

# **ASHRAE Standard 140-2023**

## **Test Results Comparison for Section 10 - HVAC Equipment Performance Tests HE100 through HE230**

Results for TRNSYS18.06.0002  
(TRNSYS18)  
vs.  
Informative Annex B16, Section B16.6 Example Results

Prepared By  
Thermal Energy System Specialists, LLC  
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Results Developed  
19-Aug-2024

**ASHRAE Standard 140-2023**  
**Participating Organizations and Computer Programs for**  
**Quasi-Analytical Solutions and Example Simulation Results**  
**Section 10 - HVAC Equipment Performance Tests HE100 through 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 c133 Analytical/Quasi-Analytical	LANL/LBNL/JJH, <sup>i,c,j</sup> USA CETC <sup>a</sup>	CETC, <sup>a</sup> Canada CETC <sup>a</sup>	DOE-2.1E/CETC 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

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 TRNSYS18.06.0002 (TRNSYS18) vs. Annex B16, Section B16.6 Example Results  
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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 B16.6-1. Total Furnace Load (GJ)**

Cases	ESP-r/HOT3000 CETC	EnergyPlus GARD	DOE-2.1E CETC	Statistics, All Results				Analytical/ Quasi-Analytical	TRNSYS18 TESS
				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	
HE110: 80% eff.	77.94	77.75	77.76	77.75	77.94	0.2%	77.74	77.76	
HE120: 80% eff., PLR=0.4	31.25	31.10	31.13	31.10	31.25	0.5%	31.10	31.11	
HE130: No Load	0.00	0.00	0.16	0.00	0.16	----	0.00	0.00	
HE140: Periodic PLR	31.26	31.10	31.12	31.10	31.26	0.5%	31.10	31.11	
HE150: Continuous Circ. Fan	29.88	29.59	29.57	29.57	29.88	1.1%	29.65	29.66	
HE160: Cycling Circ. Fan	31.26	30.46	30.49	30.46	31.26	2.6%	31.10	30.50	
HE170: Draft Fan	29.88	29.59	29.57	29.57	29.88	1.1%	29.65	29.66	
Cases	ESP-r/HOT3000 CETC	EnergyPlus GARD	DOE-2.1E CETC	Min	Max	Mean	(Max-Min) /Mean**	Analytical/ Quasi-Analytical	TRNSYS18 TESS
HE210: Realistic Weather	41.36	42.04	42.06	41.36	42.06	41.82	1.7%	-	42.06
HE220: Setback Thermostat	39.41	39.87	39.76	39.41	39.87	39.68	1.2%	-	39.84
HE230: Undersized Furnace	34.32	34.59	34.37	34.32	34.59	34.43	0.8%	-	34.67

\* 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	TRNSYS18 TESS
				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	
HE110: 80% eff.	96.92	97.22	98.02	96.92	98.02	1.1%	97.22	97.20	
HE120: 80% eff., PLR=0.4	38.41	38.27	38.56	38.27	38.56	0.8%	38.27	38.28	
HE130: No Load	0.00	0.00	0.14	0.00	0.14	----	0.00	0.00	
HE140: Periodic PLR	39.00	39.00	38.76	38.76	39.00	0.6%	39.00	38.91	
HE150: Continuous Circ. Fan	37.23	36.94	36.82	36.82	37.23	1.1%	37.02	37.04	
HE160: Cycling Circ. Fan	38.12	38.12	37.96	37.96	38.12	0.4%	38.09	38.13	
HE170: Draft Fan	37.23	36.94	36.82	36.82	37.23	1.1%	37.02	37.04	
Cases	ESP-r/HOT3000 CETC	EnergyPlus GARD	DOE-2.1E CETC	Min	Max	Mean	(Max-Min) /Mean**	Analytical/ Quasi-Analytical	TRNSYS18 TESS
HE210: Realistic Weather	50.53	52.01	52.37	50.53	52.37	51.64	3.6%	-	52.43
HE220: Setback Thermostat	47.87	49.35	49.47	47.87	49.47	48.89	3.3%	-	49.58
HE230: Undersized Furnace	41.37	42.55	43.22	41.37	43.22	42.38	4.4%	-	43.42

