Efficient Windows

“Go! Green!” Energy Challenge

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Here it is, your first impression of your new dorm room at Northern Maine Community College. For the rest of the year this is where study sessions will take place, you will hang out with your friends and sleep. If no one told you, sooner or later you'd find out that on the worst nights the temperature outside sometimes reaches negative thirty.

Energy conservation is becoming more of a necessity than ever before. With the first cut backs in years NMCC is experiencing serious deficiencies. Replacing high cost windows in Andrews, Aroostook, Penobscot, and Washington Hall with more efficient, cost effective ones will greatly improve the schools energy savings and give the students a comfortable, secure place to live while attending NMCC. With more energy efficient and newer model windows available and a noticeable energy savings it's a no brainier that this is the way to go!

In colder climates triple pane windows with glazing and a combination of argon and krypton gases, with a low-Emissive (Low-E) coating would be the ideal windows to purchase. They have a very low U-factor while allowing a reasonable amount of light to still be transmitted through compared to the single pane windows that are being used on campus.

Windows have a certain U-factor that rates heat loss. This U-factor determines how effective the window is actually insulated and how well it is resistive to heat loss. The lower the U-factor the better insulated the window is. Windows also use what is known as the R-value, which measures the insulated value of the window, the resistance of a glaze or pane of glass. It's the inverse of the U-factor, (R=1/U), so a higher R-value the more efficient the window is. For example, a single pane of glass has an R-value of about 0.9, which is used in all of the dorms and housing across NMCC's campus, compared to a triple pane window with Low-E coating that has an R-value of 4 and an U-factor of .25.

Different areas throughout the United States are assigned zones by the IECC (International Energy Conservation Code); Maine has two of them, Zone 6 and Zone 7. Zone 7 is assigned to the Aroostook County, determining the maximum U-value of windows, doors and skylights. It also determines the Solar Heat Gain Coefficient (SHGC), *see chart 1.1*. These values must be lower than those stated below, the lower the U-factor the better insulated and resistive the window is. The SHGC value is a number between zero and one; it's the amount of radiation or heat that is allowed thorough the window.

Zone 7 Chart Requirements

Zone	Window/ Door U-Factor	Skylight U-Factor	Window/ Door/ Skylight SHGC
7	0.35	0.60	No Requirement

Chart 1.1

To determine how efficient a given window is by how much heat a building actually needs, the equation of heating degree-days is used. It is the demand for energy needed to heat or cool a building by the rate at which heat is lost. Defined as the difference between a reference value or set point value inside the building of 65 degrees and the average outside temperature of that given day. Then to subtract the two would give you the number of degree-days.

To find the estimate of seasonal heating and cooling requirements just add the heating and cooling degree-days over a period of time. The rate at which heat is lost through the window, for one-degree temperature, is the U-value of the window multiplied by the area, (A x U x D x 24/1000).

The area of a casement window in Andrews Hall is about 8.25 ft^2, easily found with the dimensions of the window which are 54" x 22". The U-factor of a single pane of glass is around 1.11. It should be noted that this is only in the center of the glass and not the whole pane of glass. It should also be known that this is just the BTUs lost in the window through conduction, this does not account for air leakage which could almost double the losses depending on how bad the window is sealed and the condition of the frame.

The average annual heating degree-day in Presque Isle for 2008 was 9,155; the heating degree-day is remarkably more than the cooling degree-days, which was around 174. So taking the area, U-factor and heating degree-days we can now find the amount of heat lost in BTUs. Area (8.25 ft^2) x U-factor (1.11) x the HDD (9,155) x (24) = 2,012,086 BTUs, so a single dorm room would loose 4,024,172 BTUs in Andrews Hall.

Typically, fuel oil per gallon in a BTU is 140,000 BTU's, with the cost of oil per gallon around $2.45 to $2.83 which is closer to what the school paid in 2008 for fuel. The losses are severe if you divide 4,024,172 BTUs by 140,000 BTUs to find how many gallons in fuel were lost the amount would come to 28.7 gallons of fuel oil. Taking this number and multiplying it by the amount of which fuel oil costs, $2.83 the total loss per dorm room comes to around $81.34.

