Measurement and Verification of Heating Energy Savings Resulting From the Installation of Heat Reflector Panels

"Reflector Panels"

Site 2 Report:
Habitations L'Équerre, Sherbrooke

Project No.: 218204

Presented to:

Energy Efficiency Fund (EEF)

6 June 2005

RIGHTS AND RESPONSIBILITIES

EXECUTIVE SUMMARY

According to various academic studies and laboratory tests, installing reflector panels on the wall behind heat distribution equipment, such as cast-iron radiators or hot water baseboards (finned tubes), would lead to average energy savings of 10% during the heating period.

Thus, the EEF mandated the NGTC to verify the effect of these reflector panels by taking measurements on actual installations. First, two sites were selected, the Centre culturel Calixa-Lavallée in the City of Montréal and Habitations L'Équerre, a housing cooperative in Sherbrooke. The Montréal site uses a cast-iron radiator heat distribution system, whereas the Sherbrooke site uses baseboard heating. This document discusses the results obtained at Habitations L'Équerre. The results obtained at the Centre Calixa-Lavallée were reported last year.[1]

At Habitations L'Équerre, initial measurements took place from 24 January to 10 February 2004, prior to the installation of the reflector panels. Subsequently, following panel installation, which ended in the fall of 2004, a second series of measurements was taken from 16 February to 10 March 2005.

An analysis of the data revealed a decrease of 8% to 18% in the boiler's daily gas consumption, at an equivalent heating load (consumption adjusted for heating-degree days – HDD) following the installation of the reflector panels. On the whole, over all of the measurement periods, the panels resulted in a 10% decrease in gas consumption to heat the building, at an equivalent heating load.

At the Centre Calixa-Lavallée, the first site measured, analysis of the data available before and after panel installation pointed to estimated savings of 12% in terms of gas consumption to heat the building.

Whether at the Centre Calixa-Lavallée or at Habitations L'Équerre, monitoring gas consumption in upcoming heating seasons will make it possible to refine the results obtained in the course of the project with regard to the effect of reflector panels on a building's gas consumption. However, based on this initial analysis, the effect of these panels would be significant from the perspective of energy efficiency and the theoretical potential of 10% advanced as a result of various laboratory tests seems to be confirmed in the field.

[1] DUPHILY, C. *Mesurage et vérification des économies d'énergie de chauffage résultant de l'installation de panneaux réflecteurs de chaleur* [measurement and verification of heating energy savings resulting from the installation of heat reflector panels], Site 1 Report: Centre Calixa-Lavallée, Montréal, Project No. 218204, Natural Gas Technologies Centre, 8 July 2004.

Natural Gas
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10. Summary (maximum of 200 words) This second report presents the measurement results as well as an analysis of the energy savings associated with the installation of heat reflector panels in two of the buildings at Habitations L'Équerre in Sherbrooke, where a finned-tube heat-distribution system (baseboard) is used. There were two measurement periods, the first in the winter of 2004, prior to the installation of the reflector panels, and the second in the winter of 2005, subsequent to panel installation.			
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1.0 BACKGROUND

The EEF established a program for natural gas users to install heat reflector panels behind hot water or steam radiators.

According to various sources, it has been demonstrated that installing these panels leads to energy savings of 10%, depending on the type of radiator and building in question. However, these demonstrations were performed in a laboratory or by modelling and, except for the work carried out at the Centre Calixa-Lavallée in Montréal last year, no on-site measurements seem to have been taken in Quebec, in a real-use situation. In addition, the community of specialized professionals is slow to recommend using these panels in institutional and business settings.

2.0 OBJECTIVE

Within this context, the NGTC proposed taking on-site measurements to verify the forecast performance for these heat reflector panels and to thereby establish some case studies.

The results obtained at the first measurement site, at the Centre culturel Calixa-Lavallée in the City of Montréal, were presented last year in the first report.[2] This document presents the measurement results, as well as an analysis of the energy savings associated with the installation of heat reflector panels in two of the buildings at Habitations L'Équerre in Sherbrooke, where a hot water baseboard (finned tube) heat-distribution system is used.

