

# **ASHRAE Standard 140-2011**

## **Test Results Comparison for Section 5.4 - HVAC Equipment Performance Tests HE100-HE230**

Results for Autodesk Green Building Studio 2/13/2014

vs.

Informative Annex B16, Section B16.6 Example Results

Prepared By  
Autodesk

Results Developed  
13-Feb-2014

**ASHRAE Standard 140-2011**  
**Participating Organizations and Computer Programs for**  
**Quasi-Analytical Solutions and Example Simulation Results**  
**Section 5.4 - HVAC Equipment Performance Tests HE100-HE230**

The quasi-analytical solutions and programs used to generate the example simulation results are described below. The first column ("Model"), indicates the proper program name and version number, or indicates a quasi-analytical solution.

The second column ("Authoring Organization") indicates the national research facility, university, or industry organization with expertise in building science that wrote the simulation software or did the quasi-analytical solutions.

The third column ("Implemented By") indicates the national research facility, university, or industry organization with expertise in building science that performed the simulations or did the quasi-analytical solutions.

The entries in the fourth column are the abbreviations for the simulations and quasi-analytical solutions generally used in the tables and charts which follow.

See Standard 140, Annex B17 for further details.

**Participating Organizations and Computer Programs**

<b>Model</b>	<b>Authoring Organization</b>	<b>Implemented By</b>	<b>Abbreviation</b>
ESP-r/HOT3000 Tier 1 tests - version 1.1 Tier 2 tests - version 1.7	CETC/ESRU, <sup>a,b</sup> Canada/United Kingdom	CETC, <sup>a</sup> Canada	ESP-r/HOT3000/CETC
EnergyPlus 1.0.2.008	LBNL/UIUC/CERL/OSU/GARD Analytics/FSEC/DOE-OBT, <sup>c,d,e,f,g,h</sup>	GARD Analytics, USA	EnergyPlus/GARD
DOE-2.1E version 107	LANL/LBNL/JJH, <sup>i,c,j</sup> USA	CETC, <sup>a</sup> Canada	DOE-2.1E/CETC
Analytical/Quasi-Analytical	CETC <sup>a</sup>	CETC <sup>a</sup>	Analytical/Quasi-Analytical

<sup>a</sup>CETC CANMET Energy Technology Centre, Natural Resources Canada, Canada

<sup>b</sup>ESRU: Energy Systems Research Unit, University of Strathclyde, Scotland, United Kingdom

<sup>c</sup>LBNL: Lawrence Berkeley National Laboratory, United States

<sup>d</sup>UIUC: University of Illinois Urbana/Champaign, United States

<sup>e</sup>CERL: U.S. Army Corps of Engineers, Construction Engineering Research Laboratories, United States

<sup>f</sup>OSU: Oklahoma State University, United States

<sup>g</sup>FSEC: University of Central Florida, Florida Solar Energy Center, United States

<sup>h</sup>DOE-OBT: U.S. Department of Energy, Office of Building Technology, State and Community Programs, Energy Efficiency and Renewable Energy, United States

<sup>i</sup>LANL: Los Alamos National Laboratory, United States

<sup>j</sup>JJH: James J. Hirsch & Associates, United States

ASHRAE Standard 140-2010 Section 5.4 - HVAC Equipment Performance Tests HE100-HE230  
Autodesk Green Building Studio 2/13/2014 vs. Annex B16, Section B16.6 Example Results  
By Autodesk , 13-Feb-2014

### List of Tables

<i>Table</i>	<i>Description</i>	<i>Sheet Tab</i>	<i>Cell Range</i>
B16.6-1	Total Furnace Load (GJ)	Tables	A7 – L24
B16.6-2	Total Furnace Input (GJ)	Tables	A26 – L43
B16.6-3	Fuel Consumption (m <sup>3</sup> /s)	Tables	A45 – L62
B16.6-4	Fan Energy, both fans (kWh)	Tables	A64 – K76
B16.6-5	Mean Zone Temperature (°C)	Tables	A78 – J85
B16.6-6	Maximum Zone Temperature (°C)	Tables	A87 – J94
B16.6-7	Minimum Zone Temperature (°C)	Tables	A96 – J103

### List of Figures

<i>Figure</i>	<i>Description</i>	<i>Sheet Tab</i>
B16.6-1	Total Furnace Load (GJ)	B16.1-1 LOAD
B16.6-2	Total Furnace Input (GJ)	B16.1-2 INPUT
B16.6-3	Fuel Consumption (m <sup>3</sup> /s)	B16.1-3 FUEL
B16.6-4	Fan Energy, both fans (kWh)	B16.1-4 FANS
B16.6-5	Mean Zone Temperature (°C)	B16.1-5 MEAN T
B16.6-6	Maximum Zone Temperature (°C)	B16.1-6 MAX T
B16.6-7	Minimum Zone Temperature (°C)	B16.1-7 MIN T

