

# **ClustEnergy OpTool testing with ANSI/ASHRAE Standard 140 (BESTEST)**

## **Test objectives and overview**

The ANSI/ASHRAE Standard 140 (ASHRAE, 2020) is a comparative test that allows for validation and debugging results. The purpose is not to determine the absolute correctness of performance, but to test the ability of whole-building energy simulation programs to model the thermal fabric of the building.

The base tests considered analyze the software's ability to model building envelope loads in annual simulation in a low-mass configuration following a change in window orientation, variations in thermostat control, and nighttime ventilation.

From a validation point of view, comparative testing with other energy simulation programs will show that ClustEnergy OpTool offers reasonable computational solutions through the resolution of a linear programming problem.

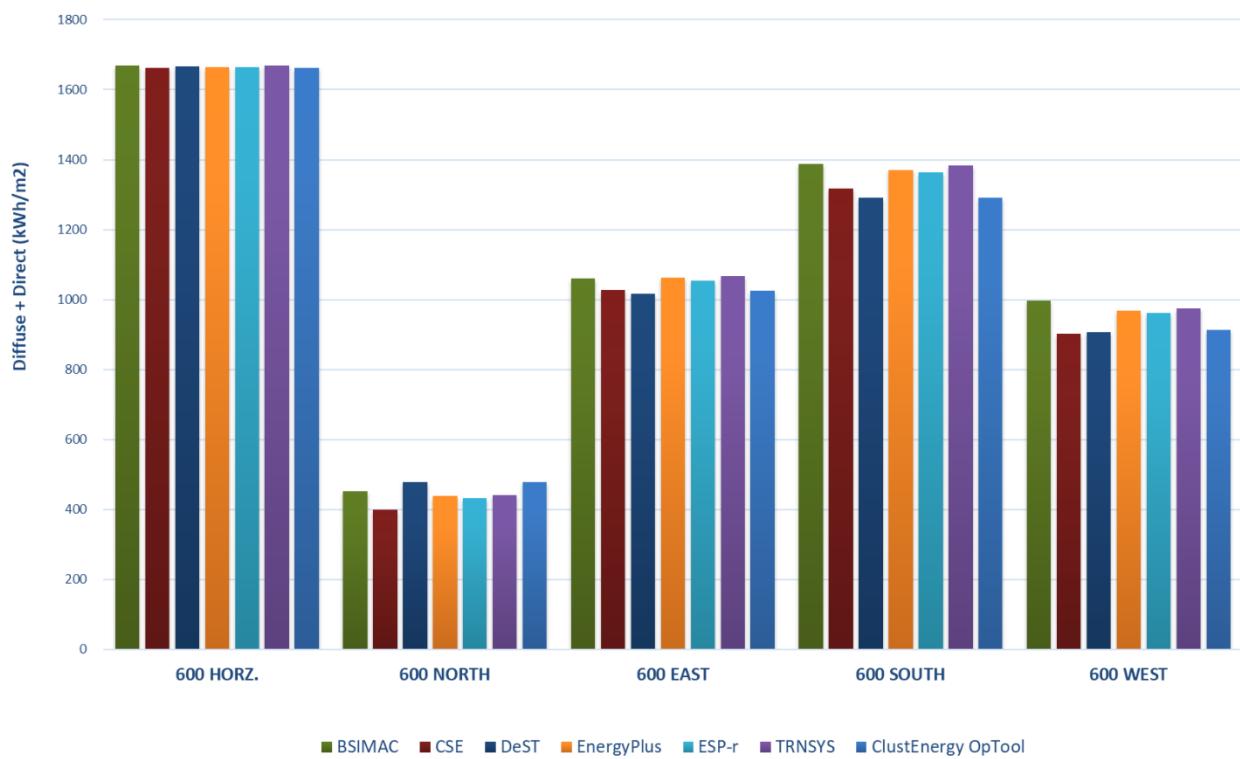
The following tests were performed as specified in the standard (ASHRAE, 2020):

- Base test "South clear double-pane windows and "20,27" Deadband thermostat" (case 600, section 5.2.1 of the Standard)
- Base tests (section 5.2.2 of the Standard)
  - Low mass test "East/West windows" (case 620),
  - Low mass test "Setback thermostat" (case 640),
  - Low mass test "Night ventilation" (case 650),
  - Low mass test "Low emissivity windows" (case 660),
  - Low mass test "Single-Bread Windows" (case 670),
  - High mass test "South clear double-pane windows and "20,27" Deadband thermostat" (case 900),
  - High mass test "East/West Windows" (case 920),
  - High mass test "Setback thermostat" (case 940),
  - High mass test "Night ventilation" (case 950),
- Basic tests without heating and mechanical cooling (Free-Float [FF] Temperatures (cases 600FF, 650FF, 900FF, and 950FF)

Below are the graphs comparing ClustEnergy OpTool results with other Building Energy Simulation Programs.

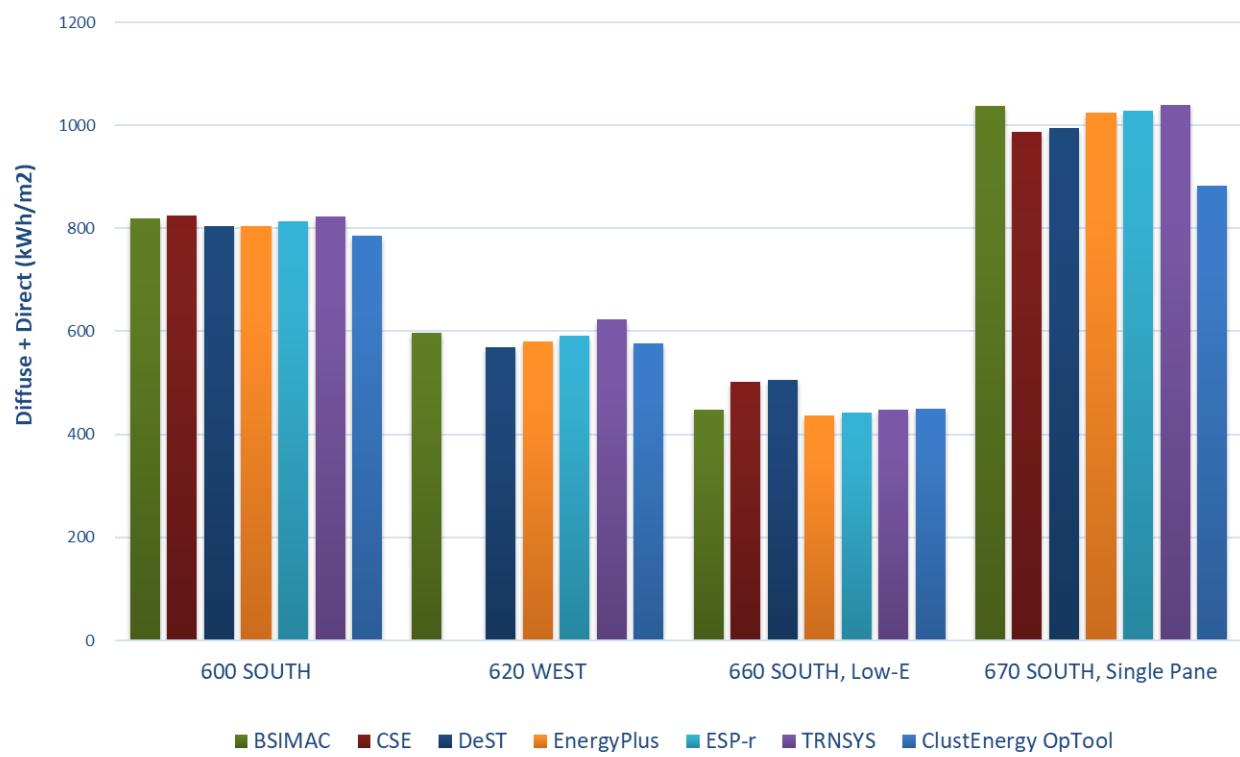
ASHRAE Standard 140-2017 Addendum A, Informative Annex B8, Section B8.1  
Example Results for Section 5.2 - Building Thermal Envelope and Fabric Load Cases 195-995 & 600FF-980FF

**Figure B8-1.**  
**Annual Incident Solar Radiation**

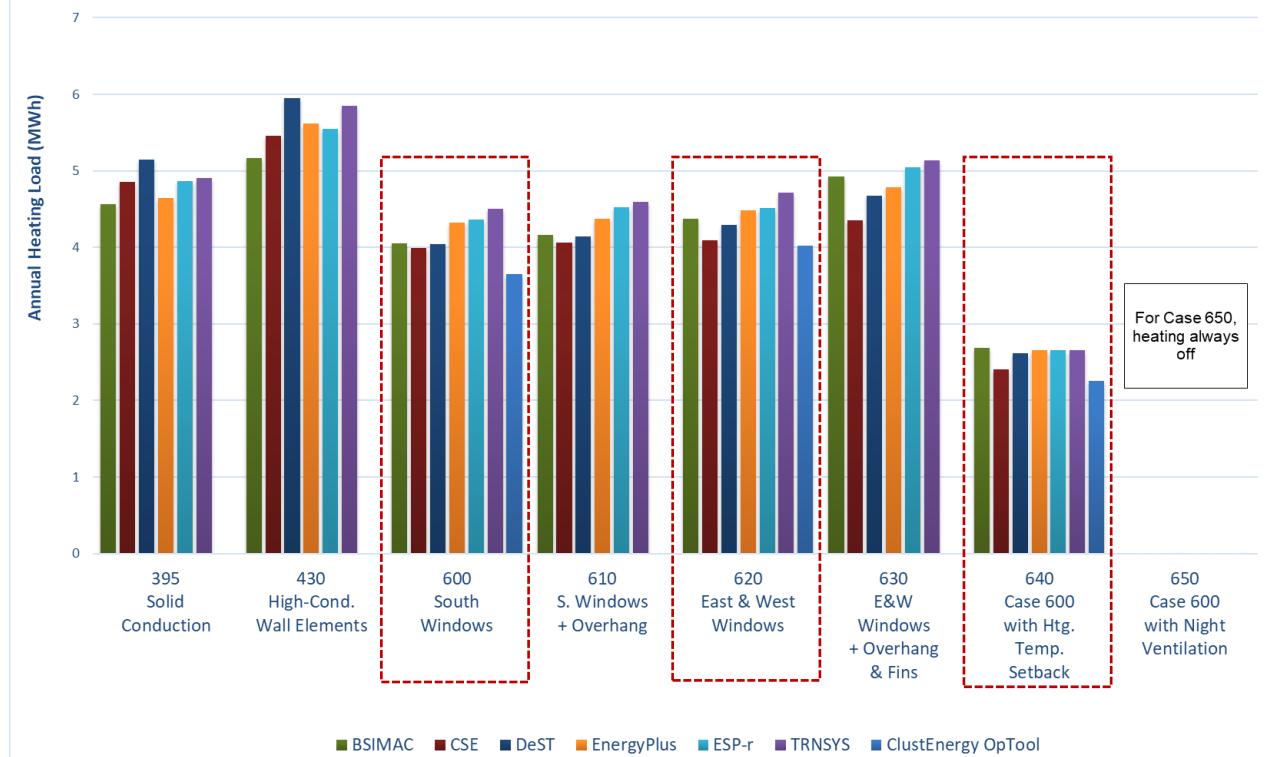


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Example Results for Section 5.2 - Building Thermal Envelope and Fabric Load Cases 195-995 & 600FF-980FF

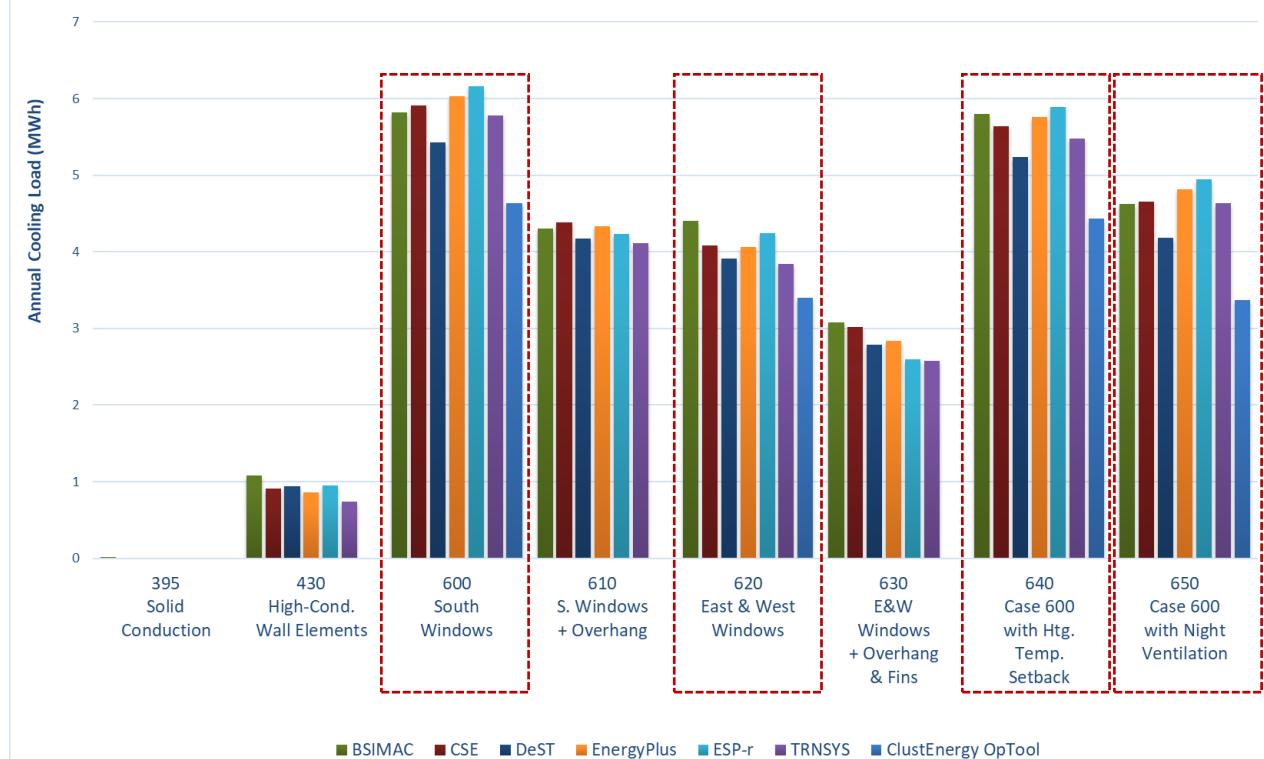
**Figure B8-2.**  
**Annual Transmitted Solar Radiation - Unshaded**