Andrews Hall has a total window area of 1180 ft^2. Using the BTU formula, (1180 ft^2) x U-factor (1.11) x the HDD (9,155) x 24 / 1000, the losses in BTU's is 287,790 MBTU's. Following the same formula to find how many gallons this accounts for the total equals 2,055 gallons, accounting for $5,815.65 lost in Andrews due to inefficiency.

In the apartments Washington, Aroostook and Penobscot Hall there are 84 windows total. The dimensions of a window in one of these apartment buildings is 65" x 84", having a total of 37.9 ft^2 per window, which comes to a total of 3,185 ft^2 for all the windows in the three buildings. The BTUs equaling 776,787 MBTU's that amounts for 5,548 gallons and $15,700.84 lost in the apartments.

A triple pane Low-E window has a U-factor of about .25; the BTUs for Andrews Hall would amount to 648,17,400 BTU's that's 462 gallons, which is a total of $1,310. The apartment total of BTUs equals 174,952,050 BTU's, that's 1,250 gallons, which is a total of $3,538. The total losses together come around to $4,848 compared to the total losses with just a single pane of glass, which was around $21,515. The total amount of money save is the school installed triple pane Low-E windows would be around $16,667 annually!

- *Please refer to Chart 1.4; Fuel Costs in 2008 to compare fuel oil consumption to Chart 1.2; Comparing Efficient & Inefficient Windows.*

Comparing Efficient & Inefficient Windows

	Andrews Hall			Apartments		
Heat Loss	MBTU's	Gallons	Costs	MBTU's	Gallons	Costs
Existing Windows	287,790	2,055 gal	$5,816	776,787	5,548 gal	$15,700
New Windows	64,817	463 gal	$1,310	174,952	1,250 gal	$3,538
Savings		1,592 gal	$4,500		4,298 gal	$12,162

Chart 1.2

Total savings = 5890 gallons of number 2 fuel oil/year at 2.83/gal

= $16,667 annual savings!

Determining which kind of windows to buy, with keeping both spending money and the pay back period in mind, has a lot of variables to consider. However, "cost really depends on durability and the energy dollars pumped through the windows each year. Energy efficient windows save money each and every month (Fisette pg. 1)." The main variables are; conduction, convention, radiant heat transfer and air leakage. All of these together can create a disastrous problem for energy savings if not properly seen to. In colder climates high visibility and solar heat gain are essential, using the effect of the suns solar power and saving money by not losing unnecessary heat loss through the windows.

In cold climates windows have a drawback because warm air comes in contact with the panes of glass, cooling the air. The cold air drops and the room, due to the hot air rising slowly becomes cold, if not freezing depending on how well the window is protected. This causes frost to accumulate on the windowpanes, indicating that the windowpane is colder than the air in the room.

One way to help windows from losing heat is to trap a low-conductive gas between the two panes of the window, like argon and krypton. The double panes of glass are used to create an airspace, which cuts heat loss. These gasses reduce the conductance inside the panes of glass. Less conductance means less heat transfer. The air movement lets the hotter air settle where there once was cold air, reducing convection currents. Argon takes up about a half an inch, krypton uses up about three eighths of this space.

The gasses have a lower chance of leaking if properly sealed and the right materials are used, lasting almost up to twenty years. If these gasses were combined with the low-E coating it is said that the coating becomes almost as effective as an additional pane, making the R-value a high R-6 for some units. The additional cost of using the gas as a fill is about $2.50 to $4.50 per square foot, the annual energy savings is about $0.40 to $0.70 per square foot. The double pane of glass itself cost an additional $0.50 to $2.00 per square foot, the annual energy savings per square foot is anywhere from $0.40 to $0.70.

Low conductance spacers also help bring down the windows U-factor and improve the overall performance of the windows resistance to heat transfer. Let’s say you were to decide on aluminum spacers, these hold apart the double-glazing on the edge of the window. Sure, they’re great, low cost and reasonably durable, however, in cold climates condensation collects on the cold surface creating frost on the windows. It’s known that “aluminum spacers are highly conductive, so the coldest part of a glazed unit is around its edges (Fisette pg. 5),” losing heat. Comparing this to the higher end materials such as; stainless steel, plastic, foam and rubber, even wood they are less conductive of heat and are alternately better in the end.