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

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

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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	TRNSYS18 TESS
				Min	Max	(Max-Min) /Analytical*			
HE100: 100% eff.	0.000263	0.000263	0.000265	0.000263	0.000265		0.9%	0.000263	0.000263
HE110: 80% eff.	0.000328	0.000329	0.000332	0.000328	0.000332		1.1%	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
HE130: No Load	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
HE150: Continuous Circ. Fan	0.000126	0.000125	0.000125	0.000125	0.000126		1.1%	0.000125	0.000125
HE160: Cycling Circ. Fan	0.000129	0.000129	0.000129	0.000129	0.000129		0.4%	0.000129	0.000129
HE170: Draft Fan	0.000126	0.000125	0.000125	0.000125	0.000126		1.1%	0.000125	0.000125
Cases	ESP-r/HOT3000 CETC	EnergyPlus GARD	DOE-2.1E CETC	Min	Max	Mean	(Max-Min) /Mean**	Analytical/ Quasi-Analytical	TRNSYS18 TESS
HE210: Realistic Weather	0.000171	0.000176	0.000177	0.000171	0.000177	0.000175	3.5%	-	0.000177
HE220: Setback Thermostat	0.000162	0.000167	0.000167	0.000162	0.000167	0.000165	3.3%	-	0.000168
HE230: Undersized Furnace	0.000140	0.000144	0.000146	0.000140	0.000146	0.000143	4.3%	-	0.000147

\* 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	TRNSYS18 TESS
				Min	Max	(Max-Min) /Analytical*			
HE150: Continuous Circ. Fan	432.0	433.3	432.1	432.0	433.3		0.3%	432.0	432.0
HE160: Cycling Circ. Fan	170.2	172.2	172.4	170.2	172.4		1.3%	172.8	169.5
HE170: Draft Fan	473.4	473.1	473.1	473.1	473.4		0.1%	473.2	473.2
Cases	ESP-r/HOT3000 CETC	EnergyPlus GARD	DOE-2.1E CETC	Min	Max	Mean	(Max-Min) /Mean**	Analytical/ Quasi-Analytical	TRNSYS18 TESS
HE210: Realistic Weather	281.6	291.4	298.9	281.6	298.9	290.6	6.0%	-	292.1
HE220: Setback Thermostat	268.3	276.1	281.2	268.3	281.2	275.2	4.7%	-	276.6
HE230: Undersized Furnace	458.3	431.4	478.4	431.4	478.4	456.0	10.3%	-	481.6

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

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

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

Cases	ESP-r/HOT3000 CETC	EnergyPlus GARD	DOE-2.1E CETC	Statistics, All Results				TRNSYS18 TESS
				Min	Max	Mean	(Max-Min) /Mean**	
HE210: Realistic Weather	20.01	20.00	19.98	19.98	20.01	20.00	0.2%	20.00
HE220: Setback Thermostat	18.75	18.53	18.53	18.53	18.75	18.60	1.2%	18.54
HE230: Undersized Furnace	15.48	15.17	15.64	15.17	15.64	15.43	3.0%	15.60

\*\*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				TRNSYS18 TESS
				Min	Max	Mean	(Max-Min) /Mean*	
HE210: Realistic Weather	21.45	20.00	20.06	20.00	21.45	20.50	7.1%	20.00
HE220: Setback Thermostat	22.70	20.00	20.11	20.00	22.70	20.94	12.9%	20.00
HE230: Undersized Furnace	20.14	20.00	20.06	20.00	20.14	20.07	0.7%	20.00

