: CMHC, 1977.

(5) Canada Mortgage and Housing Corporation. Thermal Insulation - A CMHC Technical Summary. Ottawa: CMHC, 1977.

(6) Housing and Urban Development Association of Canada. Builders' Guide to Energy Efficiency in New Housing. Toronto: HUDAC, 1980.

(7) National Association of Home Builders Research Foundation Inc. Insulation Manual - Homes Apartments. Rockville Maryland: NAHB, 1971, 1979.

(8) National Research Council of Canada. Measures for Energy Conservation in New Buildings. NRCC No. 16574. Ottawa: NRC, 1978.

(9) Scanada Consultants. Effect of High Levels of Insulation on the Heating Fuel Consumption of Canadian Houses. Prepared for Housing and Urban Development Association of Canada.

(10) Stephenson, D.G. Division of Building Research, National Research Council of Canada. Determining the Optimum Thermal Resistance for Walls and Roofs. Building Research Note No. 105. Ottawa: NRC, 1976.

(11) Toller, Brian. "Banking on Insulation." Canadian Renewable Energy News. May 1980, pp. 27.

(12) Wolfe, R. and Peter Clegg. Home Energy for the Eighties. Charlotte, Vermont: Garden Way Publishing, 1979.

(13) Product Information from the Energy Conservation Equipment Information File: 07 Insulation.

WEATHERSTRIPPING AND CAULKING

In most Canadian homes, air change ranks as the largest contributor to heat loss, accounting for 22% to 30% of the annual heating load. Under a 25 km/h (15 mph) wind, a typical house will undergo one to four complete air changes per hour through infiltration. In contrast, a well-sealed house may only undergo one half air change per hour. Though the fuel savings would be large if the air change rate were reduced to this level in an older house, it could lead to problems unless the sources of interior moisture are controlled. (1, 2, 5, 6)

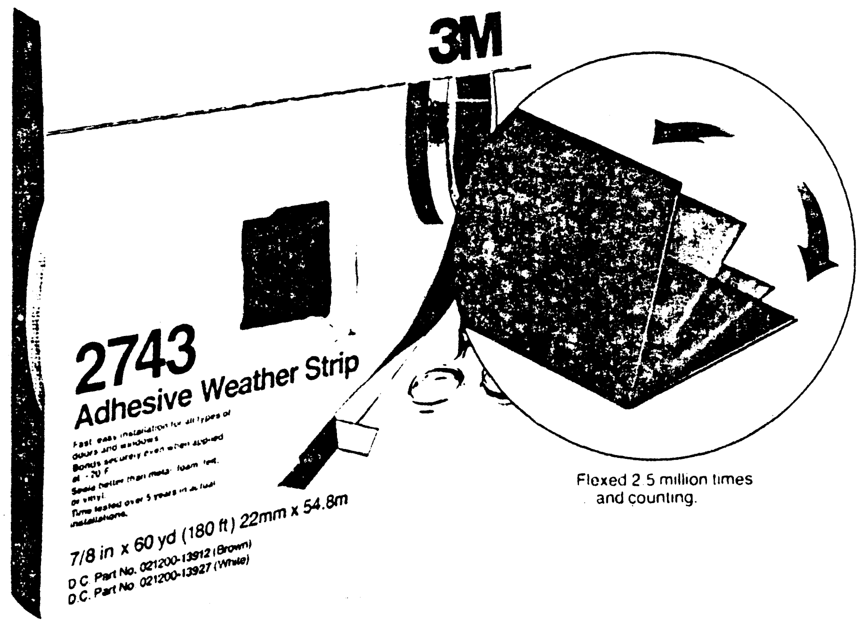
Ontario Hydro tests indicated that the main sources of air leakage were window and door seals, openings for plumbing and wiring, gaps in the exterior sheathing, porous concrete, chimneys and fireplaces. Of these sources, windows and doors are less significant contributors than is usually thought, accounting for 20% to 50% of the total air change. Ceilings account for about 20% and exterior walls can account for up to 60%. (2)

Caulking should be used in all visible cracks through which air might penetrate, ie., the corners of the building, where the walls meet the roof and foundation, around outdoor water faucets and electrical outlets, and around holes for electric, telephone, and TV antenna lines. (3, 6)

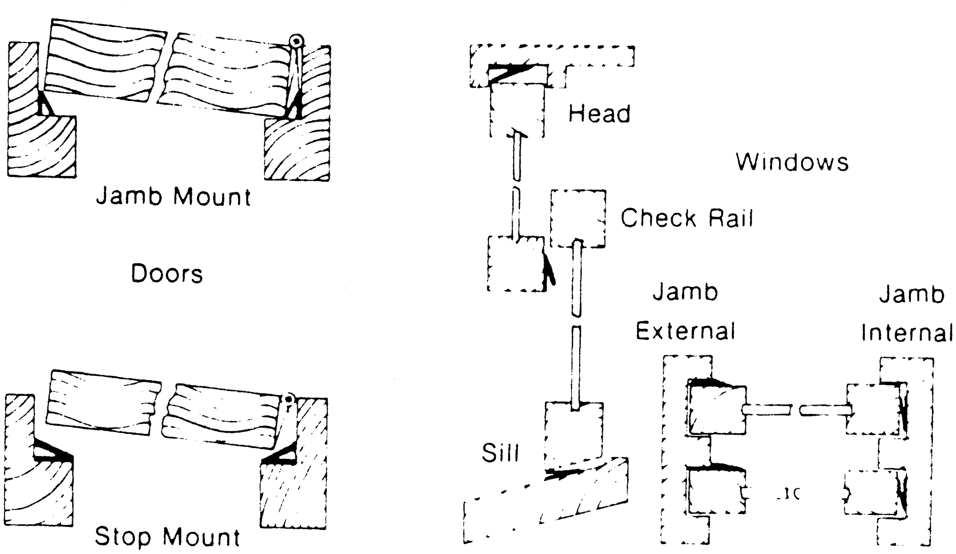
There are several types of caulk available; most come in tubes that will lay a bead of 7.5 m (25 ft). Silicone, acrylic latex and polyurethane are the most expensive at about $7 per tube but they are easy to apply and will last at least 10 years (some manufacturers claim 20 years). Vinyl or butyl rubber caulk lasts only 2 to 5 years and oil-based caulk, though the cheapest at $1.50 per tube, has an even shorter life. A new type of caulking that is now being used in the home is urethane foam; it comes in an aerosol can and when applied, it foams and fills the crack. (3, 5, 8)

Different types of weatherstripping are used in different situations. The most common types are the self-sticking foam tapes (open cell polyurethane, closed cell vinyl, neoprene sponge and sponge rubber) which come in several lengths, widths and thicknesses. In spite of its short life, it is inexpensive at $0.23/m to $0.43/m ($0.07-$0.13/ft.) and easy to install. (3, 5, 8)

Several new types of weatherstripping have appeared on the market which are superior in some ways to the older methods. The traditional bronze strip is both effective and durable but it is also expensive and sometimes difficult to install. A similar weatherstripping made of polypropylene that has been scored along the centre line to form a "V" shape with an adhesive on one leg is now available. These weatherstrippings can be quickly and easily installed without special tools and cost about $0.82/m ($0.25/ft). Unlike foam strippings which



Typical Weatherstrip Applications



deteriorate quickly, these new plastic strippings have a much longer life; one has a guarantee of 5 years. (5, 8)

If air leakage through the windows and doors accounts for 40% of the heat loss from air change in the example house, it represents a loss of 21,900 MJ per season, equivalent to 860 litres (190 gal) of fuel oil per season or $190. If the weatherstripping stops 60% to 65% of this loss, $120 per season will be saved.

If both weatherstripping and caulking were added to the example house to reduce the air change rate to one half air change per hour, there would be an annual saving of 27,400 MJ, equivalent to 1080 litres (238 gal) of fuel oil per season or $238.

To weatherstrip the windows and doors of the example house approximately 62 metres will be needed, which at $0.82/m ($0.25/ft) will cost about $51. To caulk the foundation, roof, walls and miscellaneous cracks, about 115 metres of caulking will be needed or at 8 metres per tube, 15 tubes. At $7 per tube, the caulking will cost approximately $105. It is assumed in this report that the caulking and weatherstripping are done by the homeowner so that labour charges do not apply.

Both weatherstripping and caulking produce excellent results in saving energy for the investment. Weatherstripping alone over a 10 year period will cost $100 and save $1236 in present value dollars, giving a benefit/ cost ratio of 12.57. (See A-08).

Caulking and weatherstripping the example home will cost $215 and save $2451 over 10 years in present value dollars, giving a benefit/cost ratio of 12.01. (See A-09).

OPTION	Savings per Year $	Unit Cost $	Total Cost $	Life-Cycle Expenses (present value) $	Life-Cycle Benefits (present value) $	Life-Cycle Savings (present value) $	B/C Ratio
Weatherstripping	120	0.82/m	51	102	1236	1134	12.57
Weatherstripping and Caulking	238	7/tube	156	215	2451	2236	12.01

References

(1) Canada Energy Mines and Resources, Office of Energy Conservation. Keeping the Heat In. Ottawa: EMR, 1976.

(2) Canada Mortgage and Housing Corporation. The Conservation of Energy in Housing. Ottawa: CMHC, 1977.

(3) Consumer Guide. Energy Savers Catalog. New York: G.P. Putman's Sons, 1977.

(4) Controlled Ventilation with Exhaust Air Recovery for Canadian Housing. Proceedings of CMHC Industry/Science Seminar. Research and Development Division, Professional Standards and Technology Directorate. 26 October 1978. Ottawa: CMHC, 1978.

(5) Langdon, William K. Movable Insulation. Emmaus, Pa.: Rodale Press, 1980.

(6) Leckie, Jim, G. Masters, H. Whitehouse, L. Young. Other Homes and Garbage. San Francisco: Sierra Club, 1975.

(7) Walker, Howard. Royal Architectural Institute of Canada. Energy Conservation Design Resource Handbook. Ottawa: RAIC, 1979.

(8) Product information from Energy Conservation Equipment Files:
07 Sealants
08 Hardware and Specialties - Weatherstripping.

WINDOWS AND GLAZING

Before the cost of energy became a concern, large amounts of glass were seen as desirable, but with the 'energy crisis' came the view that windows were energy wasters that should be minimized as much as possible. Only recently has there been general recognition that windows placed in certain locations can also be energy gainers.(5)

A typical home with single glazing will lose 20% to 25% of the total heat loss through the windows or 10% to 20% if it is double glazed. Windows also let heat out through air leakage accounting for 20% to 50% of the total air change. Casement and awning windows have become more popular because they have a greater resistance to air leakage than the sliding types. (1, 3, 4, 5)

A window makes a poor wall. A double glazed window loses three times as much heat as an uninsulated wall and nine times as much as a fully insulated wall of equal area. Changing from single to double glazing will reduce the heat loss through its area by 50%, but changing from double to triple glazing will reduce the heat loss by only 33%. (4, 6)

A single pane of glass has an R value of 0.20 (1.1); a double-glazed window, 0.30 (1.8); and a triple-glazed window, 0.50 (2.8). The space between the panes has a significant effect on the thermal resistance. The optimum spacing is 16 mm (5/8 in), with the performance decreasing rapidly for smaller spaces but only decreasing moderately for larger spacings. The R values given by manufacturers are usually derived from tests conducted under optimal conditions, resulting in a lower actual value when installed in a home. (4, 5, 6)

Sealed double-or triple-glazed units are available with wood, metal, plastic-covered wood or metal-clad wooden frames. They are most often purchased for new construction or when renovating. Metal-frame windows are the least expensive, but they conduct heat to the outside more easily. These frames are available with a baked enamel finish at a slightly higher cost. Metal frames incorporating a thermal break are now available on the home market. Plain wood frames offer better heat loss resistance and a choice of finish but require regular maintenance. Vinyl-clad wood frames offer the thermal resistance of wood with easy care and excellent weathering properties. Because moisture between the panes of glass will result in condensation collecting on the interior surface, the factory-sealed units are either welded at the edges with glass or they have desiccant-filled metal spacers between them to absorb the moisture. The seals on the windows are guaranteed from 5 to 20 years, depending on the manufacturer and initial cost. (2, 6)

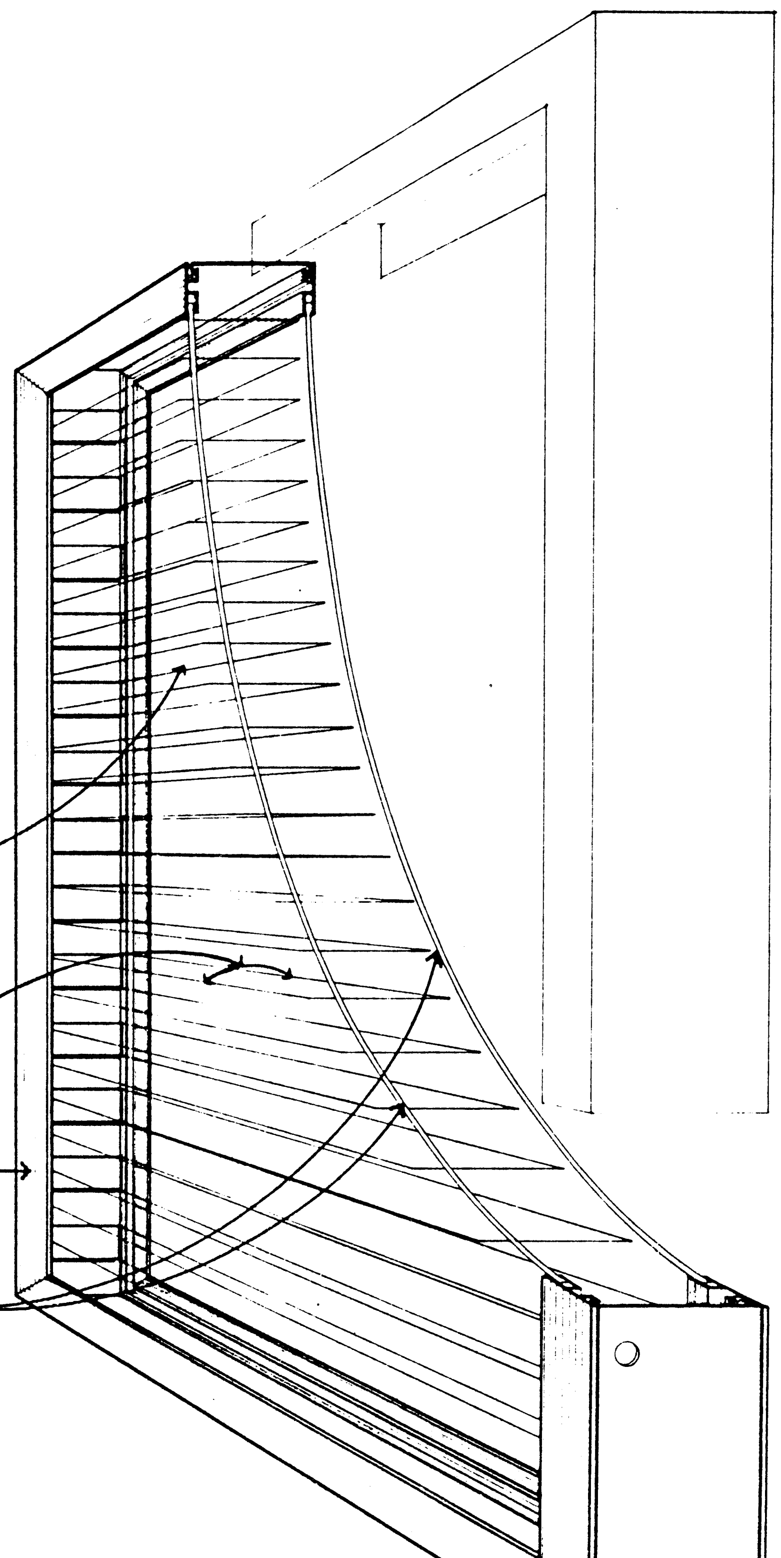
Low-iron glass is becoming more common as a glazing material because it is exceptionally clear and transmits 90% of the light it receives instead of the 86% transmitted through regular glass. It has a higher price but if maximizing solar gain is important, it can be worthwhile. And because low-iron glass is clearer, triple glazing will offer the same visibility as ordinary double glazing. (6)

Plastic glazings are also becoming more popular because they are easy to handle and lower in cost than glass. Most plastics degrade in the sunlight but the rate varies. The lifespan can range from 1 to 25 years so it is important to check specifications. Fibre-reinforced plastic glazing is also available but it is rarely used in windows; it is more commonly found on greenhouses and where visibility is not an important consideration. (6)

There are many different types of glazing available to the homeowner and consequently the unit purchase and installation price will vary. The price for a good quality, sealed double-glazed window approximately 1200 mm x 1000 mm (47" x 39"), will range from $220 to $320. Triple glazing adds about 20% to the cost of the windows and quadruple glazing is also available but at a proportionately higher cost. Installation costs, when renovating, can be estimated as being about the same as the purchase price. (5, 7)

A new Canadian made double glazed unit is now available that has an R value of 0.56 (3.2). Horizontal strips of transparent film are placed between the panes to stop convection. The price for a large 890 mm x 1955 mm (35" x 77") window is $240. (7)

Computer projections of test results show Watershed's standard 35 1/4" x 77 1/4" HeatMaze window delivers a net heat gain of 1.3 million BTU's a year on south facing applications.



This Llumar transparent film is the secret. It stops the convection. That makes the HeatMaze window a better insulator. But there's no penalty in light transmission.

3 1/2 inches of insulating air. Compare that to the 1/2 inch in standard double glazing.

R 3.2. Equal to about one inch of fibreglass insulation.

Tempered safety glass for greater strength. (Low-iron glass for maximum solar gain is optional.)

If the example house had its leaky single glazed windows replaced by new sealed double glazed units, the homeowner would save about $228 each year. But at a total cost of $7,500, the new windows would not result in a net monetary savings over ten years. If the life-cycle period was longer, better reflecting the expected life of the window units, they would be more viable. (See A-10).

OPTION	Savings per Year $	Unit Cost $	Total Cost $	Life-Cycle Expenses (present value) $	Life-Cycle Benefits (present value) $	Life-Cycle Savings (present value) $	B/C Ratio
Windows	228	500	7500	7784	3919	0	.35

New sealed double-or triple-glazed windows would be worthwhile to install if the old windows had to be replaced, but if the concern is simply saving energy, adding a storm window and sealing cracks would be almost as effective and far less costly.

References

(1) Alberta Energy and Natural Resources. Energy Conservation Branch. Energy Efficient Housing - A Prairie Approach. 1980, 1981.

(2) Canada Energy Mines and Resources. Enersave Advisory Service. Windows. Ottawa: EMR.

(3) Canada Energy Mines and Resources. Office of Energy Conservation. Keeping the Heat In. Ottawa: EMR, 1976.

(4) Canada Mortgage and Housing Corporation. The Conservation of Energy in Housing. Ottawa: CMHC, 1977.

(5) Housing and Urban Development Association of Canada and Ontario Ministry of Energy. Builders' Guide to Energy Efficiency in New Housing. Toronto: HUDAC, 1980.

(6) Langdon, W.K. Moveable Insulation. Emmaus Pa: Rodale Press, 1980.

(7) Product Information from the Energy Conservation Equipment Information File:
08 Glazing
08 Windows

WINDOW INSULATION

Up to a quarter (25%) of the heat loss through the building envelope is due to windows. The technology of window insulation has evolved quickly over the past few years and many new products are now on the market. There are four main types of window treatment which will reduce heat loss; they include the addition of film, interior storm windows, thermal blinds and thermal shutters. (1, 2, 3, 4)

Film

Two types of film, reflective and bubble, are now available for use on residential windows and each conserves the building's heat in a different way.

