

ASHRAE Standard 140-2020

Test Results Comparison for Section 5.3 - HVAC Equipment Performance Tests CE100 through CE200

Results for TRNSYS 18.05.0001
(TRNSYS18)
vs.
Informative Annex B16, Section B16.5.1 Example Results

Prepared By
Thermal Energy System Specialists, LLC
(TESS)

Results Developed
22-Mar-2023

ASHRAE Standard 140-2020
Participating Organizations and Computer Programs for
Quasi-analytical Solutions and Example Simulation Results
Section 5.3 - HVAC Equipment Performance Tests CE100 through CE200

The quasi-analytical solutions and programs used to generate the example simulation results are described in Table B17-1. The first column of Table B17-1 ("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.

TABLE B17-1
Participating Organizations and Computer Programs

Model	Authoring Organization	Implemented By	Abbreviation
Quasi-Analytical solution with ideal controller model	Hochschule Technik & Architektur Luzern, Switzerland (HTAL)	Hochschule Technik & Architektur Luzern, Switzerland	HTAL1
Quasi-Analytical solution with realistic controller model	Hochschule Technik & Architektur Luzern, Switzerland	Hochschule Technik & Architektur Luzern, Switzerland	HTAL2
Quasi-Analytical Solution with ideal controller model	Technische Universität Dresden, Germany (TUD)	Technische Universität Dresden, Germany	TUD
CA-SIS V1	Electricité de France, France (EDF)	Electricité de France, France	CA-SIS
CLIM2000 2.1.6	Electricité de France, France	Electricité de France, France	CLM2000
DOE-2.1E-088	LANL/LBNL/ESTSC, ^{a,b,c} USA	CIEMAT, ^d Spain	DOE21E/CIEMAT DOE2.1-E/CIEMAT
DOE-2.1E-133	LANL/LBNL/JJH, ^{a,b,e} USA	NREL/JNA, ^f USA	DOE21E/NREL DOE2.1-E/NREL
ENERGYPLUS 1.0.0.023	LBNL/UIUC/CERL/OSU/GARD Analytics/FSEC/DOE-OBT, ^{a,g,h,i,j,k}	GARD Analytics, USA	E+ EnergyPlus
TRNSYS 14.2-TUD with ideal controller model	University of Wisconsin, USA; Technische Universität Dresden, Ger.	Technische Universität Dresden, Germany	TRN-id TRNSYS-ideal
TRNSYS 14.2-TUD with real controller model	University of Wisconsin, USA; Technische Universität Dresden, Ger.	Technische Universität Dresden, Germany	TRN-re TRNSYS-real

^aLANL: Los Alamos National Laboratory, United States

^bLBNL: Lawrence Berkeley National Laboratory, United States

^cESTSC: Energy Science and Technology Software Center (at Oak Ridge National Laboratory), United States

^dCIEMAT: Centro de Investigaciones Energeticas, Medioambientales y Tecnologicas, Spain

^eJJH: James J. Hirsch & Associates, United States

^fNREL/JNA: National Renewable Energy Laboratory/J. Neymark & Associates, United States

^gUIUC: University of Illinois Urbana/Champaign, United States

^hCERL: U.S. Army Corps of Engineers, Construction Engineering Research Laboratories, United States

ⁱOSU: Oklahoma State University, United States

^jFSEC: University of Central Florida, Florida Solar Energy Center, United States

^kDOE-OBT: U.S. Department of Energy, Office of Building Technology, State and Community Programs, Energy Efficiency and Renewable Energy, United States

**ASHRAE Standard 140-2010 Section 5.3 - HVAC Equipment Performance Tests CE100-CE200
 TRNSYS 18.05.0001 (TRNSYS18) vs. Annex B16, Section B16.5.1 Example Results
 By Thermal Energy System Specialists, LLC (TESS), 22-Mar-2023**

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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 B16.5.1-1. Space Cooling Electricity Consumption

