CBIP Technical Review

Date: 2004 10 04

File Name: Janvier School and Community Hall EOI-1567
Location: Janvier, Alberta
Reviewer: James Love
Simulator: Nick Radom, Eco Energy Technology

Energy Performance of original submission: 82% (calculated from section 5 of performance path worksheets)
EE4 version used for original submission: 1.40
Building area: 1121 m^2

Energy Performance of reviewed file: 68.8 %
EE4 version used for review: 1.40; work around for heat pump plant implemented in DOE2
Building area: 1073 m^2

Summary

The project is a small log school building that also serves as a community hall. Space conditioning is by fan coils, with heating and cooling supplied by 8 ground-source heat pumps in a single circuit supplying the fan coils. This is not a standard system in EE4 and there was no applicable work-around when the file was prepared, so the simulator had modeled it as having gas-fired boilers. In the summer of 2004, NRCan approved a work-around and this was made available to the reviewer on Sept. 13, 2004 (Appendix B).

Prior to this, the file was returned to the simulator for correction of area calculations, as these did not follow CBIP procedures. The completion of the mandatory checklist was missing and was subsequently provided by the simulator. This has been inserted in the report.

The percent energy savings found in the review was lower than the submission primarily due to ventilation system issues. The default schedules were used for all zones. This provides correct results for zones with only office space uses, but generates fan operation outside the default school hours when zones include space functions in categories such as assembly and storage. As well, the outside air flow rates used in the simulation should have been the actual flow rates for the make-up air units rather than the high values that were calculated based on ASHRAE outside air guidelines.

The dollar savings found in the review were higher than the submission, despite the lower percent energy savings, because of the benefits conferred by the modeling procedure for the heat pump plant and because of the high cost of energy in the form of electricity.

The utility rates used were:

electricity	demand	$ 7.45 per kW
	delivery, first 200 kWh/kW	$0.0304 per kWh
	delivery, remainder	$0.0040 per kWh
	usage, remainder	$0.0775 per kWh

Table 1. Summary of CBIP Models for Janvier High School

CBIP Reference Case	**CBIP Proposed Design**
Schedules: MNECB schedule D education Floor Area: 1073 m2 No. of Stories: 1 Space Use Classification: classroom, office MNECB Region: Alberta C	
Building Envelope (Principal Heat – Heat pump)	
Exterior Walls • From Table A-3.3.3.1 MNECB Opaque exterior walls at RSI 3.3 m2-C/W	***Exterior Walls*** • Log walls RSI 2 m2-C/W
Roof • From Table A-3.3.3.1 MNECB roof at RSI 8.3 m2-C/W	***Roof*** • Type I (attic) roof RSI 6.3 m2-C/W
Below Grade Walls • none	***Below Grade Walls*** • none
Exposed Floors • none	***Exposed Floors*** • none
Floors on ground • interior RSI 1.1 m2-C/W	***Floors on ground*** • interior RSI 0.9 m2-C/W
Glazing • glazing limited to 40% • From Table A-3.3.1.2 MNECB, windows at U=2.80 W/m2-C for operable glazing • From 5.3.5.5, CS, window shading may be same as proposed or set at 0.73 • no overhangs, self-shading in the form of fins represented	***Glazing*** • glazing-to-wall ratio = 14% • double-glazed windows, low-e, argon filled with wood frames, U=2.0 W/m2-C for operable glazing • no fins or overhangs
Infiltration • From 5.3.5.9 CS, infiltration rate of 0.25 L/s m2 of gross wall area and is applied to exterior zones at all times	***Infiltration*** • Infiltration rates same as for reference case

Lighting	
• Building total, lighting power density = 16.4 W/m2	• Building total, lighting power density = 8.3 W/m2 • no occupancy or daylighting controls installed
I **Appliances and Plug Loads**	
• Office: density = 7.5 W/m2 • classroom: density = 5 W/m2 • recreational sports: density = 1 W/m2 • auditorium/exhibit: density = 2.5 W/m2 • kitchen: density = 10 W/m2 • storage: density = 1 W/m2	• must be same as reference
HVAC Equipment	
Systems • one VAV system	*Systems* • 2-pipe fan coil • one MUA for fan coil system • fan energy included for heat recovery supply and return • heat recovery effectiveness: system 1 – 0.54
Supply and Ventilation Air (DOE SV-A) report) system 1 – 5863 L/s total; 1982 L/s outside	*Supply and Ventilation Air (DOE SV-A) report)* system 1 – 1880 L/s total; 1880 L/s outside
Control • heating and cooling setpoint and setback temperatures same as for proposed design	*Control* • Heating (&setback) setpoints: 22 C (18 C) • Cooling (&setback) 24 C (35)
Heating Plant • one gas-fired boilers at 80% efficiency from table 5.2.13.1 MNECB, using the required CBIP part-load curve MNECB Supplement Appendix A-2 • fixed speed circ pump motor (65% efficiency) • 16.1 C design temperature drop	*Heating Plant* • 8 ground-source heat pumps • fixed speed circ pump motor (65% efficiency)
Cooling • 41 kW cooling	*Cooling* • 85 kW cooling
Domestic Hot Water (DHW)	
• 18 kW (electric)	• 18 kW (electric in EE4, changed to efficiency of 5 in DOE2)
Utility Rates	
• used same rates as proposed	• used applicable electricity and gas rates