**ASHRAE Standard 140-2011 Test Results Comparison for Section 5.4 - HVAC Equipment Performance Tests HE100-HE230  
Autodesk Green Building Studio 2/13/2014 vs. Annex B16, Section B16.6 Example Results  
By Autodesk , 13-Feb-2014**

Note: The statistics in the tables below are based on the Standard 140 informative example results.  
These statistics do not have any substantial importance and are not to be interpreted as acceptance criteria.

**Table B16.6-1. Total Furnace Load (GJ)**

Cases	ESP-r/HOT3000 CETC	EnergyPlus GARD	DOE-2.1E CETC	Statistics, All Results				Analytical/ Quasi-Analytical	GBS 2/13/2014 Autodesk	GBS v3.4 Autodesk
				Min	Max	(Max-Min) /Analytical*	Mean			
HE100: 100% eff.	77.94	77.75	77.76	77.75	77.94	0.2%	77.74	77.76	77.76	
HE110: 80% eff.	77.94	77.75	77.76	77.75	77.94	0.2%	77.74	77.76	77.76	
HE120: 80% eff., PLR=0.4	31.25	31.10	31.13	31.10	31.25	0.5%	31.10	31.16	31.16	
HE130: No Load	0.00	0.00	0.16	0.00	0.16	----	0.00	0.00	0.00	
HE140: Periodic PLR	31.26	31.10	31.12	31.10	31.26	0.5%	31.10	31.14	31.14	
HE150: Continuous Circ. Fan	29.88	29.59	29.57	29.57	29.88	1.1%	29.65	29.72	29.72	
HE160: Cycling Circ. Fan	31.26	30.46	30.49	30.46	31.26	2.6%	31.10	30.96	30.96	
HE170: Draft Fan	29.88	29.59	29.57	29.57	29.88	1.1%	29.65	29.58	29.58	
Cases	ESP-r/HOT3000 CETC	EnergyPlus GARD	DOE-2.1E CETC	Min	Max	Mean	(Max-Min) /Mean**	Analytical/ Quasi-Analytical	GBS 2/13/2014 Autodesk	GBS v3.4 Autodesk
HE210: Realistic Weather	41.36	42.04	42.06	41.36	42.06	41.82	1.7%	-	41.83	41.83
HE220: Setback Thermostat	39.41	39.87	39.76	39.41	39.87	39.68	1.2%	-	39.60	39.60
HE230: Undersized Furnace	34.32	34.59	34.37	34.32	34.59	34.43	0.8%	-	34.37	34.37

\* Abs[ (Max-Min) / (Analytic Solution) ]

\*\*Abs[ (Max-Min) / (Mean of Example Results) ]

**Table B16.6-2. Total Furnace Input (GJ)**

Cases	ESP-r/HOT3000 CETC	EnergyPlus GARD	DOE-2.1E CETC	Statistics, All Results				Analytical/ Quasi-Analytical	GBS 2/13/2014 Autodesk	GBS v3.4 Autodesk
				Min	Max	(Max-Min) /Analytical*	Mean			
HE100: 100% eff.	77.74	77.71	78.42	77.71	78.42	0.9%	77.71	77.76	77.76	
HE110: 80% eff.	96.92	97.22	98.02	96.92	98.02	1.1%	97.22	97.20	97.20	
HE120: 80% eff., PLR=0.4	38.41	38.27	38.56	38.27	38.56	0.8%	38.27	38.30	38.30	
HE130: No Load	0.00	0.00	0.14	0.00	0.14	----	0.00	0.00	0.00	
HE140: Periodic PLR	39.00	39.00	38.76	38.76	39.00	0.6%	39.00	38.87	38.87	
HE150: Continuous Circ. Fan	37.23	36.94	36.82	36.82	37.23	1.1%	37.02	36.89	36.89	
HE160: Cycling Circ. Fan	38.12	38.12	37.96	37.96	38.12	0.4%	38.09	38.05	38.05	
HE170: Draft Fan	37.23	36.94	36.82	36.82	37.23	1.1%	37.02	36.94	36.94	
Cases	ESP-r/HOT3000 CETC	EnergyPlus GARD	DOE-2.1E CETC	Min	Max	Mean	(Max-Min) /Mean**	Analytical/ Quasi-Analytical	GBS 2/13/2014 Autodesk	GBS v3.4 Autodesk
HE210: Realistic Weather	50.53	52.01	52.37	50.53	52.37	51.64	3.6%	-	51.15	51.15
HE220: Setback Thermostat	47.87	49.35	49.47	47.87	49.47	48.89	3.3%	-	48.30	48.30
HE230: Undersized Furnace	41.37	42.55	43.22	41.37	43.22	42.38	4.4%	-	42.65	42.65