3.0 APPROACH

The approach used in this measurement project can be summarized in five steps:

Task 1: Site identification and validation

EEF used its various contacts to identify potential sites, conducive to the installation of reflector panels and to the taking of measurements. Initially, two sites were identified: the Centre culturel Calixa-Lavallée in Montréal and Habitations L'Équerre, a housing cooperative in Sherbrooke, which is the subject of this report.

Task 2: Installation of the instrumentation and definition of the protocol

Once the sites were identified, instrumentation was put in place so that measurements could be taken to analyze the effect of the reflector panels.

The measuring equipment was selected and installed subsequent to the development of a measurement plan combined with an analysis protocol that would make it possible to estimate the extent of the energy savings attainable as a result of the reflector panels.

In addition, a survey was prepared for occupants of the equipped sites, for the purpose of conducting a qualitative analysis of the impact of the reflector panels, in terms of the occupants'

[2] *Ibid*.

comfort. This document was intended to complement the analysis conducted through measurement.

However, this survey could not be given to Habitations L'Équerre occupants in a relevant manner. Indeed, the boiler's set temperature was increased at the beginning of winter f2005, which distorted tenants' perception regarding a potential change in their comfort level associated with installation of the reflector panels. The problem was corrected over the winter and the boiler's set temperature was reduced to enable a similar energy comparison before and after installation of the panels. However, it was too late to collect the occupants' opinions because they had experienced several potential changes in their comfort level during the winters of 2004 and 2005. In addition, it would have been difficult for the results of the qualitative analysis to be representative.

Task 3: First series of measurements

Before the reflector panels were installed, an initial measurement period was used to establish the comparison reference to analyze the effect of these panels on heating energy consumption.

At Habitations L'Équerre, boiler measurements were taken for a comprehensive analysis of the building; measurements were also taken in one room in one of the apartments.

This first series of measurements was taken in the winter of 2004.

Task 4: Second series of measurements

The second series of measurements took place at the same measurement points as the first, subsequent to the installation of the reflector panels, to determine their impact.

This second series of measurements was taken in the winter of 2005 at Habitations L'Équerre.

Task 5: Data analysis

The data collected before and after the installation of the reflector panels was analyzed to assess the energy savings attained as a result of the panels. This data was adjusted for the HDD, the sum of which differs during the two measurement periods.

4.0 DATA MEASUREMENT AND ANALYSIS

Evaluating the impact of the reflector panels on the first measurement site, that is, at the Centre Calixa-Lavallée, led to the following hypothesis:

- The reflector panels act as an insulator and radiation barrier on the wall behind the hydronic heating equipment (radiators or baseboards), thereby reducing heat loss through the wall at this location, where it is the greatest due to the proximity of the heat source (convective and radiant) to the wall and the extent of the resulting temperature differential. The larger the differential between the wall's exterior and interior surface temperature, the greater the conduction through this wall.

Based on this hypothesis, the reflector panels would lead to a reduction in energy consumption to heat the room/building, under similar operating conditions.

4.1 GAS CONSUMPTION TO HEAT THE ROOM

The energy generated to the room is evaluated by adding up over time the amount of energy exchanged ($\sum_{period}$) through the baseboard located in this room, when the thermostat is in heat demand mode and water is circulating through the baseboard. This is a rather rough evaluation because a certain amount of energy is also delivered by the pipes, which are still hot, during periods when the thermostat is not in demand mode and hot water is not circulating through the baseboard.

However, the effect of the panels can still be observed through the duration and frequency of the periods in which the baseboard is "active," for similar indoor and outdoor conditions; for example, weather conditions (temperature, wind, sun), the room's temperature and heat load spread across the room (energy produced by the occupants and by other devices operating in the room or in adjacent rooms).

To perform this analysis, the following data was collected around the baseboard during the measurement periods.

- Temperature of the water entering the baseboard: $T_{entering\ baseboard}$
- Temperature of the water leaving the baseboard: $T_{leaving\ baseboard}$
- Room temperature: T_{room}

The baseboard water output is not measured because it is constant and is cancelled out during calculation of an energy consumption ratio between the period before and after the installation of the panels.

The data can be placed on a graph using points depicting the energy generated to the room by the radiator for one day based on HDD. Equation [1] is used to determine the amount of energy generated to the room, by the summation of differences in the temperature of the water entering and leaving the baseboard ($\sum \Delta T_{baseboard}$), when it is in operation.