Reflective film, installed on the interior surface of a window, reflects the sun's heat away in summer and reflects the room heat (up to 40% of radiant heat according to the manufacturer) back into the interior during the winter. A problem with this type of film is that it will also reflect winter sunlight, preventing heat gain on the south facing windows. This film varies in degrees of reflectiveness from 50% to 85%; the larger the percentage, the greater the energy saving benefit. Reflective film is usually polyester film coated with aluminum. Installation can be done by the distributor or the homeowner and consists of cleaning the window surface, cutting the film and applying it to the wet surface;

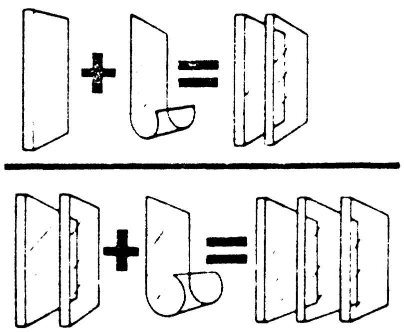
certain brands have pressure sensitive adhesive to hold it in place. Prices average about $27/m^2 ($2.50/ft^2). The lifespan is difficult to assess but one manufacturer offers a 5 year warranty against "peeling, cracking, crazing or loosening". The R value for the film alone is 0.1 (0.57) and when applied to single glass the value is 0.26 (1.47). (4)

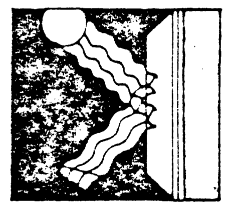
If the example house had single glazing only, the annual fuel bill would be about 5410 litres (1190 gal) and if reflective film were added to all glazed surfaces, the annual fuel saving would be 255 litres (56 gal) or $56. These savings of course do not take into consideration the amount of solar energy that has been reflected away during the winter preventing passive solar heat gain. (See A-11)

The example house already has exterior storm windows. If reflective film had been added, the new R value would be approximately 0.32 (1.8) and 165 litres (36 gal) or $36 would have been saved each year. Again, this does not take into consideration the potential solar heat gain that was prevented from entering the house. (See A-11)

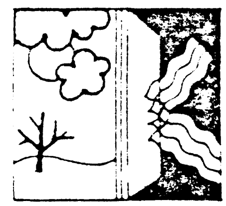
To cover the glazed surfaces of the example house would cost about $400 at $27 per square metre.

The life-cycle analysis shows that adding reflective film to single glazing will give some benefit over the 10 years

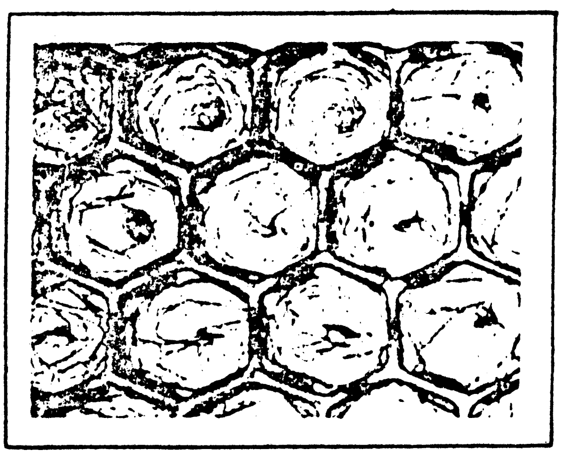


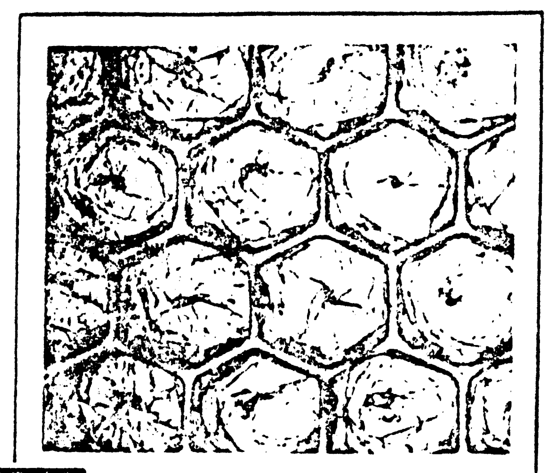


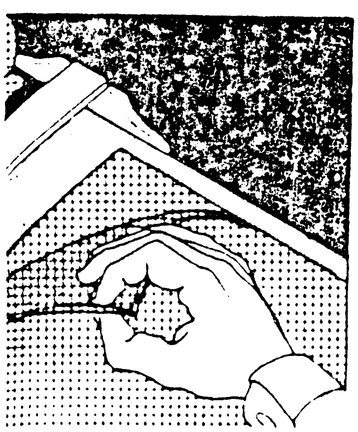
Cooling Season



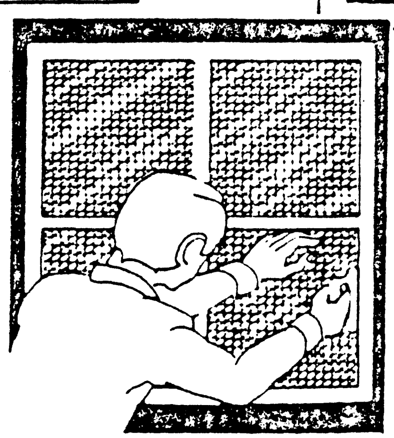
Heating Season



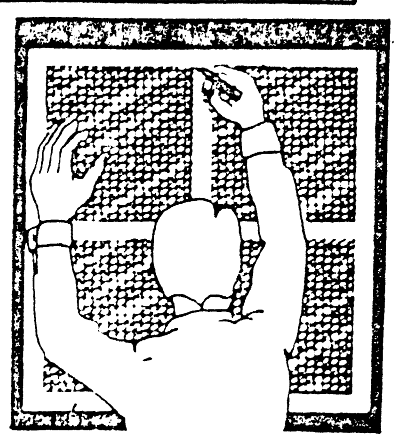




Remove release film and apply Thermalite insulation



Permanently adhere Thermalite to window, using squeegee



Trim excess, if necessary.

as long as the film can last that long. Any replacement cost will put this treatment in a very poor position, costing more than it saves. Adding reflective film to the example house with its storm windows will not save any money at all over the 10 years. (See A-11)

OPTION	Savings per Year $	Unit Cost $	Total Cost $	Life-Cycle Expenses (present value) $	Life-Cycle Benefits (present value) $	Life-Cycle Savings (present value) $	B/C Ratio
Reflective Film	56	$27/m^2$	400	432	577	145	1.36

The other type of film is one made up of air bubbles in polyethelene film. Manufacturers claim that it has a combined R value of 0.28 (1.6) when applied to single glazing. Like reflective film, it can be installed by the owner by cutting to shape and applying with an adhesive strip. Unlike reflective film, this film severely distorts the view from the window. The bubble film costs about $\$16/m^2$ ($\$1.50/ft^2$) and the life span is unknown though it is very likely that the film will have to be replaced at least once over the ten year period. (4)

If bubble film was added to single glazing it would save about 315 litres (69 gal) or $69 annually. If the film has to be replaced once over ten years, it will be economically viable. But if the film needs to be replaced more than once over ten years, or if it is applied to the glazing of the example house with an exterior storm, it will not save money over the ten year period. In any case, it is extremely unlikely that a homeowner would be willing to eliminate the view from inside the house for the minor annual savings. (See A-11)

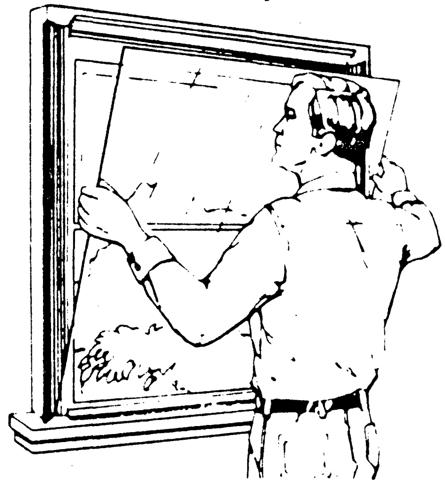
OPTION	Savings per Year $	Unit Cost $	Total Cost $	Life-Cycle Expenses (present value) $	Life-Cycle Benefits (present value) $	Life-Cycle Savings (present value) $	B/C Ratio
Bubble Film	69	16/m^2	240	479	650	171	1.37

Interior Storm Windows

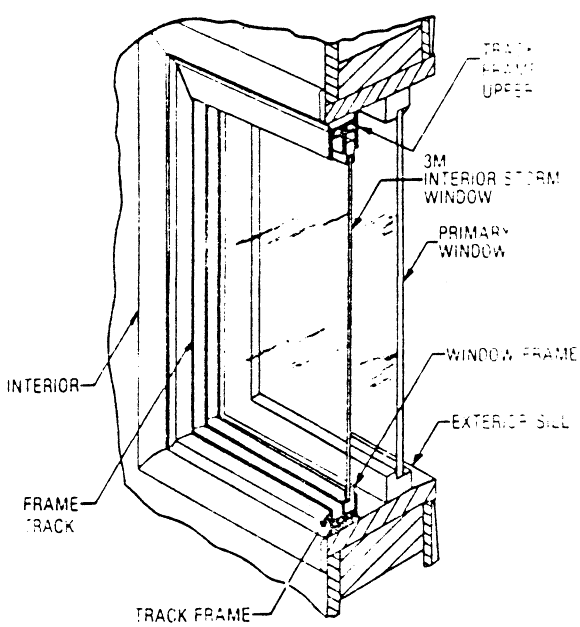
Storm windows that attach to the interior of the window, usually by magnetic strips or pressure, are becoming more common. They are constructed of acrylic glazing and claim an R value of 0.35 (2.0) when added to single glazing and a 50% reduction in air infiltration. (4)

Adding these storm windows to single glazing would save about 915 litres (200 gal) or $200 each season by increasing the R value and decreasing the heat loss due to air infiltration through the windows. If these storms

A storm window that installs inside your home



Trim adheres to frame permanently and snaps open for removal of storm window.



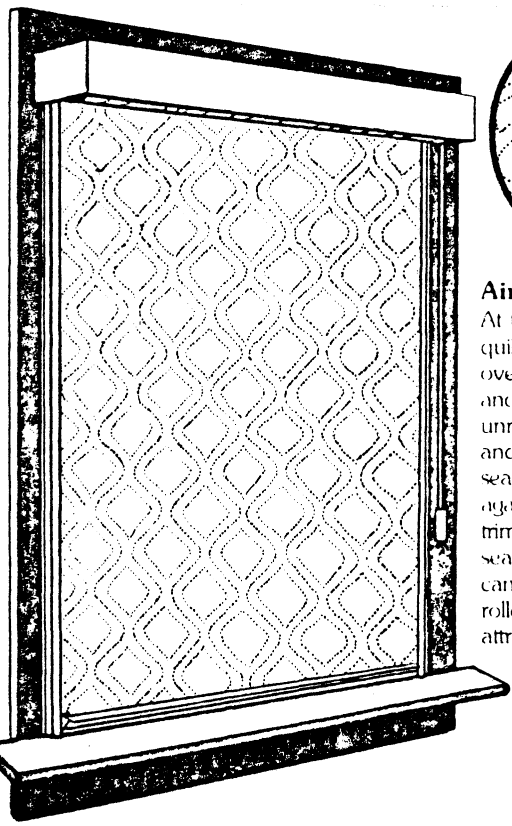
were added to the example house which already has exterior storms, they would save about 760 litres (166 gal) or $166 each year. These interior storms average about $70/m^2$ ($6.50/ft^2$) and are installed by authorized dealers or in some cases, by the homeowner. To cover all the windows in the example house would cost approximately $1050.

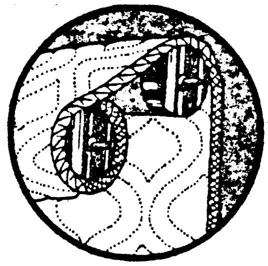
OPTION	Savings per Year $	Unit Cost $	Total Cost $	Life-Cycle Expenses (present value) $	Life-Cycle Benefits (present value) $	Life-Cycle Savings (present value) $	B/C Ratio
Interior Storm Windows	201	70/m^2	1050	1135	2070	935	1.89

Over a ten year period, the interior storms will save energy for both single glazing and single glazing with exterior storms if they perform according to manufacturers' claims. (See A-13)

Thermal Blinds

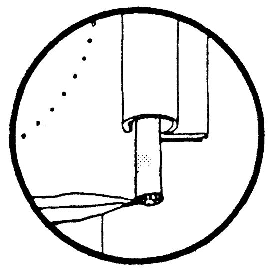
Thermal blinds usually consist of layers of polyester fibrefill batting or layers of reflective film. With both types it is necessary to completly isolate the glass area from the warmth of the room. Shades usually achieve this

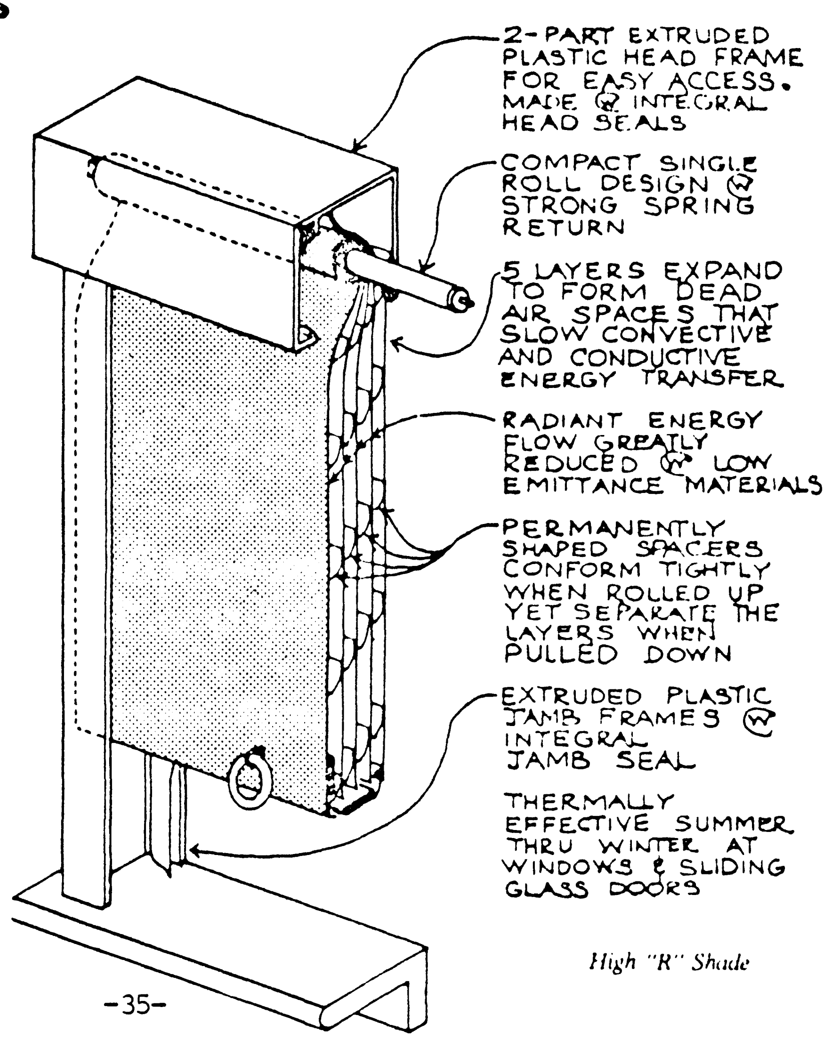




Air Seal on Top

At the core of the rolled-up quilt is the take-up roller, oversized to insure stability and long life. As the quilt unrolls it follows a path over and behind the seal roller. The seal roller presses the quilt against the upper window trim, forming an effective air seal. Should you desire, you can easily conceal the entire roller assembly under an attractive valance.





High "R" Shade

with a track running down the sides of the window frame so that when closed, no air spaces exist along the sides or bottom. A system of springs usually close off the top by pushing the material against the frame. (1)

A new type of window blind is in the process of being developed in the U.S. It is a venetian blind with a reflective surface to increase illumination during the day and when closed at night, becomes a reflective insulating blind. (4)

The manufacturers of foil shades claim an R value of approximately 1.76 (10) and a cost of about $\$43/m^2$ ($\$4.00/ft^2$). The fibrefill shades have an R value of 0.62 (3.5) and cost $\$75/m^2$ ($\$7.00/ft^2$). Thermal blinds can be made by the homeowner at a much lower cost. (4)

Adding fibrefill blinds to a single-glazed house similar to the example house will save about 430 litres (94 gal) or $94 each year, but over ten years, taking the initial cost into consideration, it will not be cost effective (See A-14). On the other hand, the life-cycle analysis shows that the reflective or foil blinds are cost effective, saving $1.69 for every dollar invested. (See A-15)

OPTION	Savings per Year $	Unit Cost $	Total Cost $	Life-Cycle Expenses (present value) $	Life-Cycle Benefits (present value) $	Life-Cycle Savings (present value) $	B/C Ratio
Foil Thermal Blinds	111	43/m^2	645	697	1143	446	1.69

OPTION	Savings per Year $	Unit Cost $	Total Cost $	Life-Cycle Expenses (present value) $	Life-Cycle Benefits (present value) $	Life-Cycle Savings (present value) $	B/C Ratio
Fibrefill Thermal Blinds	94	75/m^2	1125	1216	968	0	.78

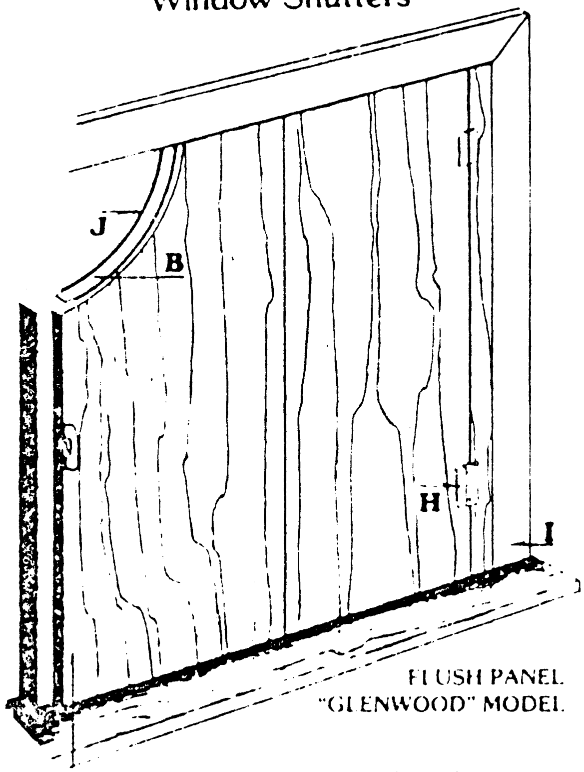
Thermal Shutters

A thermal shutter is a rigid board cut to fit very tightly inside the window frame. It can be a rigid foam covered with fabric or a wood frame filled with urethane foam, fibreglass, or layered foil. They can be installed either on the interior or exterior. Again, a tight seal and a vapour barrier are essential to prevent moisture from condensing on the window. Damage to windows can occur when the shutter is removed in the morning and the glass heats up rapidly. The R value will depend on the construction but can range from 0.77 to 1.23 (4.4-7.0) and the costs vary from $21.50 to $64.50 per square metre ($2-$6/ft^2). (1, 2, 3, 4)

If thermal shutters with an R value of 1.0 (5.7) were added to a house with single glazing for 12 hours each day, 470 litres (103 gal) or $103 would be saved each year. If they were added to the example house for 12 hours each day, 345 litres (76 gal) or $76 would be saved annually. (See A-16)

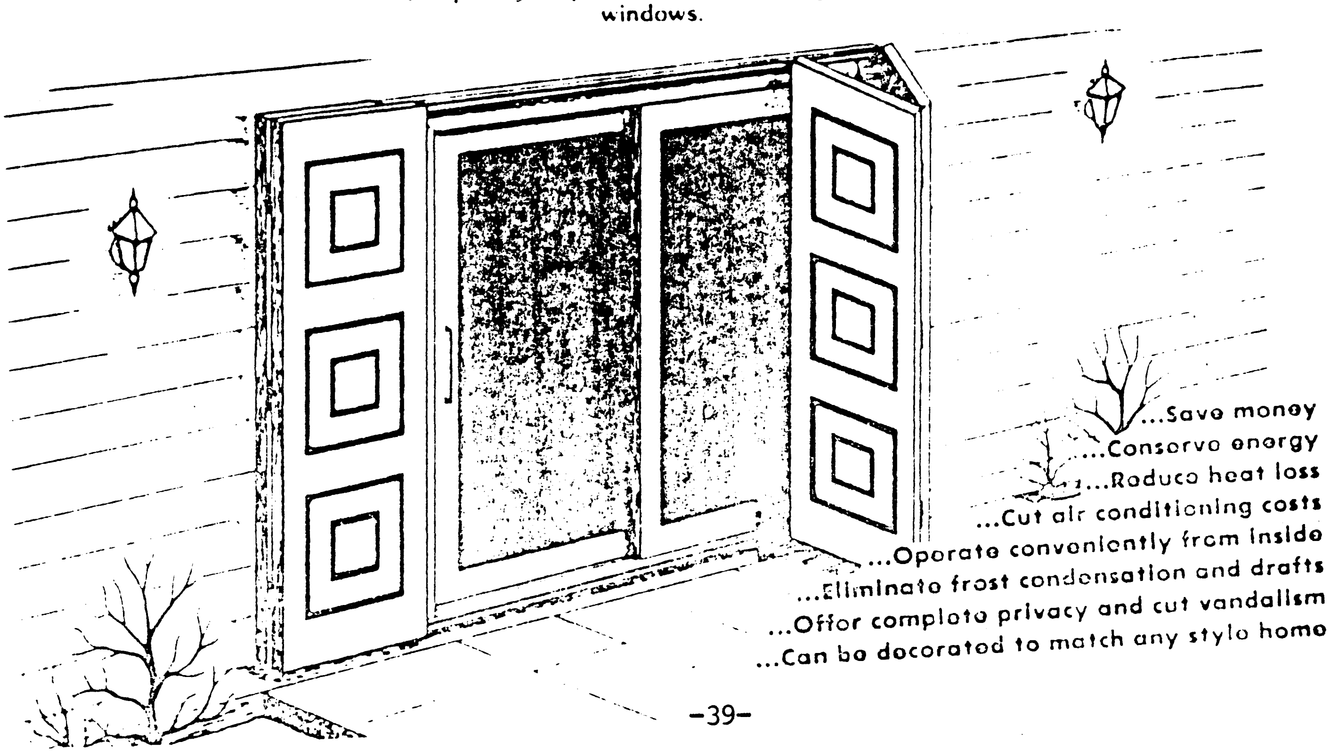
The life-cycle analysis shows that R 1.0 (5.7) thermal shutters on single glazing will be economically viable as long as the unit cost does not exceed $50/m^2. If the same shutters were put on the example house fitted with exterior storms, they would no longer be viable over a ten year period. (See A-16)