\* Abs[ (Max-Min) / (Analytic Solution) ]

\*\*Abs[ (Max-Min) / (Mean of Example Results) ]

**ASHRAE Standard 140-2011 Test Results Comparison for Section 5.4 - HVAC Equipment Performance Tests HE100-HE230  
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Note: The statistics in the tables below are based on the Standard 140 informative example results.  
These statistics do not have any substantial importance and are not to be interpreted as acceptance criteria.

**Table B16.6-3. Fuel Consumption (m<sup>3</sup>/s)**

Cases	ESP-r/HOT3000 CETC	EnergyPlus GARD	DOE-2.1E CETC	Statistics, All Results				Analytical/ Quasi-Analytical	GBS 2/13/2014 Autodesk	GBS v3.4 Autodesk
				Min	Max	(Max-Min) /Analytical*				
HE100: 100% eff.	0.000263	0.000263	0.000265	0.000263	0.000265		0.9%	0.000263	0.000263	0.000263
HE110: 80% eff.	0.000328	0.000329	0.000332	0.000328	0.000332		1.1%	0.000329	0.000329	0.000329
HE120: 80% eff., PLR=0.4	0.000130	0.000130	0.000131	0.000130	0.000131		0.8%	0.000130	0.000130	0.000130
HE130: No Load	0.000000	0.000000	0.000000	0.000000	0.000000		----	0.000000	0.000000	0.000000
HE140: Periodic PLR	0.000132	0.000132	0.000131	0.000131	0.000132		0.6%	0.000132	0.000132	0.000132
HE150: Continuous Circ. Fan	0.000126	0.000125	0.000125	0.000125	0.000126		1.1%	0.000125	0.000125	0.000125
HE160: Cycling Circ. Fan	0.000129	0.000129	0.000129	0.000129	0.000129		0.4%	0.000129	0.000129	0.000129
HE170: Draft Fan	0.000126	0.000125	0.000125	0.000125	0.000126		1.1%	0.000125	0.000125	0.000125
Cases	ESP-r/HOT3000 CETC	EnergyPlus GARD	DOE-2.1E CETC	Min	Max	Mean	(Max-Min) /Mean**	Analytical/ Quasi-Analytical	GBS 2/13/2014 Autodesk	GBS v3.4 Autodesk
HE210: Realistic Weather	0.000171	0.000176	0.000177	0.000171	0.000177	0.000175	3.5%	-	0.000173	0.000173
HE220: Setback Thermostat	0.000162	0.000167	0.000167	0.000162	0.000167	0.000165	3.3%	-	0.000163	0.000163
HE230: Undersized Furnace	0.000140	0.000144	0.000146	0.000140	0.000146	0.000143	4.3%	-	0.000144	0.000144

\* Abs[ (Max-Min) / (Analytic Solution) ]

\*\*Abs[ (Max-Min) / (Mean of Example Results) ]

**Table B16.6-4. Fan Energy, both fans (kWh)**

Cases	ESP-r/HOT3000 CETC	EnergyPlus GARD	DOE-2.1E CETC	Statistics, All Results				Analytical/ Quasi-Analytical	GBS 2/13/2014 Autodesk	GBS v3.4 Autodesk
				Min	Max	(Max-Min) /Analytical*				
HE150: Continuous Circ. Fan	432.0	433.3	432.1	432.0	433.3		0.3%	432.0	433.0	433.0
HE160: Cycling Circ. Fan	170.2	172.2	172.4	170.2	172.4		1.3%	172.8	171.9	171.9
HE170: Draft Fan	473.4	473.1	473.1	473.1	473.4		0.1%	473.2	473.3	473.3
Cases	ESP-r/HOT3000 CETC	EnergyPlus GARD	DOE-2.1E CETC	Min	Max	Mean	(Max-Min) /Mean**	Analytical/ Quasi-Analytical	GBS 2/13/2014 Autodesk	GBS v3.4 Autodesk
HE210: Realistic Weather	281.6	291.4	298.9	281.6	298.9	290.6	6.0%	-	295.7	295.7
HE220: Setback Thermostat	268.3	276.1	281.2	268.3	281.2	275.2	4.7%	-	274.3	274.3
HE230: Undersized Furnace	458.3	431.4	478.4	431.4	478.4	456.0	10.3%	-	450.6	450.6

\* Abs[ (Max-Min) / (Analytic Solution) ]

\*\*Abs[ (Max-Min) / (Mean of Example Results) ]

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**By Autodesk , 13-Feb-2014**

Note: The statistics in the tables below are based on the Standard 140 informative example results.  
These statistics do not have any substantial importance and are not to be interpreted as acceptance criteria.

