Assessing the Potential for the Implementation of a High-Performance Window Incentive Program

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The aim of this research is to evaluate the energy reduction and cost savings involved in a proposed Manitoba Hydro Demand-Side Management incentive program for the installation of high-performance windows. Manitoba homeowners generally purchase triple-glazed windows. This study analyzes whether it is financially feasible for homeowners to purchase high-performance rather than triple-glazed windows and the need for a utility window incentive program. The new technologies which improve the window thermal performance in high-performance windows include low-emissivity glazings and films, inert gas fills between panes, insulated edge spacers, and insulated frames. The analysis was carried out using an interview process to determine current window prices in the study area, computer software (WINDOW 4.0 and HOT2000), and financial screening analysis. The results indicate that very few high-performance windows pass the economic tests for both consumers and the utility. Although it was found that high-performance window technologies reduced energy loads in homes, the study concludes that the utility should not promote these through financial incentives at this time.

Le but de cette recherche est d'évaluer la réduction des besoins en énergie et les économies réalisées dans le cadre d'un programme de gestion axée sur la demande, proposé par Hydro Manitoba et encourageant l'installation de fenêtres à haut rendement énergétique. Les propriétaires du Manitoba achètent généralement des fenêtres à triple vitrage. Cette étude analyse la faisabilité financière de l'achat par les propriétaires de fenêtres à haut rendement énergétique plutôt qu'à triple vitrage et le besoin d'un programme d'en-couragement à la pose de fenêtres économisant de l'énergie. Les nouvelles technologies qui améliorent la performance thermale des fenêtres à haut rendement énergétique comprennent les verres et films à faible émissivité, le remplissage de gaz inerte entre les vitres, l'isolation des butées d'espacement des bords et l'isolation des cadres. L'analyse a été effectuée en utilisant le processus d'interview pour déterminer les prix courants des fenêtres dans le secteur concerné par l'étude, des logiciels informatiques (WINDOW 4.0 et HOT2000), et l'analyse financière. Les résultats indiquent que très peu de fenêtres à haut rendement énergétique réussissent le test économique tant du point du vue du consom-mateur que de celui du fournisseur d'énergie. Bien qu'il ait été démontré que les technologies concernant les fenêtres à haut rendement énergétique réduisent la consommation en énergie des foyers, l'étude conclut que les fournisseurs d'énergie ne devraient pas présentement en faire la promotion grâce à des encouragements financiers.

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The transition from meeting demand to managing demand, Demand-Side Management (DSM), is difficult. There is, however, great potential for energy conservation through DSM in the residential buildings sector, as it accounts for a large portion of utility load. For example, about 35% of Manitoba Hydro's electricity consumption is residential. In considering the energy conservation options available, it is important to choose those which will be of real value in a particular circumstance. A balance must be struck between the initial cost of a conservation action and the savings in operating costs which a measure may provide. Energy conservation experts generally agree that in residential buildings, the greatest energy savings can be attained by reducing air infiltration through windows and doors and by reducing conductive heat transfer through the walls and windows (Energy, Mines and Resources, 1983). Winds can decrease the exterior film of still air that usually surrounds a building and will increase the thermal vulnerability of roof, wall, and window elements.

The window industry responded to consumer demand in the mid-1980s with a host of new technologies to improve window thermal performance. These are: heat-reflecting low-emissivity coatings and films, insulated edge spacers, insulated frames, and low conductance inert gases between sealed panes.

High-performance windows, HPWs, with combinations of the above options are available in many sizes and shapes. The two common styles are operable and fixed windows. In the operable category, casement or awning-type windows are the most common in Manitoba and provide the best combination of low air leakage, ventilation, and ease of cleaning. As sliding and double-hung windows tend to lose much heat along their sliding tracks, most do not qualify as high-performance. A fixed window is the best choice for an opening which is not required for ventilation or as an emergency exit (CANMET, 1991). Fixed windows have lower air leakage rates and are less expensive than operable windows.

Unfortunately, the energy performance of advanced window systems is difficult to assess compared to other building envelope or mechanical system alternatives. A window's impact upon a house's energy consumption is heavily influenced by three interrelated factors: thermal resistance, solar heat gain, and orientation. This complicates the calculation of performance characteristics of windows (Proskiw, 1990).