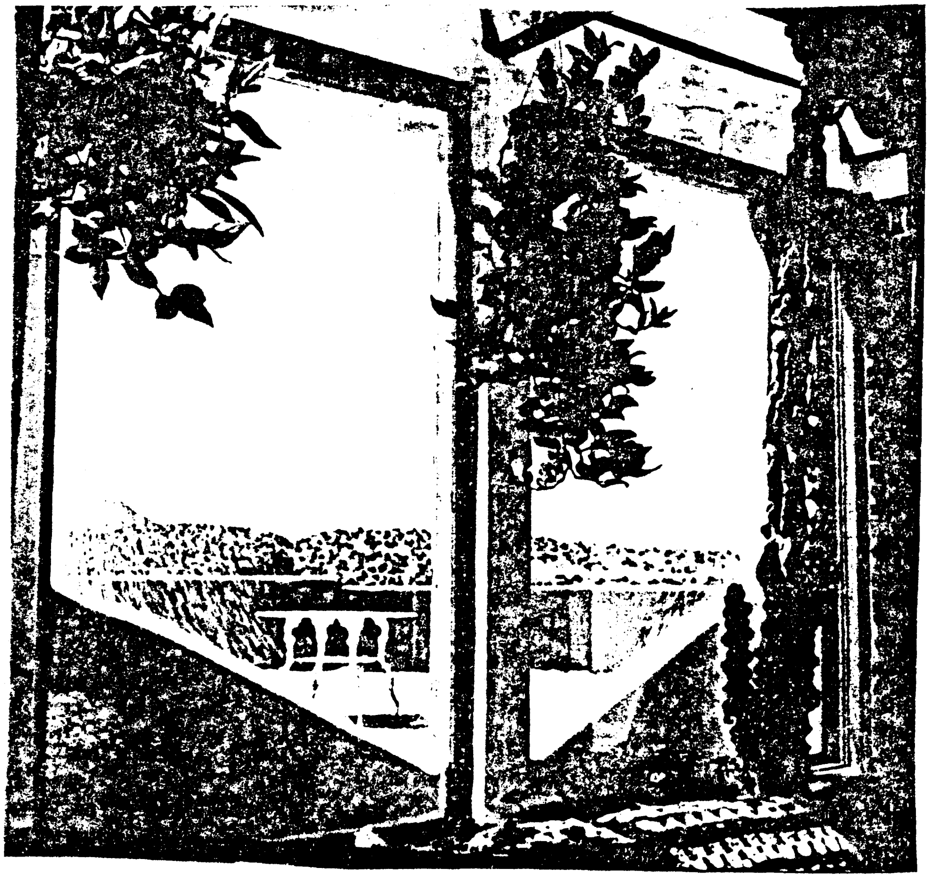
Air Tight Folding Insulated Window Shutters

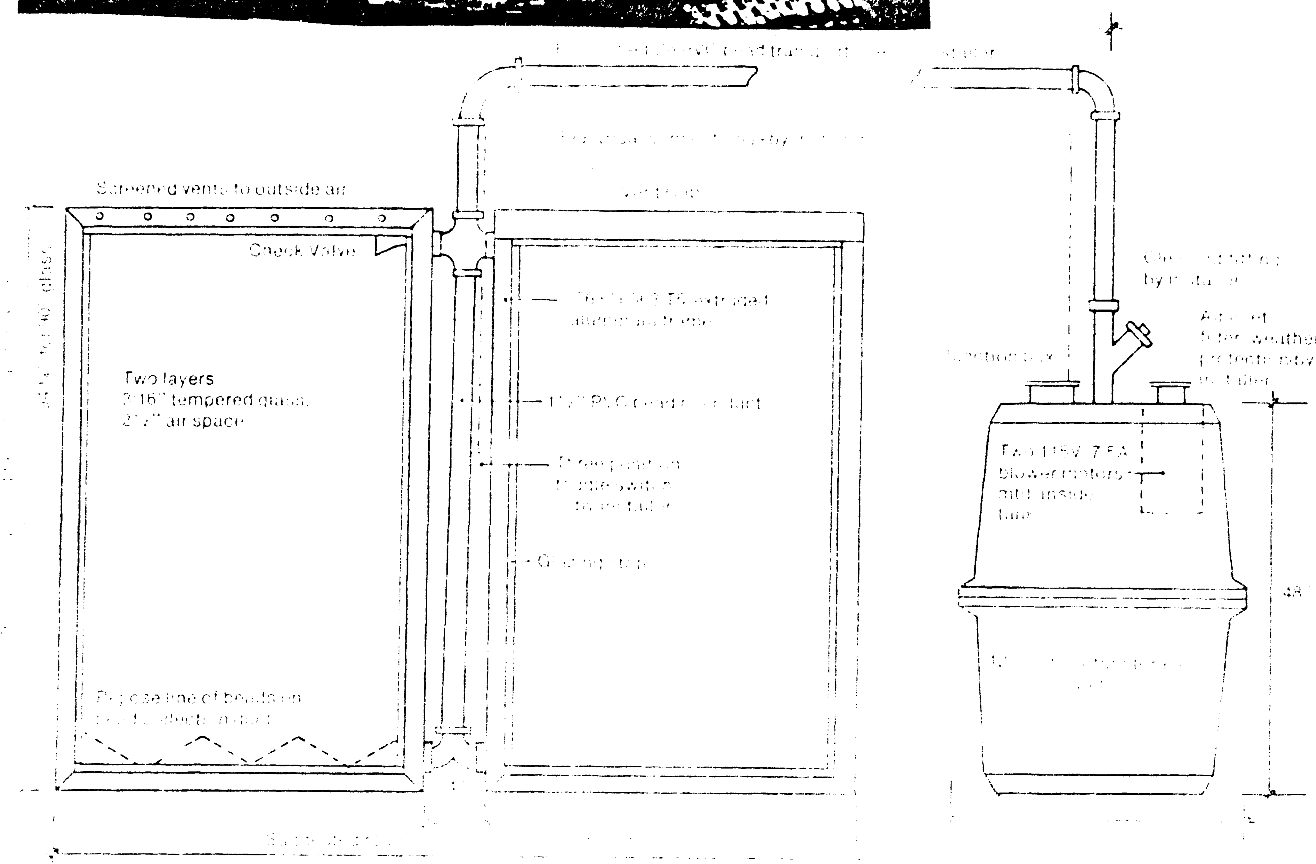


FLUSH PANEL "GLENWOOD" MODEL.

INSUL SHUTTER incorporates a rigid insulation core within a beautiful solid basswood frame to efficiently block conduction, convection, and radiation heat loss. INSUL SHUTTER completely stops cold air flow through your windows.






Screened vents to outside air
Check Valve
Two layers
3/16" tempered glass,
2 1/2" air space
48"

OPTION	$ Savings per Year	$ Unit Cost	$ Total Cost	$ Life-Cycle Expenses (present value)	$ Life-Cycle Benefits (present value)	$ Life-Cycle Savings (present value)	B/C Ratio
Thermal Shutter	103	$50/m^2$	750	811	1061	250	1.33

Blown-in Insulation

Blown-in insulation is also available for windows. Foam beads are sprayed in between double glazed windows when needed and then pumped out and returned to a remote storage unit through a concealed conduit in the ceiling. The windows are R 1.5 (8.5) when filled and they cost between \$200 and \$300 per square metre (\$19-\$27/ft^2), depending on the size of the window. (4)

Summary

Of all the types of window insulation, and under the circumstances assumed in the calculations, it seems that the addition of interior storm windows would save the most energy over a ten year period, followed closely by foil reflective blinds. Reflective and bubble film and thermal shutters will just break even if applied to single glazing but will cost more than they save if applied to single glazing with storms or to double glazing. The fibrefill thermal blinds will cost more than they save even when used with only single glazing. It should be noted that home made thermal shutters and blinds are much more cost effective than commercial types due to their lower initial cost.

References

(1) Langdon, W. Movable Insulation. Emmaus Pa.: Rodale Press, 1980.

(2) Shurcliffe, William, A. Thermal Shutters and Shades. Andover, Mass: Brick House, 1980.

(3) Szostak, Joe. "Hinged Shutters. Sliding Quilts." Canadian Renewable Energy News. August 1980, pp. 25.

(4) Product Information from the Energy Conservation Equipment Information Files: 12 Window Treatment

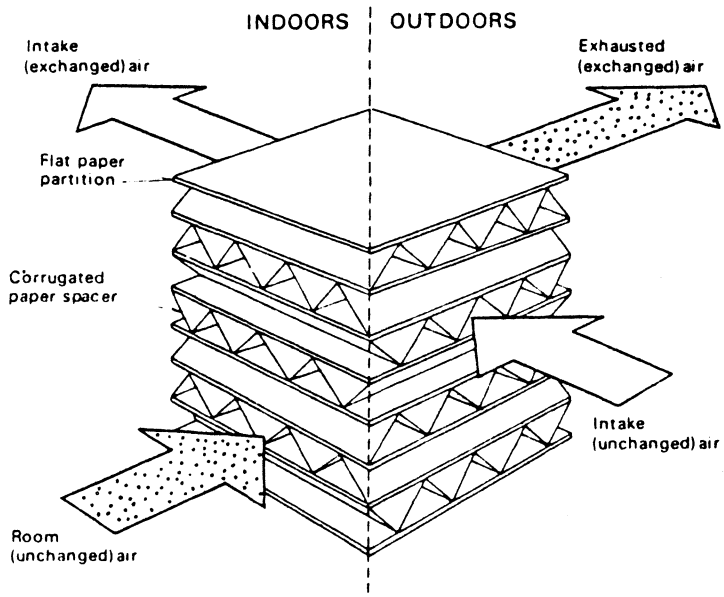
AIR TO AIR HEAT EXCHANGERS

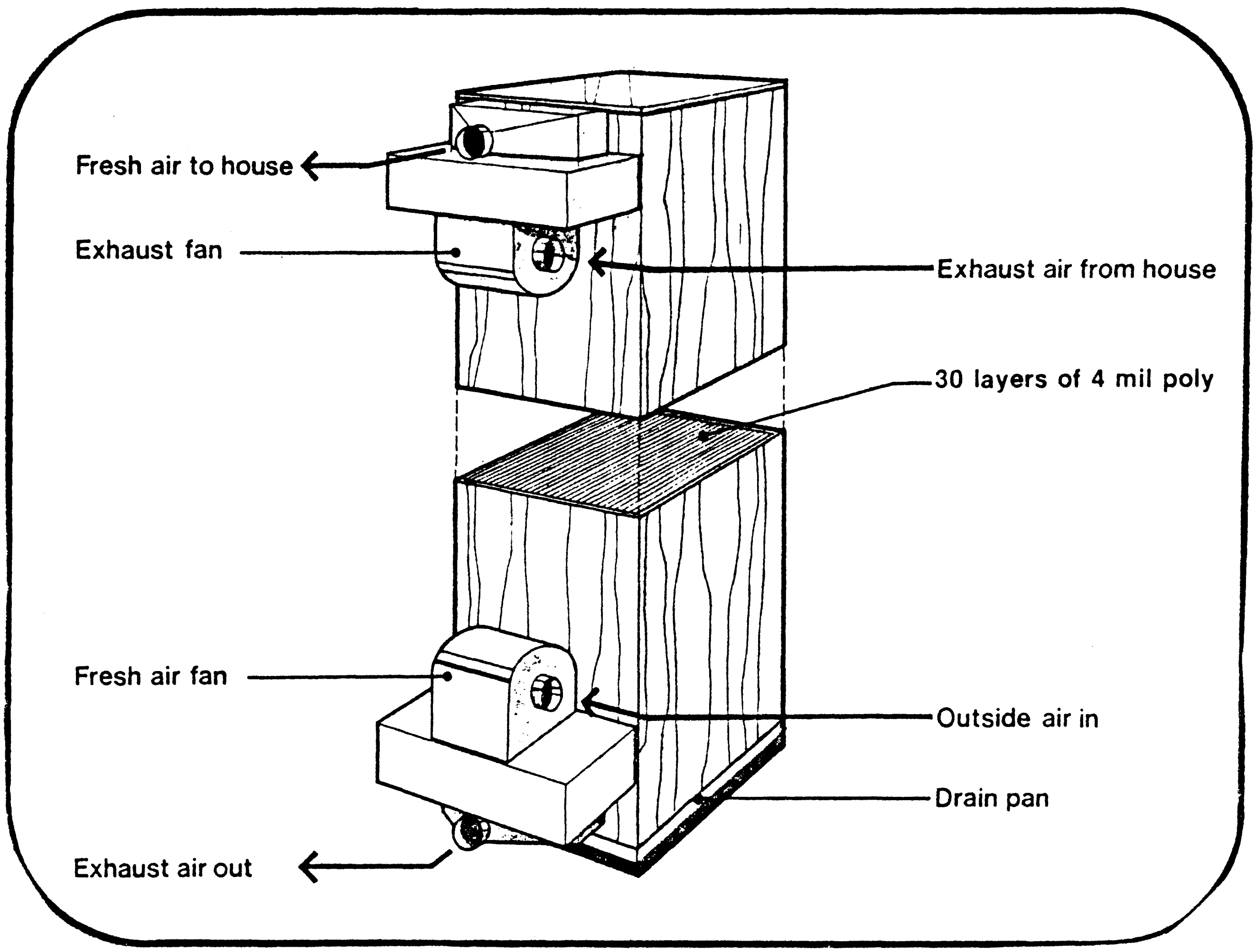
Until very recently, it was necessary to build your own air exchanger but more models are becoming available as the market increases with the greater number of buildings which approach air tightness and as the price of fuel increases. (3)

Air exchangers are used in controlling ventilation and airflow in an otherwise airtight environment or wherever a higher rate of ventilation is needed. It should be noted that where the construction of a house provides for a very low infiltration rate, controlled mechanical ventilation becomes a necessity for health reasons to maintain fresh air quality. Given this need, the use of an air to air heat exchanger, whereby heat contained in the exhaust air is recovered, acquires a greater significance.

Air to air heat exchangers are made of plastic, metal or paper mazeways that direct stale heated air alongside ducts of fresh incoming air. The room is also dehumidified in the process because of the replacement of humid interior air by dry outside air. This process of dehumidification produces water in the heat exchanger when the moisture carrying interior air is cooled below the dew point. (1, 3, 4)

The condensation of moisture in the heat exchanger can cause problems because the ice crystals which form in cold


INDOORS
OUTDOORS
Intake (exchanged) air
Exhausted (exchanged) air
Flat paper partition
Corrugated paper spacer
Intake (unchanged) air
Room (unchanged) air


Fresh air to house
Exhaust fan
Exhaust air from house
30 layers of 4 mil poly
Fresh air fan
Outside air in
Drain pan
Exhaust air out

weather will reduce the heat exchanger's efficiency, and the greater the efficiency of the unit, the greater the icing problems will be. Several solutions have been developed to help resolve this problem. They include built-in thermostats or timers which shut off or reduce the intake fans for 30 to 45 minutes per day to allow for adequate defrosting; increasing the proportion of warm exhaust to the cold intake air (which also reduces the unit's efficiency); and adding solar preheaters to increase the temperature of the incoming air, though this system is limited by the availability of sunshine. (1, 3)

In the past, there have been problems with air exchangers failing because the house was not airtight enough or freeze ups occurred when defrosting systems or pre-heaters were not included in the original package. (3)

In the next few years, more types of air exchangers and more detailed testing information should become available to the consumer. At the moment, two units are available in Canada and two more will be in production by the spring/summer of 1981, though more development will probably be needed before they can be said to be market ready. (2)

The average volume capacity of air exchangers is about 37 dm^3/s (80 cfm) with efficiencies of 63% to 70%, and prices are in the $600 to $900 range for residential models. An average model size would be 430 mm x 864 mm x 1524 mm (17" x 34" x 60"). (1, 2, 3, 4)

The calculations show that an air to air heat exchanger with a 37 dm^3/s (80 cfm) capacity and running 23 hours per day in an 4400°C (8000°F) degree day climate will save about 470 litres (104 gal) of #2 fuel oil or $104 per season. The life-cycle cost analysis shows that under these conditions, the air to air heat exchanger is not a very good investment unless the cost of the unit goes down and/or the price of oil increases substantially faster than the 18% per year assumed here. Note that the cost of operating the air circulation fan can represent a large proportion of the life cycle expenses. (See A-17)

OPTION	Savings per Year $	Unit Cost $	Total Cost $	Life-Cycle Expenses (present value) $	Life-Cycle Benefits (present value) $	Life-Cycle Savings (present value) $	B/C Ratio
Air to Air Heat Exchanger	104		700	858	1071	213	1.30

References

(1) Controlled Ventilation with Exhaust Air Heat Recovery for Canadian Housing. Proceedings of CMHC Industry/Science Seminar. Research and Development Division, Professional Standards and Technology Directorate. 26 October 1978. Ottawa: CMHC, 1978.

(2) Eyre, D. Saskatchewan Research Council. Letter to Canada Mortgage and Housing Corporation. 23 March 1981.

(3) Meissner, John. "Air to Air". Canadian Renewable Energy News. October 1980, pp. 34-35.

(4) Product Information from the Energy Conservation Equipment Information Files:
15 Air Treatment Equipment - Air to Air Heat Exchangers

FURNACE IMPROVEMENTS AND MAINTENANCE

A conventional pre-1980 oil or gas fired warm air furnace usually has an average seasonal efficiency of 45% to 60%. This efficiency can easily be improved with regular maintenance, adjustment and service, which in part can be done by the homeowner. (2, 3, 4)

Opportunities for increased efficiency include increasing the air circulating speed, regularly changing the filters, increasing the fan's "on" time and installing a smaller nozzle (oil only). There are also several "add-ons" which are available to increase the furnace efficiency eg., heat reclaimers, clutch couplings, solenoid valves (oil only), flue dampers, and retention heads or flame holders (oil only). (1, 2)

With regular maintenance and minor improvements, the older furnace efficiency can be increased up to 75%. If this were the case in the example house, by increasing the efficiency from 65% to 75%, the homeowner would save about 690 litres (150 gal) worth $150 or 13% of the fuel consumption each year. The costs of improvements and regular maintenance are very difficult to determine because they vary depending on exactly what is done, how often and the price of a maintenance visit. In the example house, the initial cost of boosting efficiency was assumed to be $100 with regular annual maintenance at $30 per year; this saved $1555 over ten year at a present value of $343, giving a benefit/cost ratio of just over

13. Note that even if the expenses were doubled, the benefit/cost ratio would still work out to a very advantageous 5.35. (See A-18)

OPTION	Savings per Year $	Unit Cost $	Total Cost $	Life-Cycle Expenses (present value) $	Life-Cycle Benefits (present value) $	Life-Cycle Savings (present value) $	B/C Ratio
Furnace Improvement and Maintenance	151	-	100	343	1555	1212	13.14

The homeowner also has the option of buying a new furnace. Both oil and gas furnaces with much improved efficiencies have appeared on the market during the last few years. All have efficiencies of at least 80% with certain models achieving better than 90% (manufacturer's claims). (4)

When choosing a new furnace, oversizing should be avoided. The new furnace should have equal or preferably less capacity than the existing one. Because an oversized furnace heats up the home quickly, there is more frequent starting and stopping which leads to increased fuel consumption. A properly sized furnace should remain on for more than 80% of the time in very cold weather. (2, 3, 4)

There are new energy-efficient features which will increase the initial cost of the furnace but should pay for themselves within a few heating seasons. These features include a high efficiency burner (achieves more complete combustion), a positive chimney damper (closes the flue pipe shortly after the burner shuts off and re-opens before it starts again), a delayed action solenoid valve (delays oil between burner and pump to encourage complete combustion), and a variable speed fan (increases speed of air over furnace heat exchanger, allowing more heat to be extracted). (1, 2)

If the example house had a new furnace with an efficiency of 90%, the annual fuel consumption bill would be about 3725 litres (820 gal) at a cost of $820, a saving of close to 1435 litres (315 gal) or $315 per year. (See A-18)

References

(1) Canada Energy Mines and Resources, Enersave Advisory Service. How to Select an Energy-Efficient Oil Furnace. Ottawa: EMR.