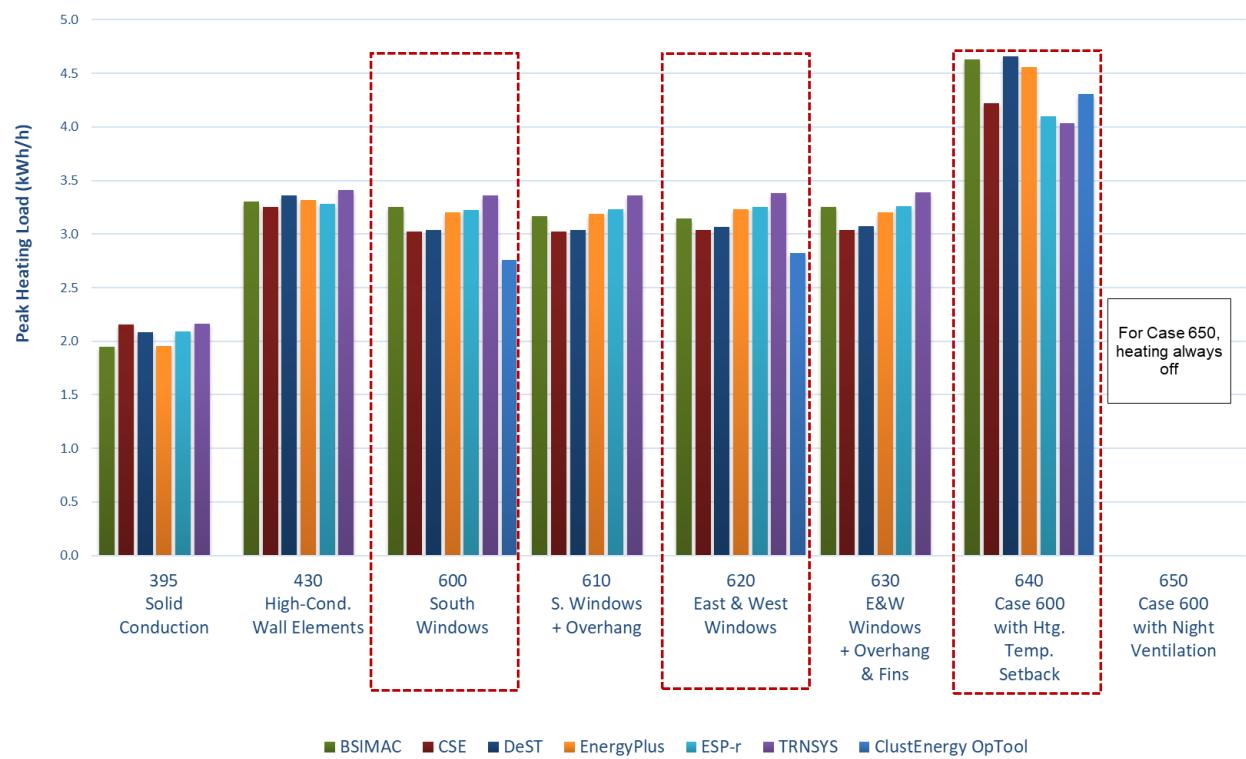
**Figure B8-7. Basic:  
 Low Mass Annual Heating**



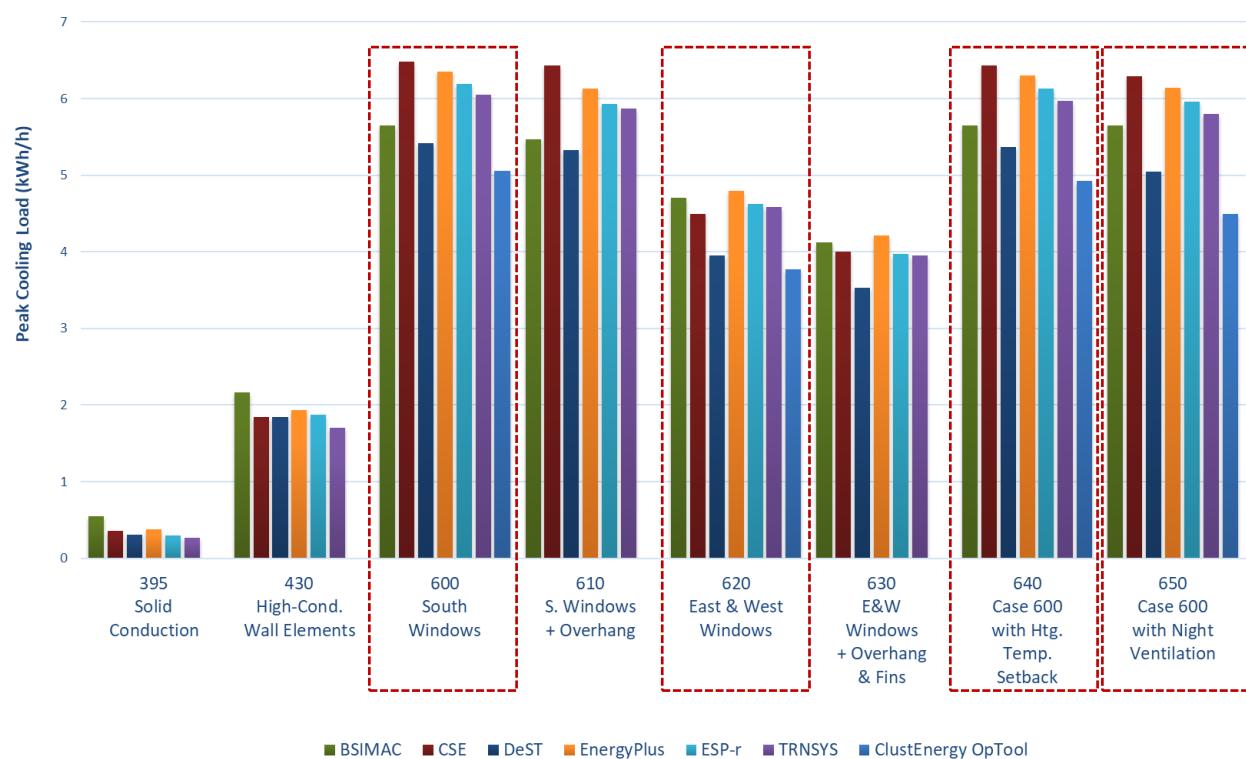
**Figure B8-8. Basic:  
 Low Mass Annual Sensible Cooling**



**Figure B8-9. Basic:  
 Low Mass Peak Heating**

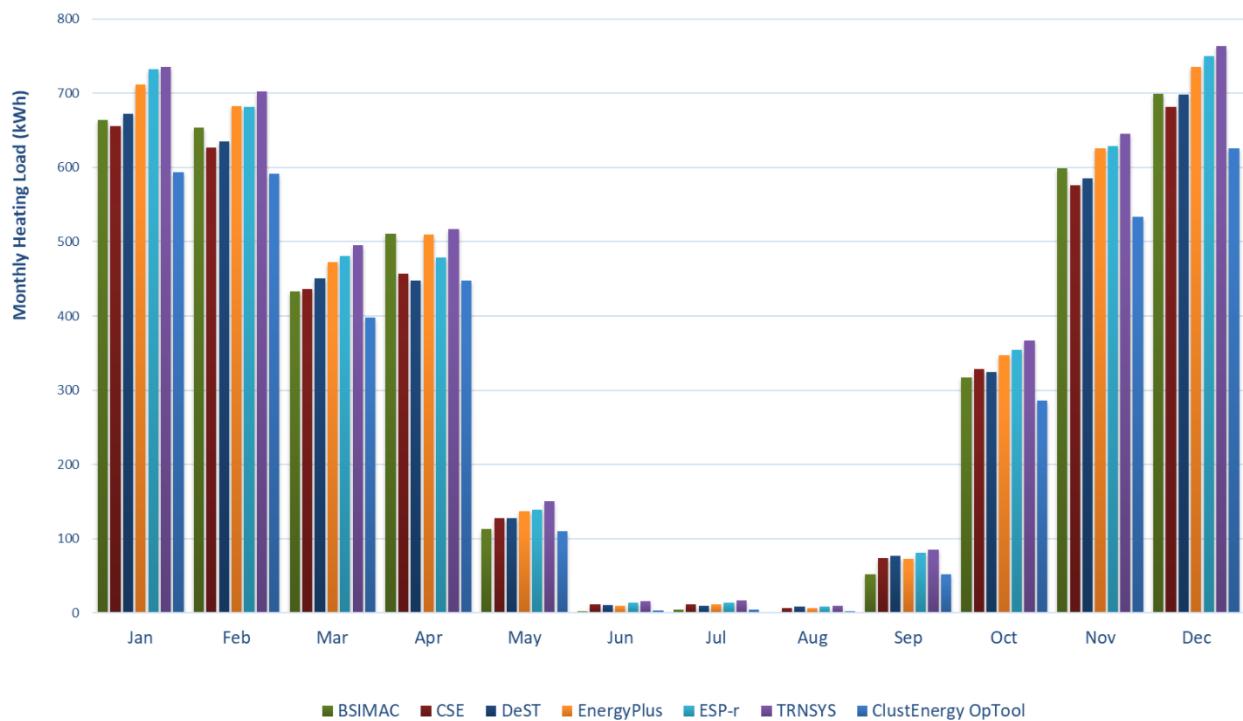


**Figure B8-10. Basic:  
 Low Mass Peak Sensible Cooling**



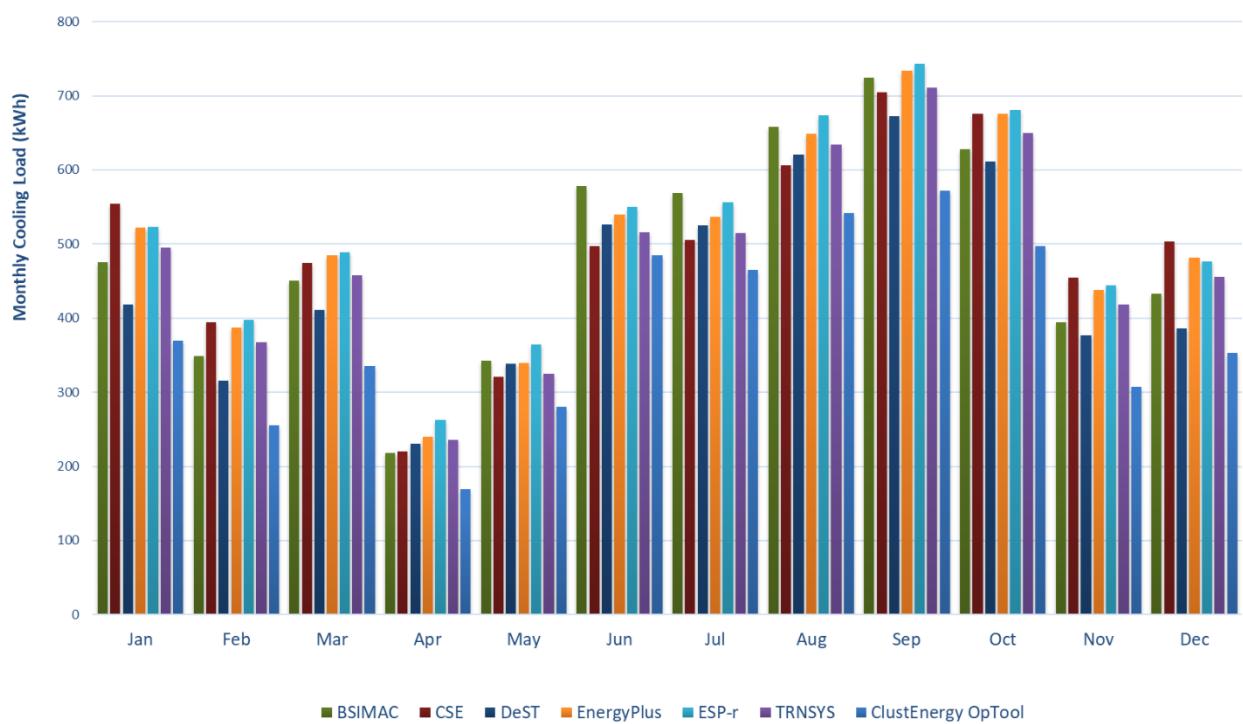
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Example Results for Section 5.2 - Building Thermal Envelope and Fabric Load Cases 195-995 & 600FF-980FF

**Figure B8-M1.**  
**Monthly Heating**  
**Case 600**



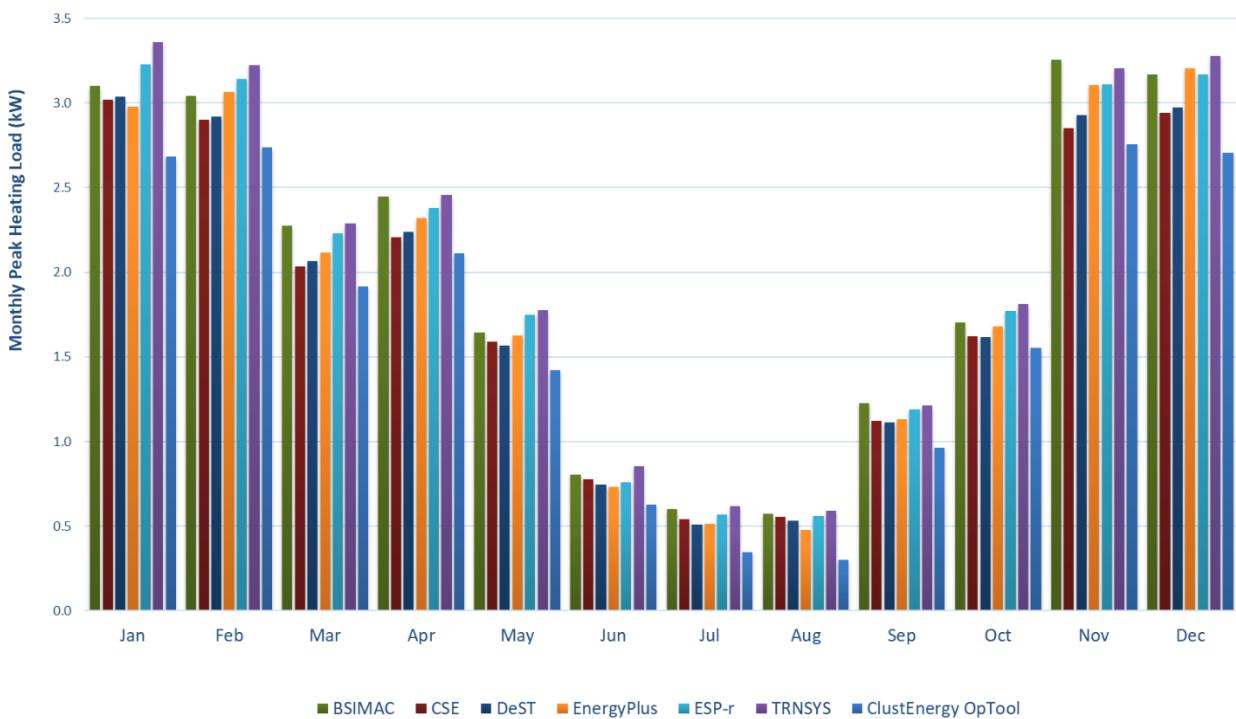
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Example Results for Section 5.2 - Building Thermal Envelope and Fabric Load Cases 195-995 & 600FF-980FF