The purpose of this paper is to evaluate the energy reduction and cost savings of a potential DSM program involving the installation of high-performance windows. As Kuhn (1992) found, support by residential consumers for energy conservation measures has declined. It is common in this regard, therefore, for utilities to offer incentives to consumers for installing conservation measures, a further consideration of this paper. The analysis is based on weather data from Winnipeg, Manitoba, where extreme winters are common.

Procedure

A review of related research and literature provided the basic knowledge needed to initiate a comprehensive study. Publications on energy conservation and windows, from Energy, Mines, and Resources Canada (EMR), Manitoba Energy and Mines, Manitoba Hydro, and Ontario Hydro were consulted for the necessary background. A collection of HPW specifications and prices was necessary to determine the incremental costs of window options for further analysis. Twelve window manufacturers in Winnipeg and in rural Manitoba were visited to obtain installed price quotations on a selected window size of 915 mm x 1220 mm (3' x 4') for different HPW options. Thirty window installers in Winnipeg were anonymously telephoned in an effort to acquire installed pricing for the aforementioned windows. Prices quoted in this paper are the installed costs for fixed windows. Upon delivery of all the HPW price quotations, the incremental costs for each HPW option were calculated.

Computer software programs were used to generate quick and cost-effective window energy performance results. WINDOW 4.0, a computer simulation program developed at the Lawrence Berkeley Laboratory, calculates optical and energy performance properties of user-defined windows. The alternative to computer simulation is to conduct expensive and time-consuming laboratory tests. WINDOW 4.0 was used to calculate the energy performance of 12 window types. The window properties were extracted from libraries found in the simulation program.

The WINDOW 4.0 results were then used to calculate the potential energy savings of windows for average Manitoba homes using HOT2000, a computer simulation software package for energy consumption in houses. HOT2000 was developed under the direction of the "R-2000 Home Program" of Energy, Mines, and Resources Canada (Canadian Home Builders' Association, 1991). This program is used by homebuilders and consultants to simulate the effects of properties such as wall and attic insulation, house size, and location on heating and cooling energy use. The program compiles input and generates output for such variables as house heating and cooling loads, hot water heating loads, and lighting and appliance load.

HOT2000 was used to calculate the yearly energy savings of each of the twelve high-performance window options used in WINDOW 4.0. All input variables were kept constant except for the windows. First, the energy performance was simulated for houses with standard triple-glazed windows. Then one window at a time in each orientation was upgraded by a high-performance option, while keeping all other windows as triple-glazed. This analysis simulated each of the high-performance window options for different conditions, keeping all other variables constant.

The economic analysis deals with consumers' financial screens of high-performance windows. It was focused on the consumers' simple payback period (SPP), internal rate of return (IRR), and net present value (NPV) for each window condition.

The financial analysis used information acquired from the HPW price survey (incremental costs including taxes) and consumer fuel cost savings per year for each window increment from the HOT2000 output. First, consumer financial analysis of each HPW option was executed without utility incentives. Those scenarios that qualified for incentives were then analyzed. The utility savings generated by each measure, over a 20-year period, were transferred to the consumers as monetary compensation and re-analyzed in the economic analysis.

Analysis

The price survey directed at HPW manufacturers and installers in Winnipeg was carried out in late 1992. It established installed prices for conventional triple-glazed windows and HPW options. The window manufacturers were very cooperative and willingly offered technical expertise. Due to the initial complacency of installers to give quotations for installing identified windows, it was necessary to approach them anonymously as a customer needing to replace an existing broken window. The prices quoted in Table 1 are those they would have charged a potential customer. Window prices increase as more options are added. Note that the window prices are the incremental installed costs over and above standard (for Manitoba) triple-glazed windows.

The WINDOW 4.0 program can be used to design and develop new window products, evaluate window performance characteristics, and aid users with quick generic window simulations. WINDOW 4.0 provides libraries of system components which can be combined into a glazing system and/or a complete window system and then analyzed.

The libraries of system components are:

Table 1: High-Performance Window Installed Prices ($/fixed window, with taxes)

Description	Incremental Costs
TG	-
TG, 1-Ar	22.85
DG, 1-HM	34.47
TG, 1-Low E	50.07
TG, HPF	54.99
TG, IES	11.08
DG, IES, 1-HM	45.55
TG, IES, 1-Ar, 1-Low E	84.00
TG, IES, 2-Ar, 2-Low E	156.92
TG, HPF, IES, 2-Ar, 2-Low E	211.91
TG, HPF, IES, 2-Ar, 1-HM, 1-Low E	196.31
DG, IES, 2-HM	164.56

where:
TG: triple-glazed
Ar: argon gas
HM: Heat Mirror
Low E: low-emissivity
HPF: high-performance frame
IES: insulated edge spacer
DG: double-glazed

1. Window Library for storing assembled window systems;
2. Glass Library;
3. Gas Library;
4. Glazing System Library for creating, analyzing, and storing glazing systems;
5. Environmental Conditions Library;
6. Frame Library; and
7. Divider Library.