Ventilation Compliance

The maximum total outside air requirement calculated by ASHRAE is 1630 L/s for expected occupancy, which is within 20% of the 1880 L/s capacity of the heat recovery ventilator the capacity of the make-up air system.

Significant Energy Conservation Design Features

The key energy-conserving features of the design are:

- ventilation heat recovery for outside air supply
- ground source heat pump
- DHW remote heated by ground source heat pump
- lighting about 50% below MNECB reference

Modifications to EE4/DOE2 Files

1. The electric demand rate was changed to $7.50/kW, the value shown in the tariff from $2.50. The energy cost for electricity is show as $0.0775/kWh on the utility bill. The tariff shows delivery charges of $0.0304/kWh for the first 200 kWh/kW and $0.004/kWh for the remainder. The rate is then $0.1079/kWh for the first 200 kWh/kW and $0.0815/kWh for the remainder. The rate was changed to this from $0.13/kWh.
2. The system was changed to 2-pipe fan coil (as shown in the drawings and confirmed with the mechanical engineer) rather than the 4-pipe fan coil in the submission. When this was done, the spring fall changeover had to be changed to July 15-August 15 to prevent underheating errors; the mechanical room also had to be assigned a lower temperature schedule.
3. Schedules for areas with functions other than education were set to schedule D to prevent the fan from running on food service hours.
4. The floor areas of the spaces were revised by the simulator after the reviewer pointed out that CBIP Modeling Procedures require that inside dimensions be used.
5. Classroom occupant density was set to 2.7 m2/occupant to bring outside air up to within 10% of the ASHRAE value as per the system design and outside air calculation.
6. The “dummy” use for washrooms was changed from “retail-A” to “education-classroom” to use an education schedule instead of a retail schedule
7. The supply fan power was changed from 1491 W to 2984 W to account for the power of both the supply and return fans (the main exhaust fan power AEF-1 appears to have been omitted from the simulation model).
8. To simulate the electric boiler as per CBIP procedure (Appendix D), the principal heat source had to be set to “electric” For this climate zone, the reference U-values are the same as for heat pump
9. All air flow rates for fan coils had to be set to the actual values.
10. The NRCan work-around for ground-source heat pump as plant with fan coil air system was implemented in DOE2. The domestic hot water heating efficiency was adjusted in the same way, because the heat pumps also supply domestic hot water.

Errors and Warnings

There was one error due to supposed inadequate plant heating capacity for the second plant; the simulator refers to MNECB-CBIP explanation of this error.

DOE2 There are numerous warnings due to the use of 2 plants. Numerous warnings about cooling capacity.

EE4

post-calc warnings 1 DOE2 warnings

DOE2

The warnings were

```
**WARNING*********************************************************************
             SYSTEM SYSTEM-1         has specified SUPPLY-CFM smaller
             than the total specified outside air

 **WARNING*********************************************************************
             ZONE SYSTEM-1-DUMMY   in SYSTEM SYSTEM-1         cannot get needed
             MIN-OA without using ASSIGNED-CFM to raise total ZONE flow
```

EE4 errors – EE4 sizes the outside air

```
 **WARNING*********************************************************************
             SYSTEM SYSTEM-1         may have inadequate cooling capability
             Check COOLING-CAPACITY and MIN-SUPPLY-T for consistency

 **WARNING*********************************************************************
             In PLANT PLANT-1          specified HWP flowrate of     116.0 GPM
             is less than calculated rate of     218.2

**WARNING*********************************************************************
             In PLANT PLANT-1          specified CHWP flowrate of     168.0
             GPM is less than calculated rate of     218.2
```

The flow rate is a value determined by EE4 rather than the simulator.

Summary Compliance Report

1 – exhaust air heat recovery - consistent with drawings and specs

2-6 – occupant density warnings

7 – DOE2 warnings

Savings & Incentive

	Electricity (MJ)	Gas (MJ)	Total (MJ)	Total (MJ/m2)	Energy Cost	Cost/m2
Proposed	478,653	0	478,653	446	$17,093	$15.93
Reference	1,534,376	0	1,534,376	1430	$57,546	$53.63
Savings	1,055,723	0	1,055,723	984	$40,453	$37.70

Reduction	68.8%	**Incentive**	$80,906	$60,000
Floor Area	1073		$60,000 maximum	

Recommendation
The file is clearly better than the 25% threshold required to earn a CBIP incentive.