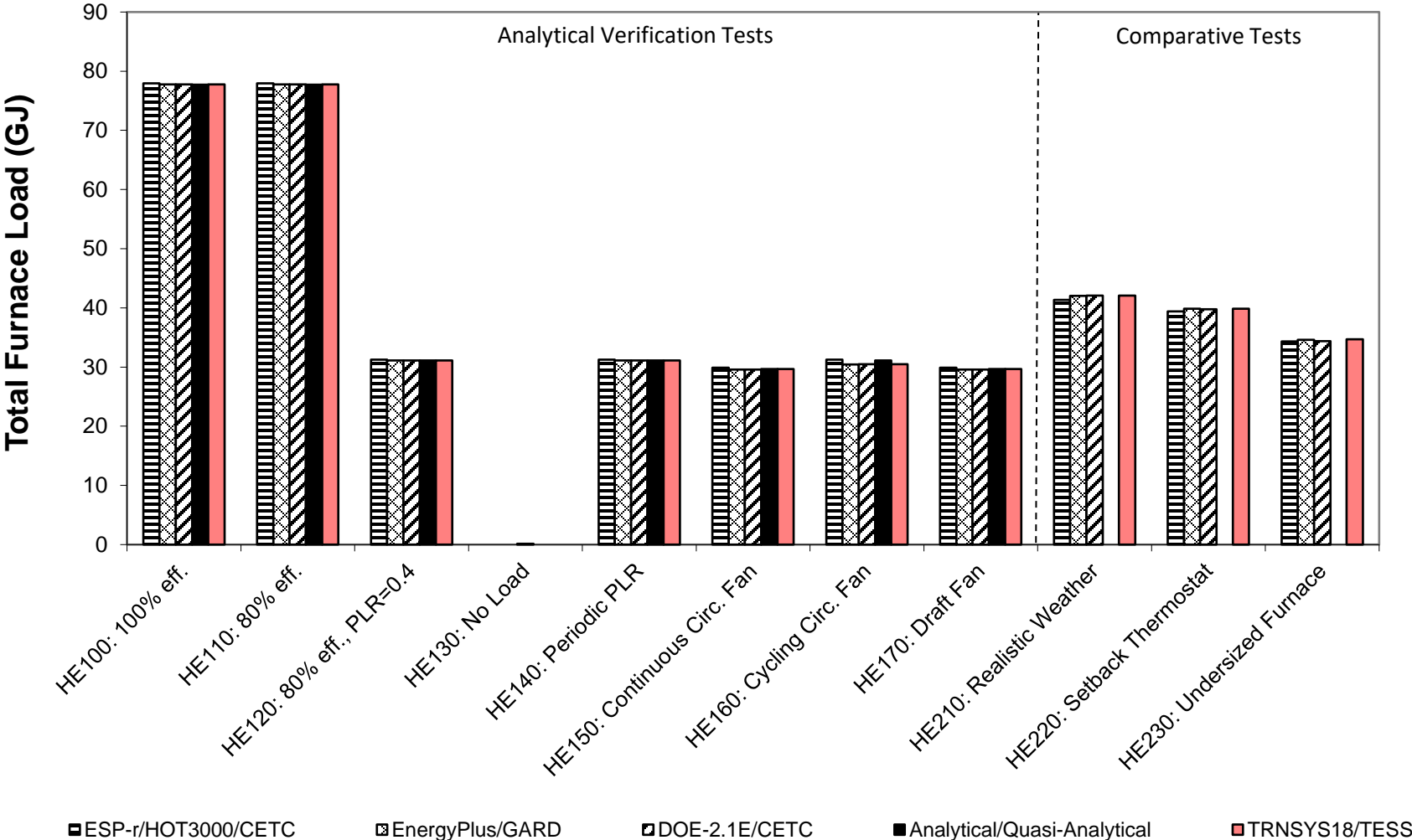
\*\*Abs[ (Max-Min) / (Mean of Example Results) ]