Energy Consumption, Total (kWh,e)									Statistics, All Results			Analytical			22-Mar-23
Case	CA-SIS EDF	CLM2000 EDF	DOE21E CIEMAT	DOE21E NREL	E+ GARD	TRN-id TUD	TRN-re TUD	Min	Max	(Max-Min) /Analytical*	TUD	HTAL1	HTAL2	TRNSYS18 TESS	
CE100	1531	1530	1521	1519	1520	1522	1512	1512	1531	1.2%	1531	1531	1531	1541	
CE110	1077	1089	1061	1065	1069	1067	1062	1061	1089	2.6%	1076	1077	1077	1085	
CE120	1012	1012	1011	1003	1006	1007	1002	1002	1012	1.0%	1013	1011	1011	1022	
CE130	110	109	105	106	109	109	110	105	110	4.3%	111	110	110	111	
CE140	68	69	65	66	68	68	69	65	69	5.8%	69	69	68	69	
CE150	1208	1207	1202	1183	1197	1199	1192	1183	1208	2.1%	1206	1207	1207	1215	
CE160	1140	1139	1138	1107	1132	1137	1133	1107	1140	2.9%	1140	1139	1139	1148	
CE165	1502	1501	1499	1470	1491	1500	1490	1470	1502	2.1%	1498	1500	1500	1511	
CE170	638	638	629	620	635	636	636	620	638	2.8%	641	638	638	646	
CE180	1083	1082	1077	1080	1082	1081	1080	1077	1083	0.5%	1083	1082	1082	1085	
CE185	1544	1543	1541	1547	1540	1542	1538	1538	1547	0.6%	1545	1543	1543	1561	
CE190	164	164	160	160	164	164	165	160	165	3.1%	165	164	164	167	
CE195	250	250	245	246	250	250	252	245	252	2.7%	252	250	250	255	
CE200	1477	1464	1468	1440	1465	1480	1480	1440	1480	2.7%	1476	1477	1477	1482	
Energy Consumption, Compressor (kWh,e)									Statistics, All Results			Analytical			22-Mar-23
Case	CA-SIS EDF	CLM2000 EDF	DOE21E CIEMAT	DOE21E NREL	E+ GARD	TRN-id TUD	TRN-re TUD	Min	Max	(Max-Min) /Analytical*	TUD	HTAL1	HTAL2	TRNSYS18 TESS	
CE100	1319	1318	1307	1311	1311	1311	1303	1303	1319	1.2%	1319	1319	1319	1329	
CE110	889	899	866	883	883	879	876	866	899	3.7%	888	889	889	896	
CE120	840	840	850	838	838	836	832	832	850	2.2%	841	839	839	849	
CE130	95	94	93	93	93	94	95	93	95	2.1%	95	94	94	96	
CE140	57	57	55	56	56	56	57	55	57	3.9%	57	57	56	57	
CE150	1000	999	1007	982	992	992	987	982	1007	2.5%	999	999	999	1007	
CE160	950	949	963	926	926	947	944	926	963	3.9%	950	949	949	958	
CE165	1283	1281	1291	1256	1280	1272	1272	1256	1291	2.8%	1279	1280	1280	1291	
CE170	531	530	539	523	528	529	529	523	539	3.0%	533	530	530	537	
CE180	909	908	914	912	907	907	906	906	914	0.9%	908	908	908	911	
CE185	1340	1339	1343	1344	1337	1334	1334	1334	1344	0.7%	1340	1339	1338	1354	
CE190	138	138	139	138	138	138	138	138	139	1.4%	138	138	138	140	
CE195	217	217	219	217	216	218	218	216	219	1.1%	219	217	217	221	
CE200	1250	1239	1249	1218	1253	1253	1253	1218	1253	2.8%	1249	1250	1250	1255	
Energy Consumption, Supply Fan (kWh,e)									Statistics, All Results			Analytical			22-Mar-23
Case	CA-SIS EDF	CLM2000 EDF	DOE21E CIEMAT	DOE21E NREL	E+ GARD	TRN-id TUD	TRN-re TUD	Min	Max	(Max-Min) /Analytical*	TUD	HTAL1	HTAL2	TRNSYS18 TESS	
CE100	144	144	145	141	144	144	142	141	145	2.9%	144	144	144	145	
CE110	128	129	133	122	128	128	127	122	133	8.5%	128	128	128	128	
CE120	117	117	110	110	116	117	115	110	117	6.3%	117	117	117	118	
CE130	10	10	8	8	10	10	10	8	10	23.1%	10	10	10	10	
CE140	8	8	7	6	8	8	8	6	8	27.2%	8	8	8	8	
CE150	141	141	133	136	140	141	139	133	141	5.7%	141	141	141	142	
CE160	129	129	119	121	128	129	128	119	129	7.8%	129	129	129	130	
CE165	149	150	142	145	149	149	148	142	150	5.6%	149	149	149	150	
CE170	73	73	61	63	73	73	73	61	73	16.1%	74	73	73	74	
CE180	118	119	111	112	118	118	118	111	119	6.9%	119	119	119	119	
CE185	139	139	135	137	139	139	139	135	139	3.0%	139	139	139	141	
CE190	18	18	14	14	18	18	18	14	18	22.9%	18	18	18	18	
CE195	23	23	18	18	23	23	23	18	23	23.3%	23	23	23	23	
CE200	154	153	149	151	153	155	155	149	155	3.5%	154	155	155	155	
Energy Consumption, Condenser Fan (kWh,e)									Statistics, All Results			Analytical			22-Mar-23
Case	CA-SIS EDF	CLM2000 EDF	DOE21E CIEMAT	DOE21E NREL	E+ GARD	TRN-id TUD	TRN-re TUD	Min	Max	(Max-Min) /Analytical*	TUD	HTAL1	HTAL2	TRNSYS18 TESS	
CE100	68	68	68	67	67	67	67	67	68	2.0%	68	68	68	68	
CE110	60	61	62	60	60	60	59	59	62	4.9%	60	60	60	60	
CE120	55	55	51	55	55	55	54	51	55	6.5%	55	55	55	55	
CE130	5	5	4	5	5	5	5	4	5	22.7%	5	5	5	5	
CE140	4	4	3	4	4	4	4	3	4	19.3%	4	4	4	4	
CE150	66	66	62	65	66	66	65	62	66	5.6%	66	66	66	67	
CE160	61	61	56	60	61	60	60	56	61	8.4%	61	61	61	61	
CE165	70	70	67	69	70	69	69	67	70	5.1%	70	70	70	70	
CE170	34	34	29	34	34	34	34	29	34	16.1%	35	34	34	35	
CE180	56	56	52	56	56	56	55	52	56	7.1%	56	56	56	56	
CE185	65	65	63	66	66	65	65	63	66	3.9%	65	65	65	66	
CE190	8	9	7	8	8	8	9	7	9	27.7%	9	9	9	9	
CE195	11	11	8	11	11	11	11	8	11	25.2%	11	11	11	11	
CE200	73	72	70	71	73	73	73	70	73	4.1%	73	73	73	73	

* ABS[(Max-Min) / (Mean of Analytical Solutions)]

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 TRNSYS 18.05.0001 (TRNSYS18) vs. Annex B16, Section B16.5.1 Example Results
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Note: The statistics in the tables below are based on the Standard 140 informative example results.
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Table B16.5.1-2. COP: Mean, and (Max-Min)/Mean

Mean COP									Statistics, All Results			Analytical			22-Mar-23
Case	CA-SIS	CLM2000	DOE21E	DOE21E	E+	TRN-id	TRN-re	TRN-re	(Max-Min)			TUD	HTAL1	HTAL2	TRNSYS18
	EDF	EDF	CIEMAT	NREL	GARD	TUD	TUD	TUD	Min	Max	/Analytical*				TESS
CE100	2.39	2.39	2.43	2.41	2.40	2.40	2.42	2.42	2.39	2.43	1.7%	2.39	2.39	2.39	2.37
CE110	3.38	3.34	3.46	3.41	3.40	3.41	3.43	3.43	3.34	3.46	3.5%	3.38	3.38	3.38	3.35
CE120	3.59	3.59	3.61	3.62	3.61	3.61	3.63	3.63	3.59	3.63	1.1%	3.59	3.59	3.59	3.55
CE130	1.91	1.91	1.98	1.95	1.90	1.92	1.92	1.92	1.90	1.98	3.8%	1.89	1.91	1.91	1.87
CE140	2.77	2.73	2.92	2.85	2.77	2.80	2.80	2.80	2.73	2.92	6.6%	2.75	2.77	2.77	2.73
CE150	3.62	3.63	3.67	3.70	3.65	3.65	3.67	3.67	3.62	3.70	2.2%	3.63	3.63	3.63	3.60
CE160	3.84	3.84	3.87	3.95	3.86	3.85	3.86	3.86	3.84	3.95	2.9%	3.83	3.84	3.84	3.81
CE165	2.92	2.92	2.95	2.99	2.94	2.93	2.94	2.94	2.92	2.99	2.2%	2.93	2.93	2.93	2.90
CE170	3.38	3.39	3.44	3.48	3.40	3.39	3.40	3.40	3.38	3.48	2.9%	3.37	3.39	3.39	3.34
CE180	4.04	4.04	4.08	4.03	4.04	4.05	4.06	4.06	4.03	4.08	1.4%	4.04	4.04	4.04	3.99
CE185	2.85	2.85	2.87	2.82	2.85	2.85	2.86	2.86	2.82	2.87	1.8%	2.85	2.85	2.85	2.81
CE190	3.41	3.41	3.49	3.46	3.39	3.41	3.40	3.40	3.39	3.49	2.7%	3.39	3.41	3.41	3.35
CE195	2.31	2.31	2.36	2.34	2.30	2.32	2.31	2.31	2.30	2.36	2.5%	2.29	2.31	2.31	2.26
CE200	3.62	3.61	3.67	3.71	3.65	3.61	3.61	3.61	3.61	3.71	2.7%	3.62	3.62	3.62	3.61