The movement of the scatter plot obtained on the graph provides an initial picture of the impact of the reflector panels on heating energy consumption, based on HDD, all other conditions combined (sun, wind, internal demand, etc). In addition, by applying a curve fitting to each of these scatter plots, it is possible to see the average difference in amplitude between the two curves obtained and the estimated percentage reduction in the energy generated by the baseboard (when it is active), associated with the panel installation, by HDD.

$$\sum \Delta T_{baseboard} = \sum_{day} (T_{entering\ baseboard} - T_{leaving\ baseboard}) \quad [1]$$

Equation [2] provides an alternative for assessing the reduction in energy generated by the baseboard (when it is active), associated with the panel installation ($\%_{\Delta Q\ room}$), this time over a period in which all of the conditions are similar. This period may be one day or more, depending on opportunities for comparison under similar conditions (outdoor temperature, room temperature, internal demand wind, sunlight). However, an adjustment can easily be made for a difference in degree-day (DD).

$$\%_{\Delta Q\ room} = \left[1 - \left(\left(\frac{\sum_{period}(T_{entering\ baseboard} - T_{leaving\ baseboard})_{after}}{\sum_{period}(T_{entering\ baseboard} - T_{leaving\ baseboard})_{before}}\right) * \frac{DD_{before}}{DD_{after}}\right)\right] * 100\% \qquad [2]$$

The daily DD available from Environment Canada are used in Equation [2].

The periods in which the baseboard is active are determined based on fluctuations in the temperature of the water entering the baseboard. Figure 4-1 presents an example of the temperature profile at the baseboard entry, with activity periods marked with an arrow.

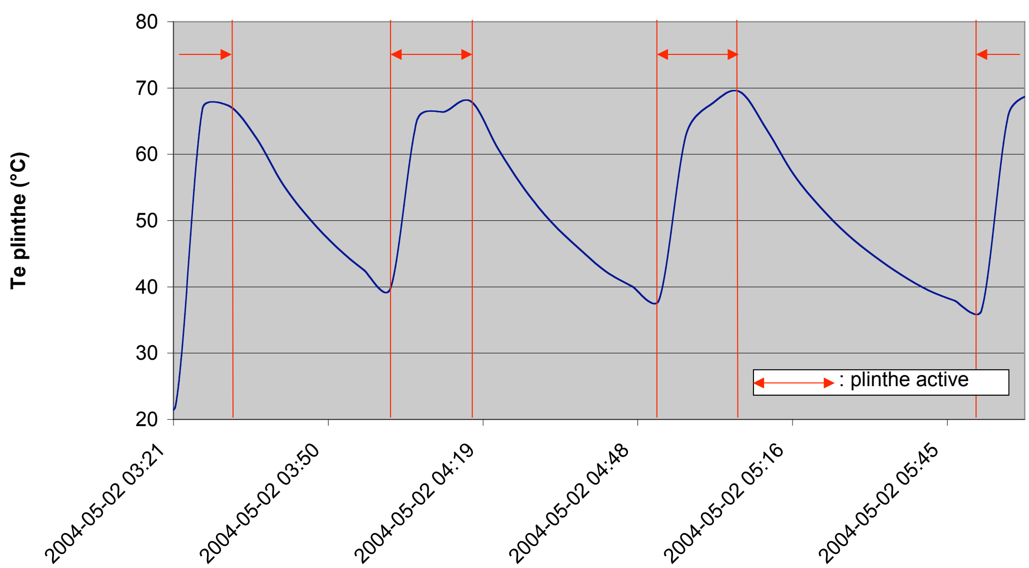

Figure 4-1 Example of temperature profile at the baseboard entry and periods of activity

4.2 BOILER GAS CONSUMPTION

The energy used to heat the entire building is assessed through boiler gas consumption (V_{gas}).

As is the case for the energy consumed in the room, daily boiler gas consumption data can be depicted on a graph as a function of HDD. By applying a curve fitting to each of the scatter plots obtained in this manner, by processing data for the periods before and after installation of the reflector panels, it is possible to quickly visualize their impact on gas consumption to heat the building, by HDD.

Equation [3] is used to evaluate the percentage of overall energy savings observable in the entire building subsequent to the installation of the reflector panels, by considering all of the measurement periods ($\%_{\Delta Q\ building}$). In addition, the energy exchanged during these periods must be adjusted to make the heating load comparison similar, that is, based on the same number of HDDs.