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

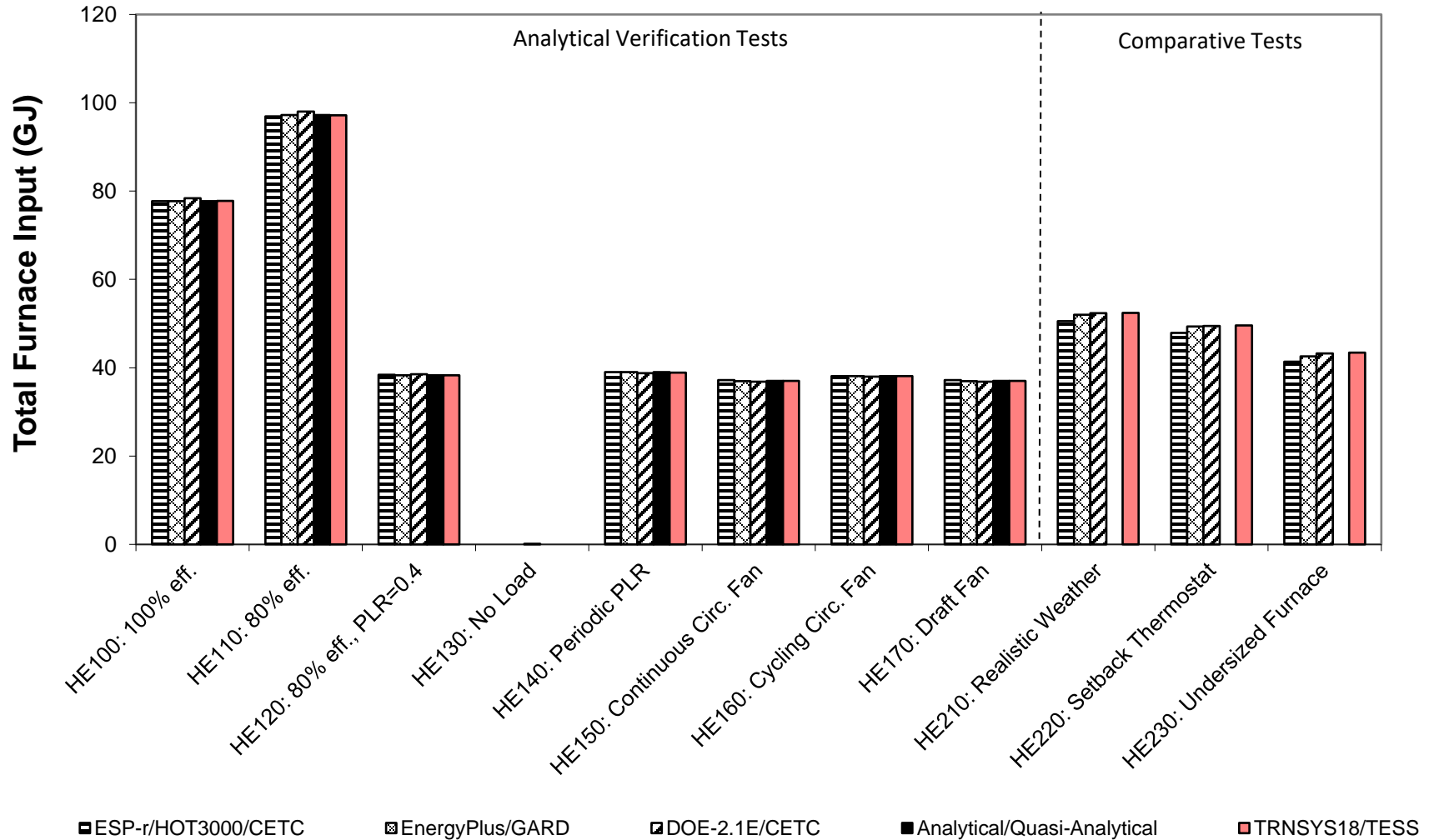
Cases	ESP-r/HOT3000 CETC	EnergyPlus GARD	DOE-2.1E CETC	Statistics, All Results				TRNSYS18 TESS
				Min	Max	Mean	(Max-Min) /Mean*	
HE210: Realistic Weather	20.00	20.00	19.89	19.89	20.00	19.96	0.6%	20.00
HE220: Setback Thermostat	15.00	15.00	14.94	14.94	15.00	14.98	0.4%	15.00
HE230: Undersized Furnace	1.45	4.48	3.22	1.45	4.48	3.05	99.3%	1.53