**Figure B8-M2.**  
**Monthly Sensible Cooling**  
**Case 600**



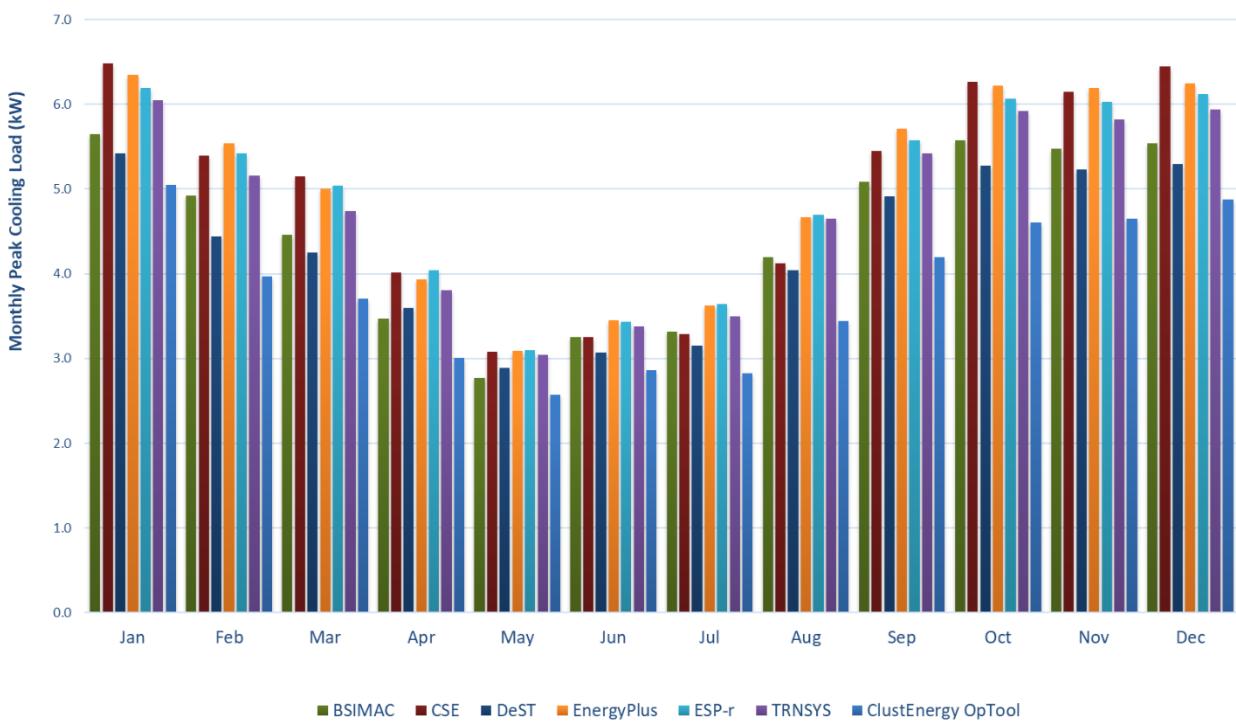
ASHRAE Standard 140-2017 Addendum A, Informative Annex B8, Section B8.1  
Example Results for Section 5.2 - Building Thermal Envelope and Fabric Load Cases 195-995 & 600FF-980FF

**Figure B8-M3.**  
**Monthly Peak Heating**  
**Case 600**

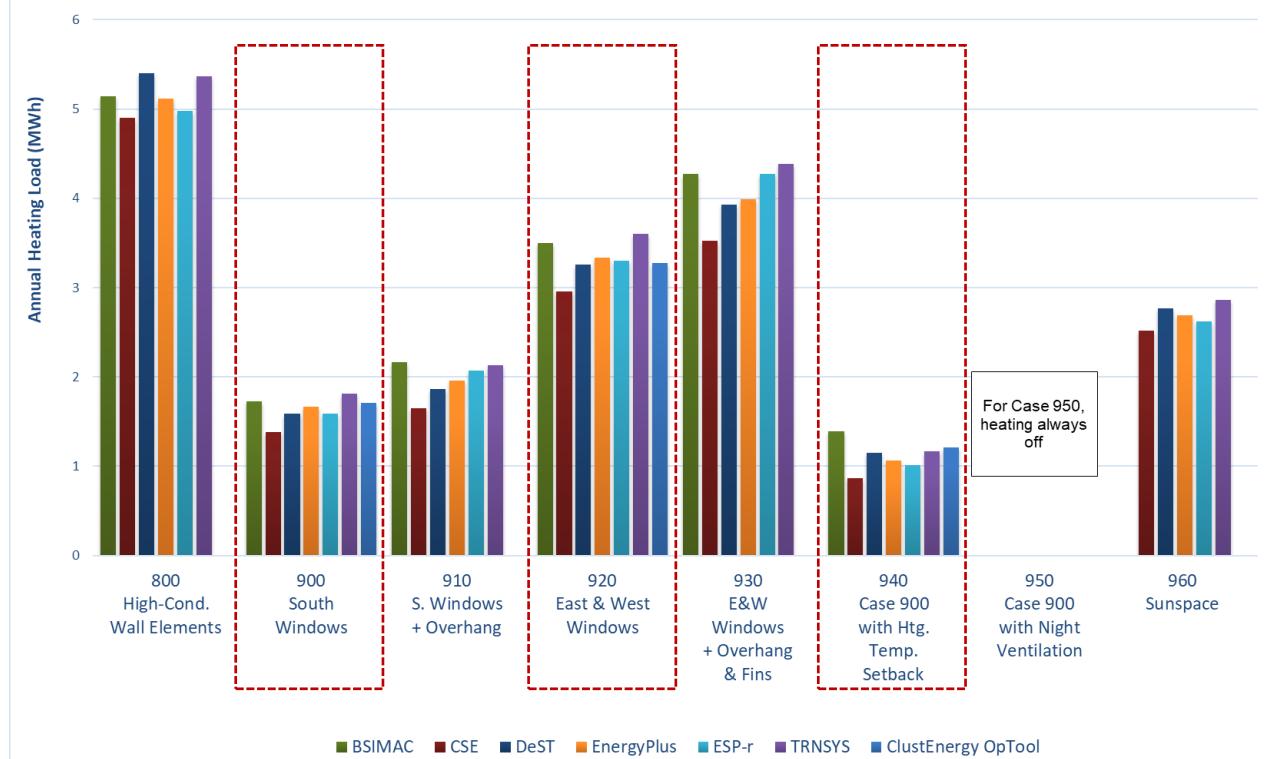


ASHRAE Standard 140-2017 Addendum A, Informative Annex B8, Section B8.1  
Example Results for Section 5.2 - Building Thermal Envelope and Fabric Load Cases 195-995 & 600FF-980FF

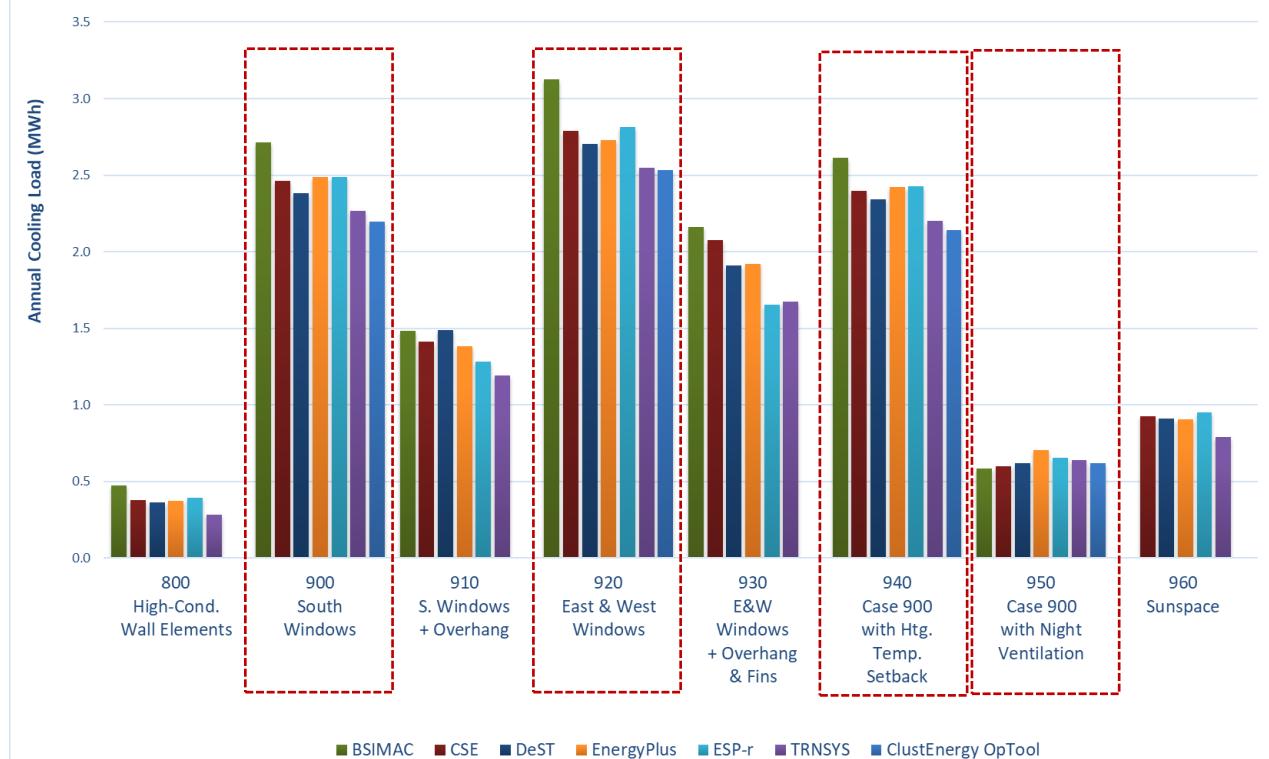
**Figure B8-M4.**  
**Monthly Peak Sensible Cooling**  
**Case 600**



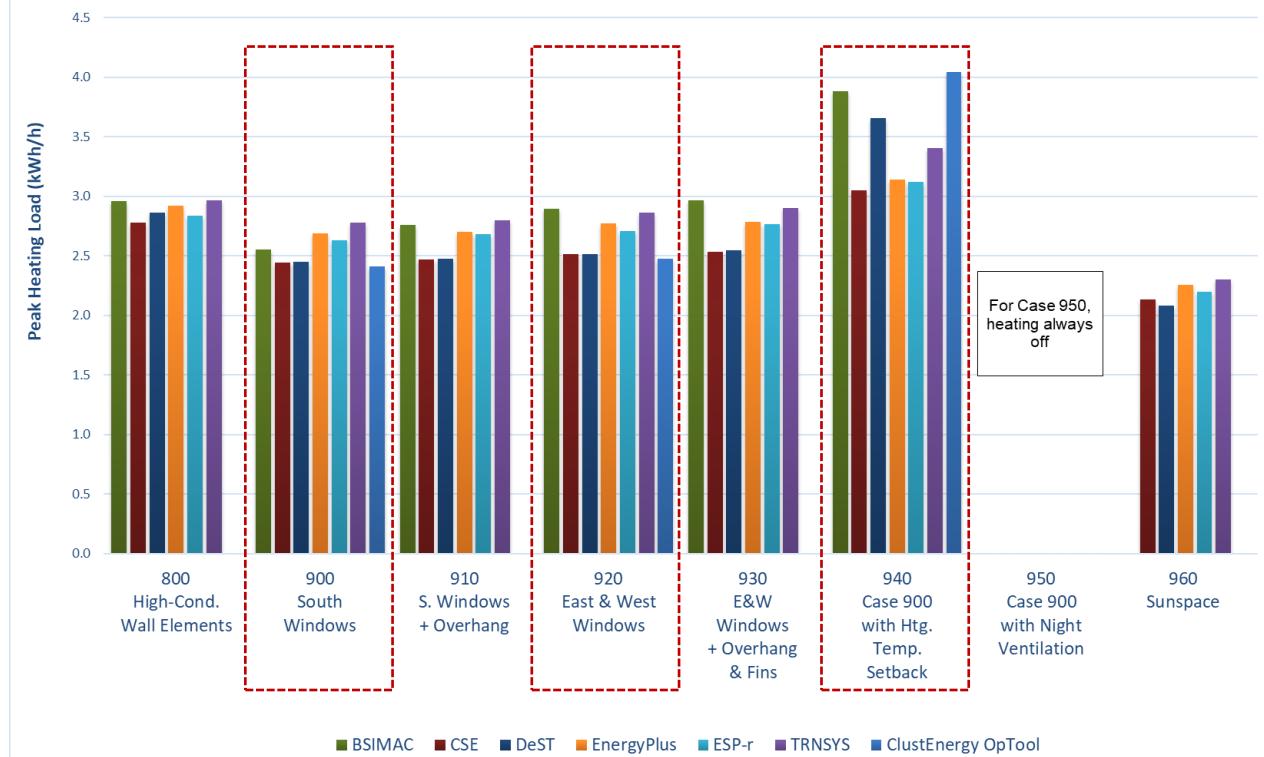
**Figure B8-11. Basic:  
 High Mass Annual Heating**



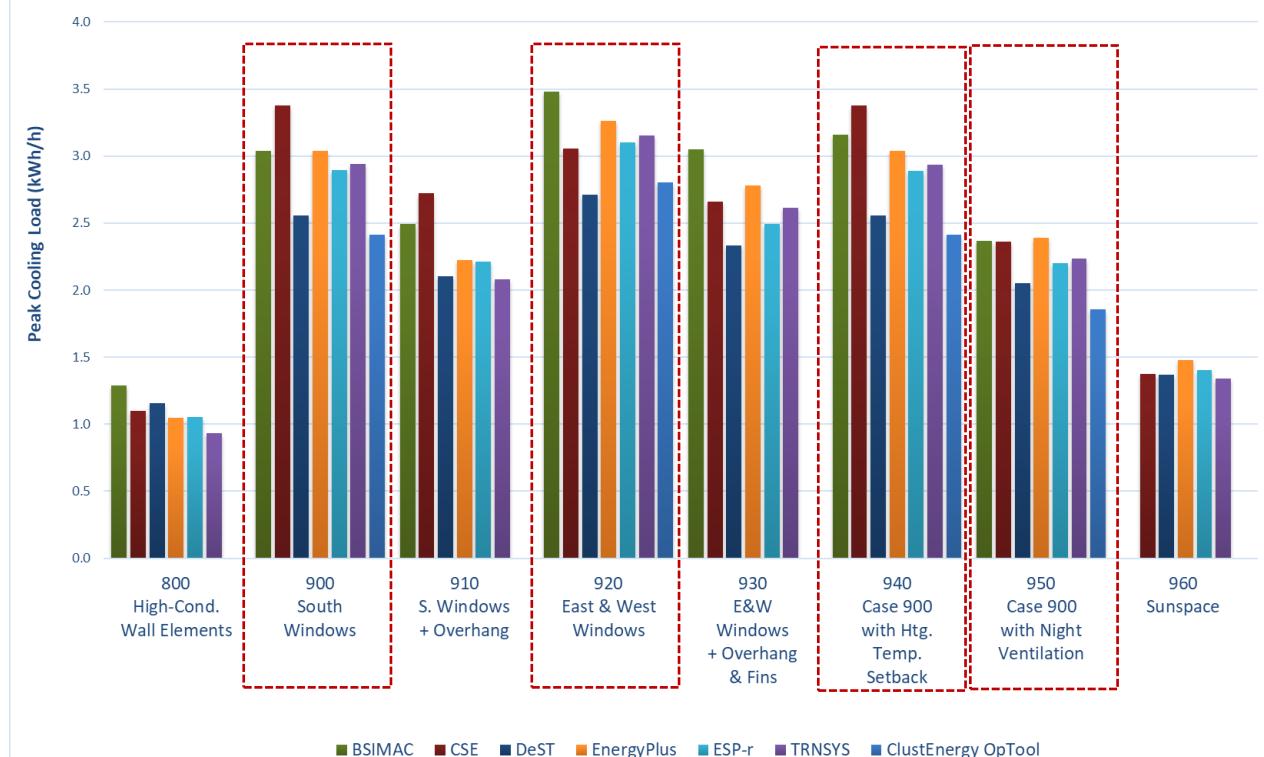
**Figure B8-12. Basic:  
 High Mass Annual Sensible Cooling**