Of course, this is an overall analysis and does not take into account the building's internal demand, which may also vary by different tenants and their habits. Furthermore, aside from temperature, weather conditions are not considered. However, it is possible to infer at first glance that the mixture of these conditions over the two measurement periods may be similar.

In order to consider and possibly control all of these factors, laboratory analysis is required, which is not the purpose of this evaluation project.

$$\%_{\Delta Q\ building} = \left[1 - \left(\left(\frac{\sum_{period} \left(V_{gas}\right)_{after}}{\sum_{period} \left(V_{gas}\right)_{before}}\right) * \frac{DD_{before}}{DD_{after}}\right)\right] * 100\% \qquad [3]$$

The daily DD available from Environment Canada are used in the various calculations.

4.3 INSTRUMENTATION

The various temperatures are measured using surface thermocouples and collected on an ongoing basis using micro data loggers (MDL).

The volume of gas consumed is measured using a gas meter specifically for the boiler, installed for the measurement period, and is also collected using these MDL.

Data is recorded every five minutes.

5.0 IMPACT OF THE PANELS AT HABITATIONS L'ÉQUERRE

Habitations L'Équerre, a housing cooperative in Sherbrooke, was the second site studied as part of this project. More specifically, the buildings located at 815 and 825 Pivoines Street were studied. These two buildings each contain eight units and share the same boiler. The hydronic heating uses a Dettson boiler (HGC Gas model) that operates at a constant set temperature and does not use control logic to compensate for the outdoor temperature (indoor-outdoor).

Heat is distributed in the units via hot water baseboards (finned tubes) that are connected to a thermostat, thus permitting one temperature control per room.

At Habitations L'Équerre, an initial measurement period took place from 24 January to 10 February 2004, prior to the installation of the reflector panels. Subsequently, following panel installation ending in the fall of 2004, a second series of measurements was taken, from 16 February to 10 March 2005.

5.1 GAS CONSUMPTION TO HEAT THE ROOM

The instrumented baseboard is in the living room of apartment No. 6, at 825 des Pivoines. Figures 5-1 and 5-2 respectively depict the instrumented baseboard prior to panel installation, and the same baseboard with the reflector panel in place. This panel is positioned behind the finned tube. It is important to note that a protective panel is usually placed in front of the finned tube. In addition, it is indeed the same baseboard and the same room; however, the carpet was removed and replaced with linoleum between the two measurement periods.

Figure 5-1 Instrumented baseboard without reflector panel

Figure 5-2 Baseboard equipped with reflector panel

Figure 5-3 depicts the daily energy generated to the room by the radiator, based on HDD, before and after panel installation. The average daily data corresponding to the two measurement periods are presented in Appendix 1.