Another benefit of reducing condensation is reducing the risk of moistness along the windows frame. Wet areas usually end with the "growth of mold, decay, and failure of finishes. Condensation affects the durability and comfort (Fisette pg. 5)." Air gaps appear along the windows frame, air leaks let cold air get through and much like the frames in Andrews Hall, makes the room about ten degrees colder.

There are many different types of frames, some affecting the U-factor more than others. Insulated vinyl, aluminum, wood clad and wood are just a few. Insulated vinyl is similar to vinyl frames; they don't require a lot of maintenance, no paint is used, and they are weather resistant. They also have empty cavities contained in the frame that hold insulation, boosting their thermal rating.

Wood clad is so named for the exterior frame on the window, which could be either vinyl or aluminum. Wood requires maintenance but has a very low U-factor, the drawback is over time and exposure the wood rots, deteriorating. See chart 1.2 to compare the U-factor for frames.

Comparing Frame U-Factors

Frame Types	**U-Factor**
Aluminum (no thermal break)	1.9-2.2
Aluminum (with thermal break)	1.0
Wood and Vinyl	0.3-0.5
Aluminum Clad Wood	0.4-0.6
Insulated Vinyl	0.2-0.3

Chart 1.3

In Andrews Hall the window frames are made out of wood. These frames, from lack of maintenance and age have broken, warped and in the end have created air leaks. A few students when questioned about their windows complained about air leaks, noises and the overall comfort of their room. One student in room 211 had to apply plastic to her window because air would get through, blowing papers off her desk. Other students in rooms 206 and 306 had towels and/or blankets against the windows to stop the cold air from getting through.

The temperature around the window compared to the room temperature in Andrews is about twenty degrees less, and thirty degrees compared to the center of the building. In the apartments such as Washington Hall in apartment 13, *(referring to the table 1.2)*, the temperature is much lower near and around the windows. One of the lowest temperatures taken was on the window's frame that was ten to fourteen degrees, the room was a low fifty degrees.

Generally when any kinds of costs are needed to accommodate the college's renovations tuition is inflated, students end up paying. But if the student's welfare and comfort are taken into consideration as well as with improving the school, there is more likely to be less animosity towards paying up if they get something out of it in return. Everybody wins.

- *Please refer to the reference Table 1.1 of the temperatures in Andrews Hall and reference Table 1.2 of the temperatures in Washington, Aroostook and Penobscot Hall. The temperature outside was in the negatives and taken at night.*

One last thing to consider is what type of glaze is to be used, if any. For cold climates much like the one in Presque Isle, a double-glazed low-E window provides a way to keep the warm air inside and the cold air outside. The "improvement boosts energy efficiency by nearly 100% over clear glass and reduces condensation (Fisette pg. 3)", the performance of the window is nearly doubled in efficiency. The additional cost is $2.00 to $4.00 per square foot, the annual energy savings is anywhere from $0.30 to $0.55 per square foot.

In hot climates the heat stays outdoors. This helps eliminate the radiant heat transfer, the movement of heat to a colder body. For example, a clear pane of glass would easily take in heat and dump it outdoors. By placing a reflective coating such as glaze on the window, it interrupts the process. The low-E coatings release less long-wave heat energy, keeping cold air out and heat in. If added the glaze ends up becoming 5% of the windows overall costs, which amounts to only several dollars per square foot. By making sure the window has the proper glaze, frame and spacers as well as a reasonable U-factor the heat loss process could be greatly reduced.

Payback for new energy efficient windows in homes takes about three to four years compared to replacing existing windows which takes about eight to ten years, depending on how much heat is lost and saved annually. Low-E coating can possibly save around a hundred dollars in a home monthly. Poorly insulated windows, doors and skylights account for 25% of heating and cooling lost, according to the U.S. Department of Energy of Energy Efficient and Renewable Energy. Comparing these results with the annual fuel put into each building shows a sufficient amount of money that was lost due to inefficiency.