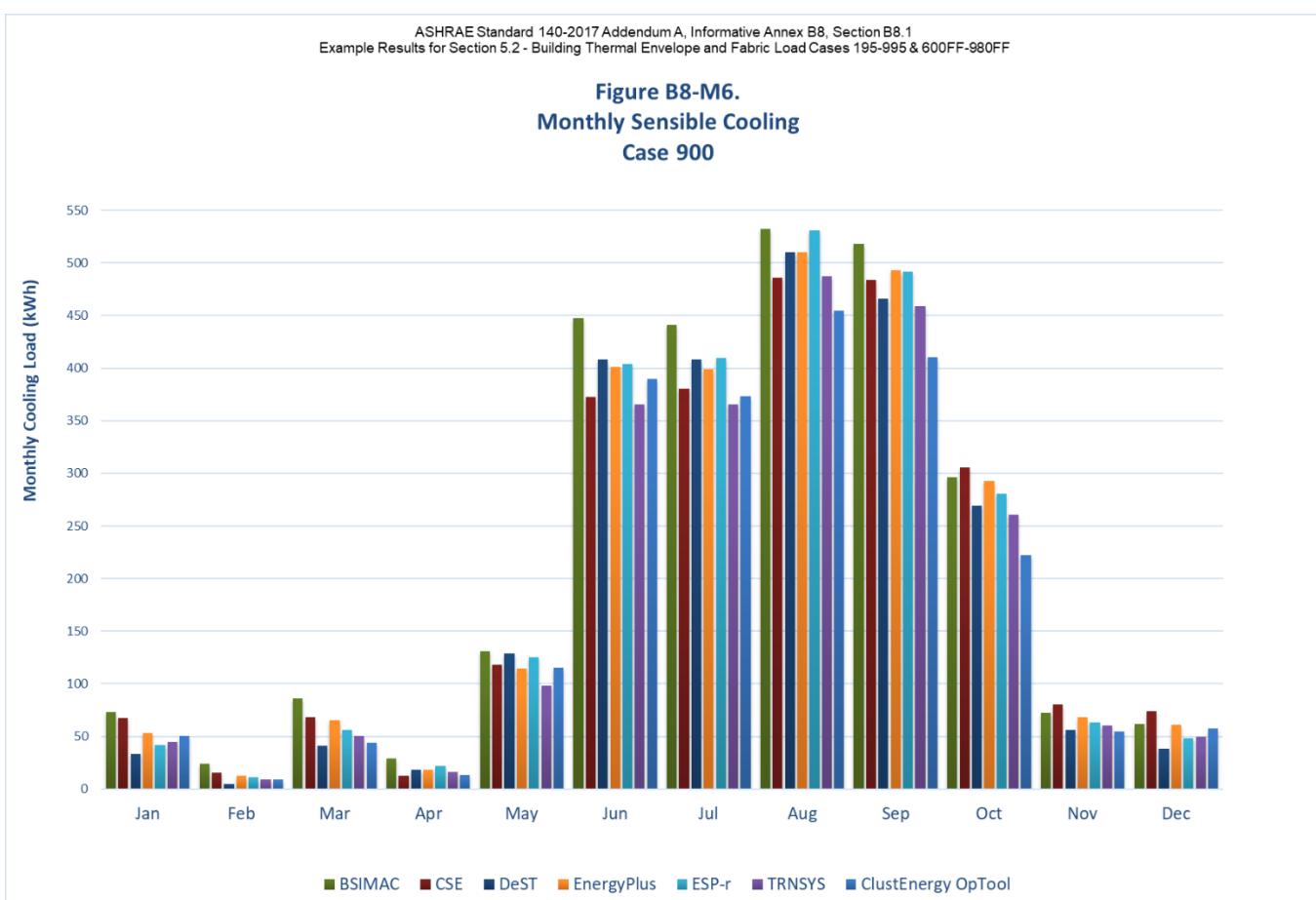
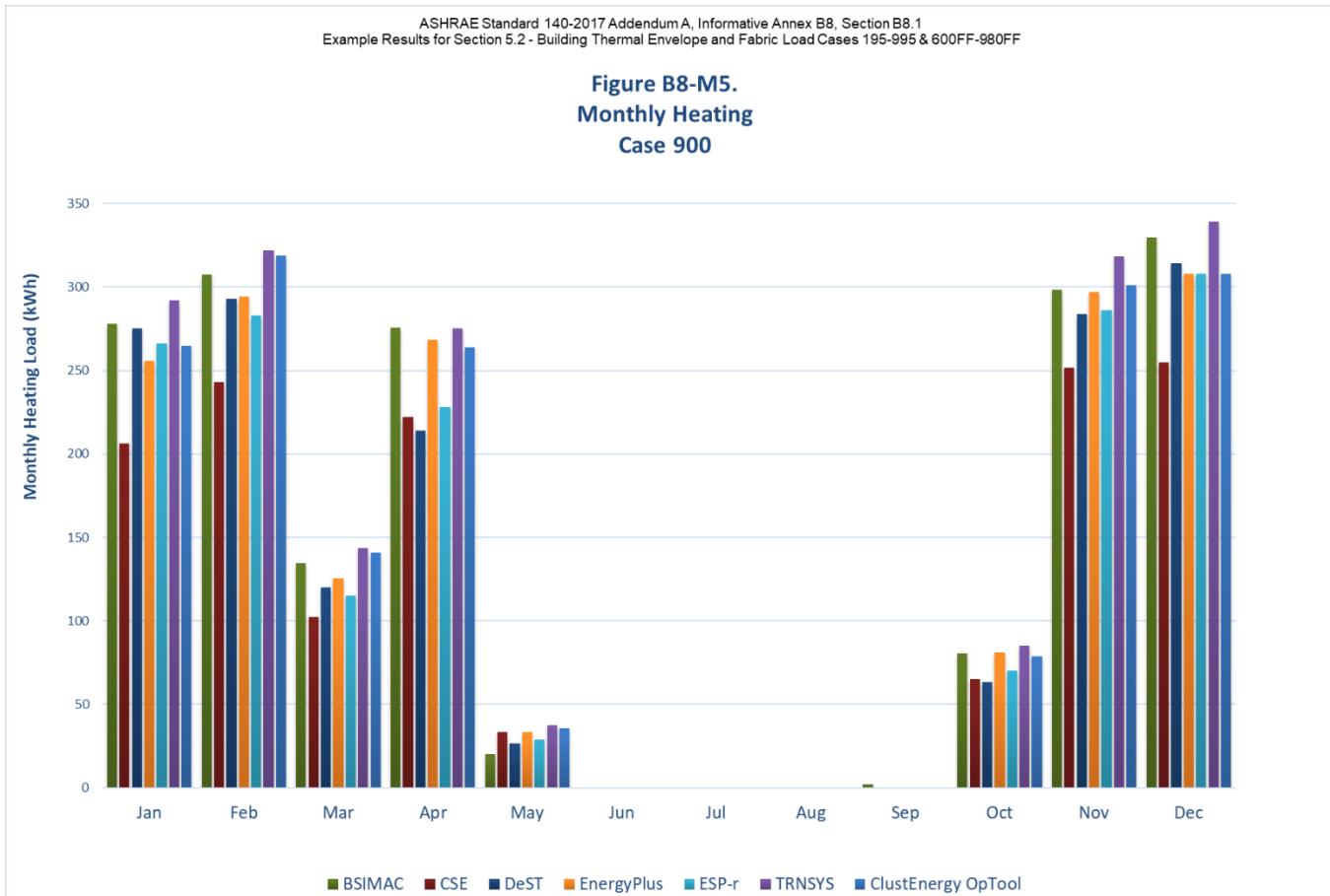


**Figure B8-13. Basic:  
 High Mass Peak Heating**



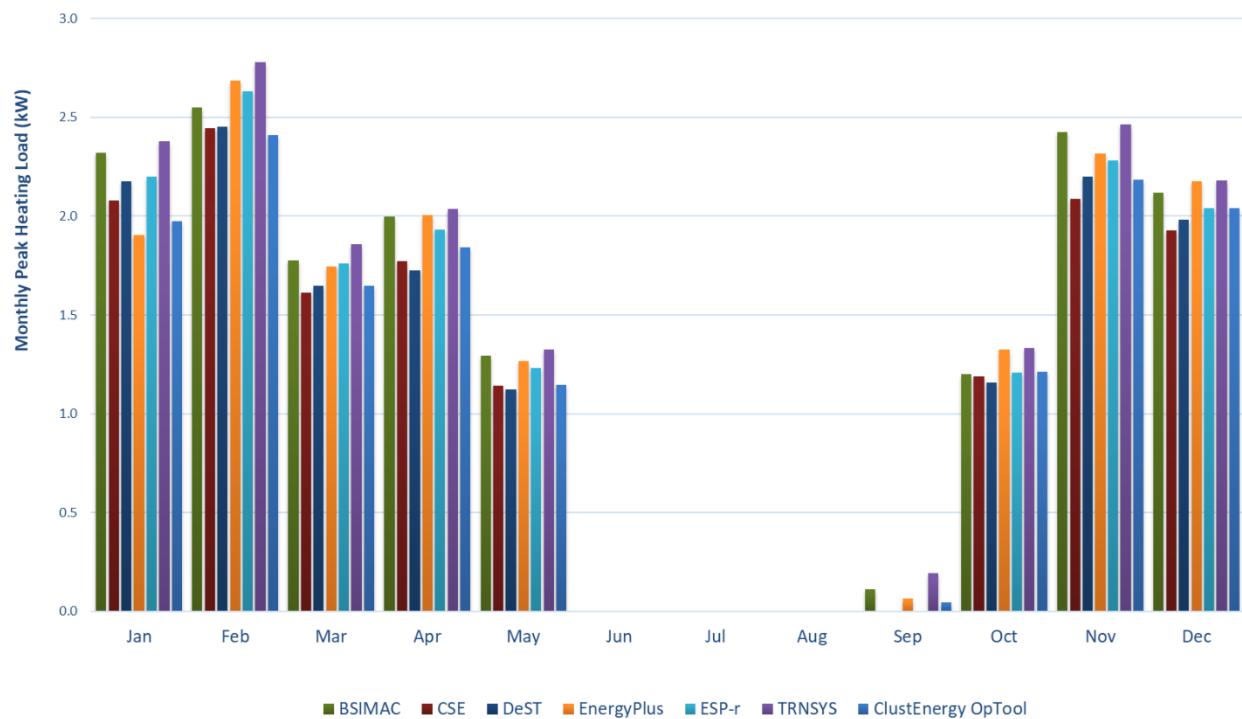
**Figure B8-14. Basic:  
 High Mass Peak Sensible Cooling**





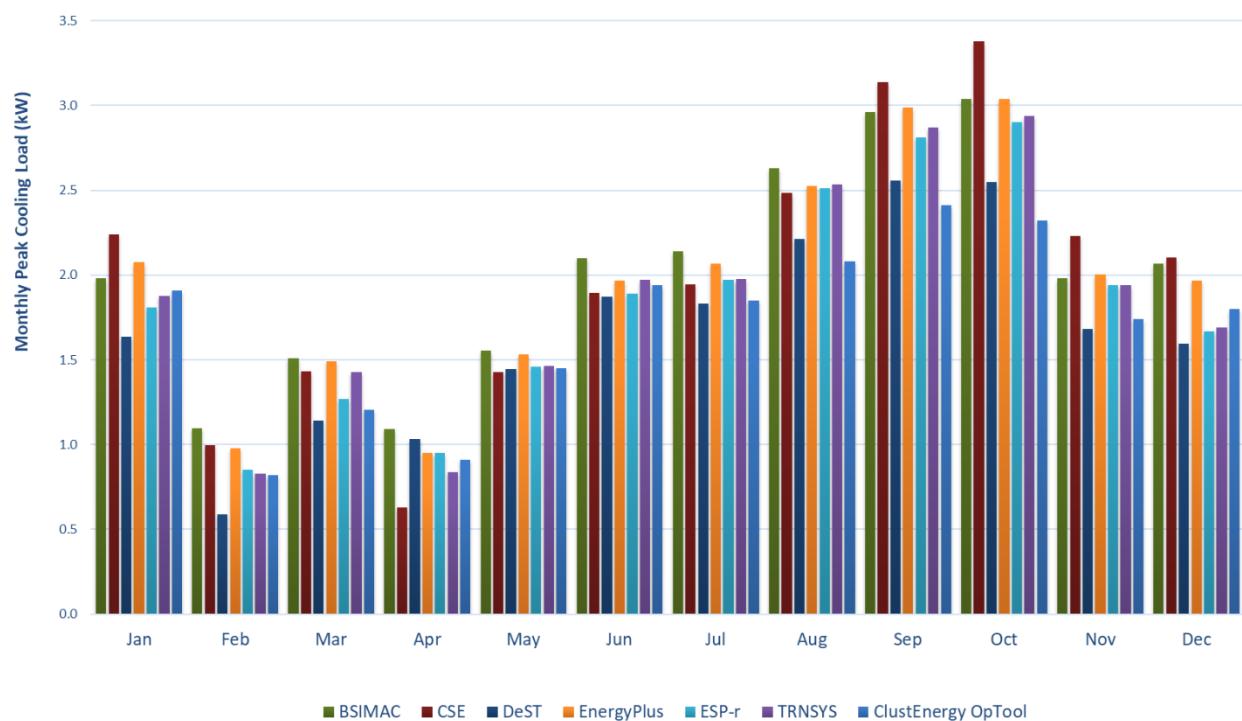
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Example Results for Section 5.2 - Building Thermal Envelope and Fabric Load Cases 195-995 & 600FF-980FF

**Figure B8-M7.**  
**Monthly Peak Heating**  
**Case 900**

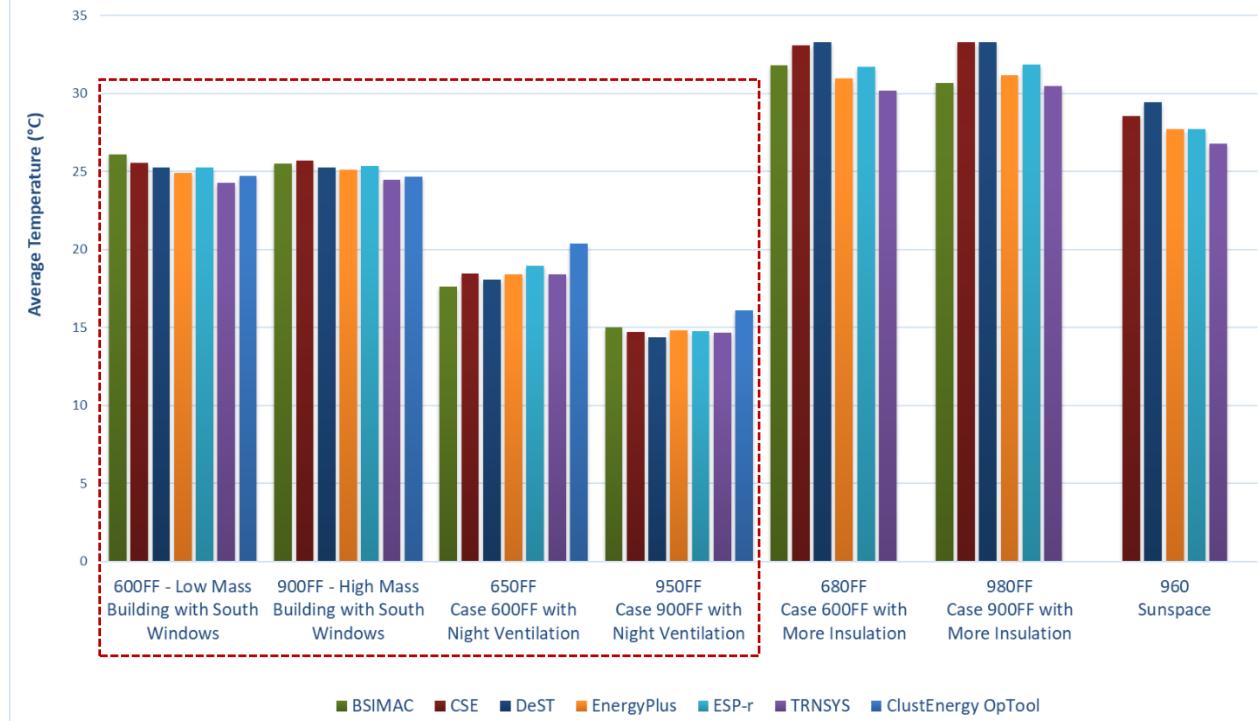


ASHRAE Standard 140-2017 Addendum A, Informative Annex B8, Section B8.1  
Example Results for Section 5.2 - Building Thermal Envelope and Fabric Load Cases 195-995 & 600FF-980FF