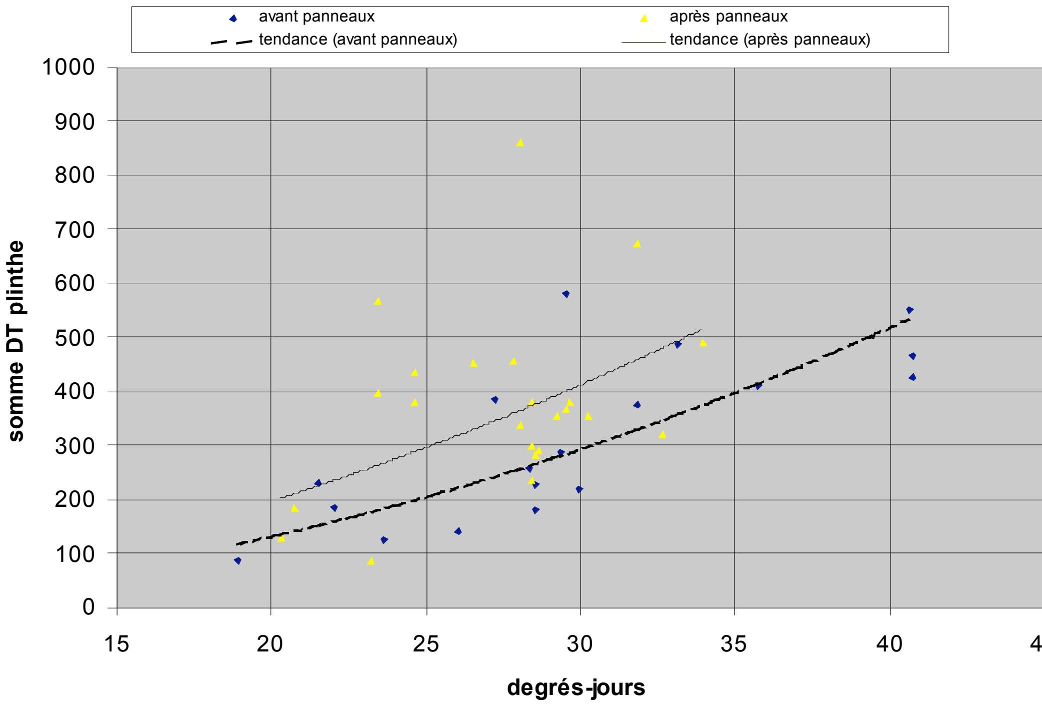

Figure 5-3 Energy generated to the room by HDD

Noting the points and curve fittings in Figure 5-3 leads to the observation that there was an overall increase in energy consumption of 35% to 50% for the instrumented baseboard between the two measurement periods. At first glance, this trend is unexpected; however, it can be attributed to a multitude of factors that may have influenced the results and prevented observation of the only effect of the panels.

As discussed after the first project report was produced (first measurement site), observing a single baseboard is very risky because the operation and performance of this baseboard are linked to a number of factors, the effect of which cannot be weighted by the presence of other baseboards and apartments. That is why in the case of on-site measurements the most comprehensive observation possible continues to be the most representative. A more detailed analysis is possible in the laboratory, where all conditions can be controlled.

For example, Figure 5-4 depicts the temperature profile of the water entering the studied baseboard for two days on which conditions were very similar before and after the installation of the panels.

	BEFORE Panels 07 February 2004	AFTER Panels 27 February 2005

Outdoor Temperature:	-10.5°C	-10.0°C
HDD:	28.5	28.0
Wind Speed:	19 km/h	18 km/h
Wind Direction:	Southwest (230°)	West-Southwest (260°)
Weather	Clouds + snow	Clear
Room Temperature:	23.4°C	23.1°C

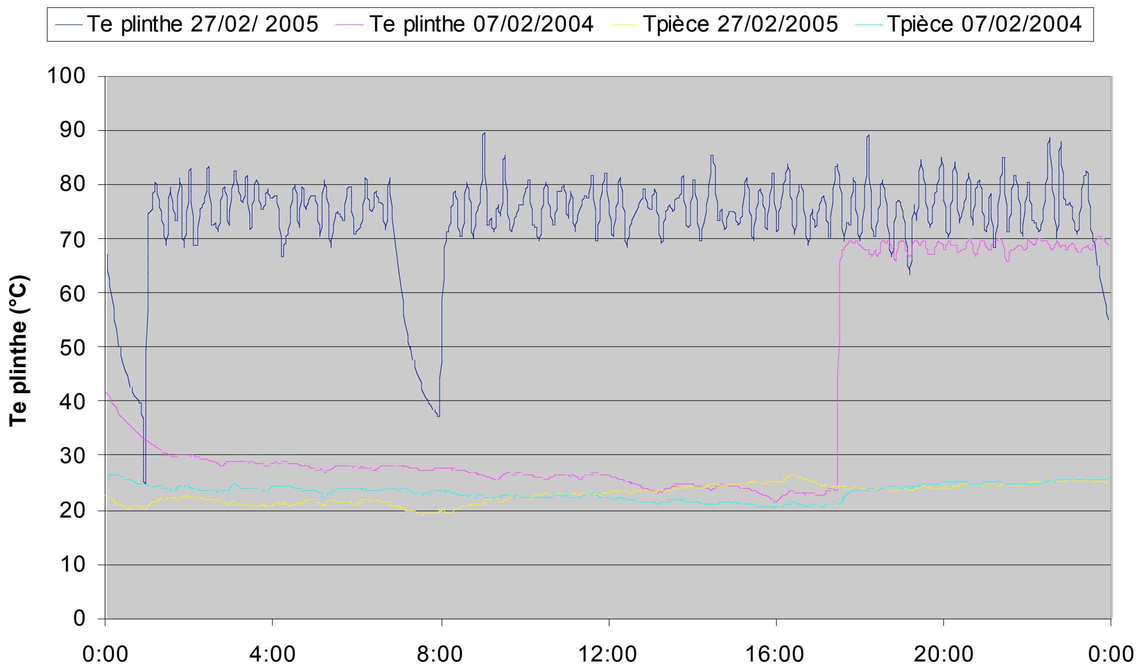

Figure 5-4 Example of the temperature profile at the baseboard entry for two similar days

