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IBPSA-USA SimBuild 2008, UC Berkeley

Comparative Simulation of a High Performance Building with EE4-DOE2.1E and EnergyPlus

Zhen Tian[1], Wei Tian[2], and James A. Love[2]

[1] Foraytek Inc., Calgary, AB, Canada
[2] University of Calgary, Calgary, AB, Canada

July 31, 2008

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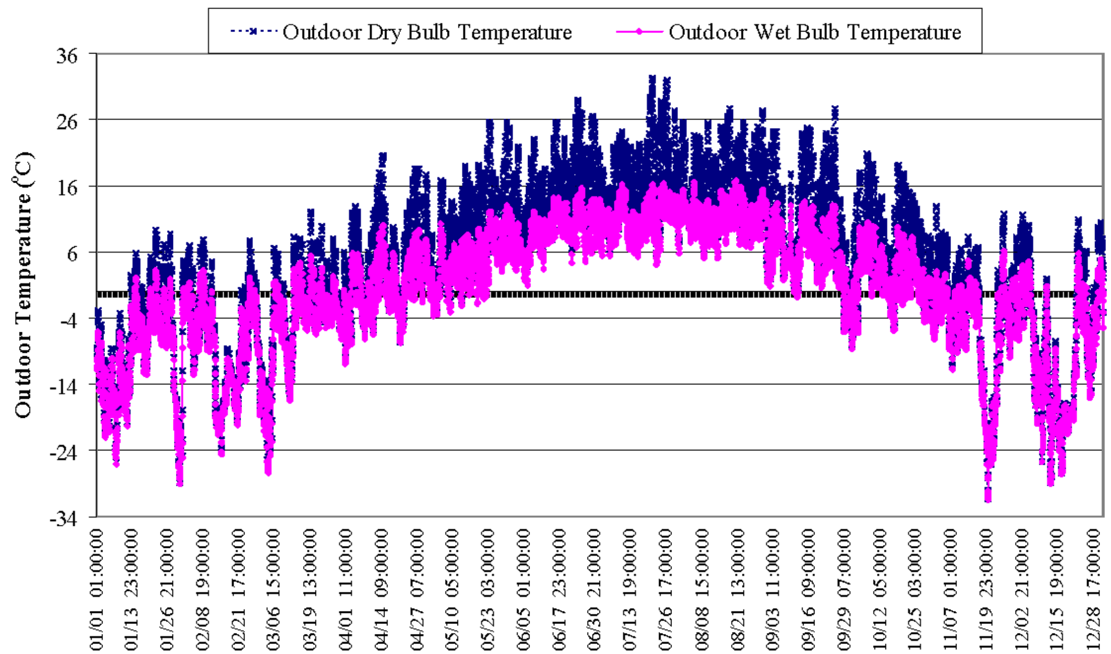
Calgary Climate Context

- Calgary is at 51º north latitude with a climate classified as “very cold” (Briggs *et al*. 2002);
- Mean annual temperature of around 4 ºC;
- 99% heating design temperature -27 ºC;
- 1% cooling design temperatures (dry bulb/wet bulb) 26 ºC/15 ºC;
- Located in semi-arid region with rarely overcast and very often clear skies.



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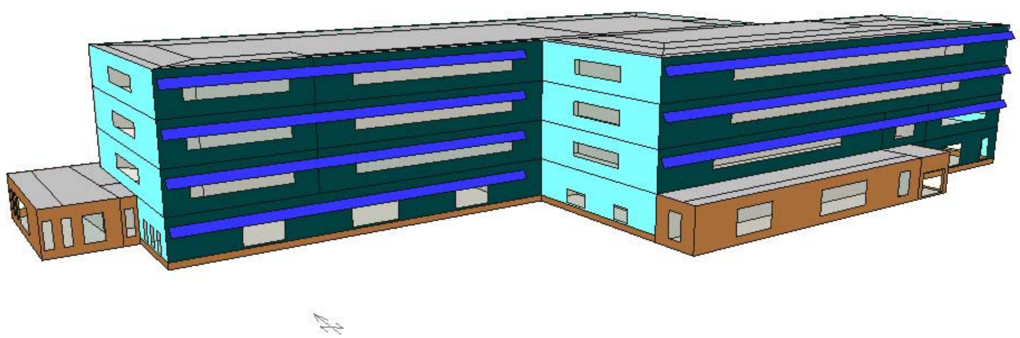
Introduction of the CDC Building

<u>The University of Calgary's Child Development Center (CDC)</u>

- Four-story, 12,000 m^2 new facility;
- Certified LEED Canada New Construction 1.0 Platinum building;
- Annual energy cost reduction of 71% relative to Model National Energy Code for Buildings (MNECB) baseline (1997).