(2) Canada Energy Mines and Resources, Office of Energy Conservation. The Billpayer's Guide to Furnace Servicing. Ottawa: EMR, 1975, 1977.

(3) Consumer Guide. Energy Savers Catalog. New York: G.P. Putman's Sons, 1977.

(4) Housing and Urban Development Association of Canada and Ontario Ministry of Energy. Builders' Guide to Energy Efficiency in New Housing. Toronto: HUDAC, 1980.

WOOD HEAT

Economics

Heating with wood is becoming more popular as the price of fuel rises, especially in areas where there is a plentiful supply at hand. Though wood heating systems do not usually replace conventional systems, wood is often able to contribute a significant proportion of needed heat when used in conjunction with another source of heat energy (usually the more conventional oil, gas and electricity). (1, 8)

Wood is sold by the cord, a volume of 1.22 m x 2.44 m x 1.22 m (4 ft x 8 ft x 4 ft), and the price varies considerably, depending on the location. In a large city, a cord of wood can cost well over $100, but if the homeowner has access to a woodlot, the price can be much lower than that.

Reliable generalizations about the economics of wood heating are difficult to make because of the large number of variables. In order to save money on fuel, the price of wood must be cheaper than oil (or whatever conventional fuel is used) for the same amount of useful heat delivered to the living area of the house. In the example house, #2 heating oil is used which has an energy content of approximately 39 MJ/L (166,600 Btu/gal); the furnace has an efficiency of 65% so that 25.35 MJ of useful heat is derived from each litre of oil burned. If oil costs $0.22

per litre ($1.00/gal), then the cost per megajoule of delivered heat is $0.009. (See A-19)

The energy content of wood is difficult to estimate since each species has a different heat content and within each type, the amount can vary. On average, the energy released from one kilogram of bone dry wood is about 20 MJ (8,600 Btu/lb). Air dried wood though is nearly 20% water by weight, so that the heat contained in the wood is closer to 16.5 MJ/kg (7,100 Btu/lb). Sugar maple has a density of 1865 kg (4100 lbs) per cord, that is an energy content of 31,000 MJ (29 MBtu) per cord. Pine has a density of 1000 kg (2200 lbs) per cord, that is an energy content of 16,500 MJ (15.6 MBtu) per cord. (See A-04)

The usual 50% efficiency of a wood heat system would give about 15400 MJ (14.5 MBtu) of useful heat for each cord of hardwood and 8250 MJ (7.5 MBtu) for a cord of softwood.

If wood is to compete with a 65% efficiency oil fired furnace using #2 oil at $0.22 per litre ($1.00/gal), then the cost of wood cannot exceed $0.009/MJ ($9.23/MBtu) of delivered heat which means that a cord of wood must be less than $135. (See A-19) In many rural locations wood is available for sale at less than $100 per cord or for the cost of one's labour and machines.

The following is a chart comparing the cost of 1 MJ of useful heat from conventional fuels and wood:

Fuel	Price	Energy Content	Efficiency	Cost of 1 MJ
electrical resistance heat	\$0.05/kWh	3.6 MJ/kWh	100%	\$0.014
#2 fuel oil	\$0.22/L	39 MJ/L	65%	\$0.009
natural gas	\$0.155/m^3	41.5 MJ/m^3	70%	\$0.005
wood	\$50 per cord	31,000 MJ per cord	50%	\$0.003
	\$100 per cord	(hardwood)		\$0.006

Wood Stoves

There are 5 basic types of stoves: simple fireplaces, high efficiency fireplaces, simple box stoves, airtight stoves and high efficiency stoves.

1. A simple fireplace generally is extremely inefficient; about 90% of the heat goes up the chimney. Efficiencies are in the 5% to 15% range; they only radiate heat in one direction and they usually encourage a high loss of room air up the chimney.

2. A more efficient fireplace is achieved with various add-on or built-in devices which are able to increase the efficiency to about 25%. These devices usually include radiant grates, glass doors, air ducts around the hearth, etc.

3. A simple box stove with an efficiency of 30% to 40% is low cost and can heat one to four rooms but the fire is

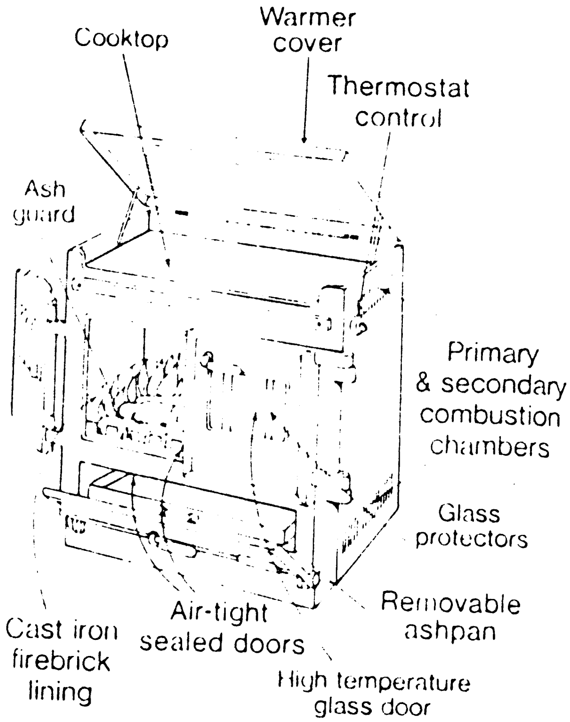
usually difficult to control, the service life is short and it still wastes 70% of the heat.

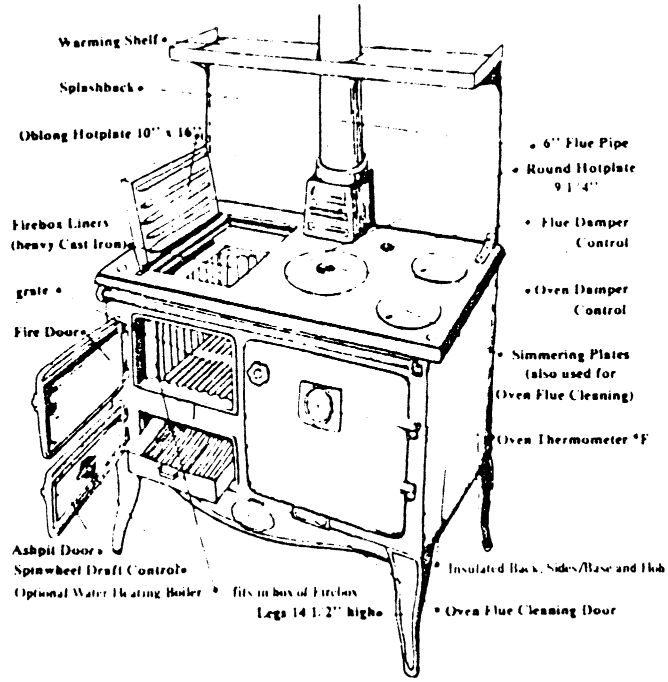
4. An airtight stove has a better efficiency (40% to 55%), longer burn time, longer service life and higher heat output. Problems include creosote build-up on a low draft setting. Airtight units admit primary air directly into the fuel bed and usually there is provision for secondary air to enter above the wood to burn the volatile gases given off during the combustion process. This complete combustion process provides long burning fires, constant temperatures and good draft control. No more air than is necessary to maintain combustion enters the firebox,thus reducing the amount of hot air which escapes up the flue. Some stoves have thermostats which automatically control the amount of air entering the firebox. Others have an interior baffle system which permits good temperature control without a thermostat. A completely airtight stove can double the efficiency of wood stoves and fires can burn for 12 or more hours between re-fuelings.

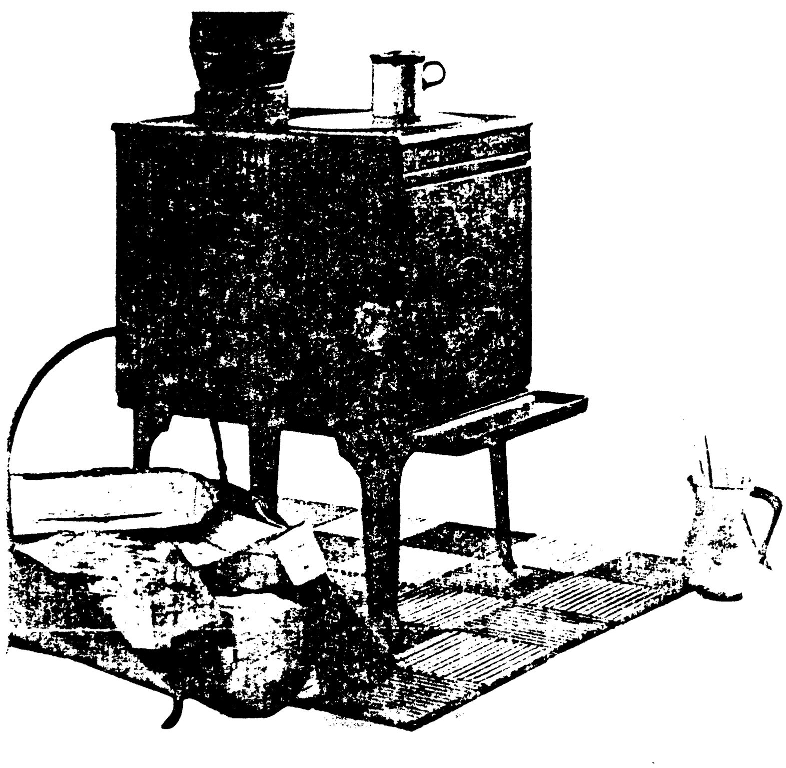
5. High efficiency stoves with efficiencies of 50% to 60% give the greatest return on wood fuel dollars, best temperature control, longest burn time and highest heat output. They also have creosote problems with a low draft setting and the highest price. (1, 14)

Stoves can also be divided into two groups: radiating and circulating. Radiating stoves heat the room by conducting heat through their walls to the air. Circulating stoves draw air in alongside the firebox, heat it and send it out into the room. (4)

Until recently, technical innovations were limited to new baffling systems or improved draft control. Catalytic converters are now being incorporated into residential woodstoves to improve efficiency and combat fire hazards by encouraging more complete combustion. Manufacturers claim efficiencies of 90% with no creosote build-up and little or no pollution. The most commonly available converter or catalytic combuster is a pyroceramic honeycomb 140 mm (5.5 in) in diameter that sits in a top chamber of the woodstove. Normally the gases given off by the burning wood will only ignite at temperatures of 700°C (1300°F), but when these gases come into contact with the catalyst, the flash point drops to 260°C (500°F). As a result, the gases ignite and then burn at their normal 700°C to 815°C (1300°F - 1500°F) temperature. The device reduces creosote formation by over 90% and improves the stove efficiency by 20% to 25% under laboratory conditions. These converters are just becoming available in Canada; several firms are about to market stoves with these devices in the $900 to $1200 price range and replacements will cost $100 to $300. The expected life of the converters is not known and there are no reliable figures available yet on their performance when installed in a home. (2, 6, 21)


Cooktop
Warmer cover
Thermostat control
Ash guard
Primary & secondary combustion chambers
Glass protectors
Removable ashpan
Air-tight sealed doors
Cast iron firebrick lining
High temperature glass door


Warming Shelf
Splashback
Oblong Hotplate 10" x 16"
Firebox Liners (heavy Cast Iron)
grate
Fire Doors
Ashpit Doors
Spinwheel Draft Controls
Optional Water Heating Boiler
Legs 14 1/2" high
6" Flue Pipe
Round Hotplate 9 1/4"
Flue Damper Control
Oven Damper Control
Simmering Plates (also used for Oven Flue Cleaning)
Oven Thermometer °F
Insulated Back, Sides/Base and Hob
Oven Flue Cleaning Door



Small stoves with a capacity of 12 kWh or 43 MJ/h (41,000 Btu/h), made of cast iron or steel will cost between $150 and $500 with most in the $300 to $400 range. Medium to large stoves with capacities of 15 to 20 kWh or 55 MJ to 70 MJ per hour (51,000-68,000 Btu/h) cost from $300 to $1000 with the average in the $400 to $800 range. Cook stoves are also available starting at $1,000. (4, 17, 22, 25)

According to Canadian sources, a well-insulated home using a modern efficient wood stove should only use 2 to 6 cords of wood each season. The example house which needs about 131,000 MJ (1.24×10^8 Btu) per season would need about 9 cords of wood if this were its only source of heat. If a wood stove were installed in the example house to supply half of its seasonal heating needs, that is 65,500 MJ (6.2×10^7 Btu) with a 50% efficiency, the stove would consume 4.5 cords of hardwood each season, saving 2580 litres (567 gal) of fuel oil.

OPTION	Savings per Year $	Unit Cost $	Total Cost $	Life-Cycle Expenses (present value) $	Life-Cycle Benefits (present value) $	Life-Cycle Savings (present value) $	B/C Ratio
Wood Stove	567	-	1000	4562	6050	1488	2.88

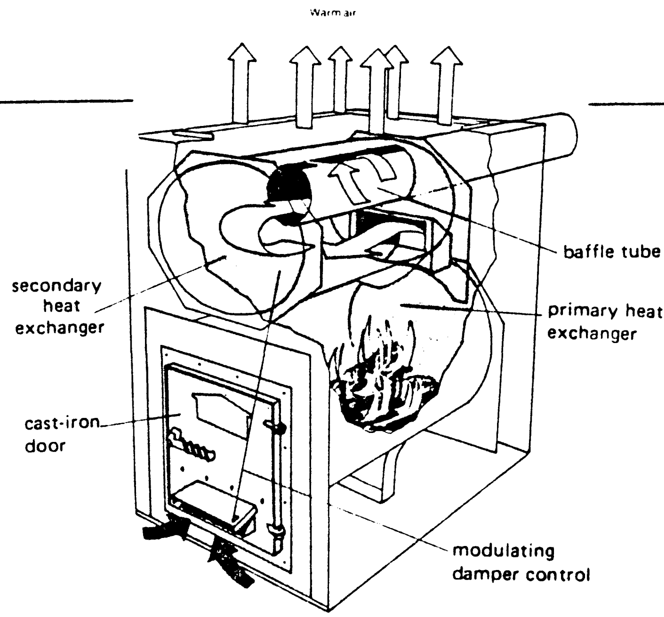
Using life cycle cost analysis, a wood stove installed in the example house would save $5840 in fuel over 10 years and the benefit/cost ratio would be 2.88. (See A-20)

It is very difficult to give reliable estimates of savings since they can vary considerably with the price of wood, the price of fuel being replaced, the initial and installation cost, the amount of heat being substituted and the heat loss of the building.

Furnaces

A wood furnace is similar to a very large circulator-type stove; to distribute the heat, air is drawn around the firebox and circulated through the ducts of a conventional forced hot-air distribution system. Some furnaces can also be used with hot water systems where the firebox is surrounded with water and then pumped to either baseboard radiators or radiant floor systems. There are also combination furnaces available which burn either wood or a fossil fuel in separate combustion chambers, switching automatically when the wood is completely burned. (1, 22)

The most interesting wood furnace on the market is one which burns at 810°C to 870°C (1500°F - 1600°F) instead of the usual 310°C to 440°C (600°F -800°F). Combustion is virtually complete so the wood burns creosote free and few pollutants are released. Logs are placed in a vertical



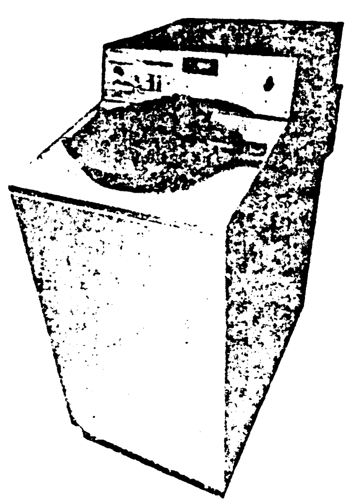
CUT-AWAY VIEW of Mini-Scotsman

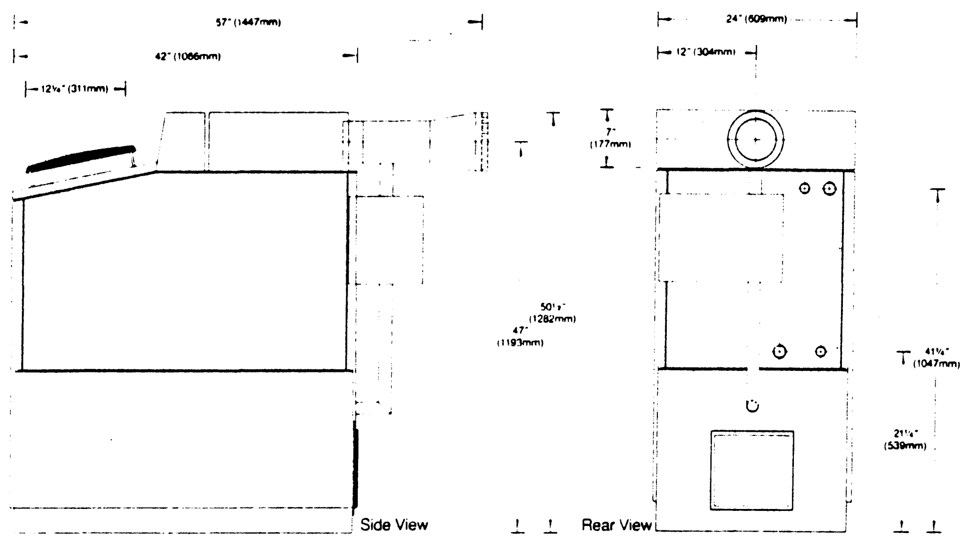
Jetstream Model 120-SB Specifications.

Standard Features: High temperature castable refractory base, pressure tested hydronic-fire-tube heat exchanger, insulated case, positive lock cast loading door with combustion air interlock, acoustically baffled fan box, dual function aquastat, 0-6 hour automatic shut down timer, 30 P.S.I. pressure/temperature relief valve.

Options:
Digital Performance Monitoring Package.
Low storage temperature warning light.

Dimensions:
Height: 50" 1270mm.
Width: 24" 610mm.
Depth: 42" 1065mm.
Weight: 1050 lbs. (475 k)





Fuel:
Hardwood or Softwood: Maximum length 40" (1016mm.)
Maximum Diameter 12" (300mm.)
Minimum Diameter 3" (75mm.)
Load Capacity 50-65 lbs. (25-30 kgs.)
Optimum Performance Diameter 4-10 inches 100-250mm.
Maximum Moisture Content by Weight 40%
Minimum Moisture Content by Weight 10%
Optimum Performance Moisture Content Range 15-25%

Performance Characteristics.

Steady State Output - 120,000 BTU's/hr.
Overall boiler efficiency 75-84% (measured by CO2 stack-loss method)*

*Output and efficiencies will vary with fuel quality.

The Jetstream concept originates from the work of Professor Richard C. Hill at the University of Maine.

loading tube and are gravity-fed into the fire. Only the burning tip is actually in the combustion chamber.

Because the temperatures are so high, a metal jacket with an air to water heat exchanger surrounds the furnace and heat is transferred to 2850 litre (625 gal) heat storage tanks and then to the house's heating system as needed. The furnace can also be used with a hot air system. A single two-or three-hour burn can produce enough heat for an average Canadian home for a day while a larger tank and an eight-or ten-hour burn can sustain the house for several days. Efficiency is 80% or better. The furnace sells for $2,275 and when heat storage and installation is added, the cost is closer to $4,000 or $5,000. (15, 25)

An investment in a wood furnace is equivalent to buying a complete house heating system. Small furnaces which produce 50-75 MJ/h (50,000-73,000 Btu/h) can be purchased and installed for $600 to $1,000. Larger systems producing 75-150 MJ/h (70,000-140,000 Btu/h) can cost from $1,000 to $1,200 and very large furnaces producing 100-300 MJ/h cost from $1,000 to $3,000. (22, 26)

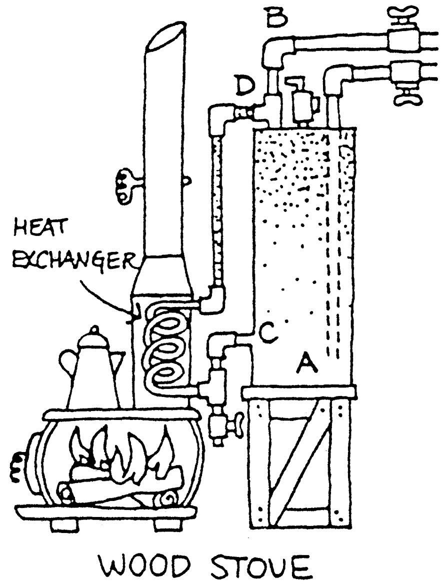
As in the case of the wood stove, reliable generalizations about savings are not possible since so much depends on the amount of heat needed, the furnace efficiency, the cost of fuel and the capacity of the furnace relative to the heating load of the building.