To construct a window, the user needs the appropriate frame elements, glazing systems, divider elements, and environmental conditions stored in their respective libraries. If the necessary components are not in the libraries, the user can create new ones.

As HPW options increase, based on WINDOW 4.0 analysis, the R-values increase while the solar heat gain coefficients (SHGC) decrease compared to the triple-glazed window results listed in the top row of Table 2. It was found that all high-performance window (HPW) options increased the overall window's R-values, but low-emissivity

Table 2: WINDOW 4.0 Output Results

Description	R-val ($m^{2o}C/W$)	SHGC
TG	0.48	0.52
TG, 1-Ar	0.49	0.52
DG, 1-HM	0.57	0.31
TG, 1-Low E	0.52	0.44
TG, HPF	0.52	0.52
TG, IES	0.52	0.52
DG, IES, 1-HM	0.66	0.31
TG, IES, 1-Ar, 1-Low E	0.60	0.45
TG, IES, 2-Ar, 2-Low E	0.73	0.37
TG, HPF, IES, 2-Ar, 2-Low E	0.81	0.37
TG, HPF, IES, 2-Ar, 1-HM, 1-Low E	0.88	0.28
DG, IES, 2-HM	1.04	0.33

coatings and films such as Low E and Heat Mirror (HM) decreased the SHGCs. It seems that concessions in SHGC performance must be made to reach the highest R-values for HPWs. The results of the analysis are shown in Table 2.

HOT2000 is a microcomputer program designed to assist builders, architects, and engineers in the design of low-rise residential buildings. Utilizing current heat loss/gain and system performance models, the program aids in the simulation and design of buildings for thermal effectiveness, passive solar heating, and the operation and performance of heating and cooling systems (Canadian Home Builders' Association, 1991).

HOT2000 lets the user input comprehensive data on a proposed building design. It uses a six-digit code to identify types of windows and glazing components for different window orientations. The following window orientations can be analyzed in HOT2000: north, south, east, west, southeast, southwest, northeast, and northwest. The output consists of air leakage and ventilation rates, a space heating/cooling summary, and an estimated annual fuel consumption summary, among others. This quick and efficient package lets the user revise and test altered designs until a satisfactory design is achieved.

In order to enter housing data into HOT2000 for analysis, a statistical representation of a Manitoba house was required. This information was acquired from Manitoba Energy and Mines and Manitoba Hydro. In the HOT2000 analysis, Energy Efficient Family Houses were evaluated. The Energy Efficient Family House is representative of R-2000 or Manitoba Hydro Power Smart homes built today. For each house type, heating loads are calculated. For each of the above conditions, fixed windows in north, south, east, and west orientations were evaluated in HOT2000.

Based on HOT2000 analysis, window performance results on the east and west orientations of a house are the same, since the simulation program does not calculate any predominant Manitoba winds. Since solar radiance is not as pronounced for these orientations, the SHGC can be sacrificed to obtain higher window R-values to achieve greatest energy performance (keeping air leakage rates low). HPW options such as Low E and "Heat Mirror" are more beneficial for these orientations. Based on economic analysis, HPW options are most suitable for north-facing windows. The greatest energy savings were recorded for this orientation. Therefore, HPWs with many options with the largest R-values, lower SHGCs, and low air leakage rates, are fairly acceptable on the north-facing window orientation. Based on results, HPWs are most efficient on the north, east/west, and south facing sides of houses in decreasing order.

The HOT2000 annual energy use for each HPW scenario has been assembled in Table 3.

The annual energy savings for each HPW option are then calculated by taking the difference of energy results between high-performance windows and respective base triple-glazed windows (TG) in Table 3. The results of these calculations are found in Table 4. Regarding general observations, it seems that as HPWs have more options, energy savings increase. The greatest energy savings occur in the north, east/west, and south orientations in decreasing order.