In spite of the similarity in the conditions, Figure 5-4 shows a significant difference in terms of the duration and number of active baseboard periods. In addition, the baseboard consumed much more energy on 27 February 2005 (subsequent to panel installation), compared to 7 February 2004 (prior to panel installation). In spite of the fact that the baseboard did not operate between midnight and 5 p.m. on 7 February 2004, the temperature maintained in the room was practically the same as on 27 February 2005, when the baseboard was much more active. At worst, given the weather conditions on these two days, 7 February 2004 should actually have been at a slight disadvantage because it was snowing, while it was sunny on 27 February 2005. However, the complete opposite effect was observed.

Thus, other factors had a significant impact on baseboard performance and are responsible for this trend that is opposite to the expected effect between the 2004 and 2005 data. For example, the activity level in the unit, the activity level in other units, or the thermostat settings in the other rooms and in the other units are factors that could explain the phenomenon.

An analysis of the building as a whole, for which more cases (a number of baseboards) would help to compensate for fluctuations in various indoor conditions in each of the apartments, should be used to determine the overall impact of the reflector panels.

5.2 BOILER GAS CONSUMPTION

By conducting a comparative analysis of boiler gas consumption, it is possible to determine the impact of the panels on gas consumption for heating the entire building.

Figure 5-5 depicts the daily energy consumed by the boiler, based on HDD, before and after installation of the panels. The daily gas volumes supplied to the boiler during the two measurement periods are presented in Appendix 2.

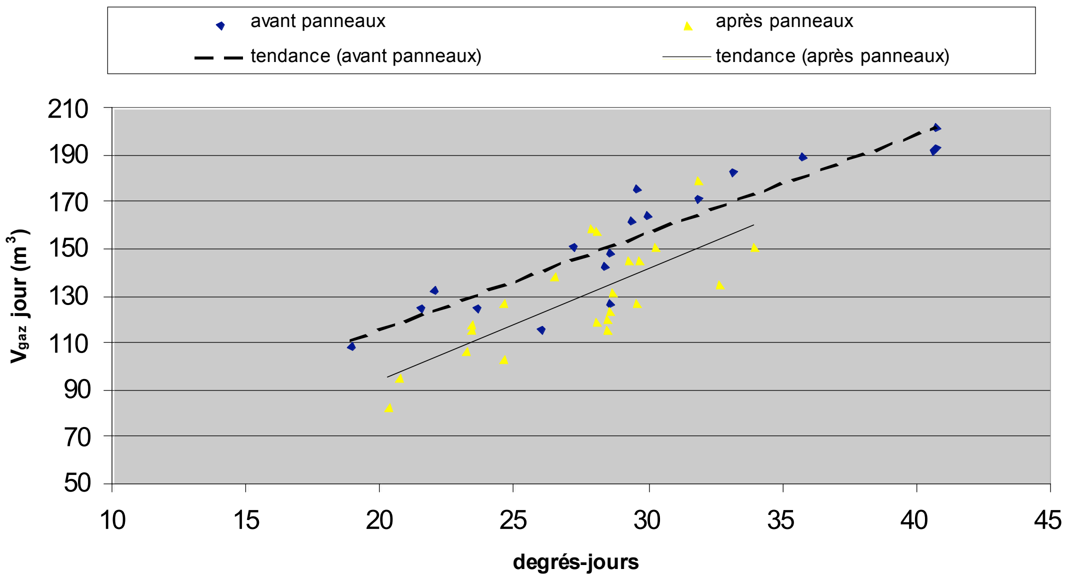

Figure 5-5 Energy consumed to heat the building by HDD

Noting the points and curve fittings in Figure 5-5 leads to an initial observation regarding the 8% to 18% decrease in boiler gas consumption for the measurement period, subsequent to the installation of the reflector panels, at an equivalent heating load (DD).