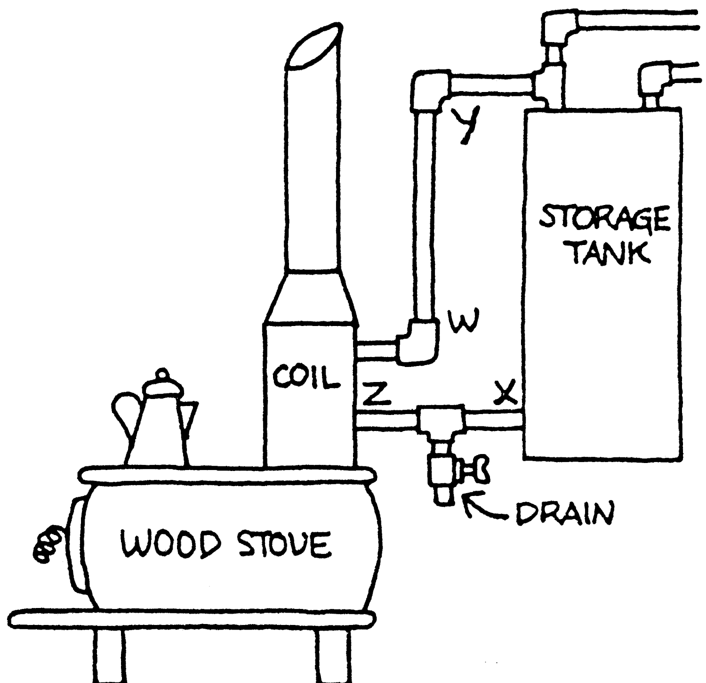
Hot Water

Heating domestic hot water with a wood burning system is becoming more common and is often used in combination with a solar system or electric backup system for summertime use.

A storage tank (the existing one can be used) is hooked up to the stove with a heat exchanger coil either on the inside or outside of the stovepipe or firebox, depending on the type of stove. Using wood to heat domestic hot water will increase wood consumption but not more than 10%.

A few hot water hook-up devices are available in Canada and are usually made by the stove manufacturers for their own products. Costs usually average about $100. (13, 19, 20, 23, 25)





(19,20)

FIGURE 11 HEAT EXCHANGERS

TYPE OF STOVE	STOVEPIPE COIL	FIREBOX COIL	FIREPLACE GRID	COMMENTS
BOX STOVE	GREAT	WRONG SHAPE	GREAT	STOVEPIPE IS EASIER TO INSTALL. FIREBOX MAKES MORE HOT WATER.
POTBELLY STOVE	GREAT	WRONG SHAPE	WRONG SHAPE	
DRUM STOVE	GOOD	GREAT	WRONG SHAPE	STOVEPIPE COIL NOT TO BE USED WITH AUTOMATIC DRUM STOVES
FIREPLACE STOVE	POOR	WRONG SHAPE	GREAT	SMOKE IS TOO COOL FOR STOVE-PIPE COIL WITH DOORS OPEN
BARREL STOVE	GREAT	GREAT	WRONG SHAPE	
COOK STOVE	POOR	WRONG SHAPE	GREAT	SMOKE IS TOO COOL FOR STOVEPIPE COIL
AIRTIGHT STOVES	POOR	GREAT	GREAT	SHAPE OF STOVE DECIDES WHICH FIREBOX HEAT EXCHANGER TO USE
FIREPLACE	POOR	WRONG SHAPE	GREAT	SMOKE IS TOO COOL FOR HEAT EXCHANGER IN FLUE

(19,20)

References

(1) Argue, R., B. Emanuel, S. Graham. The Sun Builders. Toronto: Renewable Energy in Canada, 1978.

(2) Beer, Mitchell. "Cambridge, Timberline to Market Catalytic Stoves." Canadian Renewable Energy News. April 1981, pp. 16.

(3) Canada Mortgage and Housing Corporation. Heating with Wood-Safely. Ottawa: CMHC, Jan. 1978.

(4) Canadian Consumer. "Test Report-Wood Heat". Vol. 9, No. 5, Oct. 1979.

(5) Canadian Renewable Energy News. "New Catalyst a Corning Competitor." April 1981, pp. 10.

(6) Canadian Wood Energy Institute. Installation Operation and Maintenance of Wood-Burning Appliances. Toronto: CWEI, 1979.

(7) Harris, Michael. "A Guide to Alternate Central Heating". Home Energy Digest and Woodburning Quarterly. Winter 1979.

(8) Hayden, A.C.S. and R.W. Braaten. Canadian Combustion Research Laboratory. "Effect of Wood Stove Design on Performance" for presentation at 1980 Annual Meeting of the Canadian Wood Heat Energy Institute, Toronto, March/April 1980. Report ERP/ERL 80-46, CANMET, EMR Canada, March 1980.

(9) Hayden, A.C.S. "Efficiency of Wood-Fired Appliances" prepared for Canadian Wood Energy Institute Course on wood heating. Report ERP/ERL 78-82, CANMET, EMR Canada, Oct. 1978.

(10) Hayden, A.C.S. and R.W. Braaten. Canadian Combustion Research Laboratory. "Performance of Domestic Wood-fired Appliances." Prepared for the 73rd Annual Meeting of the Air Pollution Control Association, Ottawa, June 1980.

(11) Hollo,Gyorgy. "Wood Boilers Costly." Canadian Renewable Energy News. May 1979, pp. 20.

(12) Institute of Man. Heating with Wood. Publication 1/78. Charlottetown P.E.I.: Institute of Man.

(13) Langa, Frederic S. "A Primer on Wood-Fired Water Heating". Home Energy Digest and Wood Burning Quarterly. Winter 1978.

(14) Lanza, Frederic S. "Identifying Woodburners by Type." Energy Digest and Woodburning Quarterly. Winter 1979.

(15) Mariner, Robert. "Superfurnace:" Harrowsmith. No. 27.

(16) McPhilips, Martin, editor. The Solar Age Resource Book. New York: Everest House, 1977.

(17) Schneider, Jason. "Cookstoves that do more than Cook." Home Energy Digest and Woodburning Quarterly. Winter 1979.

(18) Shelton, Jay and A. Shapiro. The Woodburners Encyclopedia. Toronto: Canadian Wood Energy Institute, 1976.

(19) Sussman, A. and R. Frazier. "Fire and Water". Home Energy Digest and Woodburning Quarterly. Summer 1980.

(20) Sussman, A. and R. Frazier. Handmade Hot Water Systems. California: Garcia River Press, 1978.

(21) Szostak, J. "New Engineering Aids Wood-Stove Efficiency." Globe and Mail. 12 December 1980. pp. BL4.

(22) Wolfe, Ralph and Peter Clegg. Home Energy for the Eighties. Charlotte Vermont: Garden Way Publishing, 1979.

(23) Wood, Chris. "'Cascade-40 Performance' From a Stove-Fired Water Heater." Canadian Renewable Energy News. Aug. 1980. pp. 18.

(24) Wood, Chris, "Novel Wood Furnace-Burns Creosote-Free". Canadian Renewable Energy News. Vol. 2, No. 7.

(25) Product Information from Energy Conservation Equipment Information Files:
15 Heat Generation - Boilers and Furnaces
15 Heat Generation - Wood Stoves
15 Heat Generation - Hot Water Hook-ups.

HEAT PUMPS

Heat pumps are devices that are used for heating buildings during the winter and cooling during the summer. They conserve energy by being able to produce up to 2.5 kW of heating or cooling for each kW of power input. This is done by extracting heat from an outdoor source such as air, earth, water or solar radiation and pumping the heat indoors. In effect, it is the reverse of the refrigeration process. Air to air heat pumps are the best known and are now widely available. They are available from most manufacturers of residential air conditioning equipment. Though the first heat pumps had maintenance problems and gained a poor reputation, the new generation of equipment is much more satisfactory. (7, 9)

There are three basic types of air to air heat pumps: a single-speed compressor, two-speed compressor, and an add-on heat pump system. (6)

A single-speed heat pump operates from the house thermostat to supply the necessary heat. If the compressor is unable to meet the load, electrical resistance heating elements switch on to provide the required additional heat. (6)

A heat pump with a two-speed compressor which will be more suitable to the Canadian climate, is in the process of being developed. Such a machine would be able to extract more heat at below freezing outdoor temperatures than a single-speed machine. The operation of a two-speed heat pump is identical to the single speed except that the compressor runs faster at sub-freezing temperatures. (6)

The add-on heat pump is identical to the single- and two-speed heat pump except that the auxillary energy required to meet the heating load is supplied by a combustion furnace and the heat pump does not function much below 0°C. The major benefit of this system arises from the fact that combustion heating is currently less expensive than electrical resistance heating. (6)

The operating efficiency of a heat pump is called its Coefficient of Performance (COP) and is defined as the ratio of useful heat obtained from the condenser to the heat equivalent of the electrical input to the system. The COP of most commercially available air source heat pumps varies from 3.2 to 2.6 at 4°C to a range of 2.6 to 1.9 at -12°C. The greatest disadvantage of an air source heat pump is that as the outside temperature decreases, so does the capacity and the COP, making the heat pump less efficient.

The COP of a single-speed heat pump is usually greater than 1 at -12°C and these machines are more cost effective in areas with 5000 DD (°C) or less. The two-speed heat pumps have a COP greater than 1 at -23°C, providing a more cost effective alternative in areas with more than

5000 DD(°C). If an add-on heat pump system is to be used, it should consist of an efficient furnace and a heat pump with a performance as above. (6)

The higher the temperature or the warmer the climate, the higher the COP is. At 10°C, the COP is typically about 3, at 0°C it is 2.3, and at -15°C the COP is lowered to approximately 1.5. However even with the lower performance, it still compares favourably to electrical resistance with a COP of 1 and to oil or gas which have an equivalent COP of about 0.8. (2)

Another common way of classifying air source heat pumps is to measure their cooling capacity in tons. There are 2, 3 and 5 ton heat pumps where one ton of air conditioning capacity is approximately 3.5 kW (12,000 Btu/h) of total heat capacity. The heating capacity of a heat pump is generally close to the cooling capacity at a specified outdoor temperature - usually 7°C (45°F). (6)

The outside air temperature at which the heating capacity of the heat pump is equal to the heating demand of the house is called the balance point. In the past, these heat pumps have been sized to meet the cooling load, allowing the balance point to fall where it may. Recently however, heat pumps have been sized so that the balance point falls at the temperature of greatest heating load frequency. When the temperature of the outside air drops below this point, resistance or combustion heat must be added to make up the deficit in capacity which results in a decrease in the overall COP. (7)

A recommended method for sizing a heat pump is to choose a unit that attains a balance point at the outside air temperature where the largest annual heating load is expected. Other factors to consider when sizing are: proper air flow for the space, the COP at operating temperatures, size and cost. (7)

When the outside air temperature drops to 4°C (40°F) or below, frost starts to form on the outside air coils degrading the operation of the system. When all factors are considered, the COP is apt to be 1.5 to 2 instead of 3 to 4. (6) The Seasonal Performance Factor (SPF) is the total heat output of the unit divided by the seasonal energy input over the entire heating season. An SPF of 1.2 to 1.6 is possible for most of Southern Canada, eg. 1.2 in Edmonton and 1.6 in Toronto. The SPF is higher in warmer areas such as Halifax (1.9) and Vancouver (2.3). (2)

Another important factor when choosing a heat pump is to ensure availability of a contractor skilled in the installation and maintenance of heat pumps. Ontario Hydro found that a significant proportion of heat pumps had not been properly installed and that the servicing of the units had reduced the performance because of improper modifications of the control setpoints. (5, 6)

Because of its complexity, a heat pump tends to be more expensive than a conventional system; a residential heat pump would probably cost more than three times as much as a gas furnace. The installed cost of an air to air heat pump can vary from $2500 to $4000 depending on the capacity. (6, 7)

Product information on heat pumps claim various reductions in energy use depending on the system chosen. The following are typical predictions of energy savings taken from the manufacturers' literature. An add-on heat pump added to a gas furnace can save 28% and an add-on heat pump added to an oil furnace can save 36% in total energy consumption. A complete heat pump system installed, used in place of an oil furnace can reduce the energy consumption by 61% and if a complete heat pump system is installed in place of electric resistance heating, the average energy saving can be 32%. Manufacturers' claims can be misleading because the percentage savings are calculated in kilowatt-hour equivalents; since the price of electricity is higher than oil or gas, the savings appear to be much larger.

A life-cycle analysis was done on the example house assuming a heat pump was installed at a cost of $3000 and the Seasonal Performance Factor (SPF) was 1.6. Although this heat pump results in a net energy saving, the cost of oil replaced is so much lower than the cost of eletricity required by the heat pump that the life-cycle savings turn out to be negative. In this application, a more efficient heat pump is needed (higher SPF) combined with more competitive pricing of electrical energy relative to combustion energy. If the example house had electrical resistance heating, then the heat pump would result in positive life-cycle savings since the dollar value of the annual savings would now exceed the operating costs. (See A-21)

OPTION	Savings per Year $	Unit Cost $	Total Cost $	Life-Cycle Expenses (present value) $	Life-Cycle Benefits (present value) $	Life-Cycle Savings (present value) $	B/C Ratio
Heat Pump	1135	-	3000	14,933	12,319	0	.10

Heat pumps can be very useful in certain circumstances but they are not necessarily for everyone. They are best if electric resistance heating is already installed in the house, if the cost of conventional fuel is high relative to the cost of electrical energy and if the climate is relatively mild (less than 4800°C DD per year). (4)

Heat pumps have become more efficient in the last few years and are likely to become more so in the future. Heat pumps may also have applications for hybrid solar systems where the ambient air from which heat is extracted by the heat pump is preheated using solar energy. (1, 2, 10)

References

(1) Brown, Terry. "Our Friend the Heat Pump." Home Energy Digest - Woodburning Quarterly. Vol. 5, No. 3, pp. 114-128.

(2) Canada Energy Mines and Resources. "Heat Pumps". Enersave Advisory Services. April 1980.

(3) Cane, R.L.D. "Residential Space Heating with the Heat Pump." Building Research Note. No. 125, Division of Building Research, National Research Council of Canada. Ottawa: NRC Jan. 1978.

(4) Cane, R.L.D. The Cost of Owning and Operating a Residential Heat Pump System in Canada. DBR Paper No. 905. Ottawa: NRC, 1980.

(5) Consumer Guide. Energy Savers Catalog. New York: G.P. Putman's Sons, 1977.

(6) Housing and Urban Development Association of Canada and Ontario Ministry of Energy. Builders' Guide to Energy Efficiency in New Housing. Toronto: HUDAC, 1980.

(7) Solar Age editors. Solar Age Catalog. Port Jervis NY: Solar vision, 1977.

(8) U.S. Department of Energy. Conservation and Solar Applications. Heat Pump Technology, A Survey of Technical Development Markets. GPO: June 1978.

(9) Walker, Howard V. Energy Conservation: Design Resource Handbook. Royal Architectural Institute of Canada. Ottawa: RAIC, 1979.

(10) Wolfe, Ralph and Peter Clegg. Home Energy for the Eighties. Charlotte Vermont: Garden Way Publishing, 1979.

(11) Product information from the Energy Conservation Equipment Information Files:
15 Heat Pumps

CONTROLS

The purpose of controls is to collect data, make decisions and implement system functions. A typical control device is the familiar thermostat. The data gathering consists of monitoring temperatures at key locations to indicate the need for more or less heating or cooling. The specific locations of the sensors are critical and will make the difference between optimum operation and poor performance. The control unit receives the temperature indications from the sensors, makes a decision and then sends the output signals to operate the electrical or mechanical parts of the system whether it be fans, pumps, dampers or auxillary heat.

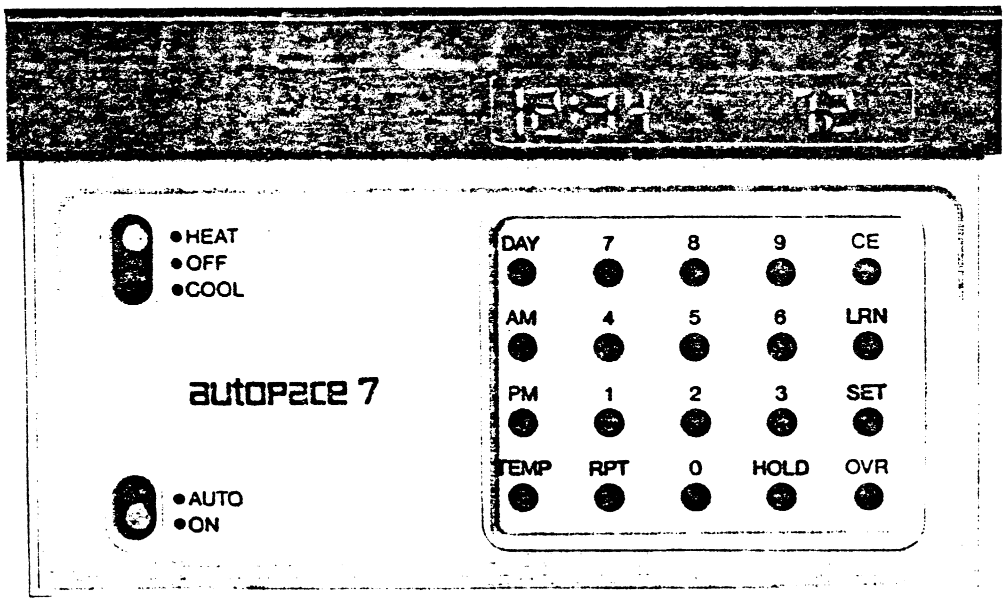
In a new house, the controls, sensors and all electrical and mechnical devices can be taken into consideration at the design stage. That is not possible in an existing house but there are many controls which can be easily retrofitted with the purpose of saving energy.

The simplest controls are time switches which will turn off ventilation fans, heaters, lights, etc. after a predetermined length of time. They can be bought from electrical wholesalers for under $20. Time switches which run on house current are also available for electric hot water heaters. They are able to turn the heater on and off according to the times set by the owner. If hot water is not used for several hours at a time, the switch can save considerable money each year depending on the amount of time the heater is off. This type of device costs about $50.

There are several new thermostats now available on the market whose purpose is to save energy by setting back the temperature at night. They range from timers which are set to change the temperature twice a day to very elaborate programmable thermostats with digital readout which can be programmed for four temperatures a day or a total of 28 temperatures a week. The cost depends on the complexity and they range from $50 to $250.

Thermostat Setback

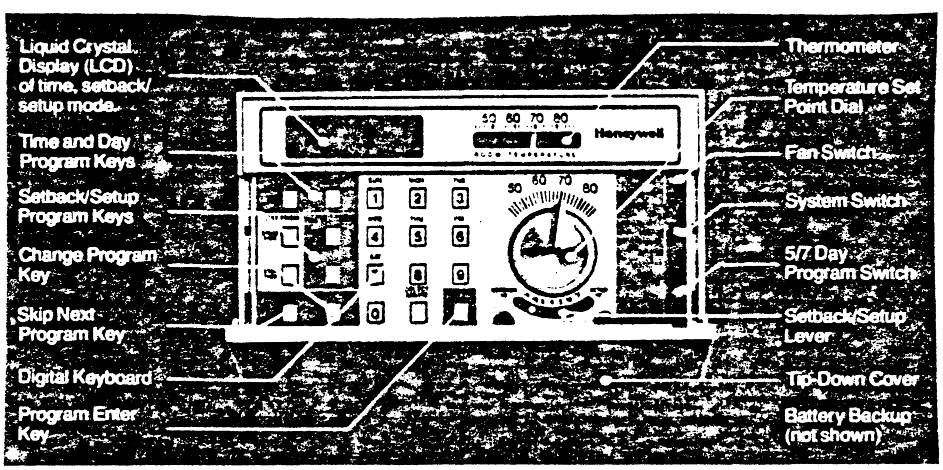
One of the most effective energy conservation strategies is to reduce the thermostat setting from 22°C to 20°C (72 °F to 68°F) during the day and to 17°C (63°F) at night. This alone can save up to 15% of the heating bill. Even greater savings can result if the setting is lowered further during the day or an average of 5% saving for each degree Celsius of setback. (2, 3) If the homeowner regularly set the thermostat back, the example house could save about 775 litres (170 gal) of fuel or $170 annually at no cost to the homeowner. If a programmable thermostat is installed at a cost of $100, the life-cycle savings will be about $1650 and the benefit/cost ratio will be 17.51.



