Gorham Middle School

Independent Evaluation of Geothermal HVAC System

Prepared for:
Maine Department of Education

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Section 1: Facility Description

Gorham Middle School includes 139,000 square feet of conditioned space with the capacity to house 900 students. The School was constructed during 2004 and 2005 and occupied at the beginning of the 2005-2006 school year, with a current enrollment of around 700 students.

Heating and cooling throughout the space is provided entirely by a ground source geothermal heating system. The architect for the project is Lyndon Keck of PDT Architects in Portland, Mechanical Engineering was provided by Richard Whitney of Whitney Engineering, and with geothermal design expertise and advice from Bob Mancini, a geothermal engineer based in Alberta, Canada.

Section 1B: Geothermal System Description

The heat source is a bore field consisting of one-hundred-sixteen, 5” diameter “bore holes”, each three-hundred-fifty-four feet deep. The system is “closed loop” with a 15% glycol solution serving as the heat transfer fluid. A loop of 1½” welded HDPE pipe is placed in each hole, and they are then grouted with a sand-clay mixture to promote efficient heat transfer. The 1½” lines from each set of four wells are combined at a manifold, with 2” welded PVC pipe leading from this junction back to the main building manifold.

The glycol solution is circulated using a 40 HP pump to move fluid between the bore field and building, coupled with a 60 HP pump to circulate fluid throughout the building loop. Both pumps are equipped with variable frequency drives that maintain system pressure and vary the flow as the load fluctuates.

Building Manifold for 2” Lines From Bore Field

Distribution within the facility is accomplished using 136 individual “low temperature” heat pumps. Thirty of the heat pumps are water-to-water units located in mechanical spaces and producing hot and/or chilled water for coils in thirteen air handling units providing ventilation for the space, with up to 40,000 cfm of outside air available. Systems to melt snow and ice at the main entry and provide for radiant heat in the slab of the vestibule are also served by these units.

Water to Water Heat Pumps Serving AHU Coils

The air handling units are also equipped with heat recovery coils that extract “waste energy” from the exhaust air and return it to the make up air via a separate glycol loop.

The remaining heat pumps are water-to-air units located throughout the building. These units are designed for quiet operation and are either ceiling mounted or located in closets within each space.

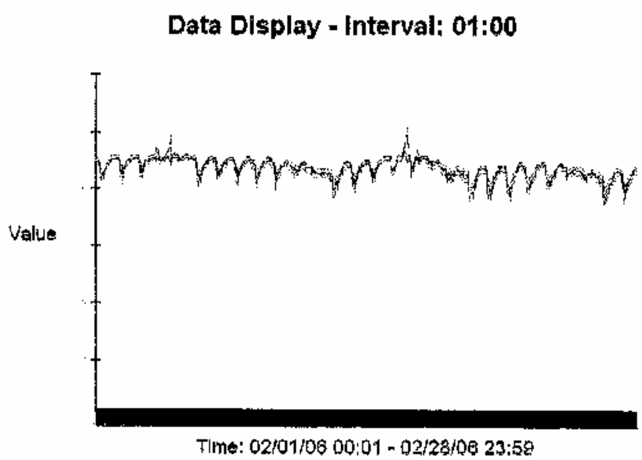
Domestic hot water is provided by a natural gas fired water heater and represents the only non-electric energy consumption in the building.

Typical Classroom Water to Air Heat Pump

Section 2: System Performance

Reports from building occupants and facility personnel indicate that he system has performed very favorably. They report that the system is relatively easy to operate, maintains a comfortable, healthy environment, and has been trouble free over the first two years of operation.

In addition to space conditions, the control system continuously monitors and provides trend reports of supply and return fluid temperatures for the building and the bore field loops as depicted below.



Facility staff report that by monitoring these temperatures, they have gained greater appreciation for the impact ventilation rates have on overall energy consumption, and have taken steps to insure the conditioned space receives appropriate levels of fresh-air without wasting energy through excess ventilation. The architect has also alluded to an enhanced appreciation of the impact of ventilation and has expressed a commitment to include demand control ventilation in future projects.

There are provisions to connect a portable boiler to the glycol loop in the event the fluid return temperatures should drop below allowable minimums. This event has not occurred in the two years of operation, and facility personnel and system designers are confident that it will never be utilized unless there is a catastrophic failure of the bore field.