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CDC Energy Strategies

- Well-insulated building envelope (about 25% better than the MNECB baseline),
- Small window-to-wall ratio (0.21 compared with the MNECB reference limit of 0.40)
- Efficient lighting system (lighting power density of 7.3 W/m2 excluding control credits),
- Displacement ventilation via low side wall diffusers for the level 1 educational spaces,
- Under-floor air distribution for the office-type spaces on the other three levels,
- Radiant cooling panels in perimeter spaces with direct sunlight,
- Exhaust air heat recovery,
- Air-side and water-side water economizers,
- High efficiency plant equipment, and
- Building-integrated photovoltaic system that shades south windows.

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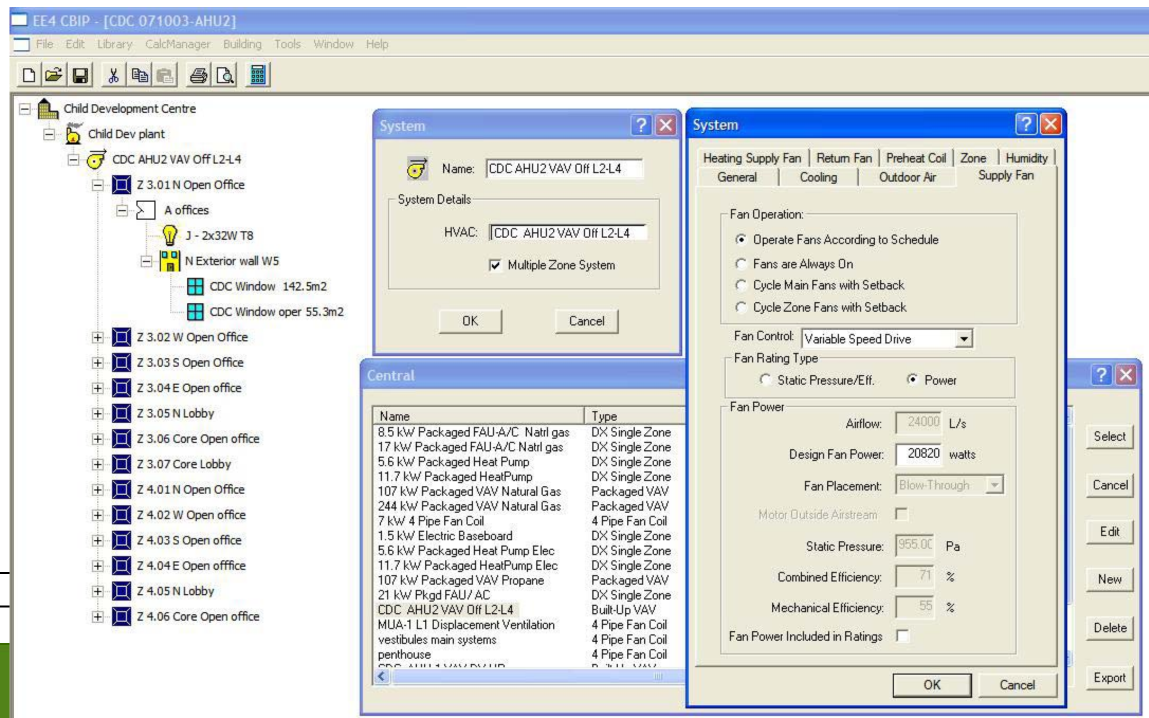
Simulation Program: EE4-DOE2.1E