Other features of Autopace 7:

- Tamper-proof security
- Constant LED display of time and temperature
- Solid state electronics
- Manual override
- Tough molded case with hinged cover
- Safety re-set function

Install Autopace 7 and start saving fuel today.



Summary of T800 Advanced Features

Liquid Crystal Display (LCD) The T800's "Information Center", with up-to-the-second information on thermostat status. ■ In normal operation the LCD is a clock providing *continuous* time-of-day display. ■ A colon separates hours and minutes. Its upper or lower dot flashes, respectively, to indicate if the T800 is operating in a setup or setback mode. ■ The LCD's A.M/P.M. indicator will flash if the thermostat is set to the "Skip Next Program" mode (see below). ■ Setback/setup entries are visible on the LCD display during programming and on command.

Time and Day Program Keys Use to set clock and

Thermometer Accurate room thermometer provides *continuous* temperature readout.

Temperature Set Point Dial Familiar dial permits precise comfort settings.

Fan Switch Use to select auto or continuous fan.

System Switch Use to select system operation...heating, cooling or off.

5/7 Day Switch Set in the five-day position to *automatically skip only the daytime program* on weekends, yet retain the nighttime program seven days a week. Both programs will occur in the 7-day position.

OPTION	Savings per Year $	Unit Cost $	Total Cost $	Life-Cycle Expenses (present value) $	Life-Cycle Benefits (present value) $	Life-Cycle Savings (present value) $	B/C Ratio
Thermostat Set Back							
(manual)	170	0	0	0	1751	1751	1751
(programmable)	170	100	100	100	1751	1651	17.51

References

(1) Reno, Vic. "Controls Demystified". Solar Age, July 1980.

(2) Product Information from the Energy Conservation Equipment Information File: 15 Mechanical Controls

WATER CONSERVATION

According to a number of Canadian figures, the average family of four consumes about 1000 litres (220 gal) of water per day. Although the proportions vary greatly among households, generally the toilet accounts for 40%, the bathtub/shower 30%, laundry 12%, cleaning 10%, lavatory 3%, and cooking and drinking account for 2%. (1, 9)

Residential hot water use in Canada is a substantial consumer of energy. The baseload has traditionally been set at 21,000 to 32,000 MJ (20-30 MBtu) per year for a household of four that is equipped with all the basics including washing machine and dishwasher. If the example household uses 68 litres (15 gal) of hot water per person per day that is heated from 10°C to 65°C (50°F - 150°F), then the baseload is about 23,000 MJ (22 MBtu) per year. Using an 85% efficiency for the hot water heater, the 23,000 MJ load requires 27,000 MJ of electricity. This household would therefore pay about $375 each year to heat its daily 270 litres (60 gal) of hot water. (See A-22) (9)

Much of this energy is wasted; some escapes from the hot water tank, even when insulated, more is lost during washing and finally, most of the energy goes down the drain as waste water and is expelled to the outside. (5)

There are many ways of reducing the consumption of both hot and cold water and reductions of 25% to 50% are feasible. Unlike energy conservation in space heating, domestic water offers no clear opportunity for major savings through built-in improvements to conventional equipment or insulation. The area where the greatest savings can be achieved is that of actual consumption and fortunately equipment can be modified to encourage or enforce more careful use. There are three main types of energy-conservation measures:

- upgrading of equipment;
- installation of rationing devices; and
- changes in operation of equipment and use. (5, 6, 7)

1. Upgrading of Equipment

a. Tank Insulation

Most electric hot water tanks have 50 mm (2 in.) of insulation which gives an R value of 1.1 (R 6), but even with this insulation, the heat loss from the tank can account for 15% of the water heating bill. If the insulation was increased to R 2.1 or R 2.6 (R 12-R 15), about 11% of the heating bill could be saved which represents 2900 MJ or $40 per year. (This heat loss often becomes a heat gain for the space heating of a unit, however it is an inefficient way to provide space heat.)

Upgrading is easily done by the homeowner for under $15 by wrapping the tank with an additional R 1.4 or R 1.8 (R 8 or R 10) mineral wool batts and covering it with a dust jacket. Water tank insulation kits are also available which add about 40 mm (1½") of fibreglass with an R value of 0.8 (R 4.5) and an outer layer of vinyl and costs about $30 each. (1, 5, 6, 11, 12) (See A-23)

OPTION	Savings per Year $	Unit Cost $	Total Cost $	Life-Cycle Expenses (present value) $	Life-Cycle Benefits (present value) $	Life-Cycle Savings (present value) $	B/C Ratio
Hot Water Tank Insulation	40		15	17.50	412	394	27.30

b. Pipe Insulation

Heat losses through piping varies widely according to patterns of use making the effects of insulation difficult to determine. It can be estimated that a house with 15 m (50 ft.) of hot water piping loses about 6% of water heating energy, but opinions vary on the advantages of insulating the hot water pipes. Some believe that there is little economic justification since losses aren't significantly reduced and especially since waiting periods between uses are often long enough for the water in the pipe to cool off completely. Others believe that the loss is significant enough to make the effort worthwhile.

If the hot water was used throughout the day and pipe insulation of R 0.7 (R 4) was added, saving 5% of the energy consumption, the homeowner would save 1350 MJ or $19 per year.

Insulation designed for piping is widely available and costs $2.60 to $3.90 per metre ($0.80 - $1.20 per ft.). To insulate the piping in the example house would cost approximately $50.

OPTION	Savings per Year $	Unit Cost $	Total Cost $	Life-Cycle Expenses (present value) $	Life-Cycle Benefits (present value) $	Life-Cycle Savings (present value) $	B/C Ratio
Pipe Insulation	19	1/m	50	54	196	142	3.82

The life-cycle cost analysis shows that in this example pipe insulation is a worthwhile investment, though probably less lucrative than other system improvements. (1, 5, 6, 8, 12) (See A-24)

c. In-line Heaters

Tankless, point-of-use or in-line heaters are electric or gas units that heat water on demand, usually when the flow is initiated by an open valve. These units can be installed at the kitchen, bathroom or laundry sink. Because there are no tank, pipe or flue losses, energy is saved, but the greatest saving is due simply to forced rationing; only a small stream of water is delivered. Temperature rises of 33°C to 39°C (60°F - 70°F) are possible though some of the units have the greatest temperature difference below a flow of 0.08 litres per second (1 gal/min) which probably makes them more appropriate as boosters rather than as primary heaters. Larger units can be placed downstream of a conventional heater that is kept at 27°C to 32°C (80°F - 90°F); the reduced losses from the tank would be complemented by the high efficiency of the tankless unit.

The larger units cost about $520 (for gas); smaller sink units cost from $140 to $170 and closer to $250 installed. Manufacturers claim savings of 33% if gas is used and 29% for electricity. (5, 6, 12)

d. Pre-heating Incoming Water

The water that enters the system is very cold, especially in winter when temperatures of 4°C (40°F) are reached; if this water could be warmed before entering the system, a great deal of energy could be saved. This preheating can be done with a woodstove, solar preheater or waste heat recovery system. A waste heat recovery system would use waste hot water from drains from baths, laundry and the dishwasher and circulate it through a heat exchanger enveloping the incoming cold water. (5, 11)

2. Rationing Devices

a. Flow Restrictors for Showers

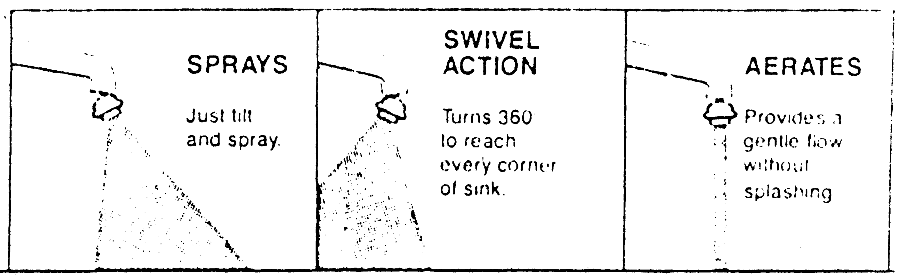
There is a variety of flow restricting showerheads on the market; some are simple rubber or plastic washers placed in the showerhead to contrict the opening and others are actual showerheads with a fine spray and low flow rates. The flow rates vary in the neighbourhood of 0.2/L (2.5 gal/min), and compare favourably with the standard showerhead flow of 0.46 L/s (6 gal/min); some also have a shut-off valve which allows the flow to be stopped entirely. The one disadvantage with these low flow showerheads is that if there is a pressure disturbance in the system, the hot and cold shocks are much more severe.

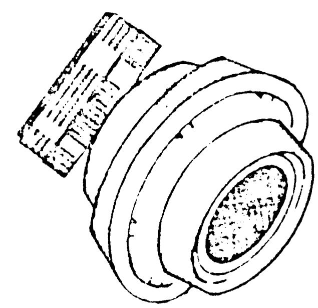
Since bathing/showering can account for 40% of the total hot water use, these restrictors can effect large savings. In the example household, if showers and baths use about 110 litres (24 gal) per day and these restrictors cut the use in half, the savings by this measure alone would be about $75 per year.

The low flow showerheads are readily available in Canada and vary in cost from $5 for the shower-reducer to $20 for the complete showerhead.

WATER GATE FAUCET SPRAY AERATOR

Uniquely styled low-profile spray aerator fits the decor of any kitchen. Dual threaded for easy installation on regular faucets with either inside or outside threads. Tilts to spray-rinse, aerates for gentle flow and turns 360° to reach every corner of the sink.



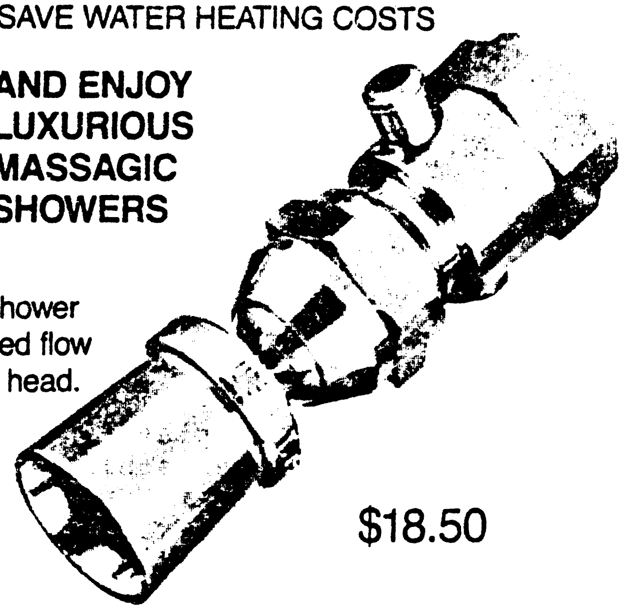


No. 0815
$2.95

SAVE WATER COSTS
SAVE SEWAGE COSTS
SAVE WATER HEATING COSTS

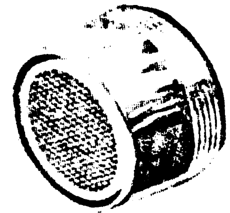
AND ENJOY LUXURIOUS MASSAGIC SHOWERS

with:
SaverShower controlled flow shower head.



$18.50

$12.25



OPTION	Savings per Year $	Unit Cost $	Total Cost $	Life-Cycle Expenses (present value) $	Life-Cycle Benefits (present value) $	Life-Cycle Savings (present value) $	B/C Ratio
Shower Restrictor	75	20	20	21.60	773	751	38.55

The life cycle analysis shows that this is a very worthwhile investment, recovering the initial cost within the first few months. (5, 6, 8, 12) (See A-25)

b. Faucet Restrictors

Common faucet aerators are widely available and are considered to reduce water use at bathroom sinks by about 25%. The low flow aerators will deliver less total savings than a showerhead because the initial consumption is lower. At a much higher cost are spray taps which can restrict consumption by as much as 90%. With no aerator, the faucet delivers 0.38 to 0.45 litres per second (5-6 gal/min); an aerator reduces this to 0.23 L/s (3 gal/min) and low flow units reduce it further to 0.13 L/s (1.5-2.0 gal/min). These faucet aerators are very inexpensive at $2 to $3 and if they reduce the water used at the sink by 25%, about 400 MJ or $5.50 will be saved annually which proves to be a good investment. (5, 11, 12) (See A-26)

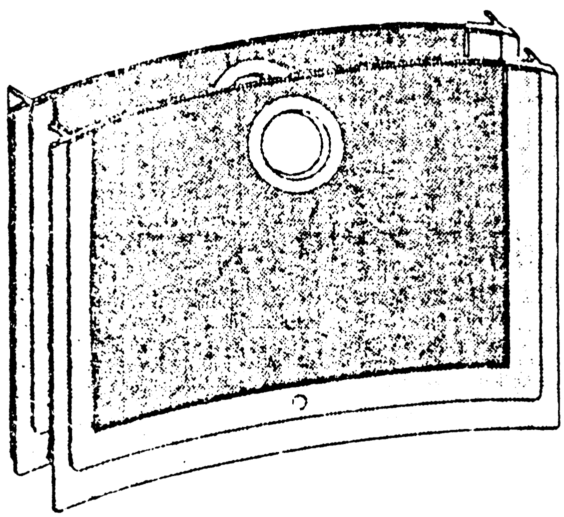
OPTION	Savings per Year $	Unit Cost $	Total Cost $	Life-Cycle Expenses (present value) $	Life-Cycle Benefits (present value) $	Life-Cycle Savings (present value) $	B/C Ratio
Faucet Restrictor	5.50	3	3	3	57	54	19.00

c. System Restrictors

Pressure reducing valves costing $25 to $50 are also available which slow the general flow rate in the whole plumbing system by 20% to 50%. (6)

d. Toilet Tank Dams

The toilet is one of the greatest users of domestic water, accounting for 40% to 50% of the daily water consumption. Twenty-seven to thirty-six litres (6-8 gal) of water are used with every flush. Toilet tank dams or savers reduce each flush to 18 litres (4 gal), saving 9 litres (2 gal) each time. These dams are in the $5 to $10 price range. If the toilet accounts for 400 litres (88 gal) of water used every day, then at $0.25 per cubic metre, the homeowner will save about 73,000 litres or $18 each year. (See A-27)



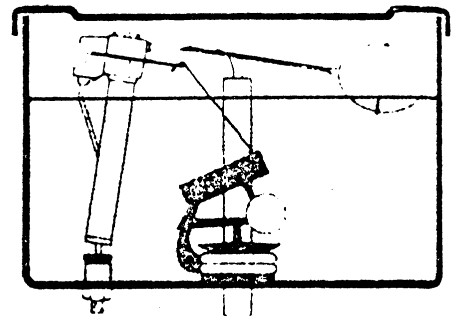
No. 0808 $4.95/pair

WATER GATE® TOILET TANK SAVER

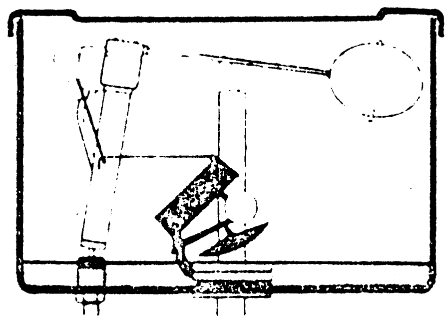
A two-piece device placed in a toilet tank forming a dam or reservoir around the drain to stop wasteful water loss during the flushing process. The non-biodegradable Water Gate, which has no moving parts and is easily installed without tools, saves approximately two gallons per flush — or 33 percent of the water expended in the average flush.

Average household flushes toilet 19.4 times daily

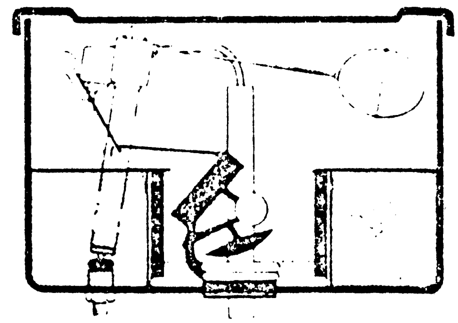
Average water used per flush	6.0 gallons
With WATER-GATE®	4.0 gallons
Savings per flush	2.0 gallons
Savings per day	38.8 gallons
Savings per week	271.6 gallons
Savings per month	1164 gallons



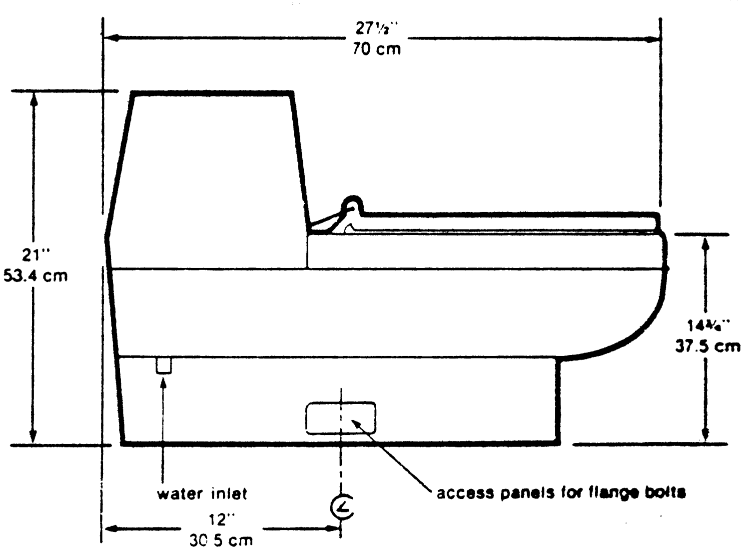
Water level before flushing



After flushing without Water-Gate®



After flushing with Water-Gate®



OPTION	Savings per Year $	Unit Cost $	Total Cost $	Life-Cycle Expenses (present value) $	Life-Cycle Benefits (present value) $	Life-Cycle Savings (present value) $	B/C Ratio
Toilet Tank Dam	18.25	10	10	10	188	178	18.80

There is also a new toilet which will be available in Canada in the spring of 1981 which flushes on 4.5 litres (1 gal) and costs about $600. (5, 6, 8, 12)

3. Changes in Operation and Use

a. Thermostat Setting

Reducing the temperature of the water inside the hot water tank is one of the most profitable energy conservation measures since energy is saved at no additional cost to the homeowner. The hot water temperature is usually set at 60°C (140°F) or higher but this can easily be reduced to 43°C (110°F), especially if there is no dishwasher. Simply by turning down the temperature in a tank insulated to R1.1 (R 6), the owner would save about 16,200 MJ or $150 each year. (5, 6, 11) (See A-28)

OPTION	Savings per Year $	Unit Cost $	Total Cost $	Life-Cycle Expenses (present value) $	Life-Cycle Benefits (present value) $	Life-Cycle Savings (present value) $	B/C Ratio
Hot Water Tank Thermostat	150	0	0	0	1545	1545	1545

b. Laundering

Washing clothes in warm wash - cold rinse instead of hot wash - warm rinse can cut the laundry consumption of energy by two-thirds. The effect on the household water heating bill varies with the volume of laundering but the average saving appears to be approximately 15%. Like changing the thermostat setting, the benefit/cost ratio is infinite since the savings are made at no cost to the homeowner.

References

(1) B.C. Hydro. Your Energy Efficient Home Planning Kit, Vol. 5 Water Heating.

(2) Bender, Tom. "No Tanks." RAIN-Journal of Appropriate Technology, Vol. 3, No. 9, July 1977, Portland Oregon.

(3) Canada Energy Mines and Resources. How to Reduce Your Hot Water Heating Costs. Enersave Advisory Service, Ottawa.

(4) Canada Energy Mines and Resources. 100 Ways to Save Energy and Money in the Home. Office of Energy Conservation. Ottawa: March 1975.

(5) Canada Mortgage and Housing Corporation. The Conservation of Energy in Housing. Ottawa: CMHC, 1977.

(6) Carter, Joe, and Robert G. Flower. "The Micro-load." Solar Age. Sept. 1980, pp. 22-30.

(7) Consumer Guide. Energy Savers Catalogue. New York: G.P. Putman's Sons, 1977.

(8) Famey, Mel. "Less is More". Home Energy Digest - Wood Burning Quarterly. Spring 1981, pp. 106-111.

(9) Housing and Urban Development Association of Canada and Ontario Ministry of Energy. Builders' Guide to Energy Efficiency in New Housing. Toronto: HUDAC, 1980.

(10) Szostak, Joe. "Hot Water - How to conserve it without getting burnt." Canadian Renewable Energy News. Sept. 1980, pp. 21.

(11) U.S. Department of Commerce. National Technical Information Service. Measurement of Energy to Produce Domestic Hot Water-Initial Study. Springfield, VA.: GPO, 1979.