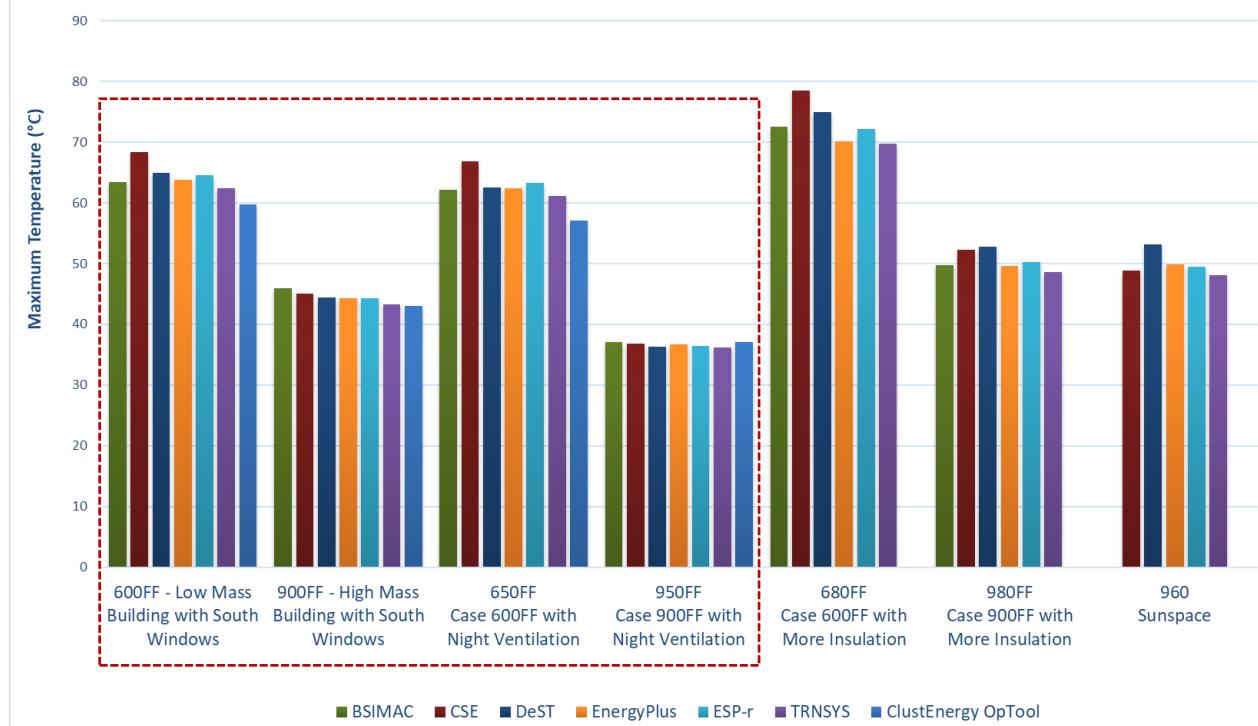
**Figure B8-M8.**  
**Monthly Peak Sensible Cooling**  
**Case 900**



**Figure B8-33. Basic:  
 Average Hourly Annual Temperature  
 Free-Float Cases**

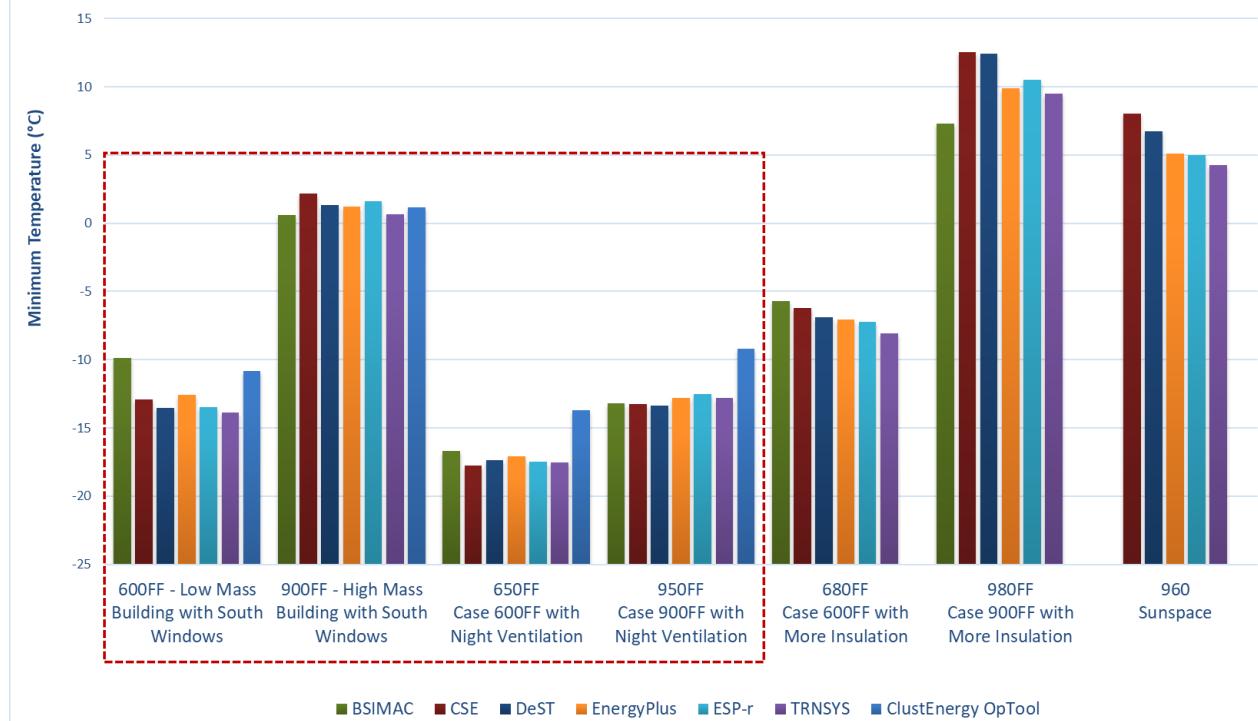


**Figure B8-34. Basic:  
 Maximum Hourly Annual Temperature  
 Free-Float Cases**



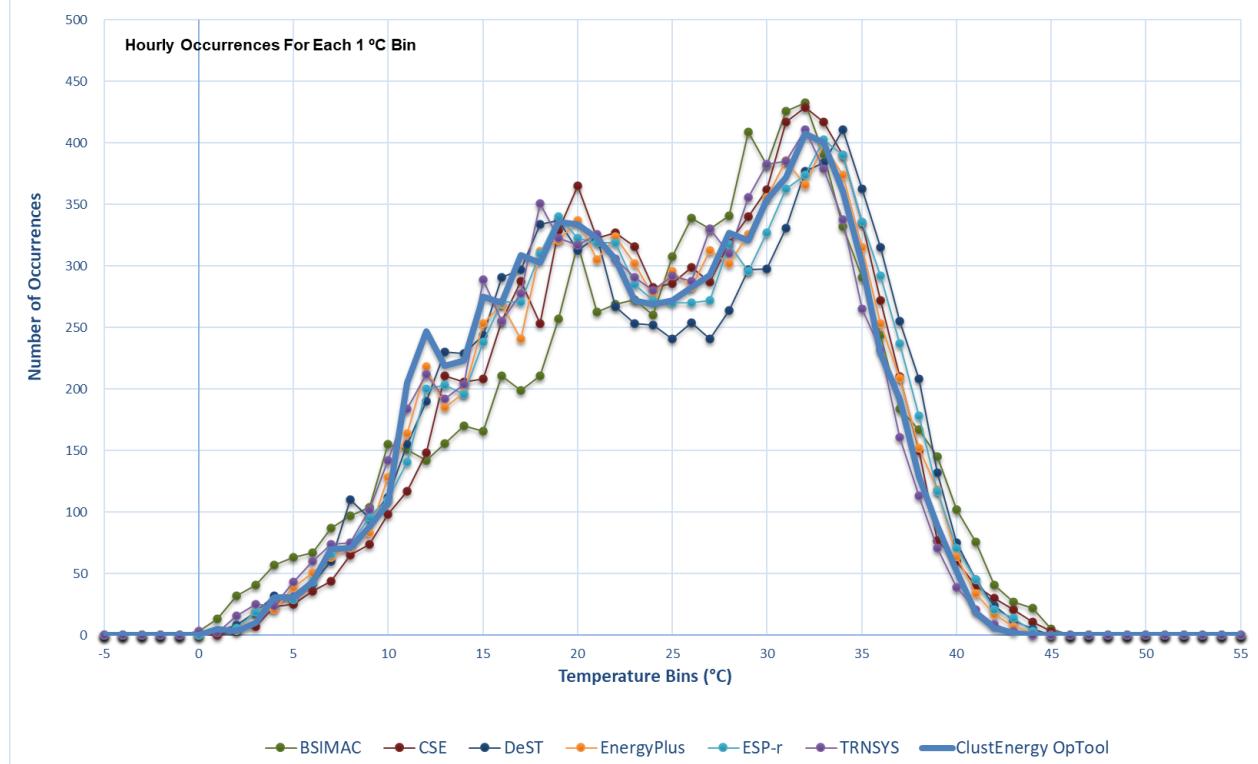
ASHRAE Standard 140-2017 Addendum A, Informative Annex B8, Section B8.1  
Example Results for Section 5.2 - Building Thermal Envelope and Fabric Load Cases 195-995 & 600FF-980FF

**Figure B8-35. Basic:  
Minimum Hourly Annual Temperature  
Free-Float Cases**



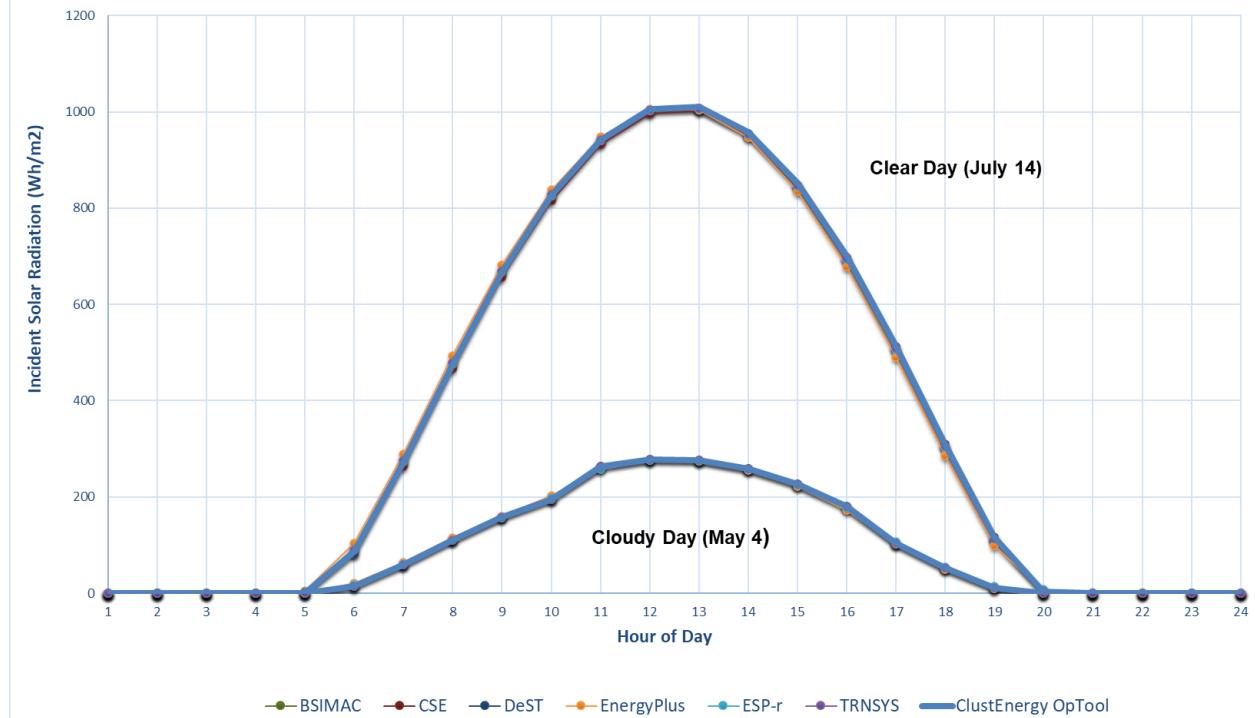
ASHRAE Standard 140-2017 Addendum A, Informative Annex B8, Section B8.1  
Example Results for Section 5.2 - Building Thermal Envelope and Fabric Load Cases 195-995 & 600FF-980FF

**Figure B8-H1. Case 900FF  
Annual Hourly Zone Air Temperature Frequency**



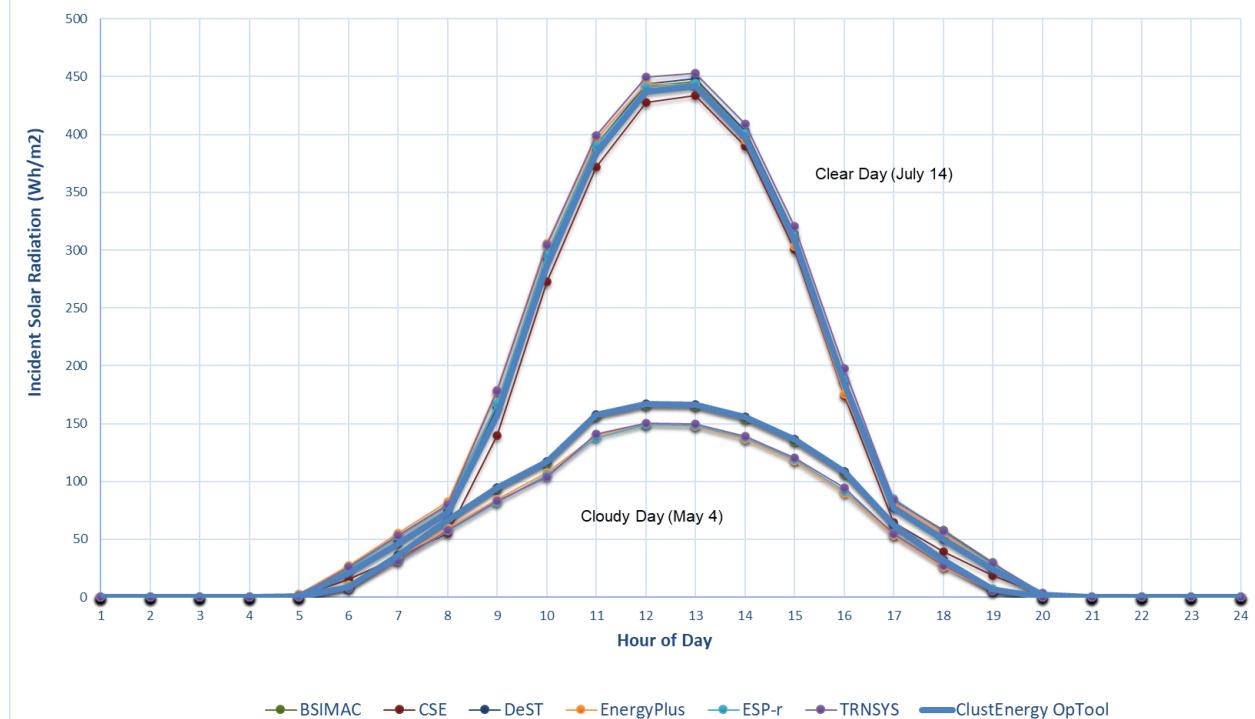
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Example Results for Section 5.2 - Building Thermal Envelope and Fabric Load Cases 195-995 & 600FF-980FF