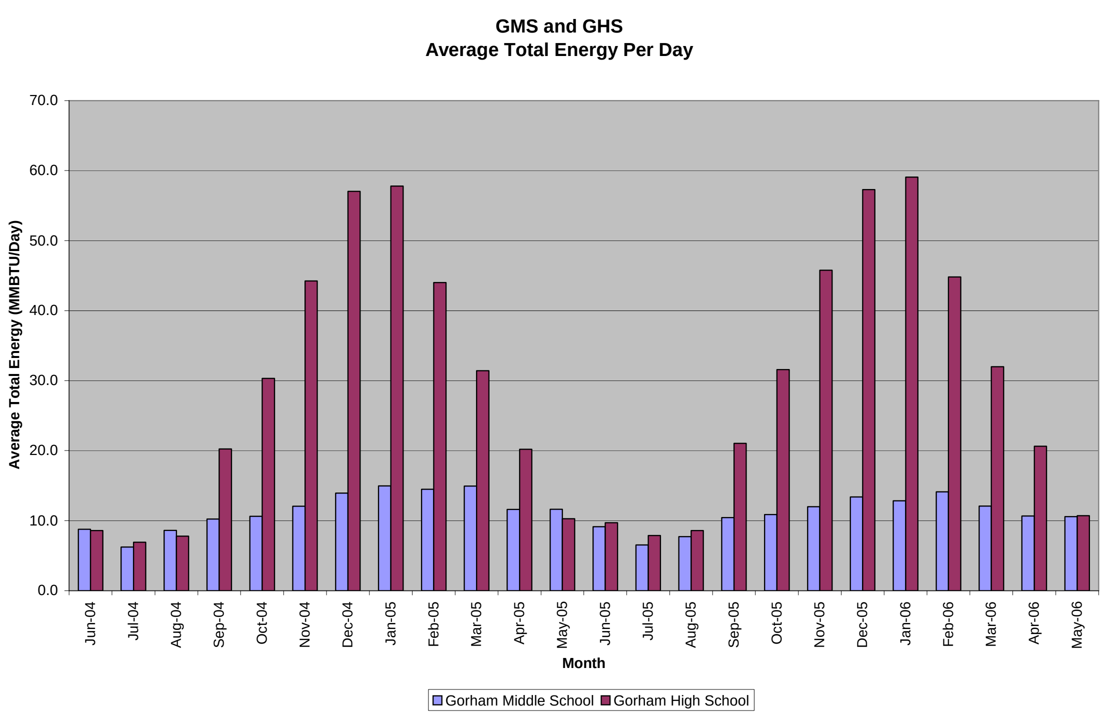
<u>Section 3: Annual Energy Costs</u>

Data relating to energy consumption and cost during the first two years of operation of this school was collected and analyzed. The energy performance was then compared to the nearby Gorham High School, to data collected from other existing Maine Schools, and to predicted performance for “High Performance” Maine schools presently under construction or recently completed. Each of these comparisons is discussed here.