**Table B16.6-5. Mean Zone Temperature (°C)**

Cases	ESP-r/HOT3000 CETC	EnergyPlus GARD	DOE-2.1E CETC	Statistics, All Results				GBS 2/13/2014 Autodesk	GBS v3.4 Autodesk
				Min	Max	Mean	(Max-Min) /Mean**		
HE210: Realistic Weather	20.01	20.00	19.98	19.98	20.01	20.00	0.2%	19.98	19.98
HE220: Setback Thermostat	18.75	18.53	18.53	18.53	18.75	18.60	1.2%	18.53	18.53
HE230: Undersized Furnace	15.48	15.17	15.64	15.17	15.64	15.43	3.0%	15.70	15.70

\*\*Abs[ (Max-Min) / (Mean of Example Results) ]

**Table B16.6-6. Maximum Zone Temperature (°C)**

Cases	ESP-r/HOT3000 CETC	EnergyPlus GARD	DOE-2.1E CETC	Statistics, All Results				GBS 2/13/2014 Autodesk	GBS v3.4 Autodesk
				Min	Max	Mean	(Max-Min) /Mean*		
HE210: Realistic Weather	21.45	20.00	20.06	20.00	21.45	20.50	7.1%	20.08	20.08
HE220: Setback Thermostat	22.70	20.00	20.11	20.00	22.70	20.94	12.9%	20.08	20.08
HE230: Undersized Furnace	20.14	20.00	20.06	20.00	20.14	20.07	0.7%	20.04	20.04

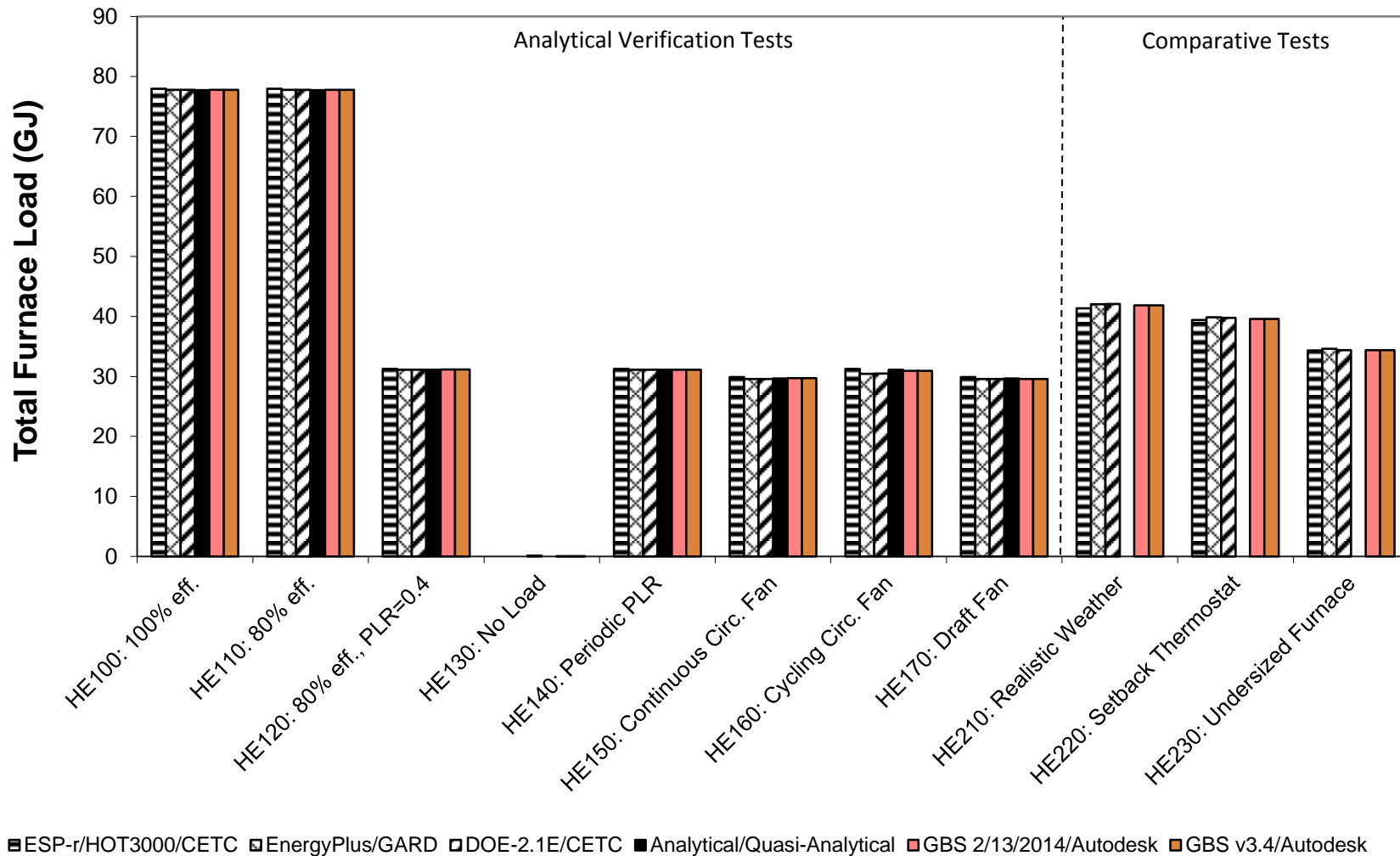
\*\*Abs[ (Max-Min) / (Mean of Example Results) ]