In addition, by using Equation [3] to calculate the percentage in gas energy savings to heat the building ($\%_{\Delta Q\ building}$), a decrease of 10.2% in gas consumption is noted between the measurement period in the winter of 2004 and the period in the winter of 2005, subsequent to the installation of the reflector panels in the entire building (815 and 825 des Pivoines). The comparison is made at an equivalent heating load (adjustment for HDD).

6.0 CONCLUSION AND RECOMMENDATIONS

As was the case at the Centre Calixa-Lavallé, the first site studied as part of this project, use of reflector panels at Habitations L'Équerre in Sherbrooke led to energy savings of 10% to heat the building.

This time, heat was distributed in the units via hot-water baseboards (finned tubes), whereas cast-iron radiators were installed at the Centre Calixa-Lavallée. In addition, the controlled environment was different for each site. Table 6-1 summarizes the characteristics of both sites as well as the overall energy savings observed.

Table 6-1 Comparison of the two sites studied as part of the project

	Site 1 Centre culturel Calixa-Lavallée Montréal	Site 2 Habitations L'Équerre Sherbrooke
Purpose of the building	Cultural	Residential (multi-rental)
Heat distribution equipment	Radiators	Hot water baseboards
Temperature control per room	-	Thermostats
Boiler temperature control	Based on outdoor temperature (indoor-outdoor)	-
Reduction in gas consumption to heat the building subsequent to panel installation	*11.9%*	*10.2%*

Whether at the Centre Calixa-Lavallée or at Habitations L'Équerre, monitoring gas consumption in upcoming heating seasons will make it possible to refine the results obtained in the course of the project with regard to the effect of reflector panels on a building's gas consumption.

However, based on this initial analysis, the effect of these panels would be significant from the perspective of energy efficiency and the theoretical potential of 10% advanced as a result of various laboratory tests seems to be confirmed in the field.

APPENDIX 1

Room: Average Daily Data

BEFORE PANELS

Average Daily Data	Temperature of Water entering the Baseboard	Sum of Baseboard TD	Room Temperature	Outdoor Temperature	Degree-Days
	T entering Baseboard °C	Baseboard TD °C	Room T °C	Outdoor T °C	DD
24/01/2004	66.72	468.44	21.19	-22.70	40.70
25/01/2004	66.96	553.90	22.54	-22.60	40.60
26/01/2004	67.72	428.62	22.88	-22.7	40.70
27/01/2004	66.40	413.73	23.15	-17.70	35.70
28/01/2004	68.02	289.27	23.12	-11.30	29.30
29/01/2004	68.31	582.35	23.58	-11.50	29.50
30/01/2004	68.10	490.26	23.67	-15.1	33.10
31/01/2004	67.97	376.95	23.80	-13.80	31.80
01/02/2004	68.07	388.13	24.00	-9.20	27.20
02/02/2004	67.26	142.88	23.63	-8.00	26.00
03/02/2004	66.37	127.99	23.97	-5.60	23.60
04/02/2004	66.68	187.79	23.44	-4.00	22.00
05/02/2004	67.27	229.57	22.71	-10.50	28.50
06/02/2004	66.66	260.24	25.15	-10.30	28.30
07/02/2004	68.79	183.29	23.41	-10.50	28.50
08/02/2004	66.40	222.06	22.38	-11.90	29.90
09/02/2004	68.16	231.49	24.10	-3.50	21.50
10/02/2004	67.98	89.66	23.15	-0.90	18.90