1) Comparison to Gorham High School

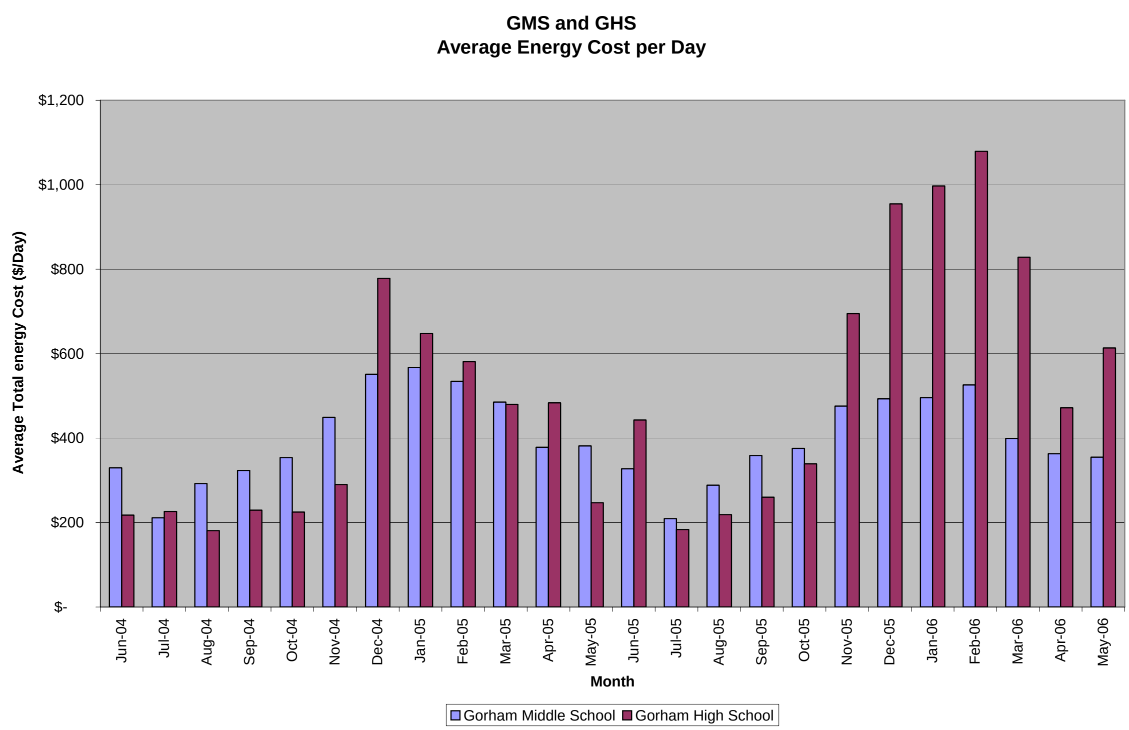
Monthly energy consumption and cost data was provided by the Gorham School Department for both schools covering the two-year period since the opening of the middle school. The two facilities are nearly identical in size, and facility staff reports that overall operating hours and building utilization is similar. The high school is heated by two oil-fired boilers, with VAV ventilation from roof top units. Air conditioning is provided for the administration, and guidance areas, as well as computer labs, and the television studio.

Total BTU consumption was calculated for each facility, based on the overall BTU content of each type of fuel consumed. Average BTU/day consumption and average $/day energy cost were calculated for each month. As illustrated in the following chart, overall energy consumption is essentially equal for the two facilities during the late spring and summer, but significantly greater for the high school during the heating season, with peak heating season consumption at the high school approximately four times that of the middle school.



While the chart accurately reflects the consumption of energy from traditional sources, it is somewhat misleading in that it does not reflect the "free" BTUs that are transferred from the ground to the middle school facility by the geothermal system. Energy consumed by the pumps and heat pumps that make up the geothermal system is reflected in the chart, but this represents only a portion of the actual BTUs delivered to the space.

From an economic perspective, a comparison of average daily energy costs between the two facilities is more meaningful. Because the cost of electricity, (expressed in $ per MMBTU), is significantly higher than that of #2 fuel oil, the differential in average daily energy cost for the two facilities is much less dramatic. Middle school cost exceed those of the high school during the summer months due to the additional air conditioning load, with the high school having significantly higher costs during the heating season. This relationship is illustrated in the following chart.



During the two years since the Middle School has opened, average annual energy bills have been $38,400 less, than those for the High School. Average consumption and cost by fuel type during this two year period is summarized in the following table.

Gorham Middle School and Gorham High School
Summary of Average Annual Energy Consumption and Cost

	Electricity		Natural Gas		Fuel Oil		Total BTU Input	
	(KWH/Year)	($/Yr)	(Therms/Yr)	($/Yr)	(Gallons/Yr)	($/Yr)	(MMBTU/Yr)	($/Yr)
Gorham Middle School	1,185,240	$ 139,557	3,457	$ 4,002			4,391	$ 143,559
Gorham High School	1,034,100	$ 102,124			49,515	$ 79,792	10,387	$ 181,916
Differential							5,996	$ 38,357

2) Comparison to Typical Maine School

Following completion of the Middle School project Richard Whitney of Whitney Engineering compiled a comparison of energy consumption per square foot for comparable Maine schools. Data from this evaluation indicates that on a BTU per square foot basis, GMS compares very favorable with all schools, including those with no air conditioning. When, current energy costs are applied to the fuel consumption data provided by the Whitney analysis, the resulting $ per square foot numbers for GMS also compare favorable for all air-conditioned schools, and for several of the schools with no AC.