(Max - Min)/Mean COP									Statistics, All Results			Analytical			22-Mar-23
Case	CA-SIS	CLM2000	DOE21E	DOE21E	E+	TRN-id	TRN-re	TRN-re	(Max-Min)			TUD	HTAL1	HTAL2	TRNSYS18
	EDF	EDF	CIEMAT	NREL	GARD	TUD	TUD	TUD	Min	Max	/Analytical*				TESS
CE100	0.000	0.001	0.002	0.001	0.003	0.000	0.000	0.000	0.000	0.003	----	0.000	0.000	0.000	0.000
CE110	0.000	0.010	0.002	0.001	0.003	0.000	0.011	0.011	0.000	0.011	----	0.000	0.000	0.000	0.000
CE120	0.000	0.004	0.001	0.001	0.003	0.000	0.012	0.012	0.000	0.012	----	0.000	0.000	0.000	0.000
CE130	0.000	0.038	0.013	0.009	0.004	0.000	0.172	0.172	0.000	0.172	----	0.000	0.000	0.000	0.000
CE140	0.000	0.056	0.011	0.019	0.004	0.000	0.204	0.204	0.000	0.204	----	0.000	0.000	0.000	0.000
CE150	0.003	0.003	0.001	0.005	0.011	0.000	0.009	0.009	0.000	0.011	----	0.000	0.001	0.001	0.000
CE160	0.003	0.005	0.001	0.003	0.011	0.000	0.010	0.010	0.000	0.011	----	0.000	0.000	0.000	0.000
CE165	0.010	0.003	0.001	0.003	0.012	0.000	0.008	0.008	0.000	0.012	----	0.000	0.000	0.000	0.000
CE170	0.000	0.006	0.002	0.004	0.015	0.000	0.043	0.043	0.000	0.043	----	0.000	0.000	0.000	0.000
CE180	0.005	0.002	0.002	0.010	0.029	0.000	0.012	0.012	0.000	0.029	----	0.000	0.000	0.000	0.000
CE185	0.007	0.004	0.002	0.010	0.034	0.000	0.009	0.009	0.000	0.034	----	0.000	0.000	0.000	0.000
CE190	0.000	0.023	0.007	0.019	0.040	0.000	0.101	0.101	0.000	0.101	----	0.000	0.000	0.000	0.001
CE195	0.000	0.017	0.008	0.017	0.043	0.000	0.086	0.086	0.000	0.086	----	0.000	0.000	0.000	0.001
CE200	0.006	0.000	0.000	0.005	0.012	0.000	0.000	0.000	0.000	0.012	----	0.000	0.000	0.000	0.000

* ABS[(Max-Min) / (Mean of Analytical Solutions)]

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Note: The statistics in the tables below are based on the Standard 140 informative example results.
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Table B16.5.1-3. Coil Loads: Total, Sensible, and Latent

Coil Load, Total (kWh,thermal)								Statistics, All Results			Analytical			22-Mar-23 TRNSYS18 TESS
Case	CA-SIS EDF	CLM2000 EDF	DOE21E CIEMAT	DOE21E NREL	E+ GARD	TRN-id TUD	TRN-re TUD	(Max-Min)			TUD	HTAL1	HTAL2	
								Min	Max	/Analytical*				
CE100	3800	3800	3841	3794	3798	3800	3798	3794	3841	1.3%	3800	3800	3800	3800
CE110	3765	3766	3804	3756	3763	3765	3763	3756	3804	1.3%	3765	3765	3765	3765
CE120	3749	3749	3763	3739	3747	3748	3747	3739	3763	0.6%	3749	3749	3749	3749
CE130	219	219	216	215	217	219	220	215	220	2.1%	219	219	219	218
CE140	198	198	196	195	196	198	199	195	199	2.0%	198	198	197	197
CE150	4517	4517	4543	4528	4509	4517	4515	4509	4543	0.8%	4518	4517	4518	4517
CE160	4501	4500	4516	4508	4491	4500	4499	4491	4516	0.6%	4501	4500	4500	4500
CE165	4538	4538	4567	4549	4529	4537	4535	4529	4567	0.9%	4537	4537	4538	4537
CE170	2233	2232	2226	2237	2225	2232	2232	2225	2237	0.5%	2232	2232	2233	2232
CE180	4495	4495	4510	4535	4481	4495	4494	4481	4535	1.2%	4495	4495	4494	4449
CE185	4507	4535	4565	4583	4523	4535	4534	4507	4583	1.7%	4535	4535	4534	4535
CE190	578	577	573	579	574	577	578	573	579	1.0%	578	577	578	577
CE195	602	601	595	602	598	601	601	595	602	1.1%	601	601	601	601
CE200	5498	5436	5534	5522	5484	5498	5498	5436	5534	1.8%	5498	5498	5498	5497

Coil Load, Sensible (kWh,thermal)								Statistics, All Results			Analytical			22-Mar-23 TRNSYS18 TESS
Case	CA-SIS EDF	CLM2000 EDF	DOE21E CIEMAT	DOE21E NREL	E+ GARD	TRN-id TUD	TRN-re TUD	(Max-Min)			TUD	HTAL1	HTAL2	
								Min	Max	/Analytical*				
CE100	3800	3800	3841	3794	3798	3800	3798	3794	3841	1.3%	3800	3800	3800	3800
CE110	3765	3766	3804	3756	3763	3765	3763	3756	3804	1.3%	3765	3765	3765	3765
CE120	3749	3749	3763	3739	3747	3748	3747	3739	3763	0.6%	3749	3749	3749	3749
CE130	219	219	216	215	217	219	220	215	220	2.1%	219	219	219	218
CE140	198	198	196	195	196	198	199	195	199	2.0%	198	198	197	197
CE150	3778	3778	3804	3786	3776	3778	3776	3776	3804	0.7%	3778	3778	3779	3778
CE160	3761	3761	3777	3769	3759	3761	3760	3759	3777	0.5%	3761	3761	3761	3761
CE165	3798	3798	3828	3809	3795	3798	3796	3795	3828	0.9%	3798	3798	3799	3798
CE170	1493	1493	1487	1498	1491	1492	1492	1487	1498	0.7%	1493	1493	1493	1493
CE180	1537	1538	1553	1607	1537	1538	1537	1537	1607	4.5%	1538	1538	1538	1538
CE185	1548	1578	1608	1653	1577	1578	1577	1548	1653	6.6%	1578	1578	1578	1579
CE190	208	208	203	212	206	208	208	203	212	4.4%	208	208	208	207
CE195	232	232	226	235	230	231	232	226	235	4.1%	232	232	232	231
CE200	4276	4215	4313	4303	4274	4277	4277	4215	4313	2.3%	4277	4277	4277	4276