**Table B16.6-7. Minimum Zone Temperature (°C)**

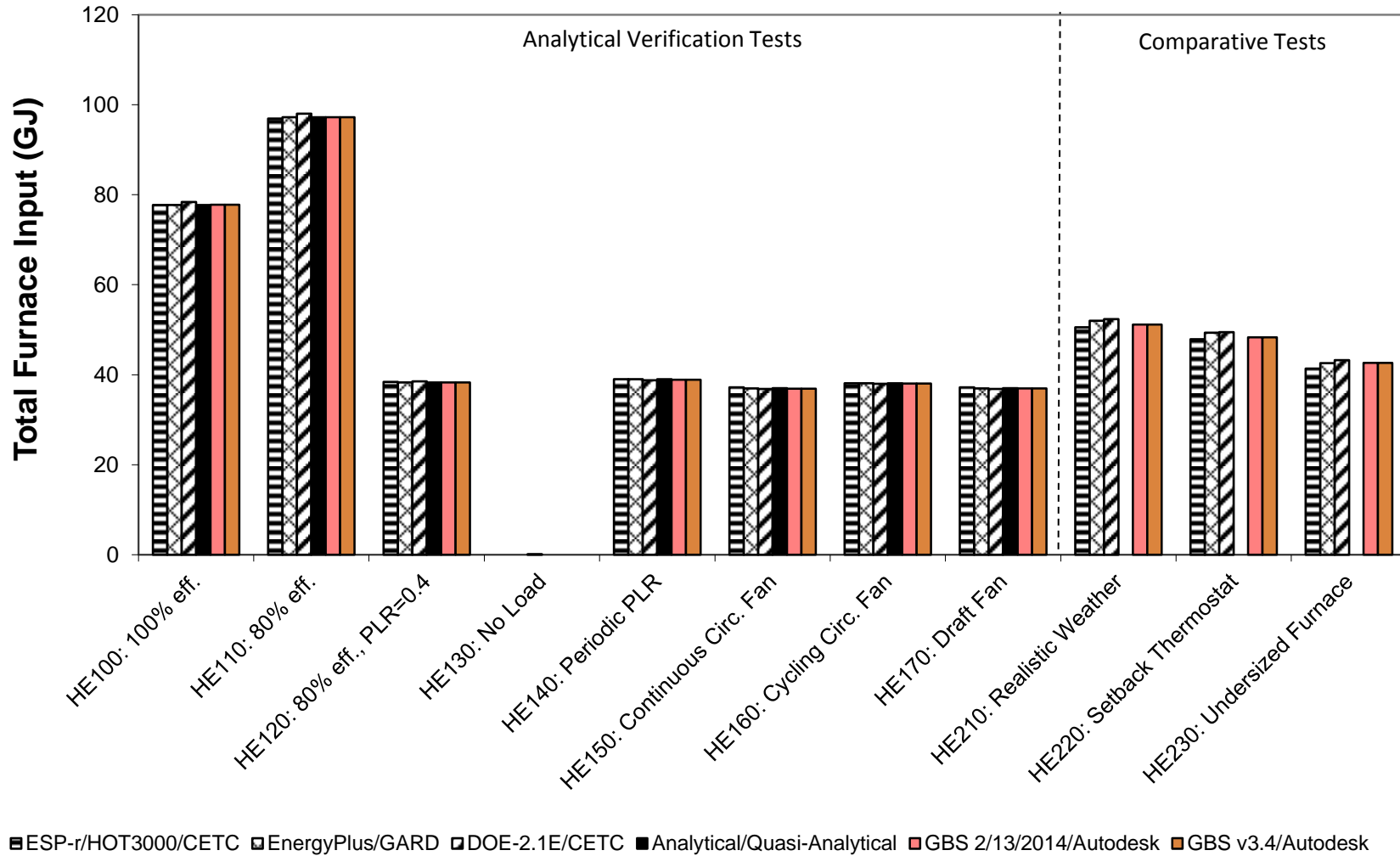
Cases	ESP-r/HOT3000 CETC	EnergyPlus GARD	DOE-2.1E CETC	Statistics, All Results				GBS 2/13/2014 Autodesk	GBS v3.4 Autodesk
				Min	Max	Mean	(Max-Min) /Mean*		
HE210: Realistic Weather	20.00	20.00	19.89	19.89	20.00	19.96	0.6%	19.88	19.88
HE220: Setback Thermostat	15.00	15.00	14.94	14.94	15.00	14.98	0.4%	14.93	14.93
HE230: Undersized Furnace	1.45	4.48	3.22	1.45	4.48	3.05	99.3%	3.73	3.73