EE4 CBIP

- DOE-2.1E as calculation engine
- Commercial Building Incentive Program (1997-2007) mandate
- Straightforward, easy to use user interface
- No building 3D geometry input, but area, orientation and tilt angle
- Generate MNECB reference case building automatically
- Limited capabilities (e.g. water-side free cooling, radiant cooling)



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Simulation Program: EnergyPlus v2.0

- *EnergyPlus* models the building, system and central plant in parallel and allows feedback among them (DOE 2007),
- Loop-based, configurable HVAC systems, allowing users to model both typical and modified systems (DOE 2007),
- Displacement ventilation (DV) module and underfloor air distribution (UFAD) system module,
- Low-temperature radiant heating/cooling system module,
- Water-side free cooling module,
- Integrated photovoltaic module for modeling generated electricity,
- No user interface, building geometry input through other programs: Ecotect, Energy Design Plugin (for SketchUp) *ect*.
- Allow more than one system in one zone,
- Much more complicated and difficult to use than EE4.

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Modeling Methods and Steps

1. Build the CDC EE4-DOE2.1E energy model, excluding radiant cooling, water-side free cooling, displacement ventilation, under-floor air distribution, and BIPV.

2. Create the CDC geometry in Ecotect (Marsh 2006), export it to EnergyPlus. The “basic” EnergyPlus model zoning, building envelope, HVAC system and internal loads consistent with the EE4-DOE2.1E model. Simulation results were compared and discrepancies were identified.

3. Add the features beyond the scope of DOE2.1E to the “basic” EnergyPlus model, create an “advanced” model and obtain the building energy performance with the additional energy efficiency measures and renewable energy systems.

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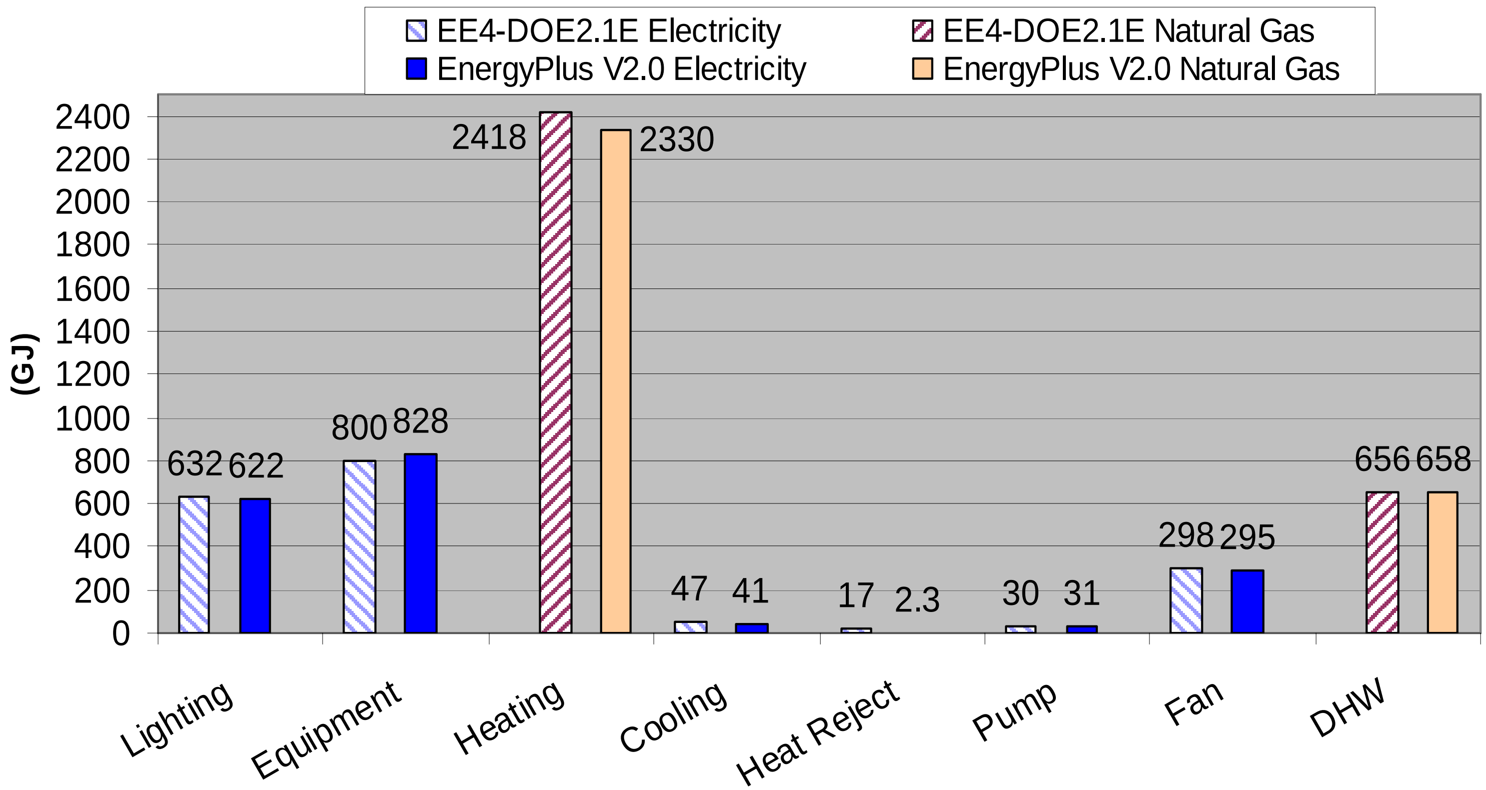
Simulation Results Comparison