Coil Load, Latent (kWh,thermal)								Statistics, All Results			Analytical			22-Mar-23 TRNSYS18 TESS
Case	CA-SIS EDF	CLM2000 EDF	DOE21E CIEMAT	DOE21E NREL	E+ GARD	TRN-id TUD	TRN-re TUD	(Max-Min)			TUD	HTAL1	HTAL2	
								Min	Max	/Analytical*				
CE100	0	0	0	0	0	0	0	0	0	----	0	0	0	0
CE110	0	0	0	0	0	0	0	0	0	----	0	0	0	0
CE120	0	0	0	0	0	0	0	0	0	----	0	0	0	0
CE130	0	0	0	0	0	0	0	0	0	----	0	0	0	0
CE140	0	0	0	0	0	0	0	0	0	----	0	0	0	0
CE150	739	739	739	742	733	739	739	733	742	1.2%	739	739	739	739
CE160	740	739	739	739	732	739	739	732	740	1.1%	739	739	739	739
CE165	740	739	739	740	733	739	739	733	740	1.0%	739	739	739	739
CE170	740	739	739	739	734	739	739	734	740	0.9%	739	739	739	739
CE180	2958	2957	2957	2928	2944	2957	2957	2928	2958	1.0%	2957	2957	2956	2912
CE185	2959	2957	2957	2930	2946	2957	2957	2930	2959	1.0%	2958	2957	2956	2957
CE190	370	370	370	366	368	370	370	366	370	1.0%	370	370	370	370
CE195	370	370	370	367	368	370	370	367	370	0.9%	370	370	370	370
CE200	1222	1221	1221	1219	1210	1221	1221	1210	1222	1.0%	1221	1221	1221	1221

* ABS[(Max-Min) / (Mean of Analytical Solutions)]

Table B16.5.1-4. Sensible Coil Load minus Zone Load (Fan Heat)

Sensible Coil - Zone Load, (Fan Heat) (kWh,thermal)								Statistics, All Results			Analytical			22-Mar-23 TRNSYS18 TESS
Case	CA-SIS EDF	CLM2000 EDF	DOE21E CIEMAT	DOE21E NREL	E+ GARD	TRN-id TUD	TRN-re TUD	(Max-Min)			TUD	HTAL1	HTAL2	
								Min	Max	/Analytical*				
CE100	144	144	187	139	144	144	142	139	187	33.6%	144	144	144	145
CE110	128	129	168	119	128	128	127	119	168	38.2%	128	128	128	128
CE120	117	117	133	108	116	117	115	108	133	21.8%	117	117	117	118
CE130	10	10	8	8	10	10	10	8	10	27.0%	10	10	10	10
CE140	8	8	7	6	8	8	8	6	8	25.6%	8	8	8	8
CE150	141	141	168	149	140	141	139	139	168	20.2%	141	141	142	142
CE160	129	129	147	137	129	129	128	128	147	14.3%	129	129	129	130
CE165	149	149	181	161	149	149	148	148	181	22.4%	149	149	150	150
CE170	73	73	69	79	73	73	73	69	79	14.2%	74	73	74	74
CE180	117	118	135	188	119	118	118	117	188	60.1%	118	119	118	119
CE185	109	139	171	215	140	139	139	109	215	76.5%	139	139	139	141
CE190	18	18	15	24	18	18	18	15	24	51.0%	18	18	18	18
CE195	23	23	18	28	23	23	23	18	28	40.8%	23	23	23	23
CE200	154	153	193	181	154	155	155	153	193	25.7%	154	155	155	155

* ABS[(Max-Min) / (Mean of Analytical Solutions)]

**ASHRAE Standard 140-2020 Test Results Comparison for Section 5.3 - HVAC Equipment Performance Tests CE100 through CE200
TRNSYS 18.05.0001 (TRNSYS18) vs. Annex B16, Section B16.5.1 Example Results
By Thermal Energy System Specialists, LLC (TESS), 22-Mar-2023**

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 B16.5.1-5. Zone Loads: Total, Sensible, and Latent