**Figure B8-H2. Case 600**  
**Cloudy & Clear Day Hourly Incident Solar**  
**Horizontal (Upward) Facing Surface**

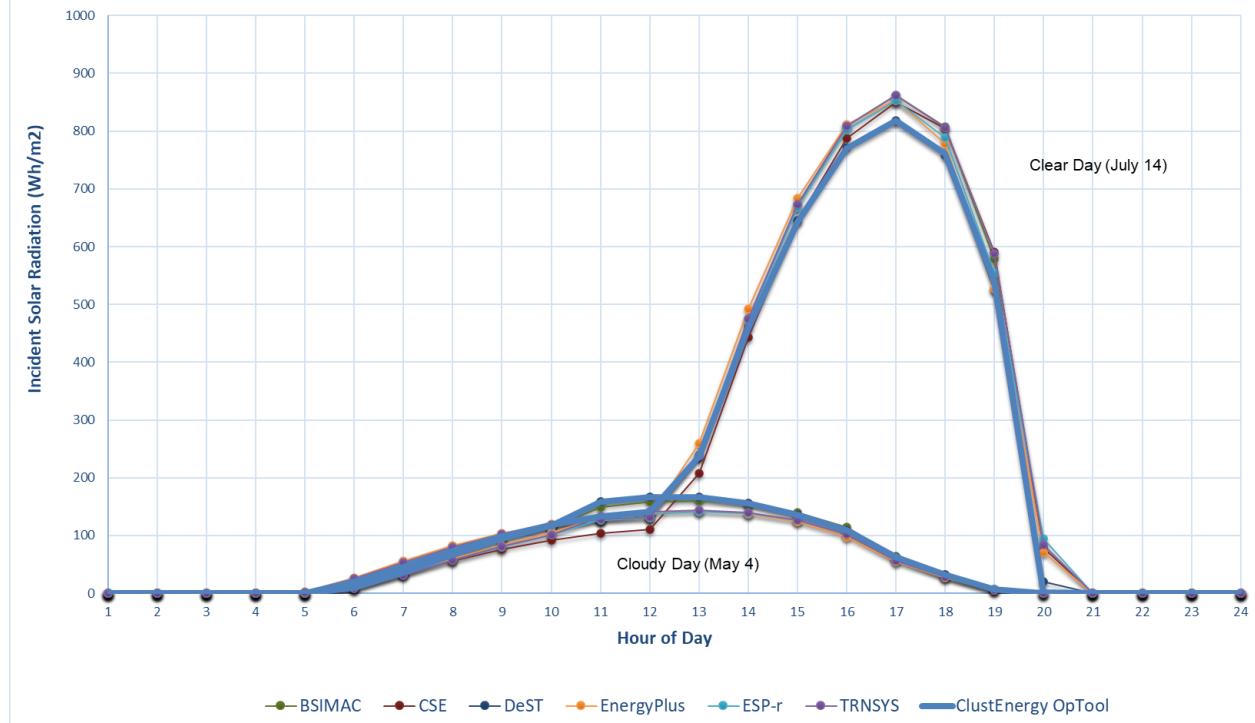


ASHRAE Standard 140-2017 Addendum A, Informative Annex B8, Section B8.1  
Example Results for Section 5.2 - Building Thermal Envelope and Fabric Load Cases 195-995 & 600FF-980FF

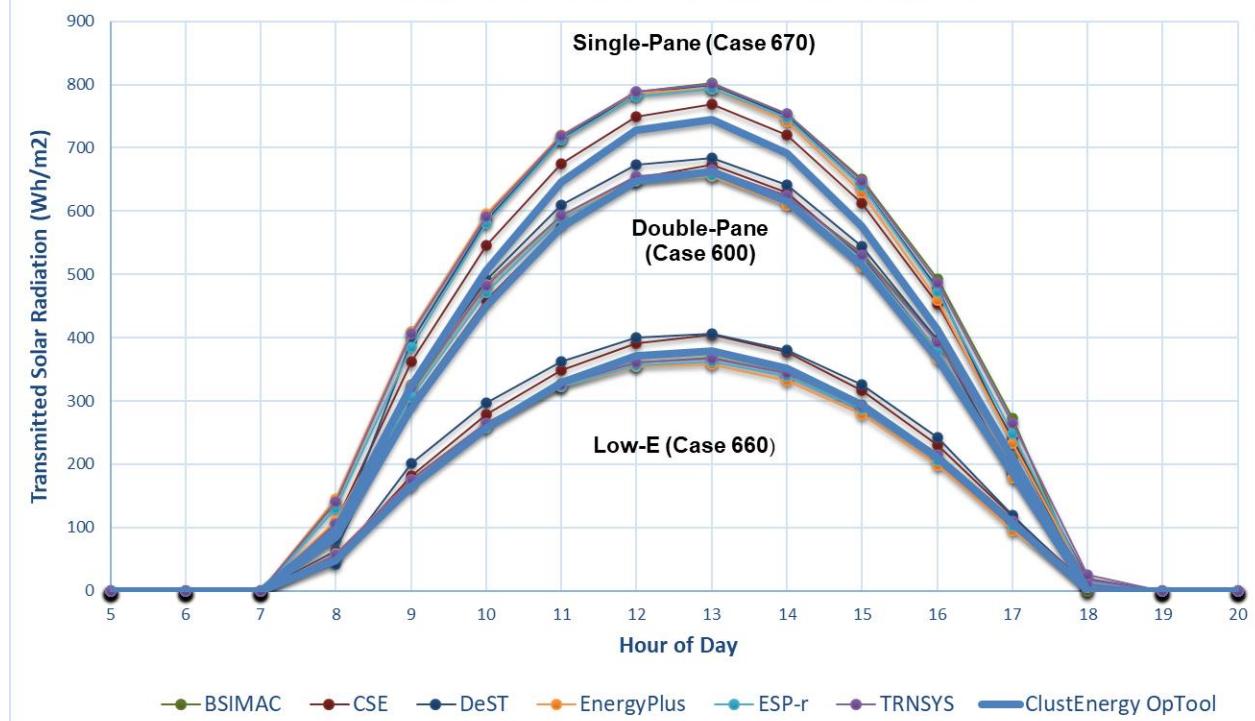
**Figure B8-H3. Case 600**  
**Cloudy & Clear Day Hourly Incident Solar**  
**South Facing Surface**



**Figure B8-H4. Case 600**  
**Cloudy & Clear Day Hourly Incident Solar**  
**West Facing Surface**

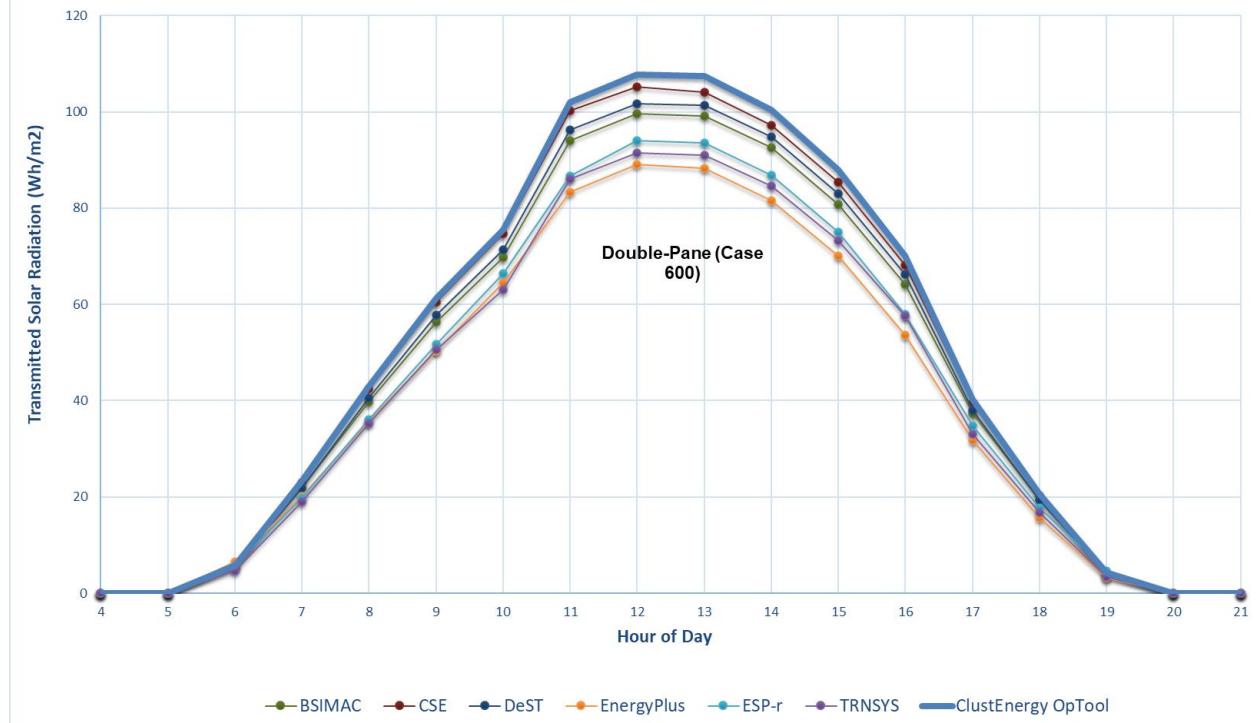


**Figure B8-H5. Cases 600, 660, 670**  
**Hourly Transmitted Solar, Clear/Cold Day (Feb 1)**  
**Double-Pane, Low-E, Single-Pane Windows**



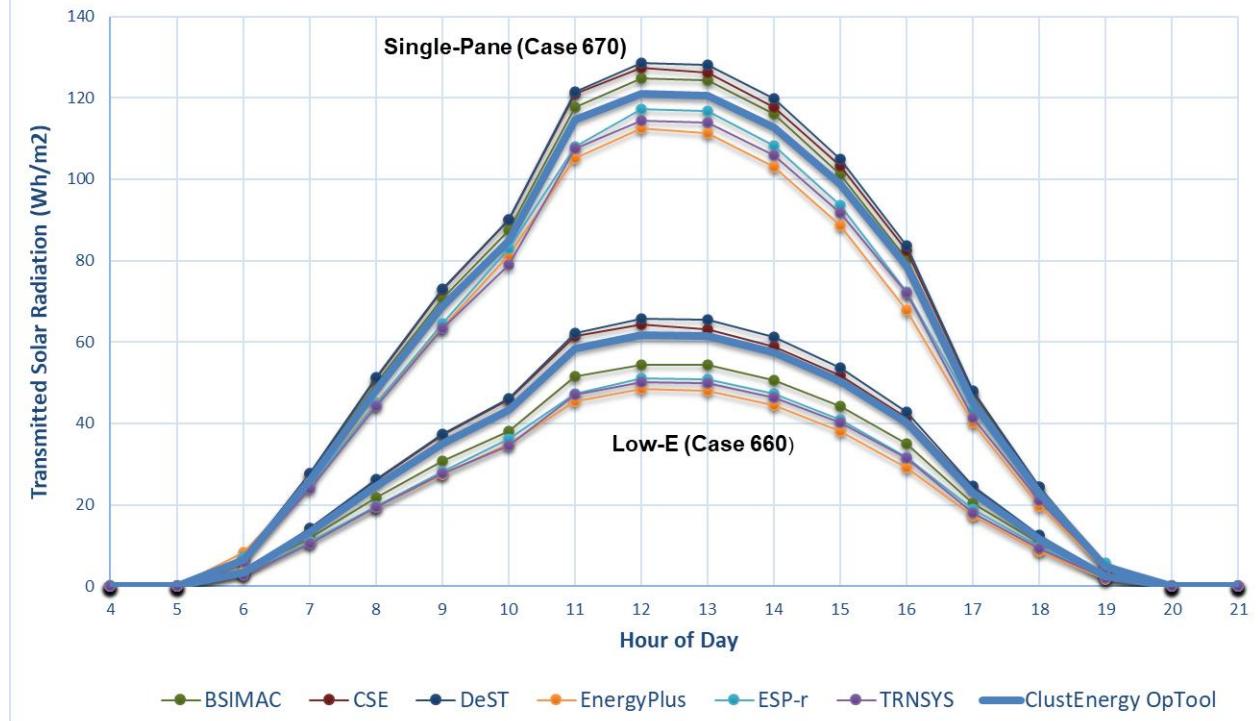
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Example Results for Section 5.2 - Building Thermal Envelope and Fabric Load Cases 195-995 & 600FF-980FF

**Figure B8-H6. Case 600**  
**Hourly Transmitted Solar, Cloudy Day (May 4)**  
**Double-Pane Windows**



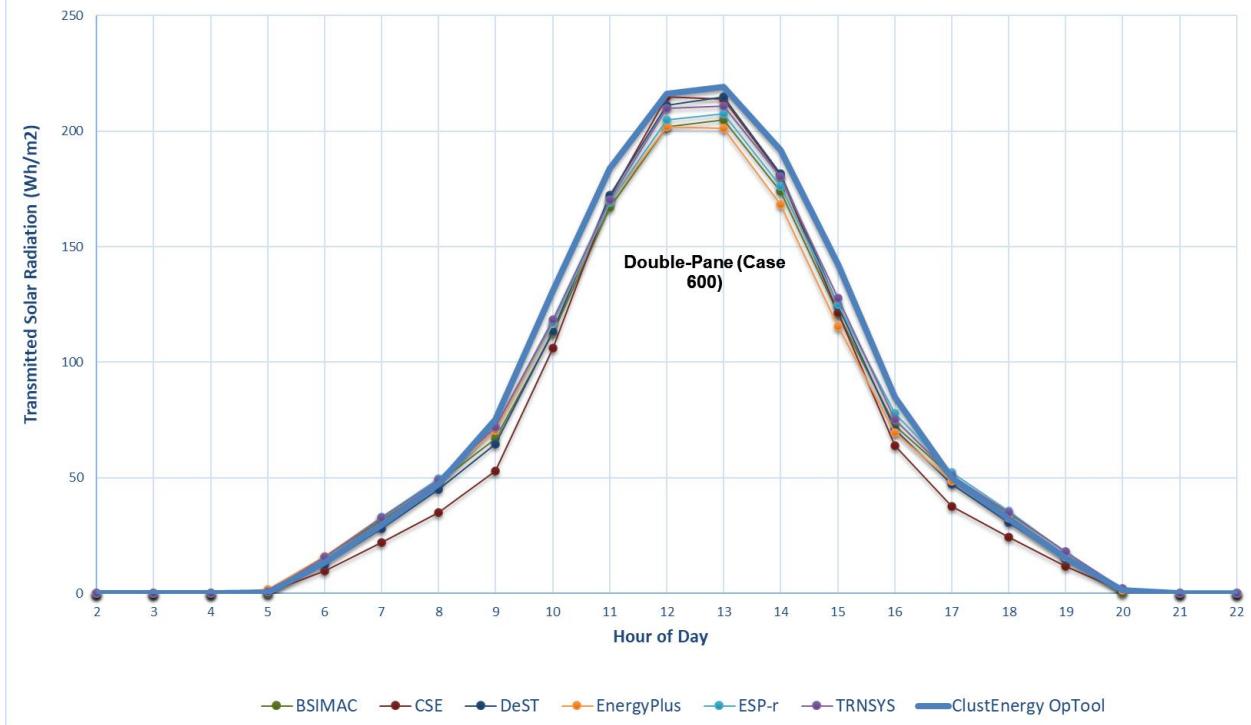
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Example Results for Section 5.2 - Building Thermal Envelope and Fabric Load Cases 195-995 & 600FF-980FF