Whole building energy end uses



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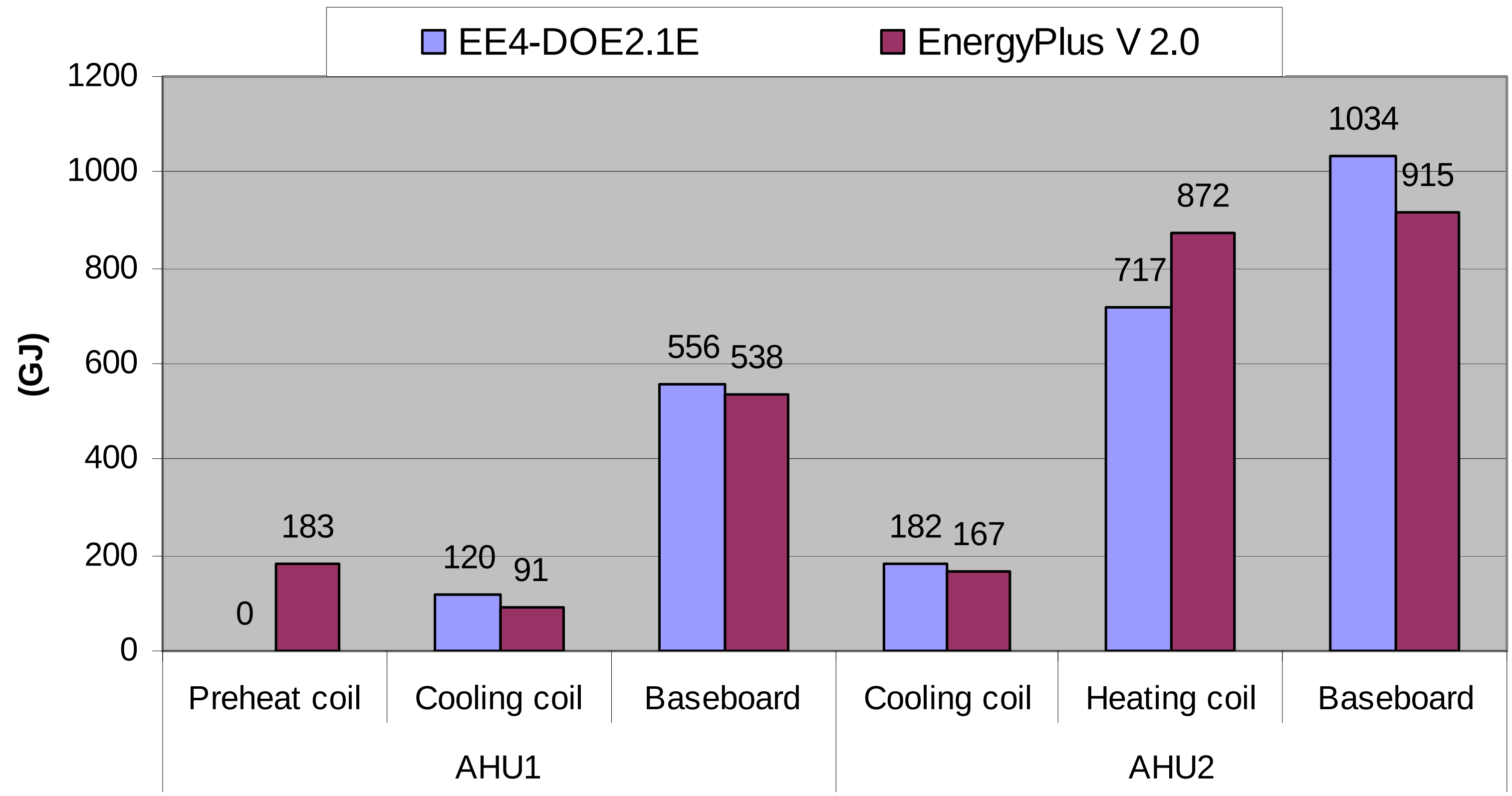
Simulation Results Comparison