(12) Product informatin from the Energy Conservation Equipment Information Files:
15 Heat Generation - In-Line Heaters
15 Plumbing Fixtures - Water Conservation Devices

For operating costs and fuel savings, the present value multiplier is 10.3 (see A-02) because they are multiple payments, N = 10 years, e = 18%, and d = 14%.

The present value multiplier for maintenance and repair costs and resale value is 8.11 (see A-02) because they are multiple payments, N = 10, i =12% and d = 14%.

The present value multiplier for replacement costs is derived from different charts because they are paid only once or twice over the life-cycle period. For an energy conservation device that has a life span of 5 years and therefore must be replaced once over the 10 years, N = 5, i = 12% and d = 14%; the present value multiplier is then .915 (A-02). If the device must be replaced twice over the 10 year life-cycle period, where d = 14%, i = 12% and N = 3.3 and 6.7,the present value multiplier will be 1.83.

$$PVM = \left[\frac{(1 + i)}{(1 + d)}\right]^{3.3} + \left[\frac{(1 + i)}{(1 + d)}\right]^{6.7}$$

N = 10

Discount Rate d%	Annual Inflation Rate i %, or Cost Escalation Rate e% 0	2	4	6	8	10	12	14	16	18
0	10.00	10.95	12.01	13.18	14.49	15.94	17.55	19.34	21.32	23.52
2	8.98	9.80	10.72	11.73	12.85	14.10	15.48	17.01	18.71	20.59
4	8.11	8.83	9.62	10.49	11.46	12.54	13.73	15.05	16.50	18.11
6	7.36	7.98	8.67	9.43	10.28	11.21	12.24	13.38	14.66	16.02
8	6.71	7.26	7.86	8.53	9.26	10.07	10.97	11.95	13.04	14.24
10	6.15	6.63	7.16	7.74	8.38	9.09	9.88	10.73	11.68	12.72
12	5.65	6.08	6.54	7.06	7.62	8.24	8.93	9.68	10.51	11.42
14	5.22	5.59	6.01	6.46	6.96	7.51	8.11	8.77	9.50	10.30
16	4.83	5.17	5.54	5.94	6.38	6.87	7.40	7.98	8.62	9.32
18	4.49	4.79	5.12	5.48	5.88	6.31	6.78	7.29	7.97	8.48

Multiple Payment Factor with Escalation

N = 5

Discount Rate d%	Rate of Price Increase - Inflation or Escalation % 0	2	4	6	8	10	12	14	16	18
0	1.000	1.104	1.217	1.338	1.469	1.611	1.762	1.925	2.100	2.288
2	0.906	1.000	1.102	1.212	1.331	1.459	1.596	1.744	1.902	2.072
4	0.822	0.907	1.000	1.100	1.208	1.324	1.449	1.583	1.726	1.880
6	0.747	0.825	0.909	1.000	1.098	1.203	1.317	1.439	1.569	1.710
8	0.681	0.751	0.828	0.911	1.000	1.096	1.199	1.310	1.429	1.557
10	0.621	0.686	0.755	0.831	0.912	1.000	1.094	1.196	1.304	1.421
12	0.567	0.626	0.690	0.759	0.834	0.914	1.000	1.093	1.192	1.298
14	0.519	0.573	0.632	0.695	0.763	0.836	0.915	1.000	1.091	1.188
16	0.476	0.526	0.579	0.637	0.700	0.767	0.839	0.917	1.000	1.089
18	0.437	0.483	0.532	0.585	0.642	0.704	0.770	0.842	0.918	1.000

Single Payment Factor with Escalation

EXAMPLE HOUSE

Area: floor = 107 m^2
wall = 127 m^2
window = 15 m^2
door = 4 m^2
ceiling = 53 m^2

R Values: walls = 1.76
windows = .26
doors = .53
ceiling = 1.94

Air Infiltration: 40% through windows and doors
20% through ceiling
40% through walls

Perimeter: windows = 50 m
doors = 12 m

Crack Length: ceilings and walls = 115 m

Air Change: one (1) per hour

Volume: 400 m^3

Degree Days: 4400 (^{o}C)

Efficiency: oil furnace = 65%
hot water heater = 85%

Cost: electricity = $0.05 per kWh
#2 heating oil = $0.22 per litre
water = $0.25 per m^3

Hot Water Consumption = 272 litres per day

Economic Parameters: i = 12%
e = 18%
d = 14%
N = 10 years

WINDOW R VALUES

single glazing = R .2

single glazing with exterior storm = R .26

double glazing = R .3

triple glazing = R .5

SPECIFIC HEAT

cp (air) = 1300 MJ/kg°C

cp (water) = .0042 MJ/kg °C

ENERGY CONTENT OF FUELS PER UNIT

Oil: 38-39 MJ / litre
(165,000 - 170,000 Btu / gal

Gas: 33.9 - 41.45 MJ / m^3
(900 - 1,100 Btu / ft^3)

Wood: hardwood = 30,770 MJ / cord
(29 M Btu / cord)

softwood = 16,500 MJ / cord
(15.6 M Btu / cord)

Electricity: 3.6 MJ/kWh
3,400 Btu/kWh

(1) Heat Loss Factor = U x A or $\frac{A}{R}$

(2) Air Change Heat Loss Factor = $\frac{\text{volume}(m^3) \times \text{no. of air changes} \times 1300}{3600}$

(3) Total Heat Loss Factor = Heat Loss Factor of basement + exterior walls + windows + doors + ceiling + air change

(4) Total Heat Loss per Season = $\frac{(\text{heat loss factor} \times 3600) \times 24 \times DD}{1{,}000{,}000}$

(5) Fuel Consumption per Season = $\frac{\text{heat loss per season}}{(\text{energy content of fuel/unit}) \times \text{efficiency (e)}}$

(6) Fuel Cost per Season = fuel consumption x cost per unit

(7) Annual Energy Consumption of Hot Water Heater = $\frac{\text{amount of water (L/day)} \times t^{\circ}C \times .0042 \times 365}{\text{efficiency of hot water heater}}$

Heat Loss Factors:

Basement = factor (1.2) x perimeter (29.2) = 35

Exterior Walls = $\frac{A}{R} = \frac{127}{1.76} = 72$ (formula 1)

Windows = $\frac{A}{R} = \frac{15}{.26} = 58$ (formula 1)

Doors = $\frac{A}{R} = \frac{4}{.53} = 7.5$ (formula 1)

Ceiling = $\frac{A}{R} = \frac{53.3}{1.94} = 27.5$ (formula 1)

Air Change = $\frac{400 \times 1 \times 1300}{3600} = 144$ (formula 2)

Total Heat Loss Factor:

= 35 + 72 + 58 + 7.5 + 27.5 + 144 = $\underline{344}$ (formula 3)

Heat Loss per Season:

$\frac{344 \times 3600 \times 24 \times 4400}{1,000,000} = \underline{130,775 \text{ MJ}}$ (formula 4)

Fuel Consumption:

$= \frac{130,775}{39 \times .65} = \underline{5159 \text{ litres}}$ (formula 5)

Fuel Cost per Season:

5159 x .22 = $\underline{\$1135}$ (formula 6)

Heat Loss Factors

Basement: improved 30% with the addition of R 1.4 polystyrene = 24.5

Exterior Walls: (upgrade from R 1.76 to 2.5) = 51 (formula 1)

Windows: (no change) = 58

Doors: (no change) = 7.5

Ceiling: (upgrade from R 1.94 to 5.1) = 10.5 (formula 1)

Air Change: (infiltration reduced by 50%) = 72 (formula 2)

Total Heat Loss Factor = 224 (formula 3)

Total Heat Loss/Season = 85,156 MJ (formula 4)

Fuel Consumption = 3360 litres (formula 5)

Fuel Cost = $739 (formula 6)

Annual Saving = (5159 - 3360) = 1799 litres or $396

LIFE-CYCLE EXPENSES (LCE)

	Cost Factor	Type of Expenses		Present Value Multiplier	Present Value ($)
		Fixed Amount	Year 1 Payments		
assume $2500	Initial Cost	2500			2500
	Operating Cost				
assume 1%	Maintenance, Repairs, etc.		25	8.11	202
assume none	Replacement Cost				
				LCE	$ 2702

LIFE-CYCLE BENEFITS (LCB)

	Saving Factor	Type of Benefits		Present Value Multiplier	Present Value ($)
		Fixed Amount	Year 1 Benefits		
	Fuel Savings		396	10.4	4090
assume 25%	Resale Value	625		.838	524
				LCB	$ 4614

LIFE-CYCLE SAVINGS (LCS): LCB - LCE $ 1912

BENEFIT/COST RATIO:

$$\frac{\text{fuel savings}(4090)-\text{operating costs}(0)-\text{maintenance}(202)}{\text{initial cost}(2500)-\text{resale value}(524)+\text{replacement}(0)} = 1.96$$

If the heat loss due to air infiltration in the example house is 54,740 MJ per season (formula 4),

Fuel Consumption = 2160 litres or $475 (formulae 5 and 6)

If windows are responsible for 40% of the heat loss due to air infiltration and weatherstripping can reduced air infiltration through windows by 63%,

Annual Savings = (2160 x .40) x .63 = 544 litres or $120

Cost of Weatherstripping = perimeter x cost = 62 m x .82 = $51 (approx.)

LIFE-CYCLE EXPENSES (LCE)

	Cost Factor	Type of Expenses: Fixed Amount	Type of Expenses: Year 1 Payments	Present Value Multiplier	Present Value ($)
assume $51	Initial Cost	51			51
	Operating Cost				
assume 1%	Maintenance, Repairs, etc.		.50	8.11	4
assume N = 5, i = 12%, d = 14%	Replacement Cost	51		.915	47
				LCE	$ 102

LIFE-CYCLE BENEFITS (LCB)

	Saving Factor	Type of Benefits: Fixed Amount	Type of Benefits: Year 1 Benefits	Present Value Multiplier	Present Value ($)
assume $120	Fuel Savings		120	10.3	1236
	Resale Value				
				LCB	$ 1236

LIFE-CYCLE SAVINGS (LCS): LCB - LCE $ 1134

BENEFIT/COST RATIO:

fuel savings(1236)-operating costs(0)-maintenance(4) / initial cost(51)-resale value(0)+replacement(47) = 12.57

If weatherstripping and caulking combined can reduce the total air infiltration by 50%, or reduce the air change to one half per hour,

Heat Loss/Season = $\frac{54,740}{2}$ = 27,370 MJ

Fuel Consumption = 1080 litres or $238

Annual Saving = (2160 - 1080) = 1080 litres or $238

Cost of Caulking: $\frac{\text{crack length}}{\text{bead length per tube}}$ x cost = $\frac{115\text{ m}}{8\text{ m/tube}}$ x \$7 = \$105

Cost of Weatherstripping = $51

Total Cost = $156

LIFE-CYCLE EXPENSES (LCE)

	Cost Factor	Type of Expenses		Present Value Multiplier	Present Value ($)
		Fixed Amount	Year 1 Payments		
	Initial Cost	156			156
	Operating Cost				
assume 1%	Maintenance, Repairs, etc.		1.50	8.11	12
assume only weatherstripping	Replacement Cost	51		.915	47
				LCE	$ 215

LIFE-CYCLE BENEFITS (LCB)

Saving Factor	Type of Benefits		Present Value Multiplier	Present Value ($)
	Fixed Amount	Year 1 Benefits		
Fuel Savings		238	10.3	2451
Resale Value				
			LCB	$ 2451

LIFE-CYCLE SAVINGS (LCS): LCB - LCE $ 2236

BENEFIT/COST RATIO:

$$\frac{\text{fuel savings (2451) - operating costs (0) - maintenance (12)}}{\text{initial cost (156) - resale value (0) + replacement (47)}} = 12.01$$

If the example house had single glazing only, the R value would be .2

Heat Loss Factor (window) = 75 (formula 1)

Total Heat Loss Factor = 361 (formula 3)

Heat Loss/Season = 137,238 MJ (formula 4)

Fuel Consumption = 5414 litres or $1191 (formulae 5 and 6)

If new double-glazed units had replaced the single glazing, the R value would be .3 and the air infiltration through the windows would be reduced by 75%.

Heat Loss Factor (windows) = 50 (formula 1)
Heat Loss Factor (air change) = 144 - ((.4 x 144) x .75) = 100
Total Heat Loss Factor = 292 (formula 3)

Heat Loss/Season = 111,007 MJ
Fuel Consumption = 4379 litres or $963 (formulae 5 and 6)

Annual Savings = (5414 - 4379) = 1035 litres or $228

Cost: $250 (for 1 m^2 window) x 15 = $3,750 purchased
x 2 = $7,500 installed

LIFE-CYCLE EXPENSES (LCE)

	Cost Factor	Type of Expenses		Present Value Multiplier	Present Value ($)
		Fixed Amount	Year 1 Payments		
assume $250 ea. purchase price	Initial Cost	7,500			7,500
	Operating Cost				
assume .5%	Maintenance, Repairs, etc.		37	8.11	284
assume none	Replacement Cost				
				LCE	$ 7,784

LIFE-CYCLE BENEFITS (LCB)

	Saving Factor	Type of Benefits		Present Value Multiplier	Present Value ($)
		Fixed Amount	Year 1 Benefits		
assume single glazing	Fuel Savings		228	10.3	2,348
assume 25%	Resale Value	1875		.838	1,571
				LCB	$ 3,919

LIFE-CYCLE SAVINGS (LCS): LCB - LCE $ 0

BENEFIT/COST RATIO:

fuel savings(2348)-operating costs(0)-maintenance(284)
initial cost(7500)-resale value(1571)+replacement(0)
= .35

If the example house had single glazing only, annual consumption of #2 heating fuel would be 5414 litres or $1191. (see Window/Glazing Calculations)

If reflective film were added, the R value would be .26

Heat Loss Factor (windows) = 58 (formula 1)

Total Heat Loss Factor = 344 (formula 3)

Heat Loss/Season = 130,775 MJ (formula 4)

Fuel Consumption = 5159 litres or $1135 (formulae 5 and 6)

Annual Savings = (5414 - 5159) = 255 litres or $56

If the reflective film had been added to the example house with single glazing and exterior storms, the annual fuel consumption would have been 4994 litres.

Annual Saving = (5159 - 4994) = 165 litres or $36

LIFE-CYCLE EXPENSES (LCE)

	Cost Factor	Type of Expenses		Present Value Multiplier	Present Value ($)
		Fixed Amount	Year 1 Payments		
assume $27/m^2$	Initial Cost	400			400
	Operating Cost				
assume 1%	Maintenance, Repairs, etc.		4	8.11	32
assume none	Replacement Cost				
				LCE	$ 432

LIFE-CYCLE BENEFITS (LCB)

	Saving Factor	Type of Benefits		Present Value Multiplier	Present Value ($)
		Fixed Amount	Year 1 Benefits		
assume single glazing	Fuel Savings		56	10.3	577
assume none	Resale Value				
				LCB	$ 577

LIFE-CYCLE SAVINGS (LCS): LCB - LCE $ 145

BENEFIT/COST RATIO:

fuel savings (577) - operating costs (0) - maintenance (32) / initial cost (400) - resale value (0) + replacement (0) = 1.36

If the example house had single glazing only, annual consumption of #2 heating oil would be 5414 litres or $1191. (see Window/Glazing Calculations)

If bubble film were added, the R value would be .28

Heat Loss Factor (windows) = 54 (formula 1)

Total Heat Loss Factor = 340 (formula 3)

Heat Loss/Season = 129,254 MJ (formula 4)

Fuel Consumption = 5099 litres or $1121 (formulae 5 and 6)

Annual Saving = (5414 - 5099) = 315 litres or $69

If the bubble film had been added to the example house with single glazing and exterior storms, the annual fuel consumption would have been 4949 litres.

Annual Saving = (5159 - 4949) = 210 litres or $46

LIFE-CYCLE EXPENSES (LCE)

	Cost Factor	Type of Expenses: Fixed Amount	Type of Expenses: Year 1 Payments	Present Value Multiplier	Present Value ($)
assume $16/m^2$	Initial Cost	240			240
	Operating Cost				
assume 1%	Maintenance, Repairs, etc.		2.40	8.11	19
assume N=5, i = 12%, d = 14%	Replacement Cost	240		.915	220
				LCE	$ 479

LIFE-CYCLE BENEFITS (LCB)

	Saving Factor	Type of Benefits: Fixed Amount	Type of Benefits: Year 1 Benefits	Present Value Multiplier	Present Value ($)
assume single glazing	Fuel Savings		69	10.3	650
assume none	Resale Value				
				LCB	$ 650

LIFE-CYCLE SAVINGS (LCS): LCB - LCE $ 171

BENEFIT/COST RATIO:

$$\frac{\text{fuel savings}(650)-\text{operating costs}(0)-\text{maintenance}(19)}{\text{initial cost}(240)-\text{resale value}(0)+\text{replacement}(220)} = 1.37$$

If the example house had single glazing only, annual consumption of #2 heating oil would be 5414 litres or $1191. (see Window/Glazing Calculation)

If interior storms were added, the R value would be .35 and air infiltration through windows would be reduced by 50% (air infiltration through windows is 40% of the total).

Heat Loss Factor (windows) = 43 (formula 1)
Heat Loss Factor (total air change) = (.6 x 144) + $\frac{(.40 \times 144)}{.50}$ = 115

Total Heat Loss Factor = 300 (formula 3)

Heat Loss/Season = 114,050 MJ (formula 4)

Fuel Consumption = 4499 litres or $9900 (formulae 5 and 6)

Annual Saving = (5414 - 4499) = 915 litres or $201

The example house has single glazing with exterior storms and an annual fuel consumption of 5159 litres or $1135. If interior storms were added, the R value would be .41.

Total Heat Loss Factor = 294 (formula 3)

Heat Loss/Season = 111,615 MJ (formula 4)
Fuel Consumption = 4403 litres or $969

Annual Saving = (5159 - 4403) = 756 litres or $166

LIFE-CYCLE EXPENSES (LCE)

	Cost Factor	Type of Expenses		Present Value Multiplier	Present Value ($)
		Fixed Amount	Year 1 Payments		
assume $70/m^2$	Initial Cost	1050			1050
	Operating Cost				
assume 1%	Maintenance, Repairs, etc.		10.50	8.11	85
assume none	Replacement Cost				
				LCE	$ 1135

LIFE-CYCLE BENEFITS (LCB)

	Saving Factor	Type of Benefits		Present Value Multiplier	Present Value ($)
		Fixed Amount	Year 1 Benefits		
assume single glazing	Fuel Savings		201	10.3	2070
assume none	Resale Value				
				LCB	$ 2070

LIFE-CYCLE SAVINGS (LCS): LCB - LCE $ 935

BENEFIT/COST RATIO:

$$\frac{\text{fuel savings}(2070)-\text{operating costs}(0)-\text{maintenance}(85)}{\text{initial cost}(1050)-\text{resale value}(0)+\text{replacement}(0)} = 1.89$$

If the example house had single glazing only, annual consumption of #2 heating oil would be 5414 litres or $1191. (see Window/Glazing Calculations)

If fibrefill thermal blinds where added to single glazing, the R value would be .82 for 12 hours each day and 12 for the remaining 12 hours.