\*\*Abs[ (Max-Min) / (Mean of Example Results) ]

**Figure B16.6-1. Comparison of the Energy Delivered for the Fuel-Fired Furnace Test Cases**



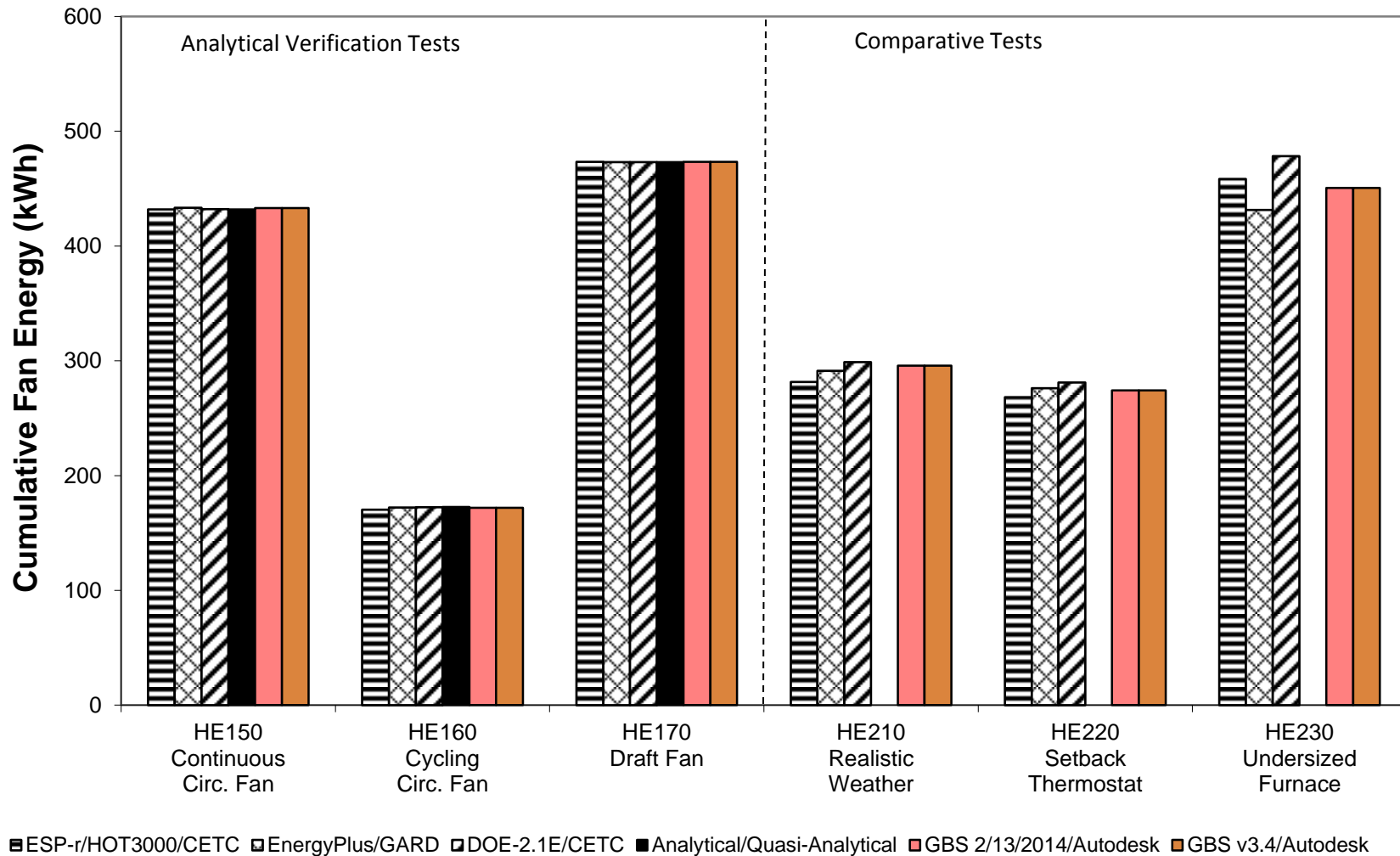
**Figure B16.6-2. Comparison of the Energy Consumed for the Fuel-Fired Furnace Test Cases**