Zone Load, Total (kWh,thermal)									Statistics, All Results			Analytical			22-Mar-23
Case	CA-SIS EDF	CLM2000 EDF	DOE21E CIEMAT	DOE21E NREL	E+ GARD	TRN-id TUD	TRN-re TUD	(Max-Min) Min	(Max-Min) Max	(Max-Min) /Analytical*	TUD	HTAL1	HTAL2	TRNSYS18 TESS	
CE100	3656	3656	3654	3655	3654	3656	3656	3654	3656	0.1%	3656	3656	3656	3655	
CE110	3637	3637	3636	3637	3636	3637	3637	3636	3637	0.0%	3637	3637	3637	3636	
CE120	3632	3632	3630	3632	3631	3632	3631	3630	3632	0.0%	3632	3632	3632	3631	
CE130	209	209	207	208	207	209	209	207	209	1.3%	209	209	209	208	
CE140	190	190	189	188	188	190	190	188	190	1.1%	190	190	190	189	
CE150	4376	4376	4375	4376	4375	4376	4376	4375	4376	0.0%	4376	4376	4376	4376	
CE160	4371	4371	4370	4371	4370	4371	4371	4370	4371	0.0%	4371	4371	4371	4370	
CE165	4388	4388	4386	4387	4386	4388	4387	4386	4388	0.0%	4388	4388	4388	4387	
CE170	2159	2159	2157	2158	2157	2159	2159	2157	2159	0.1%	2159	2159	2159	2158	
CE180	4376	4376	4375	4376	4375	4376	4376	4375	4376	0.0%	4376	4376	4376	4330	
CE185	4396	4396	4394	4395	4393	4395	4395	4393	4396	0.1%	4396	4396	4396	4394	
CE190	557	559	558	558	558	559	559	557	559	0.4%	559	559	559	559	
CE195	576	579	577	577	576	578	579	576	579	0.5%	579	579	579	578	
CE200	5343	5283	5342	5343	5342	5343	5343	5283	5343	1.1%	5343	5343	5343	5342	
Zone Load, Sensible (kWh,thermal)									Statistics, All Results			Analytical			22-Mar-23
Case	CA-SIS EDF	CLM2000 EDF	DOE21E CIEMAT	DOE21E NREL	E+ GARD	TRN-id TUD	TRN-re TUD	(Max-Min) Min	(Max-Min) Max	(Max-Min) /Analytical*	TUD	HTAL1	HTAL2	TRNSYS18 TESS	
CE100	3656	3656	3654	3655	3654	3656	3656	3654	3656	0.1%	3656	3656	3656	3655	
CE110	3637	3637	3636	3637	3636	3637	3637	3636	3637	0.0%	3637	3637	3637	3636	
CE120	3632	3632	3630	3632	3631	3632	3631	3630	3632	0.0%	3632	3632	3632	3631	
CE130	209	209	207	208	207	209	209	207	209	1.3%	209	209	209	208	
CE140	190	190	189	188	188	190	190	188	190	1.1%	190	190	190	189	
CE150	3637	3637	3636	3637	3636	3637	3636	3636	3637	0.0%	3637	3637	3637	3636	
CE160	3632	3632	3630	3632	3631	3632	3631	3630	3632	0.0%	3632	3632	3632	3631	
CE165	3649	3649	3647	3648	3647	3649	3648	3647	3649	0.1%	3649	3649	3649	3648	
CE170	1420	1420	1418	1419	1418	1419	1419	1418	1420	0.1%	1420	1420	1420	1419	
CE180	1420	1420	1418	1419	1418	1419	1419	1418	1420	0.1%	1420	1420	1420	1419	
CE185	1439	1439	1437	1437	1437	1438	1438	1437	1439	0.2%	1439	1439	1439	1438	
CE190	190	190	188	188	188	190	190	188	190	1.0%	190	190	190	189	
CE195	209	209	207	208	207	209	209	207	209	1.1%	209	209	209	208	
CE200	4122	4062	4121	4122	4121	4122	4122	4062	4122	1.5%	4122	4122	4122	4121	
Zone Load, Latent (kWh,thermal)									Statistics, All Results			Analytical			22-Mar-23
Case	CA-SIS EDF	CLM2000 EDF	DOE21E CIEMAT	DOE21E NREL	E+ GARD	TRN-id TUD	TRN-re TUD	(Max-Min) Min	(Max-Min) Max	(Max-Min) /Analytical*	TUD	HTAL1	HTAL2	TRNSYS18 TESS	
CE100	0	0	0	0	0	0	0	0	0	----	0	0	0	0	
CE110	0	0	0	0	0	0	0	0	0	----	0	0	0	0	
CE120	0	0	0	0	0	0	0	0	0	----	0	0	0	0	
CE130	0	0	0	0	0	0	0	0	0	----	0	0	0	0	
CE140	0	0	0	0	0	0	0	0	0	----	0	0	0	0	
CE150	739	739	739	739	739	739	739	739	739	0.1%	739	739	739	739	
CE160	739	739	739	739	739	739	739	739	739	0.1%	739	739	739	739	
CE165	739	739	739	739	739	739	739	739	739	0.1%	739	739	739	739	
CE170	739	739	739	739	739	739	739	739	739	0.1%	739	739	739	739	
CE180	2957	2957	2957	2958	2957	2957	2957	2957	2958	0.0%	2957	2957	2957	2912	
CE185	2957	2957	2957	2958	2957	2957	2957	2957	2958	0.0%	2957	2957	2957	2957	
CE190	367	370	370	370	370	370	370	367	370	0.8%	370	370	370	370	
CE195	367	370	370	370	370	370	370	367	370	0.8%	370	370	370	370	
CE200	1221	1221	1221	1221	1221	1221	1221	1221	1221	0.0%	1221	1221	1221	1221	

* ABS[(Max-Min) / (Mean of Analytical Solutions)]

Table B16.5.1-6. Latent Coil Load minus Zone Load (Should be 0)

Latent Coil - Zone Load, (Should be 0) (kWh,thermal)								Statistics, All Results			Analytical			22-Mar-23
Case	CA-SIS EDF	CLM2000 EDF	DOE21E CIEMAT	DOE21E NREL	E+ GARD	TRN-id TUD	TRN-re TUD	(Max-Min) Min	(Max-Min) Max	(Max-Min) /Analytical*	TUD	HTAL1	HTAL2	TRNSYS18 TESS
CE100	0	0	0	0	0	0	0	0	0	----	0	0	0	0
CE110	0	0	0	0	0	0	0	0	0	----	0	0	0	0
CE120	0	0	0	0	0	0	0	0	0	----	0	0	0	0
CE130	0	0	0	0	0	0	0	0	0	----	0	0	0	0
CE140	0	0	0	0	0	0	0	0	0	----	0	0	0	0
CE150	0	0	0	2	-7	0	0	-7	2	----	0	0	0	0
CE160	1	0	0	0	-7	0	0	-7	1	----	0	0	0	0
CE165	1	0	0	1	-6	0	0	-6	1	----	0	0	0	0
CE170	1	0	0	-1	-6	0	0	-6	1	----	0	0	0	0
CE180	1	0	0	-30	-13	0	0	-30	1	----	1	0	-1	0
CE185	2	0	0	-28	-11	0	0	-28	2	----	1	0	-1	0
CE190	3	0	0	-3	-2	0	0	-3	3	----	0	0	0	0
CE195	3	0	0	-3	-1	0	0	-3	3	----	0	0	0	0
CE200	1	0	0	-2	-11	0	0	-11	1	----	0	0	0	0

* ABS[(Max-Min) / (Mean of Analytical Solutions)]

ASHRAE Standard 140-2020 Test Results Comparison for Section 5.3 - HVAC Equipment Performance Tests CE100 through CE200
TRNSYS 18.05.0001 (TRNSYS18) vs. Annex B16, Section B16.5.1 Example Results
By Thermal Energy System Specialists, LLC (TESS), 22-Mar-2023

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 B16.5.1-9. Indoor Drybulb Temperature: Mean and (Max-Min)/Mean