Heat Loss Factor (with blinds) = 18 (formula 1)
Heat Loss Factor (no blinds) = 75 (formula 1)

Total Heat Loss Factor (with blinds) = 304 (formula 3)
Total Heat Loss Factor (no blinds) = 361 (formula 3)

$$\text{Heat Loss/Season} = \frac{361 \times 3600 \times 12 \times 4400}{1{,}000{,}000} + \frac{304 \times 3600 \times 12 \times 4400}{1{,}000{,}000}$$
$$= 126{,}403 \text{ MJ}$$

Fuel Consumption = 4986 litres or $1097

Annual Saving = (5414 - 4986) = 428 litres or $94

LIFE-CYCLE EXPENSES (LCE)

	Cost Factor	Type of Expenses		Present Value Multiplier	Present Value ($)
		Fixed Amount	Year 1 Payments		
assume $75/m^2	Initial Cost	1125			1125
	Operating Cost				
assume 1%	Maintenance, Repairs, etc.		11.25	8.11	91
assume none	Replacement Cost				
				LCE	$ 1216

LIFE-CYCLE BENEFITS (LCB)

	Saving Factor	Type of Benefits		Present Value Multiplier	Present Value ($)
		Fixed Amount	Year 1 Benefits		
assume single glazing	Fuel Savings		94	10.3	968
	Resale Value				
				LCB	$ 968

LIFE-CYCLE SAVINGS (LCS): LCB - LCE $ 0

BENEFIT/COST RATIO:

$$\frac{\text{fuel savings}(968)-\text{operating costs}(0)-\text{maintenance}(91)}{\text{initial cost}(1125)-\text{resale value}(0)+\text{replacement}(0)} = .78$$

If the example house had single glazing only, annual consumption of #2 heating oil would be 5414 litres or $1191. (see Window/Glazing Calculations)

If foil thermal blinds were added to single glazing, the R value would be .2 + 1.76 or 1.96. (for 12 hours per day)

Heat Loss Factor (with blinds) = 7.6 (formula 1)
Heat Loss Factor (no blinds) = 75 (formula 1)

Total Heat Loss Factor (with blinds) = 293.6 (formula 3)
Total Heat Loss Factor (no blinds) = 361 (formula 3)

$$\text{Heat Loss/Season} = \frac{361 \times 3600 \times 12 \times 4400}{1{,}000{,}000} + \frac{293.6 \times 3600 \times 12 \times 4400}{1{,}000{,}000}$$
$$= 124{,}426 \text{ MJ}$$

Fuel Consumption = 4908 litres or $1079

Annual Saving = (5414 - 4908) = 506 litres or $111

LIFE-CYCLE EXPENSES (LCE)

	Cost Factor	Type of Expenses		Present Value Multiplier	Present Value ($)
		Fixed Amount	Year 1 Payments		
assume $43/m^2$	Initial Cost	645			645
	Operating Cost				
assume 1%	Maintenance, Repairs, etc.		6.45	8.11	52
assume none	Replacement Cost				
				LCE	$ 697

LIFE-CYCLE BENEFITS (LCB)

	Saving Factor	Type of Benefits		Present Value Multiplier	Present Value ($)
		Fixed Amount	Year 1 Benefits		
assume single glazing	Fuel Savings		111	10.3	1143
assume none	Resale Value				
				LCB	$ 1143

LIFE-CYCLE SAVINGS (LCS): LCB - LCE $ 446

BENEFIT/COST RATIO:

$$\frac{\text{fuel savings}(1143) - \text{operating costs}(0) - \text{maintenance}(52)}{\text{initial cost}(645) - \text{resale value}(0) + \text{replacement}(0)} = 1.69$$

If the example house had single glazing only, annual consumption of #2 heating oil would be 5414 litres or $1191. (see Window/Glazing Calculations)

If thermal shutters were added to single glazing, the Rvalue would be 1.2

Heat Loss Factor (with shutters) = 12.5 (formula 1)
Heat Loss Factor (no shutters) = 75 (formula 1)

Total Heat Loss Factor (with shutters) = 298.5 (formula 3)
Total Heat Loss Factor (no shutters) = 361 (formula 3)

$$\text{Heat Loss/Season} = \frac{361 \times 3600 \times 12 \times 4400}{1{,}000{,}000} + \frac{298.5 \times 3600 \times 12 \times 4400}{1{,}000{,}000}$$

$$= 125{,}358 \text{ MJ}$$

Fuel Consumption = 4945 litres or $1088 (formulae 5 and 6)

Annual Saving = (5414 - 4945) = 469 litres or $103

The example house has single glazing and exterior storms with an annual fuel consumption of 5159 litres or $1135. (see Detailed House Calculations) If thermal shutters were added 12 hours per day, the windows would have an R value of .26 + 1.0 or 1.26.

Fuel Consumption = 4814 litres or $1059

Annual Savings = 345 litres or $76

LIFE-CYCLE EXPENSES (LCE)

	Cost Factor	Type of Expenses		Present Value Multiplier	Present Value ($)
		Fixed Amount	Year 1 Payments		
assume $50/m^2$	Initial Cost	750			750
	Operating Cost				
assume 1%	Maintenance, Repairs, etc.		7.50	8.11	61
	Replacement Cost				
				LCE	$ 811

LIFE-CYCLE BENEFITS (LCB)

	Saving Factor	Type of Benefits		Present Value Multiplier	Present Value ($)
		Fixed Amount	Year 1 Benefits		
assume single glazing	Fuel Savings		103	10.3	1061
	Resale Value				
				LCB	$ 1061

LIFE-CYCLE SAVINGS (LCS): LCB - LCE $ 250

BENEFIT/COST RATIO:

$$\frac{\text{fuel savings}(1061) - \text{operating costs}(0) - \text{maintenance}(61)}{\text{initial cost}(750) - \text{resale value}(0) + \text{replacement}(0)} = 1.33$$

If the volume or flow of the heat exchanger is 37 dm^3/s or 134 m^3/h,

Heat Loss Factor (air change) = 48.4 (formula 2)

Heat Loss per Season (air change) = 18,400 MJ (formula 4)

If a 65% efficiency oil furnace had to replace 18,400 MJ lost by ventilation, it would need 726 litres of oil, costing $160. (formulae 5 and 6)

If the air exchanger has an efficiency of 65%, it would be able to recover 65% of the lost heat, or 11,960 MJ, worth 472 litres of oil.

Annual Saving = 472 litres or $104 (formulae 5 and 6)

If the air exchanger runs 23 hours per day or 4380 hours per season and has a power of 45 watts, it will use 197 kWh of electricity each season.

Operating Cost = 197 kWh x $0.05 = $9.85

LIFE-CYCLE EXPENSES (LCE)

	Cost Factor	Type of Expenses		Present Value Multiplier	Present Value ($)
		Fixed Amount	Year 1 Payments		
assume $700	Initial Cost	700			700
	Operating Cost		9.85	10.3	101
assume 1%	Maintenance, Repairs, etc.		7	8.11	57
assume none	Replacement Cost				
				LCE	$ 858

LIFE-CYCLE BENEFITS (LCB)

Saving Factor	Type of Benefits		Present Value Multiplier	Present Value ($)
	Fixed Amount	Year 1 Benefits		
Fuel Savings		104	10.3	1071
Resale Value				
			LCB	$ 1071

LIFE-CYCLE SAVINGS (LCS): LCB - LCE $ 213

BENEFIT/COST RATIO:

$$\frac{\text{fuel savings}(1071)-\text{operating costs}(101)-\text{maintenance}(57)}{\text{initial cost}(700)-\text{resale value}(0)+\text{replacement}(0)} = 1.30$$

Total Heat Loss/Season = 130,775 (see Detailed Example House Calculations)
If the efficiency (e) of the furnace was increased to 75%,

Fuel Consumption = 4471 litres or $984 (formulae 5 and 6)

Annual Savings = (5159 - 4471) = 688 litres or $151

Total Heat Loss/Season = 130,775 (see Deatailed Example House Calculations)
If the efficiency (e) of the furnace was 90%,

Fuel Consumption = 3726 litres or $820 (formulae 5 and 6)

Annual Savings = (5159 - 3726) = 1433 litres or $315

LIFE-CYCLE EXPENSES (LCE)

	Cost Factor	Type of Expenses		Present Value Multiplier	Present Value ($)
		Fixed Amount	Year 1 Payments		
assume $100	Initial Cost	100			100
	Operating Cost				
assume $30/year	Maintenance, Repairs, etc.		30	8.11	245
	Replacement Cost				
				LCE	$ 343

LIFE-CYCLE BENEFITS (LCB)

Saving Factor	Type of Benefits		Present Value Multiplier	Present Value ($)
	Fixed Amount	Year 1 Benefits		
Fuel Savings		151	10.3	1555
Resale Value				
			LCB	$ 1555

LIFE-CYCLE SAVINGS (LCS): LCB - LCE $ 1212

BENEFIT/COST RATIO:

fuel savings(1555)-operating costs(0)-maintenance(243)
/ initial cost(100)-resale value(0)+replacement(0) = 13.12

$$\text{Cost of Fuel per MJ} = \frac{\text{cost of fuel per unit}}{\text{energy content of fuel per unit} \times \text{efficiency}}$$

$$\text{Cost of \#2 oil per MJ} = \frac{.22}{39 \times .65} = \$0.0087$$

$$\text{Cost of wood per MJ} = \frac{\text{cost per cord}}{30{,}770 \times .5}$$

If cost of hardwood per MJ, were to equal #2 fuel oil per MJ at $0.0087,

Cost of hardwood per cord = $134

If a wood stove with a 50% efficiency used hardwood to heat the example house with and annual heat loss of 130,775 MJ,

Fuel Consumption = 8.5 cords of hardwood (formula 5)

If the wood stove supplied half of the needed heat, 4.5 cords would be needed.

Operating Cost = 4.5 cords x $75/cord = $338 (formula 6)

If oil was needed to supply only 65,388 MJ or half of the original requirements,

Annual Saving = 2580 litres x $0.05/L = $567 (formulae 5 and 6)

LIFE-CYCLE EXPENSES (LCE)

	Cost Factor	Type of Expenses		Present Value Multiplier	Present Value ($)
		Fixed Amount	Year 1 Payments		
assume installed	Initial Cost	1,000			1000
assume $75/cord	Operating Cost		338	10.3	3481
assume 1%	Maintenance, Repairs, etc.		10	8.11	81
assume none	Replacement Cost				
				LCE	$ 4562

LIFE-CYCLE BENEFITS (LCB)

	Saving Factor	Type of Benefits		Present Value Multiplier	Present Value ($)
		Fixed Amount	Year 1 Benefits		
assume $0.05/L	Fuel Savings		567	10.3	5840
assume 25%	Resale Value	250		.838	210
				LCB	$ 6050

LIFE-CYCLE SAVINGS (LCS): LCB - LCE $ 1488

BENEFIT/COST RATIO:

fuel savings(5840)-operating costs(3481)-maintenance(81) / initial cost(1000)-resale value(210)+replacement(0) = 2.88

If the example house has previously had a fuel bill of 5159 litres for an annual heating load of 130,775 MJ or 36,316 kWh, and the heat pump has an SPF of 1.6 (and assuming it can completely meet the heating load with no back up system,

$$\text{Fuel Consumption} = \frac{36,316}{1.6} = 22,698 \text{ kWh}$$

<u>Operating Cost</u> = 22,698 kWh x $0.05 = <u>$1135</u> (formula 6)

If the heat pump replaces the oil furnace completely,

<u>Annual Saving</u> = 5159 litres x $0.22 = <u>$1135</u> (formula 6)

LIFE-CYCLE EXPENSES (LCE)

	Cost Factor	Type of Expenses		Present Value Multiplier	Present Value ($)
		Fixed Amount	Year 1 Payments		
assume installed	Initial Cost	3000			3000
assume $0.05/kWh	Operating Cost		1135	10.3	11690
assume 1%	Maintenance, Repairs, etc.		30	8.11	243
assume none	Replacement Cost				
				LCE	$ 14933

LIFE-CYCLE BENEFITS (LCB)

	Saving Factor	Type of Benefits		Present Value Multiplier	Present Value ($)
		Fixed Amount	Year 1 Benefits		
assume $0.22/l	Fuel Savings		1135	10.3	11690
assume 25%	Resale Value	750		.838	629
				LCB	$ 12319

LIFE-CYCLE SAVINGS (LCS): LCB - LCE $ 0

BENEFIT/COST RATIO:

fuel savings(11690)-operating costs(11690)-maintenance(243) / initial cost(3000)-resale value(629)+replacement(0) = .10

If 272 litres of hot water were used by the example house each day, the water was heated from 10°C to 65°C, and the hot water heater had an efficiency of 85%,

Annual Energy Consumption $= \frac{272 \times 55 \times .0042 \times 355}{.85}$ (formula 7)

$= 26,980$ MJ

$= 7,490$ kWh

Fuel Cost @ \$0.05/kWh = \$375

If the hot water tank in the example house had additional insulation and 11% of the annual heating bill was saved,

<u>Annual Savings</u> = .11 x $375
= <u>$40</u>

LIFE-CYCLE EXPENSES (LCE)

Cost Factor	Type of Expenses		Present Value Multiplier	Present Value ($)
	Fixed Amount	Year 1 Payments		
Initial Cost	15			15
Operating Cost				
Maintenance, Repairs, etc.		.30	8.11	2.50
Replacement Cost				
			LCE	$ 17.50

LIFE-CYCLE BENEFITS (LCB)

Saving Factor	Type of Benefits		Present Value Multiplier	Present Value ($)
	Fixed Amount	Year 1 Benefits		
Fuel Savings		40	10.3	412
Resale Value				
			LCB	$ 412

LIFE-CYCLE SAVINGS (LCS): LCB - LCE $ 394

BENEFIT/COST RATIO:

$$\frac{\text{fuel savings}(412)-\text{operating costs}(0)-\text{maintenance}(2.50)}{\text{initial cost}(15)-\text{resale value}(0)+\text{replacement}(0)} = 27.3$$

If the 50 metres of piping in the example house was insulated at $1.00 per metre, and saved 5% of the energy consumption,

Annual Savings =.05 x $375
= $19

LIFE-CYCLE EXPENSES (LCE)

Cost Factor	Type of Expenses		Present Value Multiplier	Present Value ($)
	Fixed Amount	Year 1 Payments		
Initial Cost	$50			50
Operating Cost				
Maintenance, Repairs, etc. (assume 1%)		.50	8.11	4
Replacement Cost				
			LCE	$ 54

LIFE-CYCLE BENEFITS (LCB)

Saving Factor	Type of Benefits		Present Value Multiplier	Present Value ($)
	Fixed Amount	Year 1 Benefits		
Fuel Savings		19	10.3	196
Resale Value				
			LCB	$ 196

LIFE-CYCLE SAVINGS (LCS): LCB - LCE $ 142

BENEFIT/COST RATIO:

$$\frac{\text{fuel savings}(196)-\text{operating costs}(0)-\text{maintenance}(4)}{\text{initial cost}(50)-\text{resale value}(0)+\text{replacement}(0)} = 3.82$$

If 40% of the hot water consumed in the example house is used for showers, and the flow is reduced by 50%,

$$\text{Annual Savings} = \frac{.40 \times \$375}{2} = \$75$$

LIFE-CYCLE EXPENSES (LCE)

	Cost Factor	Type of Expenses: Fixed Amount	Type of Expenses: Year 1 Payments	Present Value Multiplier	Present Value ($)
	Initial Cost	$20			$20
	Operating Cost				
assume 1%	Maintenance, Repairs, etc.		.20	8.11	1.60
	Replacement Cost				
				LCE	$ 21.60

LIFE-CYCLE BENEFITS (LCB)

Saving Factor	Type of Benefits: Fixed Amount	Type of Benefits: Year 1 Benefits	Present Value Multiplier	Present Value ($)
Fuel Savings		75	10.3	773
Resale Value				
			LCB	$ 773

LIFE-CYCLE SAVINGS (LCS): LCB - LCE $ 751

BENEFIT/COST RATIO:

$$\frac{\text{fuel savings}(773)-\text{operating costs}(0)-\text{maintenance}(1.60)}{\text{initial cost}(20)-\text{resale value}(0)+\text{replacement}(0)} = 38.55$$

If a bathroom sink uses 15 litres of hot water per day and an aerator can save 4 litres or 25% per day,

Annual Savings = 397 MJ (formula 7)
= 110 kWh @ $0.05/kWh
= $5.50

LIFE-CYCLE EXPENSES (LCE)

Cost Factor	Type of Expenses		Present Value Multiplier	Present Value ($)
	Fixed Amount	Year 1 Payments		
Initial Cost	$3			$3
Operating Cost				
Maintenance, Repairs, etc.				
Replacement Cost				
			LCE	$ 3

LIFE-CYCLE BENEFITS (LCB)

Saving Factor	Type of Benefits		Present Value Multiplier	Present Value ($)
	Fixed Amount	Year 1 Benefits		
Fuel Savings		$5.50	10.3	$57
Resale Value				
			LCB	$ 57

LIFE-CYCLE SAVINGS (LCS): LCB - LCE $ 54

BENEFIT/COST RATIO:

$$\frac{\text{fuel savings}(57)-\text{operating costs}(0)-\text{maintenance}(0)}{\text{initial cost}(3)-\text{resale value}(0)+\text{replacement}(0)} = 19$$

If the toilet in the example house uses 400 litres each day, and the dam can reduce this volume by 50%,

Annual Saving = 200 litres x 365 days
= 73,000 litres per year
= 73 m^3 @ $0.25/$m^3$
= $18.25

LIFE-CYCLE EXPENSES (LCE)

Cost Factor	Type of Expenses		Present Value Multiplier	Present Value ($)
	Fixed Amount	Year 1 Payments		
Initial Cost	$10			$10
Operating Cost				
Maintenance, Repairs, etc.				
Replacement Cost				
			LCE	$ $10

LIFE-CYCLE BENEFITS (LCB)

Saving Factor	Type of Benefits		Present Value Multiplier	Present Value ($)
	Fixed Amount	Year 1 Benefits		
Fuel Savings		$18.25	10.3	$188
Resale Value				
			LCB	$ 188

LIFE-CYCLE SAVINGS (LCS): LCB - LCE $ 178

BENEFIT/COST RATIO:

fuel savings(188)-operating costs(0)-maintenance(0) / initial cost(10)-resale value(0)+replacement(0) = 18.8

If the thermostat setting was turned down from 60°C to 43°C, and the same 272 litres of hot water were used each day,

Annual Energy Consumption of Hot Water Tank $= \frac{272 \times 33 \times .0042 \times 365}{.85}$ (formula 7)

= 16,188 MJ

= 4496 kWh @ $0.05/kWh

= $225

Annual Saving if thermostat is turned down = $375 - $225 = $150

LIFE-CYCLE EXPENSES (LCE)

Cost Factor	Type of Expenses		Present Value Multiplier	Present Value ($)
	Fixed Amount	Year 1 Payments		
Initial Cost	0			
Operating Cost				
Maintenance, Repairs, etc.				
Replacement Cost				
			LCE	$ 0

LIFE-CYCLE BENEFITS (LCB)

Saving Factor	Type of Benefits		Present Value Multiplier	Present Value ($)
	Fixed Amount	Year 1 Benefits		
Fuel Savings		$150	10.3	$1545
Resale Value				
			LCB	$ 1545

LIFE-CYCLE SAVINGS (LCS): LCB - LCE $ 1545

BENEFIT/COST RATIO:

fuel savings(1545)-operating costs(0)-maintenance(0) / initial cost( )-resale value( )+replacement( ) = 1545+

METRIC CONVERSION

Linear Measure

1 inche (in)	x	0.305	= millimetres (mm)
1 foot (ft)	x	25.4	= metre (m)
1 mile (mi)	x	1.609	= kilometres (km)
$/foot ($/ft)	x	3.28	= $/metre ($/m)
1 millimetre (mm)	x	0.039	= inch (in)
1 metre (m)	x	3.28	= feet (ft)
1 kilometre (km)	x	0.62	= mile (mi)
$/metre ($/m)	x	0.305	= $/foot ($/ft)

Square Measure

1 square foot (ft^2)	x	0.093	= square metre (m^2)
$/square foot ($/ft^2)	x	10.76	= $/square metre ($/m^2)
1 square metre (m^2)	x	10.76	= square feet (ft^2)
$/square metre ($/m^2)	x	0.093	= $/square metre ($/m^2)

Cubic Measure

1 cubic foot (ft^3)	x	0.028	= cubic metre (m^3)
$/cubic foot ($/ft^3)	x	35.315	= $/cubic metre ($/m^3)
1 cubic metre (m^3)	x	35.315	= cubic feet (ft^3)
$/cubic metre ($/m^3)	x	0.028	= $/cubic feet ($/ft^3)

Liquid Measure

1 gallon (gal)	x	4.55	= litres (l)
1 US gal (US gal)	x	3.78	= litres (l)
1 litre (l)	x	0.22	= gallon (gal)

Mass and Density

1 pound (lb)	x	0.45	= kilogram (kg)
1 kilogram (kg)	x	2.2	= pounds (lb)

Temperature

1 F degree (F°) interval	x	0.5556	= C degree interval
(degree F − 32)	x	0.555	= degree C (°C)
1 C degree (C°) interval	x	1.8	= F degree interval
(degree C x 1.8) + 32			= degree F (°F)

Velocity and Rate of Flow

1 foot per minute (ft/min)	x	0.005	= metre per second (m/s)
1 mile per hour (mph)	x	1.609	= kilometres/hour (km/h)
1 cubic foot per minute (ft^3/min)	x	0.000472	= cubic metre/second (m^3/s)
1 gallon per minute (gal/min)	x	0.076	= litres/second (l/s)
1 metre per second (m/s)	x	3.28	= feet/second (ft/sec)
1 kilometre per hour (km/h)	x	0.621	= mile per hour (mph)
1 cubic metre per second (m^3/s)	x	2118.88	= cubic feet/min (ft^3/min)
1 litre per second (l/s)	x	13.2	= gallons per minute (gal/min)

Energy, Heat and Work

1 British Thermal Unit (Btu)	x	0.001055	= megajoule (MJ)
1 million Btu (MBtu)	x	1055	= megajoules (MJ)
1 kilowatt hour (kWh)	x	3.6	= megajoules (MJ)
1 megajoule (MJ)	x	947.8	= British Thermal Units (Btu)
1 megajoule (MJ)	x	0.000947	= million Btu (MBtu)
1 megajoule (MJ)	x	0.2777	= kilowatt hour (kWh)
1 R-value (imperial)	x	0.176	= R-value (metric)
1 R-value (metric)	x	5.68	= R-value (imperial)