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

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

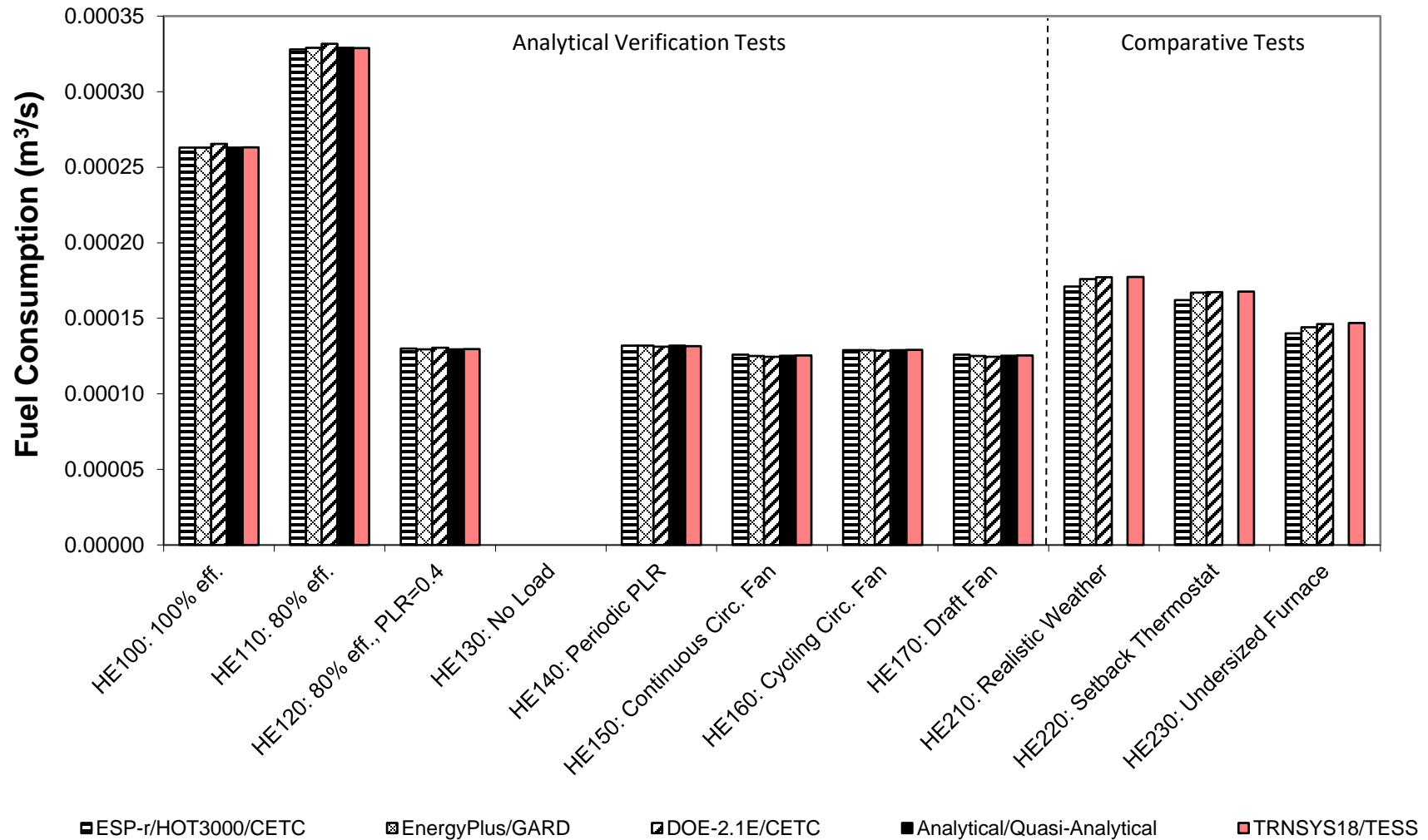