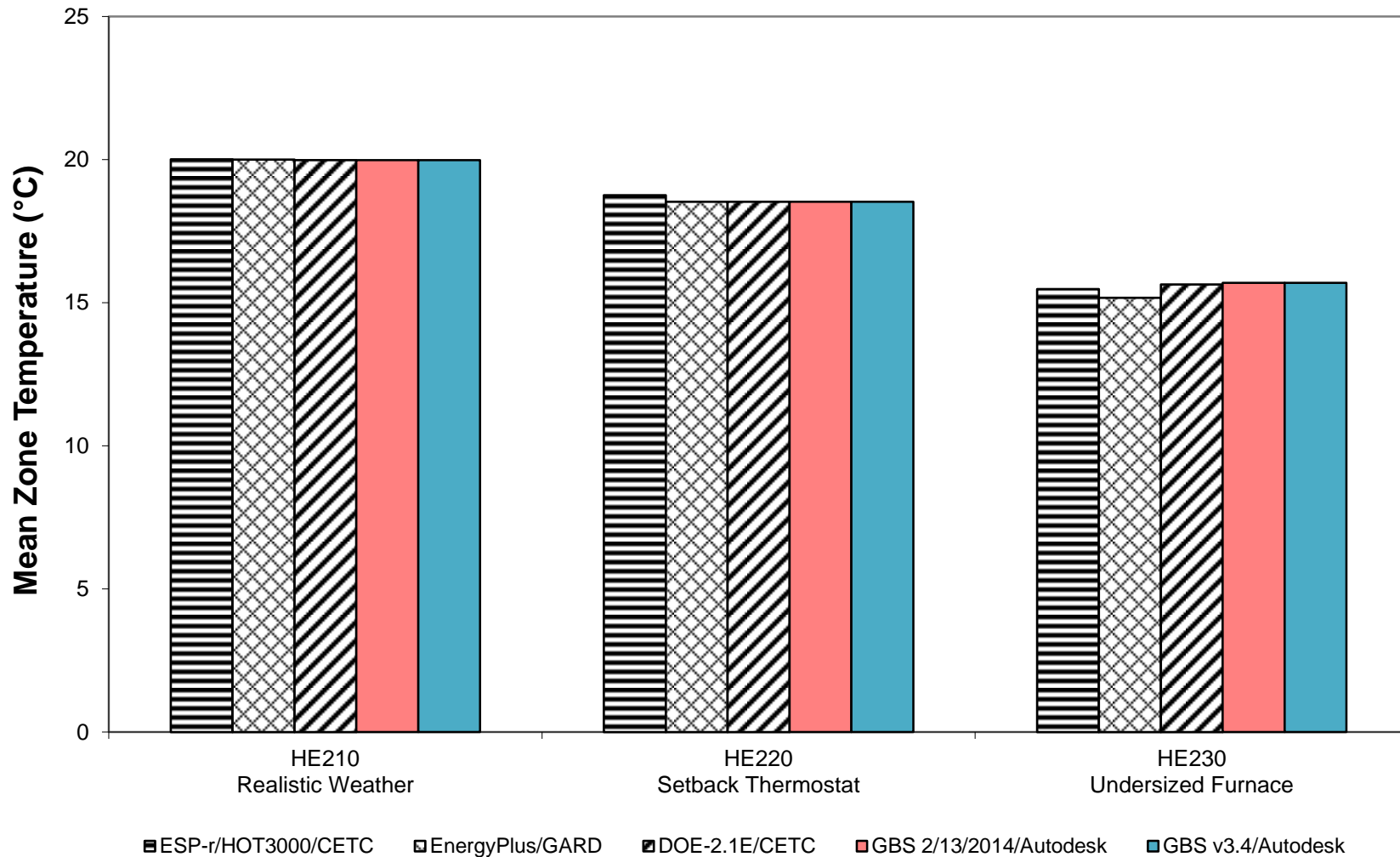




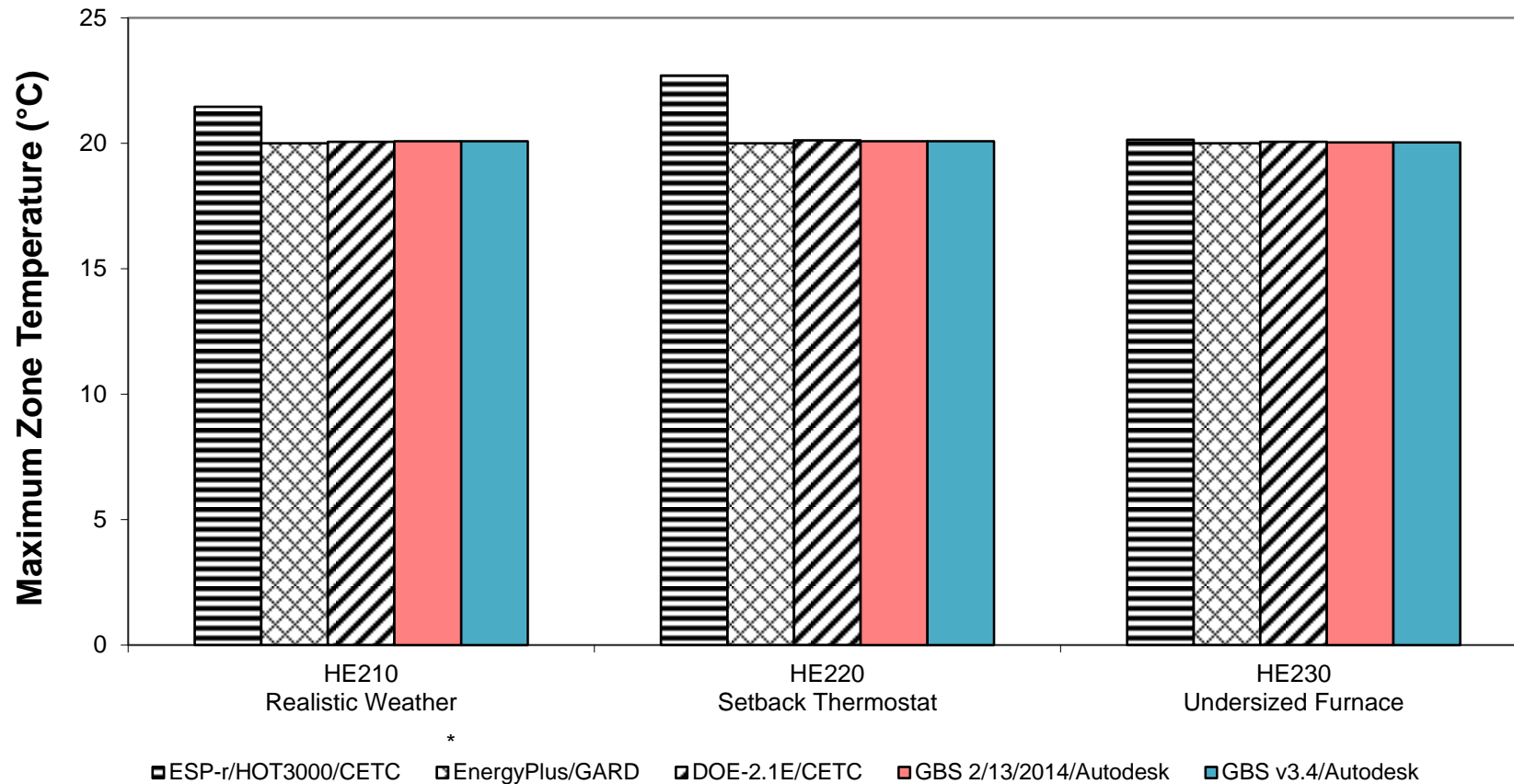
**Figure B16.6-4. Comparison of the Fan Energy for the Fuel-Fired Furnace Test Cases**



**Figure B16.6-5. Comparison of the Mean Zone Temperature for the Fuel-Fired Furnace Comparative Test Cases**



**Figure B16.6-6. Comparison of the Maximum Zone Temperature for the Fuel-Fired Furnace Comparative Test Cases**



**Figure B16.6-7. Comparison of the Minimum Zone Temperature for the Fuel-Fired Furnace Comparative Test Cases**