**Figure B8-H7. Cases 660, 670**  
**Hourly Transmitted Solar, Cloudy Day (May 4)**  
**Low-E and Single-Pane Windows**



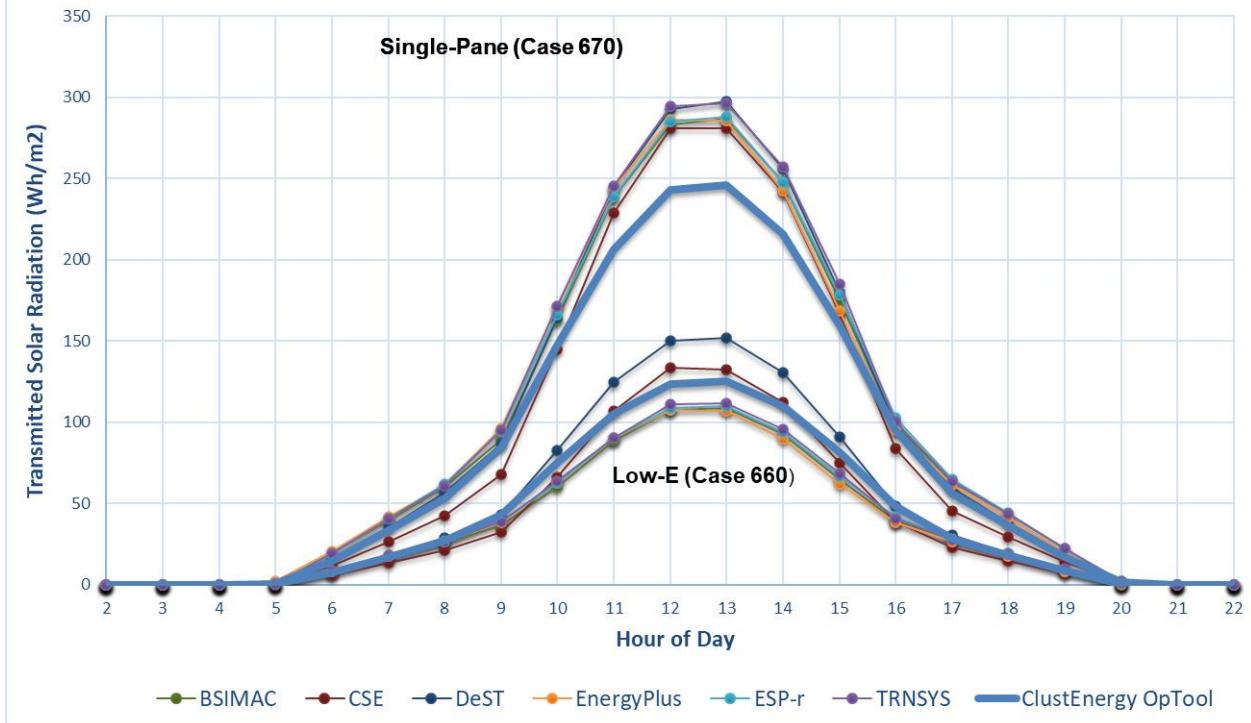
ASHRAE Standard 140-2017 Addendum A, Informative Annex B8, Section B8.1  
Example Results for Section 5.2 - Building Thermal Envelope and Fabric Load Cases 195-995 & 600FF-980FF

**Figure B8-H8. Case 600**  
**Hourly Transmitted Solar, Clear/Hot Day (Jul 14)**  
**Double-Pane Windows**

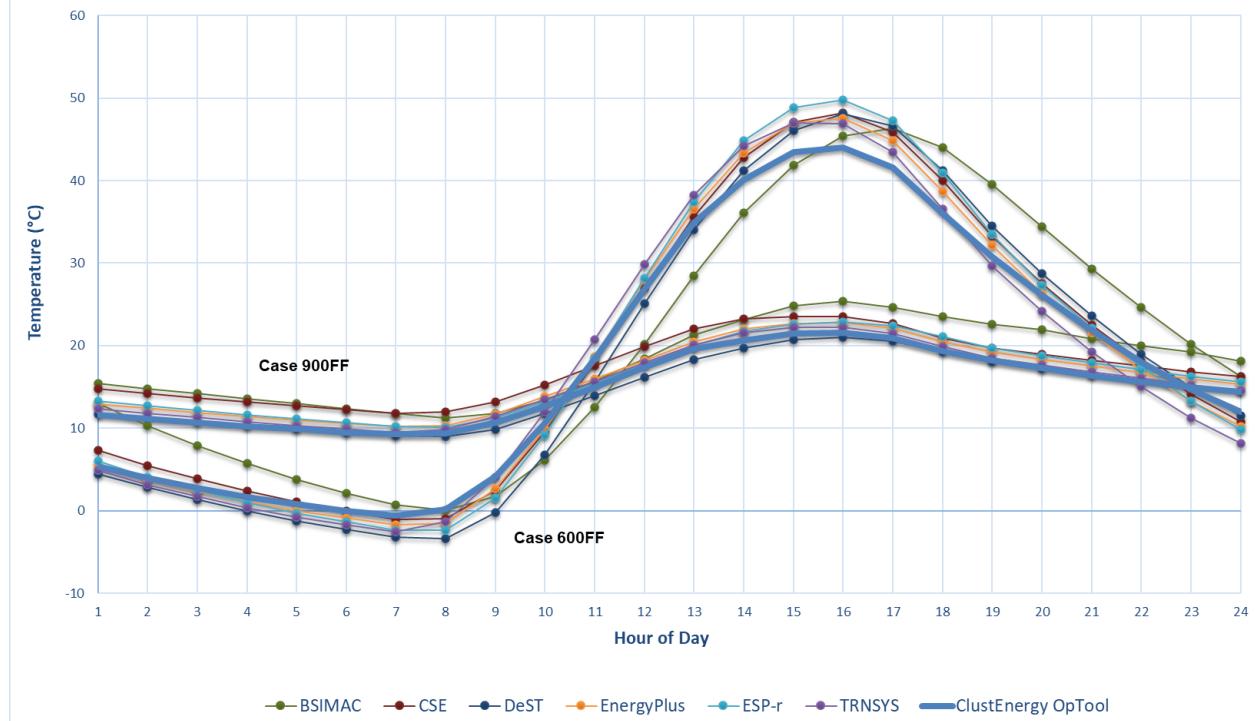


ASHRAE Standard 140-2017 Addendum A, Informative Annex B8, Section B8.1  
Example Results for Section 5.2 - Building Thermal Envelope and Fabric Load Cases 195-995 & 600FF-980FF

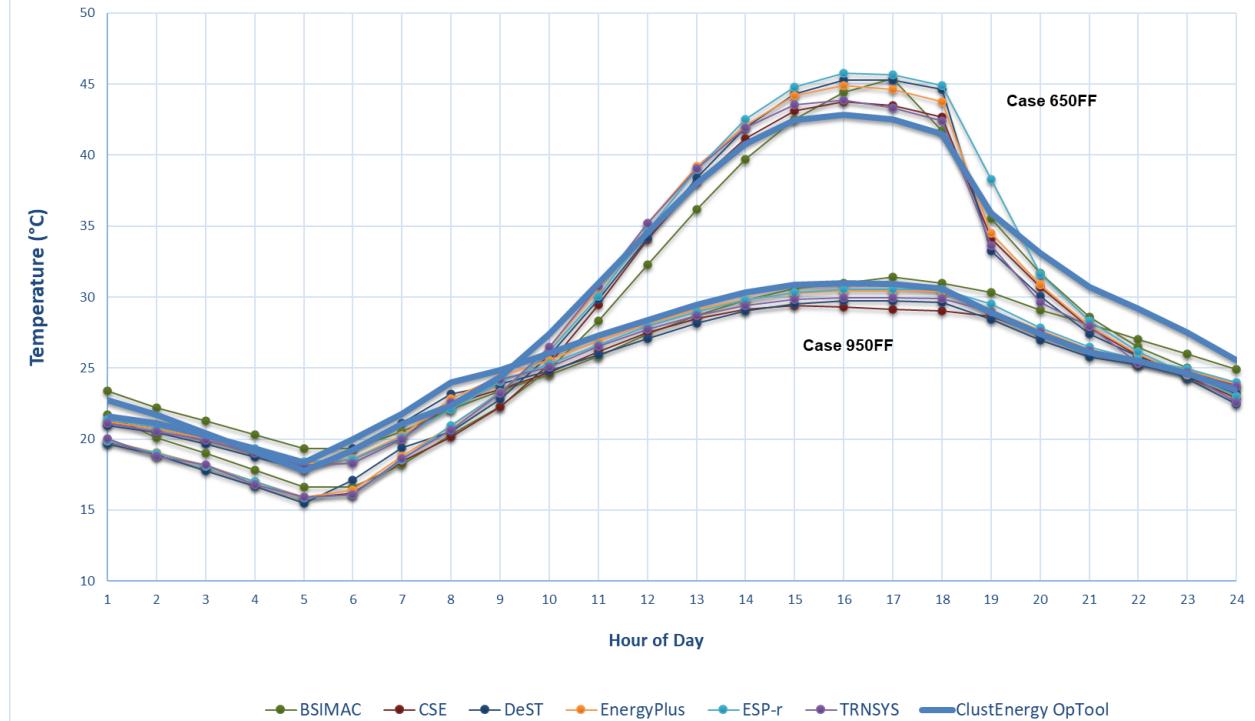
**Figure B8-H9. Cases 660, 670**  
**Hourly Transmitted Solar, Clear/Hot Day (Jul 14)**  
**Low-E and Single-Pane Windows**



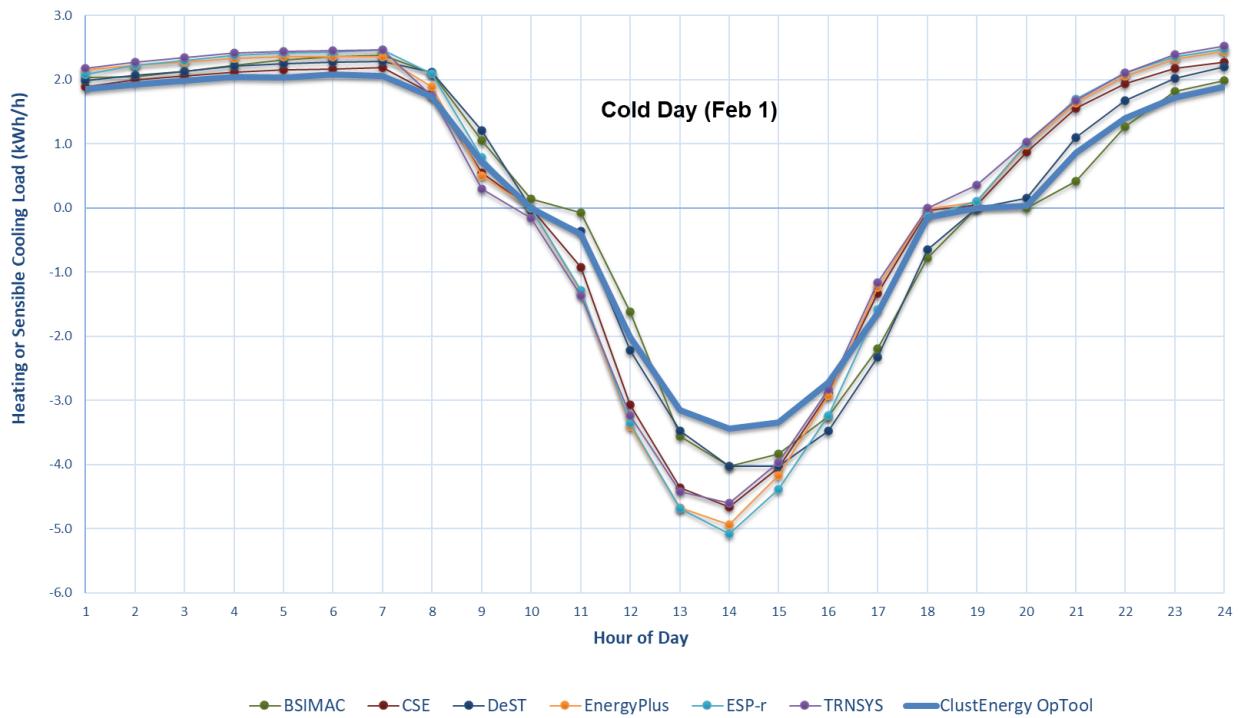
**Figure B8-H12.**  
**Hourly Free-Float Temperatures**  
**Clear Cold Day (Feb 1), Cases 600FF and 900FF**



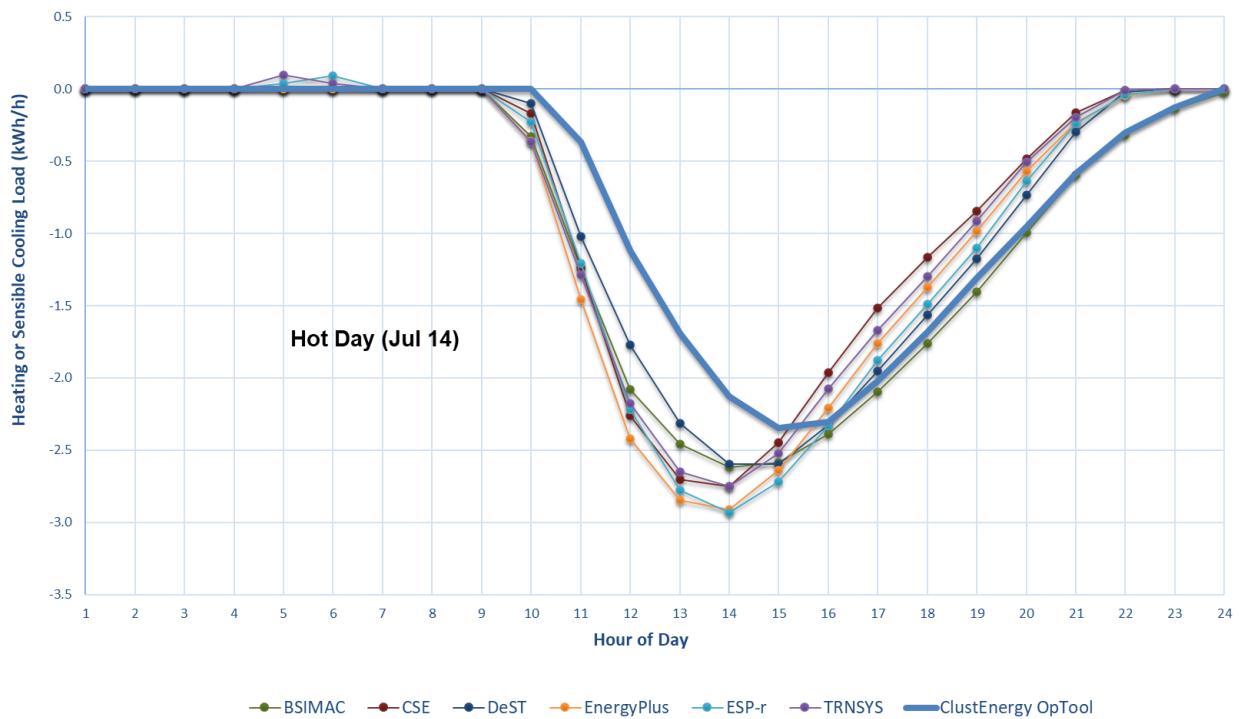
**Figure B8-H13.**  
**Hourly Free-Float Temperatures**  
**Clear Hot Day (Jul 14), Cases 650FF and 950FF**