Coil and baseboard energy uses



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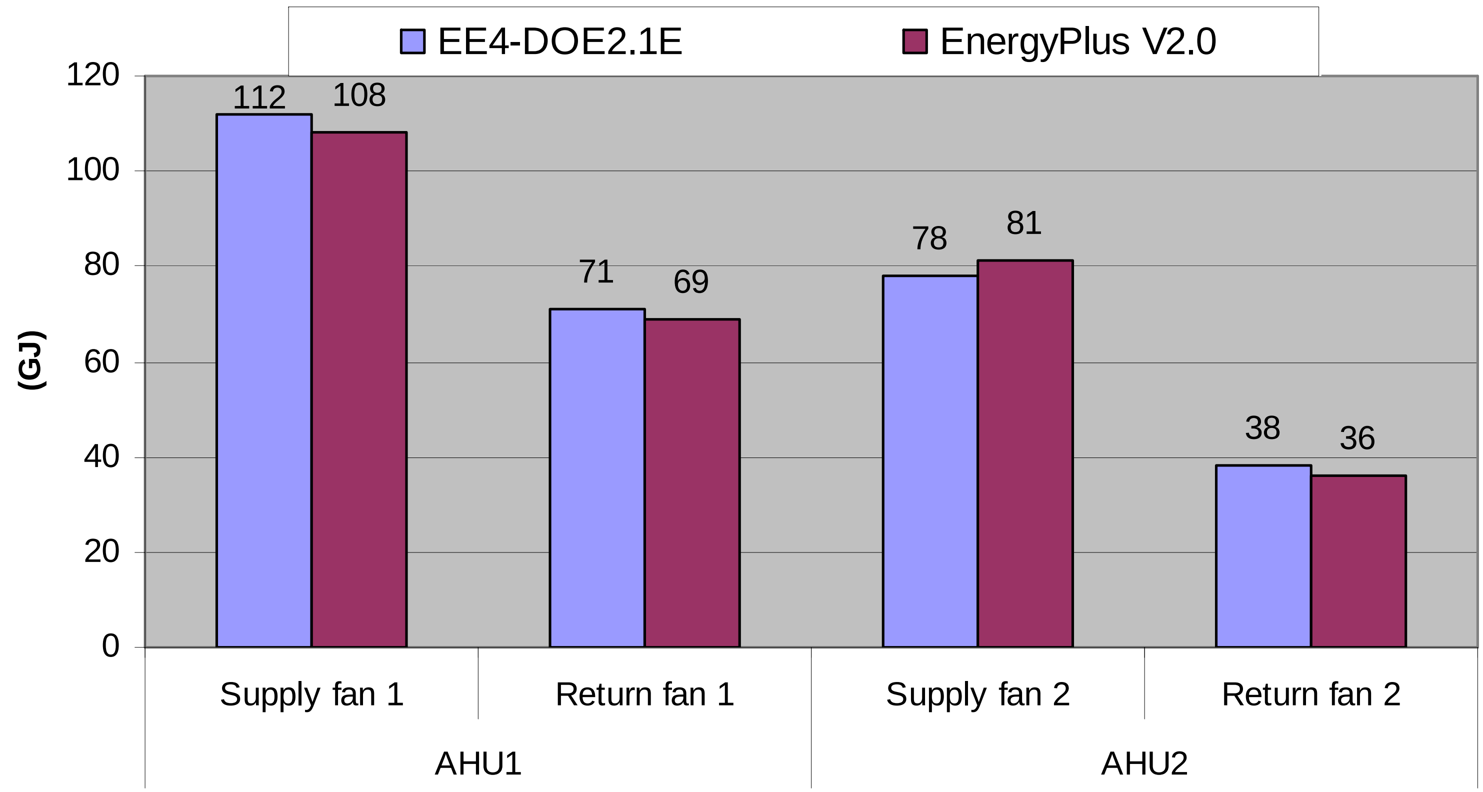
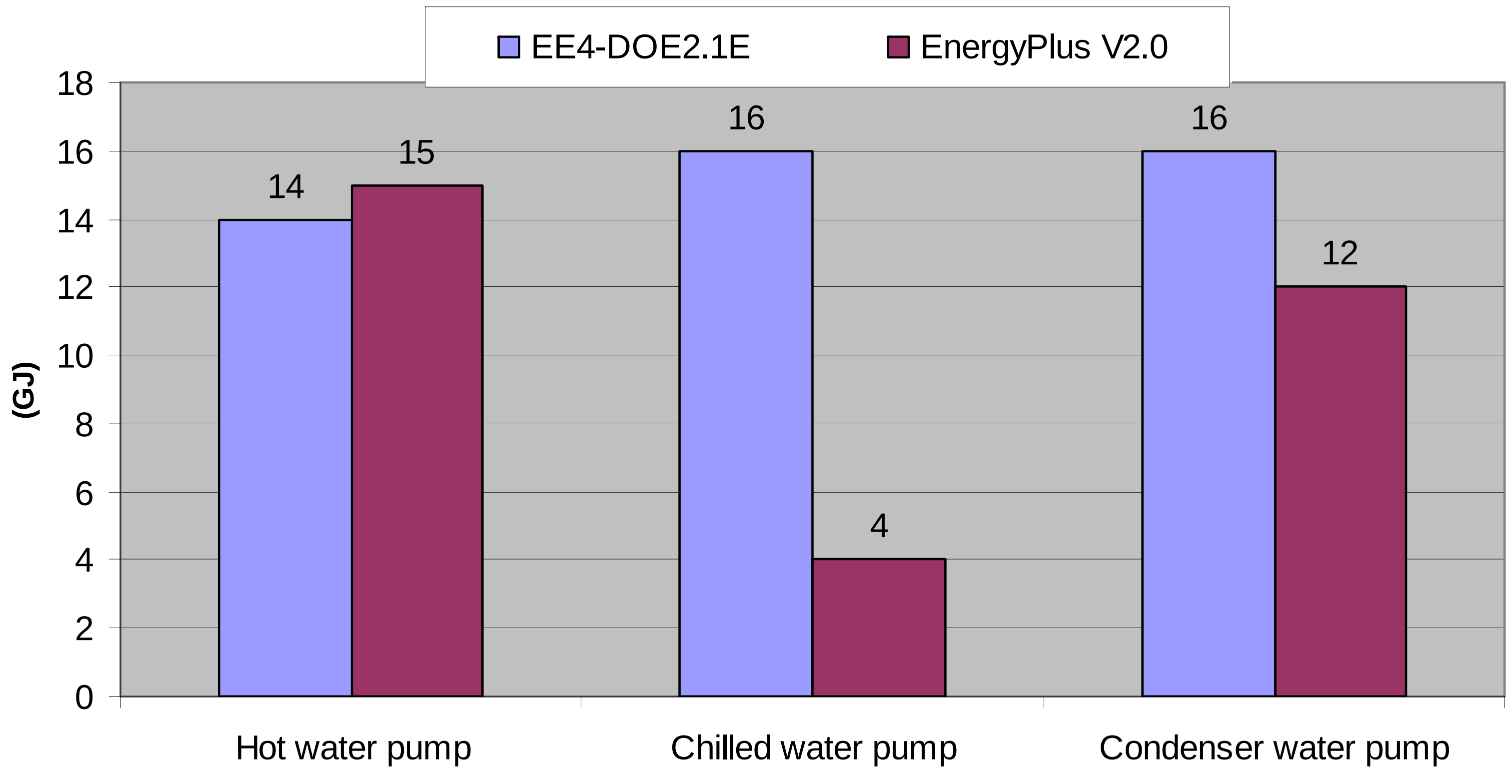
Simulation Results Comparison