Another survey of 104 Maine schools, undertaken by Anthony J. Lisa Jr. during 2004, predicts overall average, per square foot consumption for electricity and fuel oils, The table below provides a comparison of consumption and cost on a square foot basis between GMS and data from each of these analysis.

Gorham Middle School
Comparison of Overall Energy Consumption to Existing Maine Schools

School	Square Feet	Electric (KWH)	Fuel Oil (Gallons)	Natural Gas (Therms)	Total Energy (MMBTU)	Electric (KWH/SF)	Fuels (KBTU/SF)	Combined (BTU/SF)	($)	($/SF)
Data from Gorham School Department										
Gorham Middle School (Full AC)	138,400	1,185,240	-	3,457	4,391	8.6	2.5	31,726	$152,994	$ 1.11
Selected School From Whitney Analysis (May 2006)										
Middle School T (Full AC)	105,000	976,200	28,615		7,295	9.3	37.7	69,476	$173,532	$ 1.65
Middle School U (Full AC)	140,758	1,239,199	16,800		6,556	8.8	16.5	46,578	$185,140	$ 1.32
High School D	140,000	547,160	62,443		10,516	3.9	61.8	75,113	$180,792	$ 1.29
High School K	131,206	678,800	28,318		6,239	5.2	29.9	47,550	$135,822	$ 1.04
Middle School L	47,722	199,305	19,770		3,418	4.2	57.4	71,631	$60,499	$ 1.27
Middle School Q	58,800	100,320	17,063		2,706	1.7	40.2	46,014	$43,253	$ 0.74
High School R	85,852	562,790	38,622		7,270	6.6	62.3	84,680	$139,868	$ 1.63
	709,338	4,303,774	211,631	-	44,000			62,029	$918,908	$ 1.30
Average Existing Maine School (per square foot data from A. J. Lisa Survey - 2004)										
Projection for 138,400 sf School	138,400	780,576	56,744		10,523	5.6	56.8	76,034	$199,711	$ 1.44

Basis of Cost Derivation:

Typical Average Energy Costs:			(2006 school year)	
Electricity @	$0.125	per KWH	$ 36.62	per MMBTU
Fuel Oil @	$1.80	per gallon	$ 13.00	per MMBTU
Natural Gas @	$1.40	per therm	$ 14.00	per MMBTU

Annual predicted energy cost savings for GMS compared to the average existing school, based on per square foot data from the Lisa survey and current fuel prices, is $46,700.

3) Comparison to Recently Designed Maine Schools

Finally, the table provided below, provides a comparison of actual energy consumption and cost for GMS to projections of energy consumption for schools that have participated in the Maine High Performance Schools (MHPS) program. Each of the five schools represented here is presently under construction or has recently been completed. The design for each of these schools included energy saving features that were in part funded through the MHPS program.

Gorham Middle School
Comparison of Overall Energy Consumption to Projected Consumption of High Performance Schools

School	Square Feet	Electric (KWH)	Fuel Oil (Gallons)	Natural Gas (Therms)	Total Energy (MMBTU)	Electric (KWH/SF)	Fuels (KBTU/SF)	Combined (BTU/SF)	($)	($/SF)
Data from Gorham School Department										
Gorham Middle School (Full AC)	138,400	1,185,240	-	3,457	4,391	8.6	2.5	31,726	$152,994	$ 1.11
Recently Designed Maine Schools										
Elementary School AA	70,610	277,265	24,383		4,323	3.9	47.8	61,229	$78,548	$ 1.11
High School BB - (Full AC)	162,669	977,635	32,974		7,904	6.0	28.1	48,587	$181,558	$ 1.12
Middle School CC - (Partial AC)	80,000	776,920	4,532		3,279	9.7	7.8	40,991	$105,272	$ 1.32
Elementary School DD	47,300	249,383	13,822		2,765	5.3	40.5	58,467	$56,052	$ 1.19
Middle School EE (Partial AC)	119,000	774,146	26,189		6,269	6.5	30.5	52,684	$143,908	$ 1.21
Total for Five Designs	479,579	3,055,349	101,900		24,541	6.4	29.4	51,172	$565,338	$ 1.18
Projection for 138,400 sf School	138,400	881,732	29,407	-	7,082	6.4	29.4	51,172	$163,149	$ 1.18

BASIS:

Typical Average Energy Costs:			(2006 school year)	
Electricity @	$0.125	per KWH	$ 36.62	per MMBTU
Fuel Oil @	$1.80	per gallon	$ 13.00	per MMBTU
Natural Gas @	$1.40	per therm	$ 14.00	per MMBTU

While not necessarily pertinent to this analysis, it is interesting to note that overall projected annual heating fuel consumption of these five High Performance schools, (in BTU/sf), is 48% less than for the average existing school[1], while projected annual electric energy consumption, (in KWH/sf), is actually 13% greater than the average existing school. This is in part explained by the trend toward greater year round utilization of school buildings, and the increased prevalence of air-conditioning. On a financial basis, the projected annul energy cost for theses high performance schools, (in $/sf), is 18% less than for the average existing school.

Actual data from GMS over its first two years of operation results in overall annual energy consumption 38% less than the average projected for the High Performance schools, with overall annual energy cost coming in at 6% less, ($10,200 per year), than projections for the High Performance schools.

- [1] Average existing school data from the 2004 Lisa Survey

Section 4: Ongoing Maintenance Expenses

In terms of routine maintenance, while one might intuitively expect additional costs associated with the large numbers of belts and filters, these cost have not yet materialized at GMS. There is a preventative maintenance contract in place with an annual fee of $15,000. This contract covers replacement of filters and belts, replenishment of glycol in the loop, inspection of equipment, and other routine maintenance. The facilities department reports that a similar contract for service of the more traditional HVAC system at Gorham High School carries an annual cost of $18,000.

While it is not possible to accurately project future maintenance costs, some general assumptions can be made. With 136 individual heat pumps serving this facility, the frequency of failure associated with these units in later years, will be greater than for a more centralized system with fewer mechanical components. The cost associated with an individual repair to these small components will be less than for larger centralized equipment, but it is reasonable to assume that the overall annual downstream maintenance cost will be greater for this system.

A conversation with the facility director from a similar sized school equipped with over 100 heat pumps, revealed that while he has experienced only a handful of significant maintenance issues during the first 10 years of operation, he does anticipate that units will begin to fail more frequently, and is beginning to include money for more significant maintenance in his budget. For the purpose of the life cycle cost analysis, discussed later in this report, four iterations of the analysis were run with varying levels of additional annual maintenance cost, beginning in year ten. The first iteration assumes no additional cost, with successive iterations reflecting additional expenses of $5,000, $10,000 and $15,000 per year.

Section 5: Initial Cost Differential

The overall project budget for the school was $11.8 million, or between $84 and $85 per square foot. Of this amount, the overall HVAC system cost were approximately $1,958,000 with “internal HVAC” system cost estimated at $1,300,000. Additional cost associated with geothermal consultants, design, and installation of the geothermal field totaled $658,000.

Bid alternate pricing, obtained for a “conventional heat pump” system including a boiler and cooling tower, indicates this option would result in additional internal HVAC system cost totaling $114,000, or net project savings of approximately $544,000 compared to the geothermal system.

The incremental cost between the installed geothermal / heat pump system and a more traditional design with perimeter radiation, rooftop VAV ventilation, and DX air conditioning was not quantified for this project. Data from the National Best Practices Manual for Schools, and budget line items from similar schools, suggest the initial installed cost would be similar to the $1,300,000 “internal HVAC” cost identified for this school, producing a net incremental cost of the heat pump / geothermal system of $658,000. The table provided below summarizes the cost for each of these options and identifies estimated incremental cost.

Gorham Middle School Geothermal HVAC System
Projection of Incremental Construction Costs

	Internal HVAC System	Geothermal Design	Bore Field Installation	Overall HVAC
Installed Geothermal System	$ 1,300,000	$ 50,000	$ 608,000	$ 1,958,000
Conventional Heat Pump System	$ 1,414,000	$ -	$ -	$ 1,414,000
Traditional HAVC System	$ 1,300,000	$ -	$ -	$ 1,300,000
Incremental cost compared to "Conventional" (Boiler & Cooling Tower) Heat Pump System:				$ 544,000
Incremental cost compared to "Traditional" (VAV, Rooftop) HVAC System:				$ 658,000

It is worthy of note that the incremental cost reported for the efficiency upgrades included in the five recently designed High Performance Schools, whose projected energy consumption is included in Section 3, averaged $2.37 per square foot, equating to $329,000 for a school the size of Gorham Middle school.