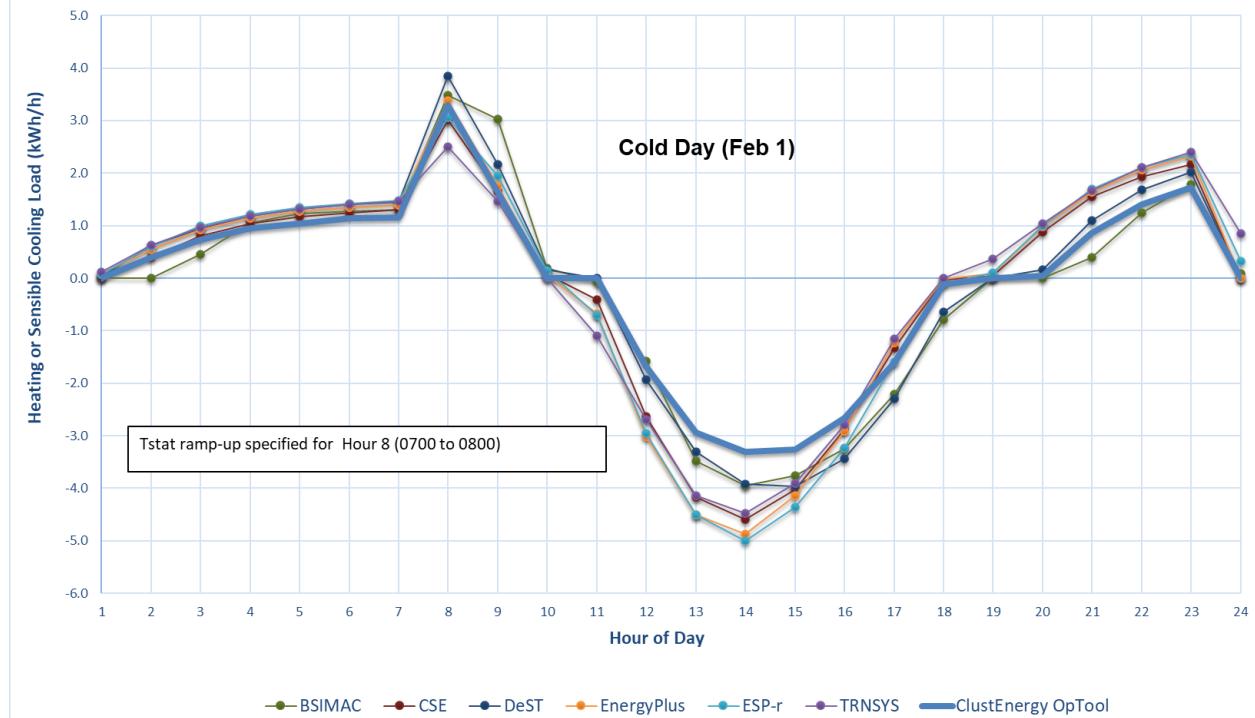
**Figure B8-H15. Hourly Loads**  
**Clear Cold Day, Case 600 (Low Mass, Double-Clear Window)**  
**Heating (+), Sensible Cooling (-)**



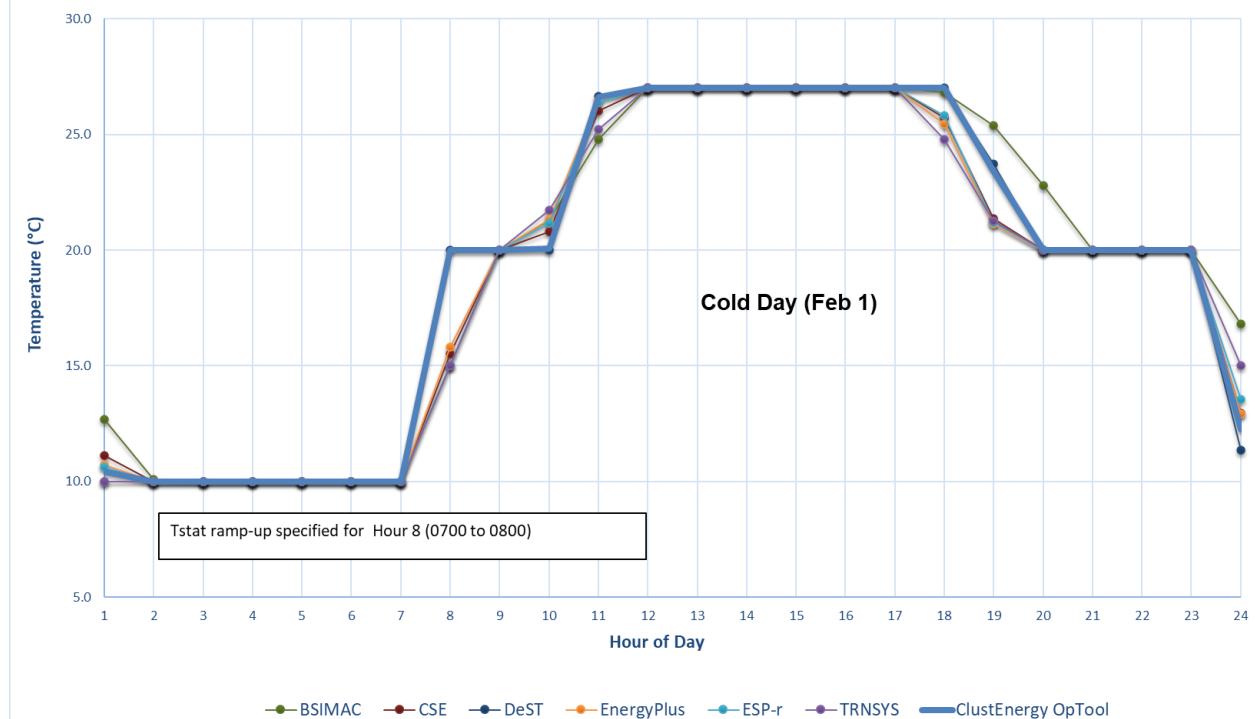
**Figure B8-H16. Hourly Loads**  
**Clear Hot Day, Case 600 (Low Mass, Double-Clear Window)**  
**Heating (+), Sensible Cooling (-)**



**Figure B8-H17. Hourly Loads**  
**Clear Cold Day, Case 640 (Low Mass, Night Setback)**  
**Heating (+), Sensible Cooling (-)**

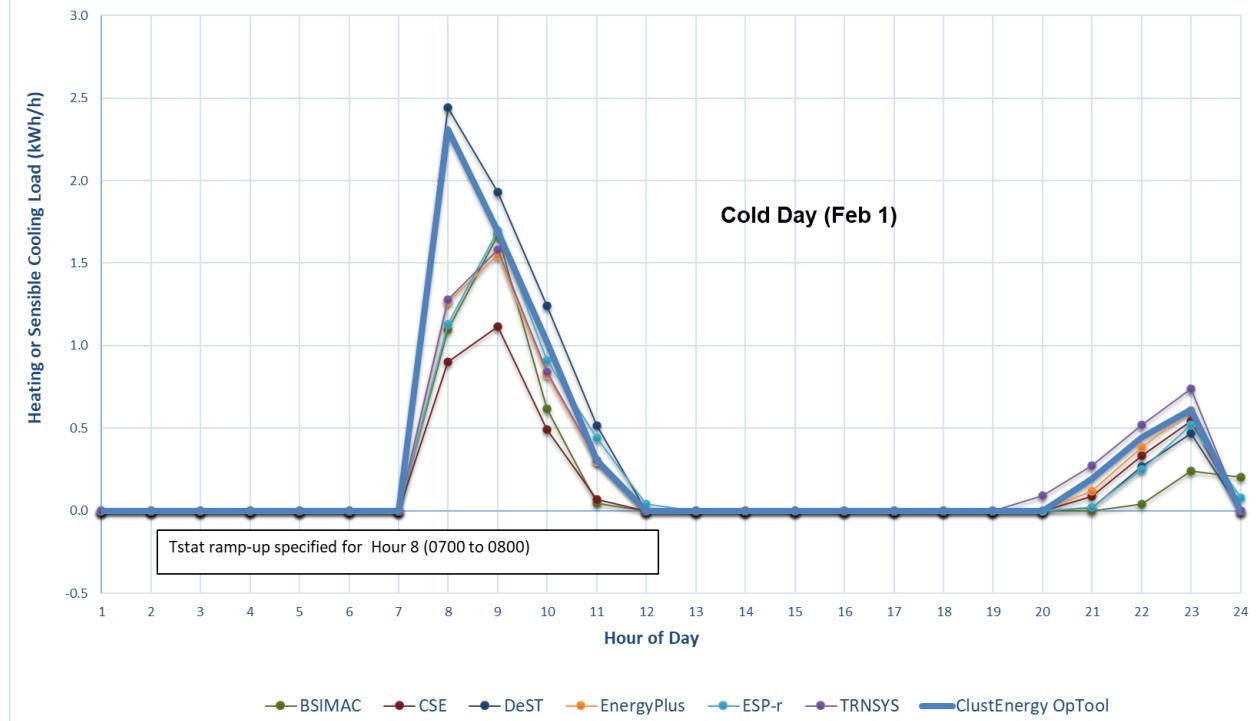


**Figure B8-H18.**  
**Hourly Conditioned Zone Temperatures**  
**Clear Cold Day, Case 640**



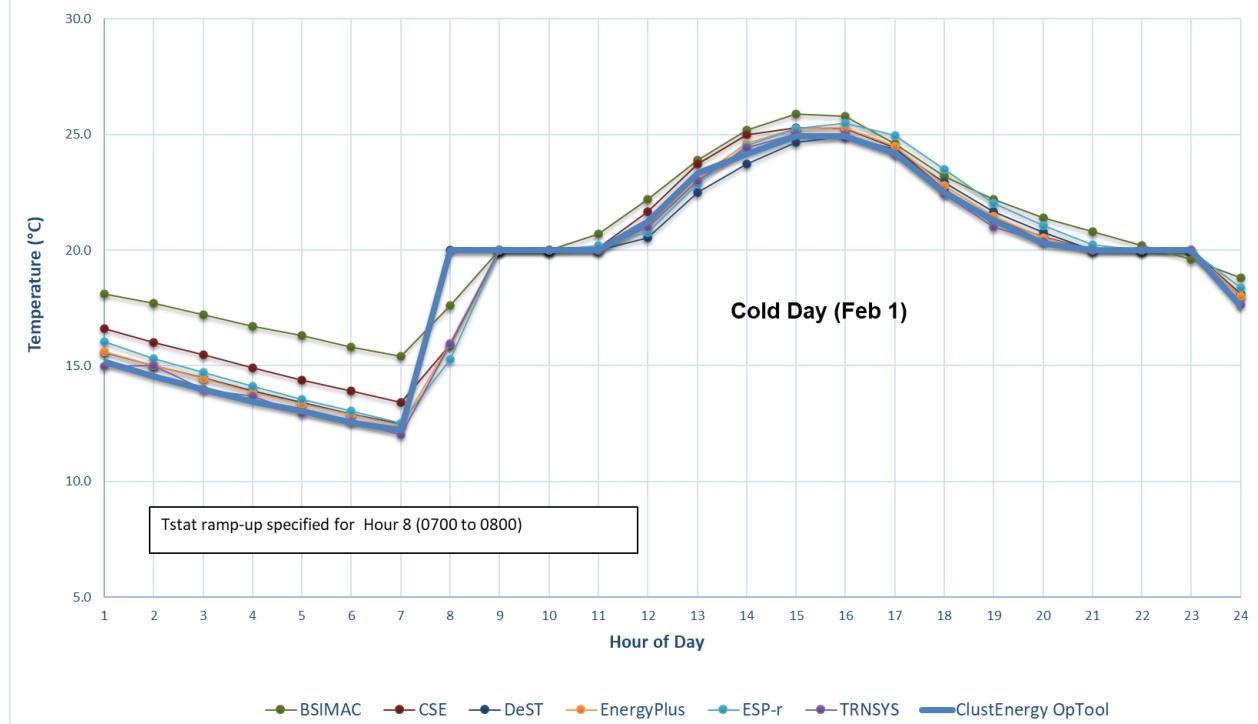
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Example Results for Section 5.2 - Building Thermal Envelope and Fabric Load Cases 195-995 & 600FF-980FF

**Figure B8-H19. Hourly Loads**  
**Clear Cold Day, Case 940 (High Mass, Night Setback)**  
**Heating (+), Sensible Cooling (-)**

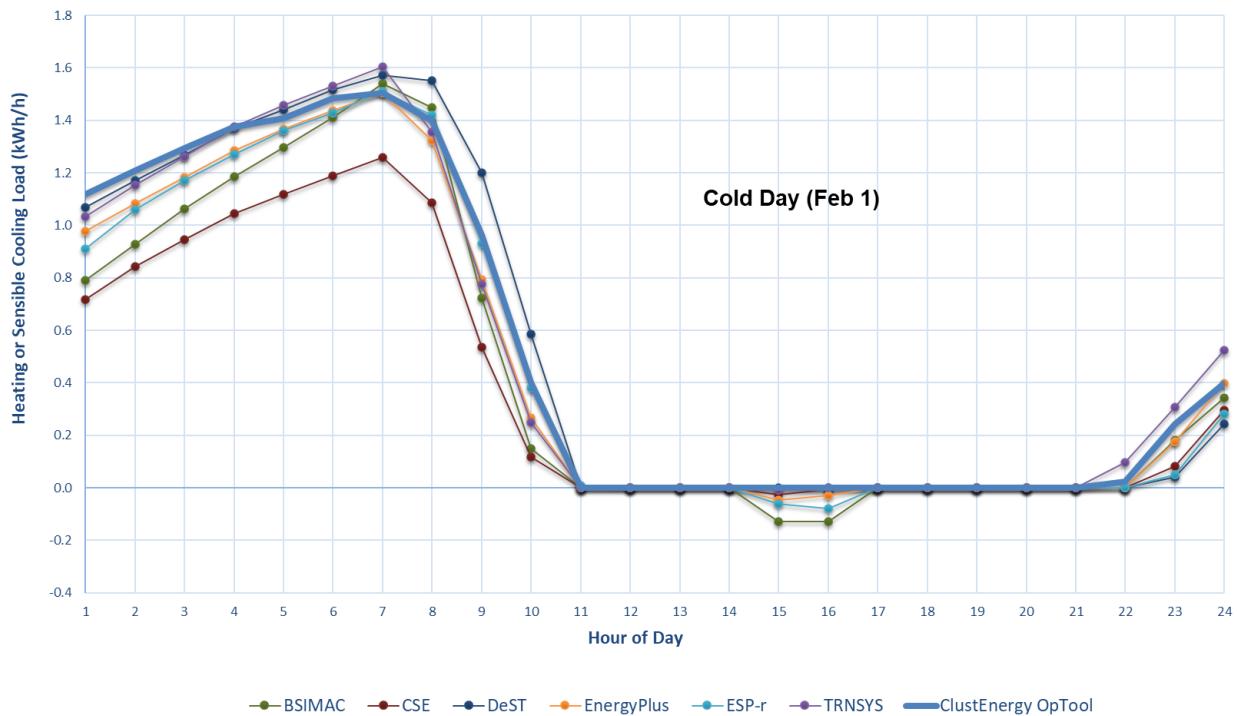


ASHRAE Standard 140-2017 Addendum A, Informative Annex B8, Section B8.1  
Example Results for Section 5.2 - Building Thermal Envelope and Fabric Load Cases 195-995 & 600FF-980FF

**Figure B8-H20.**  
**Hourly Conditioned Zone Temperatures**  
**Clear Cold Day, Case 940**



**Figure B8-H31. Hourly Loads**  
**Clear Cold Day, Case 900 (High Mass)**  
**Heating (+), Sensible Cooling (-)**



**Figure B8-H32. Hourly Loads**  
**Clear Hot Day, Case 900 (High Mass)**  
**Heating (+), Sensible Cooling (-)**