The simple payback period (SPP), internal rate of return (IRR), and net present value (NPV) were calculated for each HPW scenario. The incremental HPW option costs from the HPW price survey and the fuel cost savings from HOT2000 analyses were required for these evaluations. The

Table 3: HOT2000 Annual Energy Results (kWh/yr)

House Type: Energy Efficient Family House
Air Conditioning: No
Window Type: Fixed/Operable

Window Description	South	East/ West	North
TG	23483	23483	23483
TG, 1-Ar	23475	23475	23475
DG, 1-HM	23639	23527	23467
TG, 1-Low E	23535	23493	23470
TG, HPF	23452	23452	23452
TG, IES	23452	23452	23452
DG, IES, 1-HM	23591	23480	23420
TG, IES, 1-Ar, 1-Low E	23474	23437	23417
TG, IES, 2-Ar, 2-Low E	23500	23420	23377
TG, HPF, IES, 2-Ar, 2-Low E	23473	23393	23351
TG, HPF, IES, 2-Ar, 1-HM, 1-Low E	23548	23421	23352
DG, IES, 2-HM	23461	23360	23306

Table 4: Annual Energy Savings for HPW Options (kWh/yr)

House Type: Energy Efficient Family House
Air Conditioning: No
Window Type: Fixed/Operable

Window Description	South	East/ West	North
TG	-	-	-
TG → TG, 1-Ar	8	8	8
TG → DG, 1-HM	-155	-44	16
TG → TG, 1-Low E	-52	-9	13
TG → TG, HPF	31	31	31
TG → TG, IES	31	31	31
TG → DG, IES, 1-HM	-108	3	63
TG → TG, IES, 1-Ar, 1-Low E	9	46	65
TG → TG, IES, 2-Ar, 2-Low E	-16	63	105
TG → TG, HPF, IES, 2-Ar, 2-Low E	10	89	132
TG → TG, HPF, IES, 2-Ar, 1-HM, 1-Low E	-65	62	130
TG → DG, IES, 2-HM	22	122	176

HPW option costs, with 14% taxes (PST and GST), were used in the consumers' economic analysis.

A sample of the results of the consumer economic analysis are tabulated and shown in Table 5. Most measures failed the consumer economic indicators due to low consumer savings for very expensive high-performance window (HPW) options. In Table 5, most simple payback periods are very high, internal rates of return are very low, and net present values are usually negative. The three economic tests used are closely related and so it is not surprising that the results are similar.

The best economic results for window options are the HPWs with insulated edge spacers (TG, IES) and double-glazed windows with insulated edge spacers with Heat Mirrors (DG, IES, 1-HM). Also, triple-glazed windows with insulated edge spacers, one argon gas fill, and one Low E coated glazing (TG, IES, 1-Ar, 1-Low E) performed marginally well overall in economic analysis. Table 6 has been extracted from Table 5 and illustrates the best consumer economic analysis results without incentives.

Economic results are similar in common window groupings. The greatest energy saving potential (shown by highest SPP, IRR, AND NPV levels) occurs on the north, east/west, and south orientations in decreasing order.

The utility offers DSM financial incentives to consumers if they purchase windows that generate overall savings for the utility. Each scenario was analyzed to establish whether incentives were applicable for a 20-year window life according to the following methodology assembled by the research team:

- If the NPV of annual fuel cost savings - the NPV of the incremental cost of the HPW option (including taxes) is positive, there is no need to offer utility incentives, since these options have a good payback.
- If it is negative, the utility may offer incentives if the absolute value of the result is smaller than the NPV of utility avoided cost benefits. Otherwise, no incentive is offered.

Once the incentives are offered to qualifying measures, a net present value of 0 for a 20 year life stream results. Maximum potential incentive levels are limited by the utility's avoided costs calculated in its Economic Screen Test for each

Table 5: Economic Results

House Type: Energy Efficient Family House
Air Conditioning: No
Window Type: Fixed/Operable
Orientation: North

Window Description	Consumer Economic Analysis without Incentives		
	SPP (yrs)	IRR	NPV ($)
TG	-	-	-
TG → TG, 1-Ar	60.1	-0.088	-18.31
TG → DG, 1-HM	46.6	-0.070	-25.63
TG → TG, 1-Low E	83.4	-0.100	-42.85
TG → TG, HPF	37.9	-0.054	-37.66
TG → TG, IES	7.6	0.116	6.25
TG → DG, IES, 1-HM	15.6	0.025	-10.77
TG → TG, IES, 1-Ar, 1-Low E	27.7	-0.029	-47.70
TG → TG, IES, 2-Ar, 2-Low E	32.3	-0.042	-98.84
TG → TG, HPF, IES, 2-Ar, 2-Low E	34.8	-0.048	-139.13
TG → TG, HPF, IES, 2-Ar, 1-HM, 1-Low E	32.6	-0.043	-124.37
TG → DG, IES, 2-HM	20.2	-0.001	-67.28