Section 6: Life Cycle Cost Analysis

Life cycle cost analysis comparing the added investment in the geothermal / heat pump design to typical existing Maine schools, and to recently designed High Performance Maine schools, were completed, using the cost and saving values derived in this analysis.

For the comparison to existing schools, an initial incremental investment of $658,000 and 1st year energy savings of $46,700 were input. For the comparison to recent High Performance designs the incremental cost was reduced by $329,000 (to reflect the additional cost of "high performance upgrades" included in those designs), and a first year savings of $10,200 was input.

Each analysis assumed a 30-year measure life with a bond rate of 5%. Energy and maintenance costs are escalated at 2.5% per year, and a net present value is calculated based on a 5% NPV discount rate.

Four iterations of each analysis were run with additional annual maintenance costs of $0, $5,000, $10,000, and $15,000 starting in year ten. Spreadsheets illustrating each scenario are contained in the appendix to this report. The table included below summarizes the finding of the analysis.

Summary of Life Cycle Cost Analysis Projections

Comparison to Traditional Schools:	**$658,000 Incremental cost** **30 year life** **$46,700 1st Year Savings**	
Incremental Maintenance	Cumulative Positive Cash Flow	Net Present Value
$ -	$ 761,105	$ 273,214
$ 5,000	$ 686,793	$ 236,269
$ 10,000	$ 550,877	$ 185,071
$ 15,000	$ 414,960	$ 133,873

Comparison to High Performance Designs:	**$329,000 Incremental cost** **30 year life** **$10,200 1st Year Savings**	
Incremental Maintenance	Cumulative Positive Cash Flow	Net Present Value
$ -	$ (170,201)	$ (580,419)

This Life Cycle Cost Analysis suggests, that when compared to the energy consumed by a typical existing school, and the initial cost of a baseline traditional design, the savings produced by the geothermal / heat pump design, produce a reasonable return on required incremental investment.

However, the results obtained when comparing this option to the predicted performance, and reported costs for other recently designed “High Performance Schools”, the economics are not favorable. This suggests that the bulk of the energy cost savings achieved by the geothermal / heat pump design could be more economical obtained through the optimization of more traditional designs.

Section 7: Conclusions

In terms of system performance there are no reported problems with the system at this time, with all associated parties expressing a high level of satisfaction regarding performance, ease of operation, and operating cost.

A rigorous analysis of energy consumption and cost data for this facility, for other existing schools, and of projected energy consumption for schools presently under design or construction was completed. This analysis concludes that the energy performance of this school is significantly better than the typical existing school, and marginally better than other high performance schools presently under construction.

If looked at in terms of overall BTU input to the facility from electricity and fossil fuels, (neglecting the “free energy” taken from the ground), the facility out performs every school in the analysis, and is vastly more efficient than most, including many without air conditioning and with significantly lower operating hours.   If considered in terms of annual energy cost, the differential is smaller, but GMS still out performs existing schools by a wide margin, and the surpasses the average projections for new “high performance” schools by a smaller margin.   The bottom line is, GMS is a very energy efficient facility.

The Bore Field, also known as, the SoccerField.

Projections of the initial incremental cost associated with this design, and of future incremental maintenance cost, are based on information provided by the design team, discussions with other design and facilities maintenance professionals, and per square foot data taken from published sources. While the determination of these values was not as rigorous as the energy analysis, it is my belief that the values derived represent reasonable approximations of these values.

The life cycle cost analysis is intended to evaluate the cost effectiveness of the required incremental investment, and includes iterations with varying levels of incremental maintenance costs due to relative unpredictability of this value. The analysis predicts favorable life cycle economics when savings are based on a comparison to existing schools, and downstream maintenances cost do not exceed those of a conventional HVAC system by more than $15,000 per year. However, the analysis also suggests that much of the savings produced by this design could potentially be obtained in a more cost effective manner through the optimization of more traditional designs.

While this design does not represent the single most cost effective means of constructing efficient schools, it certainly must be considered a very successful project. Aside from economics, there are societal benefits derived from the minimal consumption of BTUs, and the facility offers a very high degree of year round functionality and flexibility. I believe it represent a viable alternative for new school design, where year round occupancy is anticipated, and full facility air conditioning is deemed appropriate.