Mean IDB (°C)									Statistics, All Results					22-Mar-23
Case	CA-SIS EDF	CLM2000 EDF	DOE21E CIEMAT	DOE21E NREL	E+ GARD	TRN-id TUD	TRN-re TUD	(Max-Min) /Analytical*	Analytical TUD	HTAL1	HTAL2	TRNSYS18 TESS		
CE100	22.2	22.2	22.3	22.3	22.2	22.2	22.6	2.0%	22.2	22.2	22.2	22.2		
CE110	22.2	22.2	22.3	22.3	22.2	22.2	22.5	1.5%	22.2	22.2	22.2	22.2		
CE120	26.7	26.7	26.8	26.7	26.7	26.7	27.1	1.4%	26.7	26.7	26.7	26.7		
CE130	22.2	22.2	22.1	22.1	22.2	22.2	21.6	2.5%	22.2	22.2	22.2	22.2		
CE140	22.2	22.2	22.1	22.1	22.2	22.2	21.5	3.1%	22.2	22.2	22.2	22.2		
CE150	22.2	22.2	22.3	22.3	22.2	22.2	22.7	2.1%	22.2	22.2	22.2	22.2		
CE160	26.7	26.7	26.8	26.7	26.7	26.7	27.0	1.1%	26.7	26.7	26.7	26.7		
CE165	23.3	23.3	23.4	23.4	23.3	23.3	23.8	2.1%	23.3	23.3	23.3	23.3		
CE170	22.2	22.2	22.2	22.2	22.2	22.2	22.1	0.5%	22.2	22.2	22.2	22.2		
CE180	22.2	22.2	22.3	22.3	22.2	22.2	22.3	0.6%	22.2	22.2	22.2	22.2		
CE185	22.2	22.2	22.3	22.3	22.2	22.2	22.4	0.8%	22.2	22.2	22.2	22.2		
CE190	22.2	22.2	22.1	22.1	22.2	22.2	21.9	1.1%	22.2	22.2	22.2	22.2		
CE195	22.2	22.2	22.1	22.1	22.2	22.2	22.0	0.9%	22.2	22.2	22.2	22.2		
CE200	26.7	26.7	26.8	26.8	26.7	26.7	26.7	0.4%	26.7	26.7	26.7	26.7		

(Max - Min)/Mean IDB (°C)									Statistics, All Results					22-Mar-23
Case	CA-SIS EDF	CLM2000 EDF	DOE21E CIEMAT	DOE21E NREL	E+ GARD	TRN-id TUD	TRN-re TUD	(Max-Min) /Analytical*	Analytical TUD	HTAL1	HTAL2	TRNSYS18 TESS		
CE100	0.000	0.000	0.000	0.000	0.000	0.000	0.049	---	0.000	0.002	0.000	0.000		
CE110	0.000	0.000	0.000	0.000	0.000	0.000	0.048	---	0.000	0.002	0.000	0.000		
CE120	0.000	0.000	0.000	0.000	0.000	0.000	0.077	---	0.000	0.002	0.000	0.000		
CE130	0.000	0.000	0.000	0.000	0.000	0.000	0.056	---	0.000	0.001	0.000	0.000		
CE140	0.000	0.000	0.000	0.000	0.000	0.000	0.069	---	0.000	0.002	0.000	0.000		
CE150	0.000	0.000	0.000	0.000	0.000	0.000	0.054	---	0.000	0.002	0.000	0.000		
CE160	0.000	0.000	0.000	0.000	0.000	0.000	0.045	---	0.000	0.002	0.000	0.000		
CE165	0.000	0.000	0.000	0.000	0.000	0.000	0.051	---	0.000	0.002	0.000	0.000		
CE170	0.000	0.000	0.000	0.000	0.000	0.000	0.050	---	0.000	0.001	0.000	0.000		
CE180	0.000	0.000	0.000	0.000	0.000	0.000	0.035	---	0.000	0.001	0.000	0.000		
CE185	0.000	0.000	0.000	0.000	0.000	0.000	0.021	---	0.000	0.001	0.000	0.000		
CE190	0.000	0.000	0.000	0.000	0.000	0.000	0.028	---	0.000	0.001	0.000	0.000		
CE195	0.000	0.000	0.000	0.000	0.000	0.000	0.023	---	0.000	0.001	0.000	0.000		
CE200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	---	0.000	0.000	0.000	0.000		

* ABS[(Max-Min) / (Mean of Analytical Solutions)]

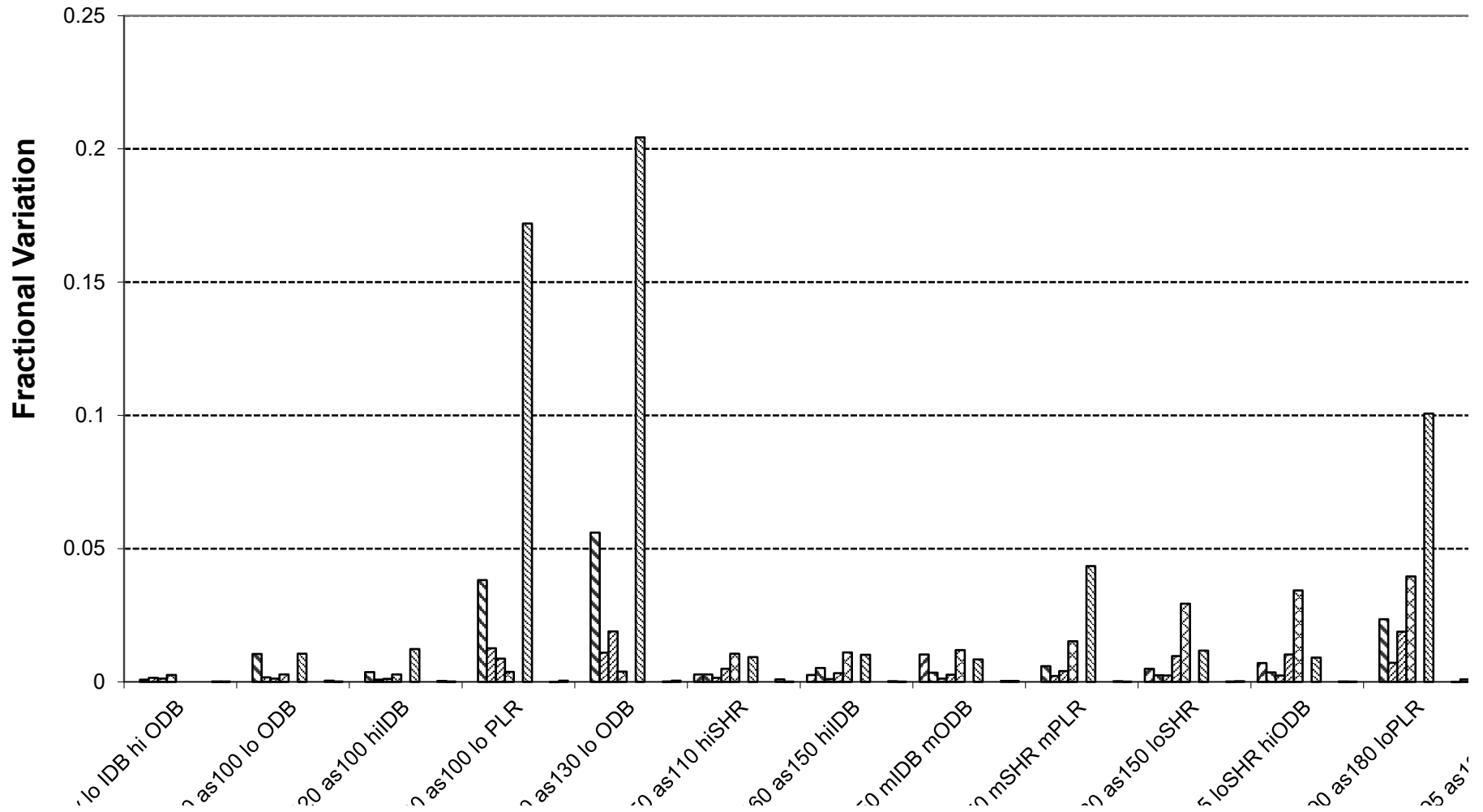
Table B16.5.1-10. Humidity Ratio: Mean and (Max-Min)/Mean