**Figure B16.6-2. Comparison of the Energy Consumed for the Fuel-Fired Furnace Test Cases**

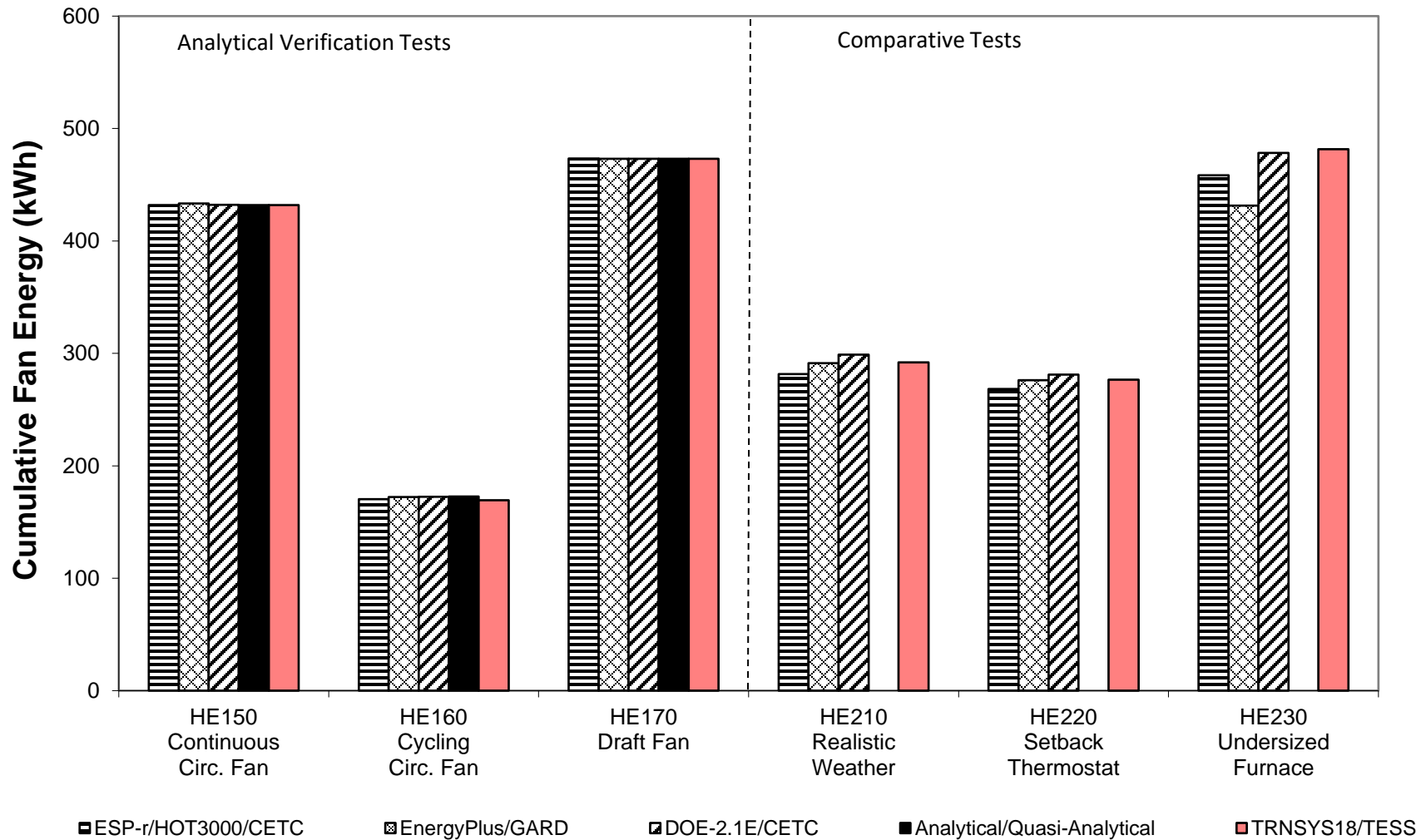