For example Washington Hall in 2008 used 3,900 gallons of fuel, which ended up costing NMCC $11, 037. The cost of fuel at the time for all the buildings at NMCC was around $341,991 with a total of 120,817 gallons of fuel. If there were a way to cut back on unnecessary losses by improving the windows efficiency, less fuel would go into the buildings and save the school more money.

- *Please refer to chart 1.4 for consumption of fuel in NMCC buildings and overall costs.*

Fuel Costs in 2008

NMCC Buildings	**Fuel (in gallons)**	**Costs $**
Andrews Hall	14, 078	39, 840
Penobscot Hall	6, 175	17, 475
Washington Hall	3, 900	11, 037
Aroostook Hall	4, 200	11, 886
Total =	28, 353	80, 239

Chart 1.4

Using the four drawbacks of an inefficient window, conductance, air leaks, condensation and radiant heat transfer, the windows efficiency can easily be determined and fixed. The energy efficiency comes from using the proper materials and design that are applied to the certain climate that the windows are going to be used in. Glazing, spacers, and frames as well as additional panes of glass all are very important when choosing the appropriate selection of your window.

Weather-stripping the windows in Andrews Hall and in the apartments, Washington, Aroostook, and Pencobscot Hall, could also potentially reduce heat loss. It's a quick fix that allows a little flexibility if cost is an issue. The materials used are self-adhesive foam insulation, v-channel weather-stripping and finish nails. This process in a home can take less than a day given how many windows are being finished, please refer to the *figure 1.1; Weather Stripping A Window*. Overall the benefit can be as great as 15% and increasing the efficiency of the window and building. Silicone cocking can also be used to seal unwanted cracks in and around the window frames.

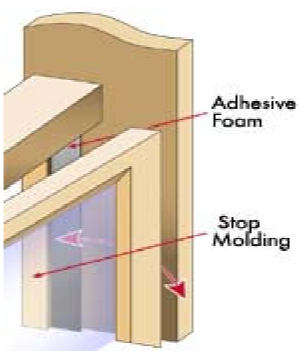

Figure 1.1; Weather Striping A Window

When debating if energy efficient windows are the way to go, comparing cost of windows and installation fees is the last process in deciding to replace inefficient windows. The installation fee depending on the company can sometimes go for $100 per window in Andrews Hall. In Washington, Aroostook and Penobscot Hall the cost to install a window would be around $150, together all four buildings would end up being $26,900 in labor. These fees are just and estimate for labor, not taking into account staging or any extra costs that might need to accommodate installing the new windows.

The windows being purchased would be around $1000 per window in Andrews Hall. Multiplied by the total amount of windows, that's $143,000. In the apartments the cost per window would be around $800 per window which would cost the school $67,200 to replace all of them. Together bringing the amount to $210,200. The payback period just for the windows would be 12.6 years.

Having already found that switching the old windows out with the triple pane Low-E coating could save the school around $16,667 a year in fuel oil costs, the pay back to buy and install the windows would end up being 12.6 years. It should be known that not all the windows on campus would need to be replaced, waiving the cost and payback period.

- *Refer to page 17 for references on contact information.*

NMCC will undoubtedly save fuel and money with the appropriate window dressings that, over time pay for themselves. By replacing the existing windows in the housing halls that are around 46 degrees or less, with new frames, coatings and/or glaze as well as new windows, depending on the individual condition of the window, the overall performance of the buildings will function better and more efficiently, and as a result, saving NMCC money as well as giving back to the students and doing our part in conserving energy by going green.

Andrews Hall

Second Floor Third Floor

Room Numbers	Frame	Window	Room Numbers	Frame	Window
201	36	56	301		
202			302	52	51
203	46	44	303		
204	43	40	304		
205	34	50	305	50	48
206	56	58	306	50	50
207	37	37	307	45	40
208	20/34	30/42	308	53	47
209	48	48	309		
210	51	51	310	40	34/ 46
211	49	49	311		
212			312	46	40
213	50	46	313	46	46
214	50		314		
215	45	40	315	53	64
216	46	50	316	67	65
217	46	53	317		
218			318	53	49
219	47	54	319	38	48
220	60	58	320	51	49
Lobby	27		Lobby	29	