Fan energy use



Simulation Results Comparison

Pump energy use



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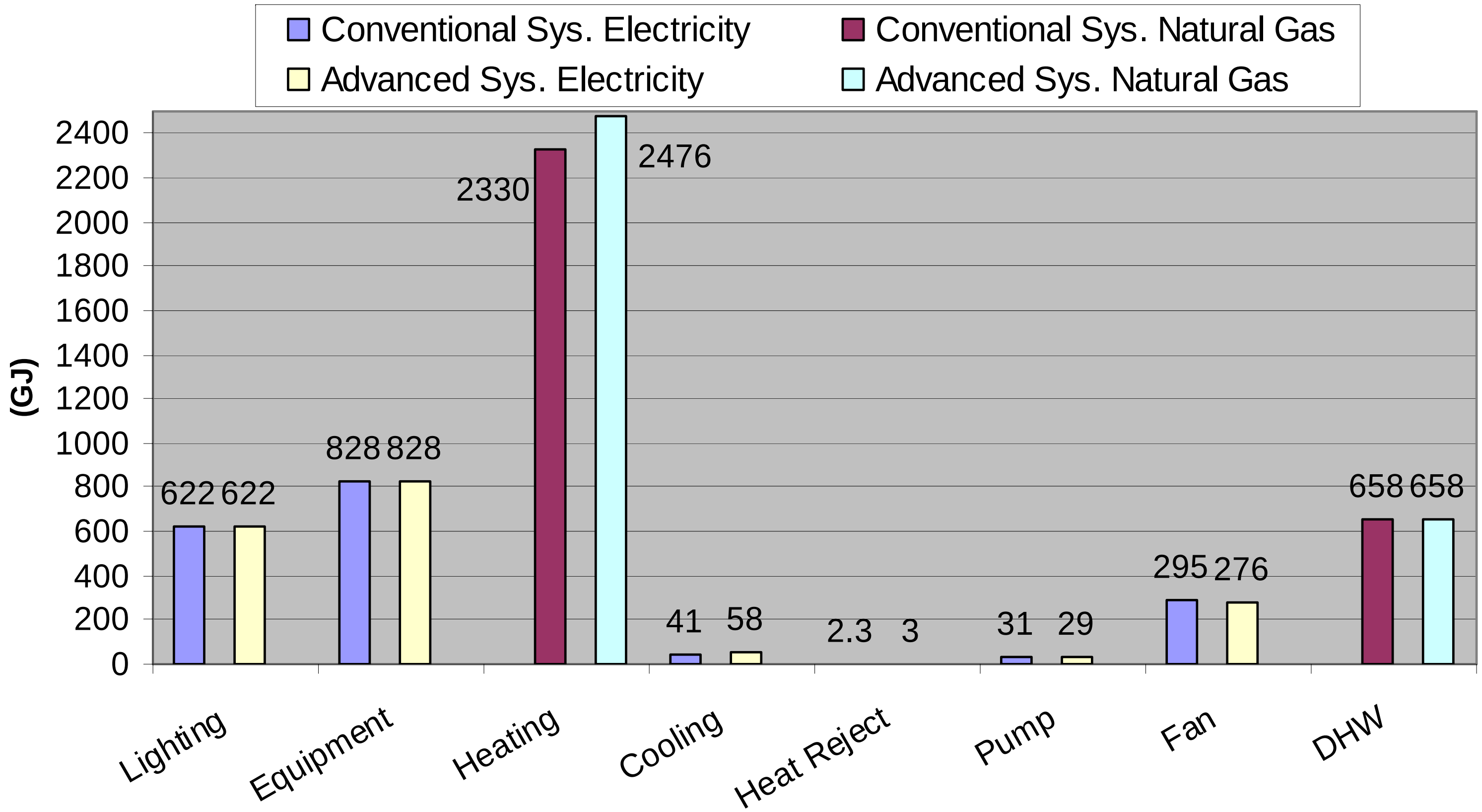
Simulation Results Comparison