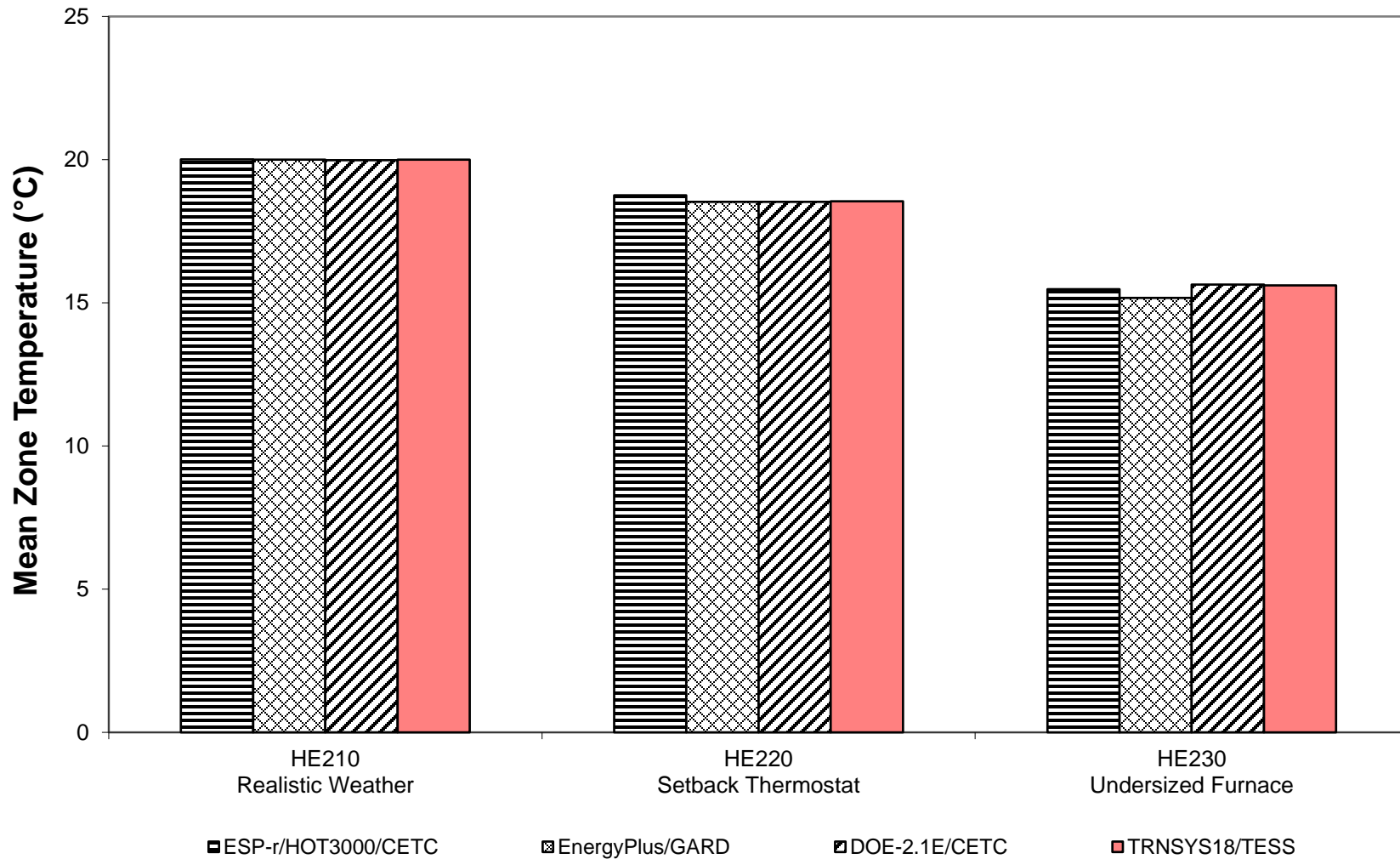
**Figure B16.6-3. Comparison of the Fuel Consumed for the Fuel-Fired Furnace Test Cases**