Table 6: Best Consumer Economic Analysis Test Results

House Type: Energy Efficient Family House
Air Conditioning: No
Window Type: Fixed
Orientation: North

Window Description	Consumer Economic Analysis without Incentives		
	SPP (yrs)	IRR	NPV ($)
TG → TG, IES	7.6	0.116	6.25
TG → DG, IES, 1-HM	15.6	0.025	-10.77

respective scenario. Measures qualified for incentives only when the net present value of the avoided costs for a 20 year period were larger than the incremental costs of each respective HPW option. Therefore the utility covers the additional costs associated with HPW options.

The best consumer economic analysis results including incentives are found in Table 7. For those measures receiving the incentives, the SPP is 12 years (the payback would have been 20 years using a 5.5% discount rate), the IRR is 5.5% (the interest rate used in calculations) and the NPV is zero.

Conclusions

In order to optimize HPW selections for each orientation, the proper combinations of R-value/SHGC characteristics must be chosen. In Manitoba, on the south-face of houses, the highest combination of R-value and SHGC should be obtained while keeping the air leakage rates low to achieve the best energy performance results. Based on economic results, Low E and HM should not be used on south-facing walls of houses. They decrease SHGCs and reduce "free" passive solar energy intake. All other HPW options, that increase R-values, should be promoted on the south-facing side of houses.

Based on computer simulations and economic analyses, most HPW options were not favorable for consumers and the utility. Most HPWs did not pass the consumers' financial analysis SPP, IRR, and NPV tests. Although most HPW options did not perform well in economic analysis, two options were the exception to the rule. Insulated edge spacers and Heat Mirror options passed the consumer and utility economic analyses, but for north-facing windows only.

According to our analysis, on economic criteria a HPW incentive program in Manitoba appears to be unsuitable at present. Furthermore, based on Manitoba Hydro's cost data, to make HPW options economically viable it would be necessary to have substantial increases in avoided cost and electricity rates, or substantial decreases in incremental window costs.

The improved edge spacers, such as butyl-metal or insulated spacers, performed very well economically. Utilities should promote improved edge spacers in their Power Smart publications, but without subsidy or incentive payments. Manitoba Hydro is already involved in discussions with manufacturers with regard to HPWs. Perhaps

Table 7: Best Consumer Economic Analysis Test Results with Incentives

House Type: Energy Efficient Family House
Air Conditioning: No
Window Type: Fixed
Orientation: North

Window Description	Consumer Economic Analysis without Incentives		
	SPP (yrs)	IRR	NPV ($)
TG → DG, IES, 1-HM	12.0	0.055	0.00
TG → TG, IES, 1-Ar, 1-Low E	12.0	0.055	0.00

a program to help the manufacturers set up production of improved edge spacer technologies would be more appropriate at this time than a general HPW incentive program.

A residential survey of existing window types, a forecast of window purchases, and general perspectives on windows should be conducted. The questionnaire could be included in the "Manitoba Hydro Residential Energy Use Survey" conducted by Manitoba Hydro every two to three years. The results could be useful for future reference in the event that changes occur in markets affecting high-performance windows initiating further window studies.

Further research should analyze the economic benefits (or losses) associated when replacing older windows (such as dual-pane storm windows) with high-performance windows. The methodology of this study analyzed the economic data of HPWs by taking the difference in energy savings relative to basic triple-glazed windows. Since there are numerous "old" windows in Manitoba, a study to evaluate the energy savings introduced with high-performance windows is warranted. The energy savings may be large. Costs involved would be the total installed costs for HPWs, rather than only the incremental costs for each option.

In future research, the continued use of the incremental cost approach for new technologies in Demand-Side Management planning is recommended. This method can be used in calculating economic feasibility in future window studies, future Power Smart feasibility studies, and general Demand-Side Management studies. The incremental cost approach offers a valid method of establishing the economic feasibility studies of new technologies.

Finally, important externalities (such as flooding, health and quality-of-life impacts) were not accounted for in Manitoba Hydro's avoided costs of electricity, which were used in this study. It would be useful to reapply this research methodology using avoided costs that would more accurately value the benefits of decreased environmental degradation.

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