Mean Humidity Ratio									Statistics, All Results					22-Mar-23
Case	CA-SIS EDF	CLM2000 EDF	DOE21E CIEMAT	DOE21E NREL	E+ GARD	TRN-id TUD	TRN-re TUD	(Max-Min) /Analytical*	Analytical TUD	HTAL1	HTAL2	TRNSYS18 TESS		
CE100	0.0075	0.0069	0.0076	0.0074	0.0075	0.0075	0.0075	9.4%	0.0074	0.0073	0.0073	0.0077		
CE110	0.0066	0.0069	0.0070	0.0064	0.0066	0.0066	0.0066	9.8%	0.0065	0.0064	0.0064	0.0067		
CE120	0.0080	0.0070	0.0078	0.0078	0.0080	0.0080	0.0080	13.2%	0.0079	0.0079	0.0079	0.0080		
CE130	0.0075	0.0069	0.0076	0.0073	0.0075	0.0075	0.0075	9.4%	0.0074	0.0073	0.0073	0.0077		
CE140	0.0065	0.0069	0.0071	0.0064	0.0066	0.0066	0.0066	10.2%	0.0065	0.0064	0.0064	0.0067		
CE150	0.0083	0.0085	0.0082	0.0083	0.0084	0.0083	0.0085	4.0%	0.0082	0.0082	0.0082	0.0085		
CE160	0.0102	0.0101	0.0097	0.0099	0.0103	0.0101	0.0102	5.8%	0.0100	0.0099	0.0099	0.0102		
CE165	0.0093	0.0099	0.0090	0.0092	0.0094	0.0093	0.0095	9.2%	0.0093	0.0092	0.0092	0.0095		
CE170	0.0106	0.0107	0.0105	0.0105	0.0106	0.0105	0.0105	2.2%	0.0104	0.0105	0.0105	0.0106		
CE180	0.0164	0.0164	0.0166	0.0164	0.0162	0.0163	0.0164	2.6%	0.0162	0.0162	0.0162	0.0169		
CE185	0.0162	0.0171	0.0164	0.0162	0.0161	0.0162	0.0163	6.4%	0.0161	0.0161	0.0161	0.0161		
CE190	0.0160	0.0161	0.0163	0.0159	0.0159	0.0159	0.0157	3.5%	0.0158	0.0159	0.0159	0.0158		
CE195	0.0156	0.0164	0.0158	0.0155	0.0154	0.0155	0.0153	7.0%	0.0154	0.0154	0.0154	0.0154		
CE200	0.0114	0.0115	0.0109	0.0111	0.0115	0.0113	0.0113	5.1%	0.0111	0.0111	0.0111	0.0114		

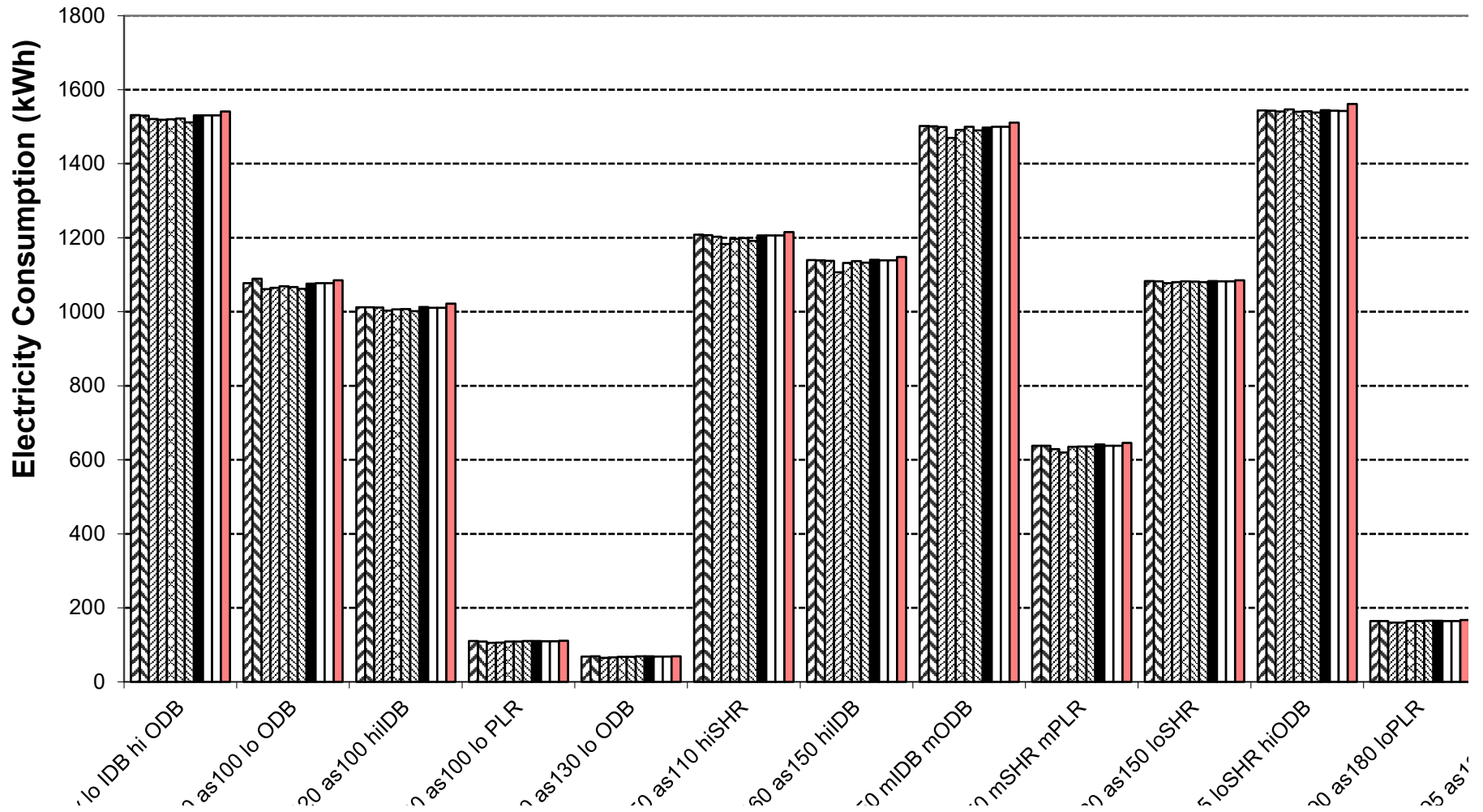
(Max - Min)/Mean Humidity Ratio									Statistics, All Results					22-Mar-23
Case	CA-SIS EDF	CLM2000 EDF	DOE21E CIEMAT	DOE21E NREL	E+ GARD	TRN-id TUD	TRN-re TUD	(Max-Min) /Analytical*	Analytical TUD	HTAL1	HTAL2	TRNSYS18 TESS		
CE100	0.000	0.022	0.000	0.000	0.001	0.000	0.000	---	0.000	0.000	0.000	0.000		
CE110	0.000	0.022	0.014	0.000	0.000	0.000	0.000	---	0.000	0.000	0.000	0.000		
CE120	0.000	0.000	0.000	0.000	0.001	0.000	0.000	---	0.000	0.000	0.000	0.000		
CE130	0.000	0.010	0.000	0.000	0.001	0.000	0.000	---	0.000	0.000	0.000	0.000		
CE140	0.000	0.012	0.014	0.000	0.001	0.000	0.000	---	0.000	0.000	0.000	0.000		
CE150	0.012	0.000	0.000	0.000	0.013	0.000	0.013	---	0.000	0.000	0.000	0.000		
CE160	0.020	0.000	0.010	0.010	0.013	0.000	0.011	---	0.000	0.000	0.000	0.000		
CE165	0.011	0.001	0.011	0.000	0.013	0.000	0.013	---	0.000	0.000	0.000	0.001		
CE170	0.000	0.000	0.010	0.000	0.011	0.000	0.024	---	0.000	0.001	0.000	0.000		
CE180	0.018	0.000	0.012	0.012	0.010	0.000	0.040	---	0.000	0.001	0.000	0.000		
CE185	0.012	0.006	0.018	0.012	0.011	0.000	0.025	---	0.000	0.001	0.000	0.000		
CE190	0.000	0.000	0.018	0.019	0.014	0.000	0.031	---	0.000	0.001	0.001	0.003		
CE195	0.000	0.006	0.019	0.019	0.014	0.000	0.024	---	0.000	0.001	0.001	0.003		
CE200	0.018	0.000	0.009	0.009	0.013	0.000	0.000	---	0.000	0.000	0.000	0.000		