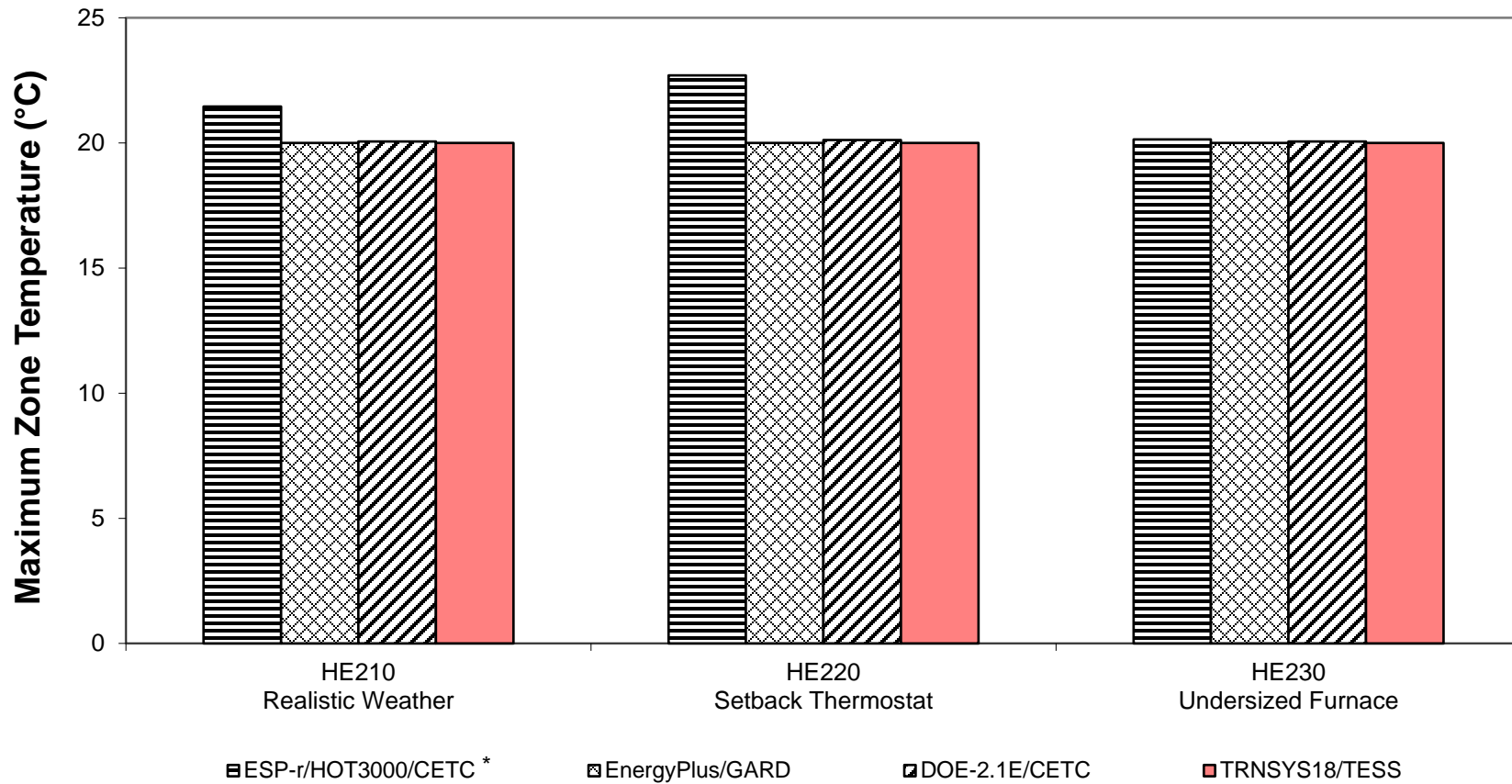
**Figure B16.6-4. Comparison of the Fan Energy for the Fuel-Fired Furnace Test Cases**



**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**



\* ESP-r's finite-difference discretization scheme with respect to time can be fully explicit, fully implicit, or any weighting in between. The program's default 50/50 weighting was employed for the simulations reported here and was found to produce some temperature solution oscillations for particular cases. However, subsequent analysis revealed that these oscillations had no effect upon the predicted fuel and electricity consumptions, the metrics of primary interest in these test cases.

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