Modeling Advanced Features



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Simulation Results Comparison

BIPV simulation results

Electric Sources	Electricity (GJ)	Percent (%)
Photovoltaic Power	249	14
Electricity From Utility	1599	88
Surplus Electricity To Utility	32	2
Net Electricity From Utility	1567	86
Total On-Site and Utility Electricity	1816	100

Discussions: Simulation Programs

- EE4 simplifies DOE2.1E modeling (building shell and control systems), but with limited access to DOE2.1E parameters.
- EE4 automatically generates the MNECB baseline energy model.
- The dual EE4-DOE2.1E and EnergyPlus results allowed comparison of whole building and specific equipment energy performance.
- The initial EnergyPlus simulation results differed widely from the EE4 model results (input errors related to the many parameters and complexity of the EnergyPlus model).
- This modeling process and comparison helped identify these errors.
- The extra time required is justified by the quality improvement and is recommended.

Discussions: Simulation Results

- In the EE4 and “basic” EnergyPlus simulation models, lighting, plug loads (equipment), heating and domestic water heating account for about 94 % of annual energy use.
- Reduced energy use with some advanced features (e.g., reduced air flow and fan power with displacement ventilation and underfloor air distribution) was largely accounted for in these “basic” models.
- The EE4 and “basic” EnergyPlus models could not be used to predict the indoor temperature trends (radiant cooling system not included).
- Radiant cooling contributes to some reduction in fan energy use in the “advanced” EnergyPlus model relative to the “basic” model.
- Fan energy use accounts for only about 6 % of annual energy use.
- This leads to the small difference between whole building estimates for the “basic” and “advanced” EnergyPlus models.

Discussions: EnergyPlus Modeling 1

- Programs such as Ecotect and the “Compact HVAC” module have reduced data entry in EnergyPlus.
- Extensive input efforts may still be necessary when modeling unconventional HVAC systems and when revising the model to reflect changes in design process.
- For example, adding a water-side free cooling to conventional HVAC systems in EnergyPlus, several types of parameters in several parts of EnergyPlus model need to be setup: 1) schedules, 2) plant-condenser loops, 3) set point managers, 4) condenser equipment, 5) node-branch management, and 6) plant-condenser flow control.
- Complexity may lead to data entry errors, especially for new users.
- Barriers for users in the building energy consulting industry.

Discussions: EnergyPlus Modeling 2

- Errors in modeling the case of UCSD Displacement Ventilation + Radiant Cooling.

  “Severe ** Temperature out of bounds (219.18) for surface=SUBOBJ:0468
  ** ~~~ ** in Zone=Z106
  ** ~~~ ** Occurrence info=CALGARY INT'L AB CAN WYEC2-B-25110 WMO#=718770, 01/02 05:05 - 05:06”

- Uncertainty: much larger hourly temperature difference in modeled UCDS under-floor air distribution + radiant cooling, compared with overhead air handling + radiant cooling.

- Uncertainty: big difference for the chilled water pump energy use when set from “intermittent” to “continuous” operation: 4 GJ to 64 GJ.

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Discussions: Building in Use

- CDC Building occupancy status: Level 1 & 2, occupied; Levels 3 & 4 unoccupied.
- Preliminary building energy use data: estimated annual energy use around 480 MJ/m^2, based on metered energy use of 7 months.
- Simulated electricity use 1862 GJ, estimated 1375 GJ; simulated natural gas use 3525 GJ, estimated 4379 GJ.
- The discrepancies will decrease as the vacant spaces fill up; the electrical use will go up and the gas use will go down (due to heat from people, lights, etc).

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Thank you!

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Questions?

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