Table 1.1

- Notes
  - *Highlighted areas are 46 degrees and less, possible windows that need to be replaced.*
  - *Temperatures were taken at night and the temperature outside was about negative three, while inside the building was 70 degrees. The rooms were colder the closer you were to the edge of the room and windows. The room temperatures were around 60 degrees.*

Apartments

Washington Hall Penobscot Hall

Apartment Number 13	Frame	Window	Apartment Number 10	Frame	Window
Living Room	22	30	Living Room	40	37
Room Number 1	22/15	30	Room Number 1	40	35
Room Number 2	14/10	24	Room Number 2	39	26

Table 1.2

Aroostook Hall

Apartment Number	Frame	Window
Living Room	45	49
Room Number 1	45	39
Room Number 2	44	37

Table 1.2 (Continued)

- Notes:
  - *In Aroostook Hall the heat was turned down; no students were living in this apartment at the time the temperatures were taken.*

Contact Information:

Name: Jackson, Guy

Phone: 768-2781

Email: gjackson@nmcc.edu

Title: Instructor for Residential Construction

Gave useful information on a rough estimate on labor for installing windows on campus.

Name: Buck, Pamela

Phone: -

Email: pbuck@nmcc.edu

Title: Instructor for Drafting

Helped find proper amounts of window losses on NMCC's campus and gave a rough estimate of cots per window plus total annual savings.

Work Cited:

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Finding Loses

Constants throughout essay:
Fuel oil per gallon in BTUs = 140,000 BTU's
Fuel oil per gallon in costs = $2.83, *what NMCC paid for fuel oil in 2008*
Heating Degree-Days for 2008 = 9,155.04
U-factor for single pane window = 1.11
U-factor for triple pane window = .25
Total windows in Andrews Hall = 71.5, so 143 in total
Total windows in Apartments = 84
Finding square footage: (W) x (L)
MBTU Formula: (Area) x (U-factor) x (the Heating Degree-Days) x (24) / (1000)
Finding Fuel oil per gallon: (BTU's) / (140,000 BTU's per gallon)
Finding fuel oil costs: (lost gallons) / ($2.83 per gallon)

Single Pane Windows

Andrews Hall:
Formulas used to fine loses

Find ft^2:
= (1.83') x (4.5')
= 8.25 ft^2

Find total ft^2:
= (71.5) (8.25 ft^2)
= 1180 ft^2

BTU's Lost:
= (1180 ft^2) x (1.11) x (9,155) x (24) / (1000)
= 287,790 MBTU's

Gallons Lost:
= (287,790 MBTU's)
(140,000 BTU's / per gallon)
= 2,055 gallons

Costs Lost:
= (2,055) x ($2.83)
= $5,815.65

<u>Apartments Washington, Aroostook, Penobscot Hall:</u>
Formulas used to find loses

Find ft^2:
= (5.41') x (7')
= 37.8 ft^2

Find total ft^2:
= (84) x (37.8 ft^2)
= 3,185 ft^2

BTU's Lost:
= (3,185 ft^2) x (1.11) x (9,155) x (24) / (1000)
= 776,787 MBTU's

Gallons Lost:
= <u>(776,787 M BTU's)</u>
(140,000 BTU's / per gallon)
= 5,548 gallons

Costs Lost:
= (5,548 gallons) x ($2.83)
= $15,700

Triple Pane windows with Low-E coating

<u>Andrews Hall:</u>
BTU's Lost:
= (1180 ft^2) x (.25) x (9,155) x (24)
= 64,817,400 BTU's

Gallons Lost:
= <u>(64,817,400 BTU's)</u>
(140,000BTU's / gallon)
= 462 gallons

Costs Lost:
= (462 gallons) x ($2.83)
= $1,310

Apartments:

BTU's Lost:

$= (3{,}185\ ft^2) \times (.25) \times (9{,}155.04) \times (24)$

$= 174{,}952{,}050$ BTU's

Gallons Lost:

$$= \frac{(174{,}952{,}050 \text{ BTU's})}{(140{,}000 \text{ BTU's / gallon})}$$

= 1,250 gallons

Costs Lost:

= (1,250 gallons) x ($2.83)

= $3,538