Comments
The simulator was faced with a difficult task, given that no procedure existed for this system-plant combination and the fact that he was unable to obtain help via the assessor's network. The high cost of electricity and the modeling rules result in a very large grant for a small building. The building was modelled with a gas-fired boiler as an alternate, and the estimated operating cost is lower than with the heat pump system, and the grant would be much lower.

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Appendix A
Detailed Notes re First Set of Changes to Simulation File

1) Zoning: Main Hall should be divided into north and south zones

2) Zones - Principal heat source should be heat pump

3) Space – space function for administration 102 is auditorium/assembly

4) The roof area is about 10% less than the floor area, which should not be the case of a single storey building

5) Area measurements (walls – also check floor areas) are supposed to be from inside wall surface to mid partition; it appears that you measured grid line to grid line

6) Lighting :

Zone Corridor 117 – lighting is missing
Zone Main Hall - lighting is missing
Zone Washrooms – wrong count
Zone Classroom 126 – wrong count

Appendix B
Application of NRCan Modeling Procedure for Ground Source Heat Pump as Plant

1. Number of plants

A single plant was used, because all eight heat pumps serve a single loop feeding the fan coils. Heat pump heating capacity is 10.6 kW x 8 = 84.8 kW; cooling is 10.6 kW x 8 = 84.8 kW.

The DOE2 proposed file was modified to assign an E-I-R of 0.2 to the boiler.

2. Cooling

Cooling is 10.6 kW x 8 = 84.8 kW. Because this is less than 700 kW, it is modelled as a reciprocating chiller.

Appendix B
NRCan Modeling Procedure for Ground Source Heat Pump as Plant

Janvier: EOI 1567

Issue:

Project is uses a fan coil heating/cooling distribution system but instead of a boiler/chiller/cooling tower heating/cooling source uses a ground source heat pump (8 Versatec units).

EE4 does not model this combination, therefore the simulator is required to either model a full distributed heat pump system or a fan coil system.

It was determined that the modeling of a fan coil system best represents the actual design. The ground source heat pump can be represented as a high efficiency electric boiler with the efficiency modelled as the reciprocal of the COP.

A DOE2 workaround to model a high efficiency electric boiler is attached.

There are a couple of outstanding issues that the simulator needs to address.

1. Number of plants:

The information provided by the simulator indicates 8 Versatec units. This could be interpretated a number of ways:

   1. 8 heating plants serving distinct air handling systems assigned to each of the 8 ground source heat pumps, which could be modelled as 8 plants with 8 AHUs and a number of zones within EE4;

   2. 8 heating plants serving air handling systems in combination; which could be modelled as a single plant or number of plants depending on the connection to the air handling systems;

   3. a single heating plant with 8 sequenced boilers each representing a ground source heating pump (single capacity) if the ground source heat pumps are sequenced in operation

   4. a single heating plant if all 8 ground source heat pumps are required to heat the building which would be modelled as a single plant with the capacities of the 8 ground source heat pumps added together as the single plant capacity

2. Cooling:

A chiller must declared in the proposed case to represent ground source heat pump cooling. The number of a chillers will depend on the decision for the number of heating plants. This theoretically should match, if cooling is provided to the same air handling units and zones as the heating.

However the selection of the type of cooling depends on the total cooling load of the building.

If the total cooling capacity of the 8 heat pumps is less than 200 tons (700 kW), define a reciprocating chiller.

If the total cooling capacity of the 8 heat pumps is greater than 200 tons (700 kW) but less than 600 tons (2100 kW) define a centrifugal chiller.

If the total cooling capacity of the 8 heat pumps is greater than 600 tons (2100 kW), define a 2 centrifugal chillers (at 50% capacity each).

If the proposed design contains a cooling tower, then select cooling tower as the condensate cooling method. If the ground source heat pump configuration does not contain a cooling tower, then define the condensate cooling method as air cooled.

Convert the EER to a COP by dividing by 3.41 and convert the COP to an E.I.R as required in DOE2 by taking the reciprocal of the derived COP.

3. Cooling Tower:

If the design already incorporates a cooling tower, then enter those specifications. If the ground source heat pump design does not contain a cooling tower, then you should have defined an air cooled condensor strategy.

4. Pumps:

Enter the pump(s) for the ground source heat pump configuration as the boiler and chiller pumps. If a single distribution pump is used in the ground source heat pump configuration, enter the same pump for both the boiler and chiller. If a combination of pumps exist in the design, then group according to the operation and the modelling manual guidelines.