AFTER PANELS

Average Daily Data	Temperature of Water entering Baseboard	Sum of Baseboard TD	Room Temperature	Outdoor Temperature	Degree-Days
	T entering Baseboard °C	Baseboard TD °C	Room T °C	Outdoor T °C	DD
16/02/2005	76.01	155.40	22.63	-2.3	20.3
17/02/2005	77.67	357.24	22.80	-6.6	24.6
18/02/2005	76.65	351.24	22.79	-11.5	29.5
19/02/2005	74.91	366.64	21.71	-12.2	30.2
20/02/2005	75.90	492.68	21.96	-15.9	33.9
21/02/2005	73.73	401.64	23.09	-9.8	27.8
22/02/2005	74.59	389.56	24.19	-5.4	23.4
23/02/2005	76.60	244.96	21.78	-10.4	28.4
24/02/2005	74.94	303.20	22.06	-14.6	32.6
25/02/2005	75.56	268.08	23.11	-10.5	28.5
26/02/2005	76.27	291.44	20.82	-10.4	28.4
27/02/2005	76.22	942.28	23.12	-10.0	28.0
28/02/2005	77.01	321.60	23.34	-10.0	28.0
01/03/2005	77.20	90.80	22.71	-5.2	23.2
02/03/2005	76.25	447.28	22.04	-6.6	24.6
03/03/2005	76.45	410.60	21.35	-11.6	29.6
04/03/2005	76.74	500.44	22.45	-8.5	26.5
05/03/2005	77.70	605.92	23.37	-5.4	23.4
06/03/2005	75.54	192.56	22.86	-2.7	20.7
07/03/2005	77.94	343.16	23.39	-10.4	28.4
08/03/2005	75.28	338.68	22.90	-10.6	28.6
09/03/2005	75.65	849.64	21.73	-13.8	31.8
10/03/2005	75.71	405.48	22.30	-11.2	29.2

APPENDIX 2

Boiler Room: Daily Boiler Consumption

BEFORE PANELS

	Daily Gas Volume Consumed by the Boiler		Outdoor Temperature	Degree-Days
	V_{gas}		Outdoor T	DD
	ft^3	m^3	°C	
24/01/2004	7,140.67	202.23	-22.70	40.70
25/01/2004	6,791.90	192.35	-22.60	40.60
26/01/2004	6,834.24	193.55	-22.7	40.70
27/01/2004	6,689.09	189.44	-17.70	35.70
28/01/2004	5,723.42	162.09	-11.30	29.30
29/01/2004	6,213.31	175.96	-11.50	29.50
30/01/2004	6,477.41	183.44	-15.1	33.10
31/01/2004	6,062.11	171.68	-13.80	31.80
01/02/2004	5,346.43	151.41	-9.20	27.20
02/02/2004	4,102.56	116.19	-8.00	26.00
03/02/2004	4,419.07	125.15	-5.60	23.60
04/02/2004	4,685.18	132.69	-4.00	22.00
05/02/2004	5,247.65	148.62	-10.50	28.50
06/02/2004	5,033.95	142.56	-10.30	28.30
07/02/2004	4,489.63	127.15	-10.50	28.50
08/02/2004	5,814.14	164.66	-11.90	29.90
09/02/2004	4,423.10	125.26	-3.50	21.50
10/02/2004	3,844.51	108.88	-0.90	18.90

AFTER PANELS

	Daily Gas Volume Consumed by the Boiler		Outdoor Temperature	Degree-Days
	V_{gas}		Outdoor T	DD
	ft^3	m^3	°C	
16/02/2005	2,909.09	82.39	-2.3	20.3
17/02/2005	3,642.91	103.17	-6.6	24.6
18/02/2005	4,501.73	127.49	-11.5	29.5
19/02/2005	5,314.18	150.50	-12.2	30.2
20/02/2005	5,344.42	151.36	-15.9	33.9
21/02/2005	5,634.72	159.58	-9.8	27.8
22/02/2005	4,163.04	117.90	-5.4	23.4
23/02/2005	4,259.81	120.64	-10.4	28.4
24/02/2005	4,779.94	135.37	-14.6	32.6
25/02/2005	4,352.54	123.27	-10.5	28.5
26/02/2005	4,098.53	116.07	-10.4	28.4
27/02/2005	5,580.29	158.04	-10.0	28.0
28/02/2005	4,197.31	118.87	-10.0	28.0
01/03/2005	3,786.05	107.22	-5.2	23.2
02/03/2005	4,483.58	126.98	-6.6	24.6
03/03/2005	5,146.85	145.76	-11.6	29.6
04/03/2005	4,902.91	138.85	-8.5	26.5
05/03/2005	4,088.45	115.79	-5.4	23.4
06/03/2005	3,366.72	95.35	-2.7	20.7
07/03/2005	4,092.48	115.90	-10.4	28.4
08/03/2005	4,656.96	131.89	-10.6	28.6
09/03/2005	6,332.26	179.33	-13.8	31.8
10/03/2005	5,148.86	145.82	-11.2	29.2