* ABS[(Max-Min) / (Mean of Analytical Solutions)]

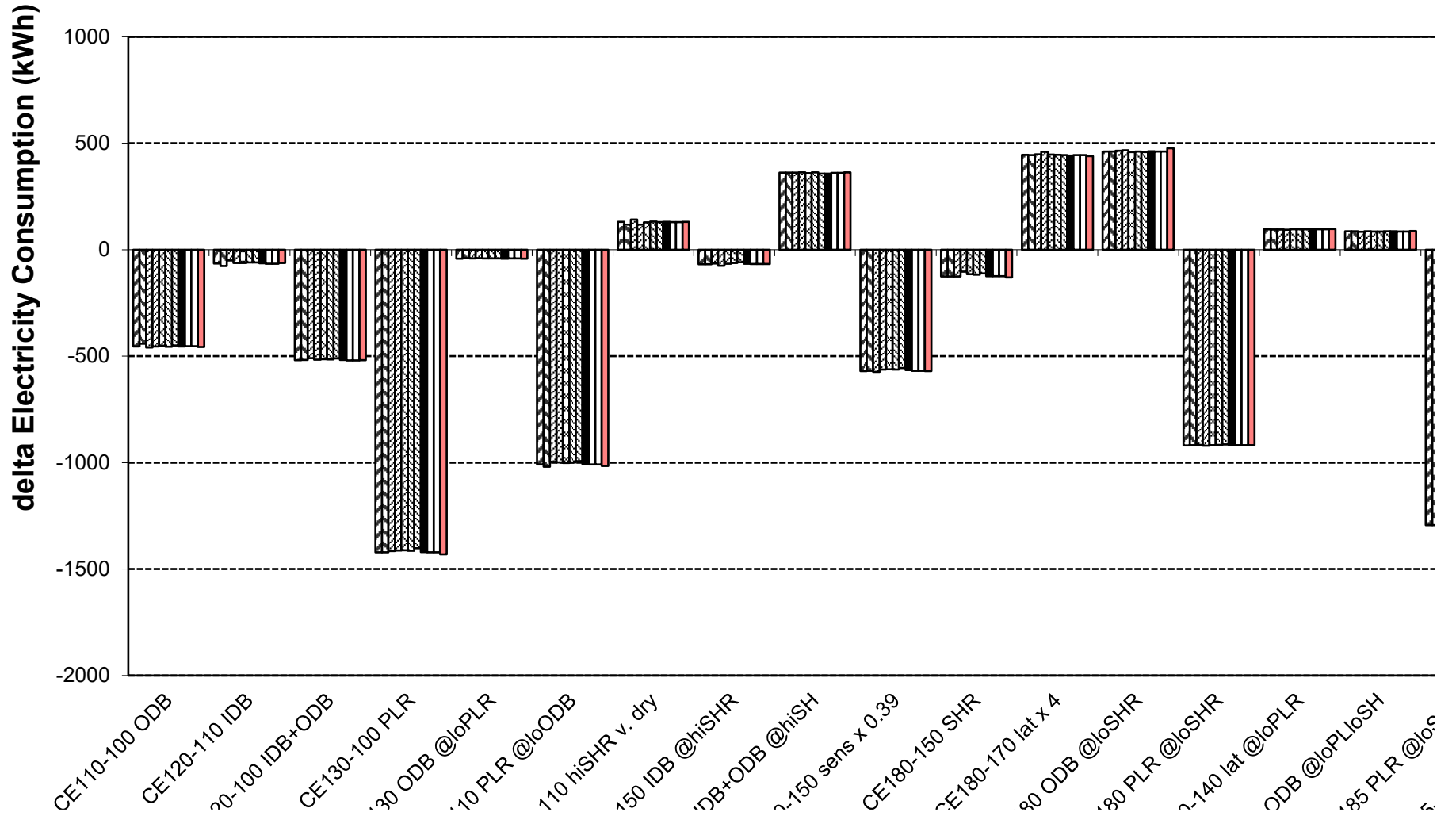
Figure B16.5.1-2.
HVAC BESTEST: (Maximum - Minimum)/Mean COP



**Figure B16.5.1-4.
HVAC BESTEST: Total Space Cooling Electricity Consumption**



**Figure B16.5.1-5.
HVAC BESTEST: Total Space Cooling Electricity Sensitivities**



**Figure B16.5.1-6.
HVAC BESTEST: Compressor Electricity Consumption**

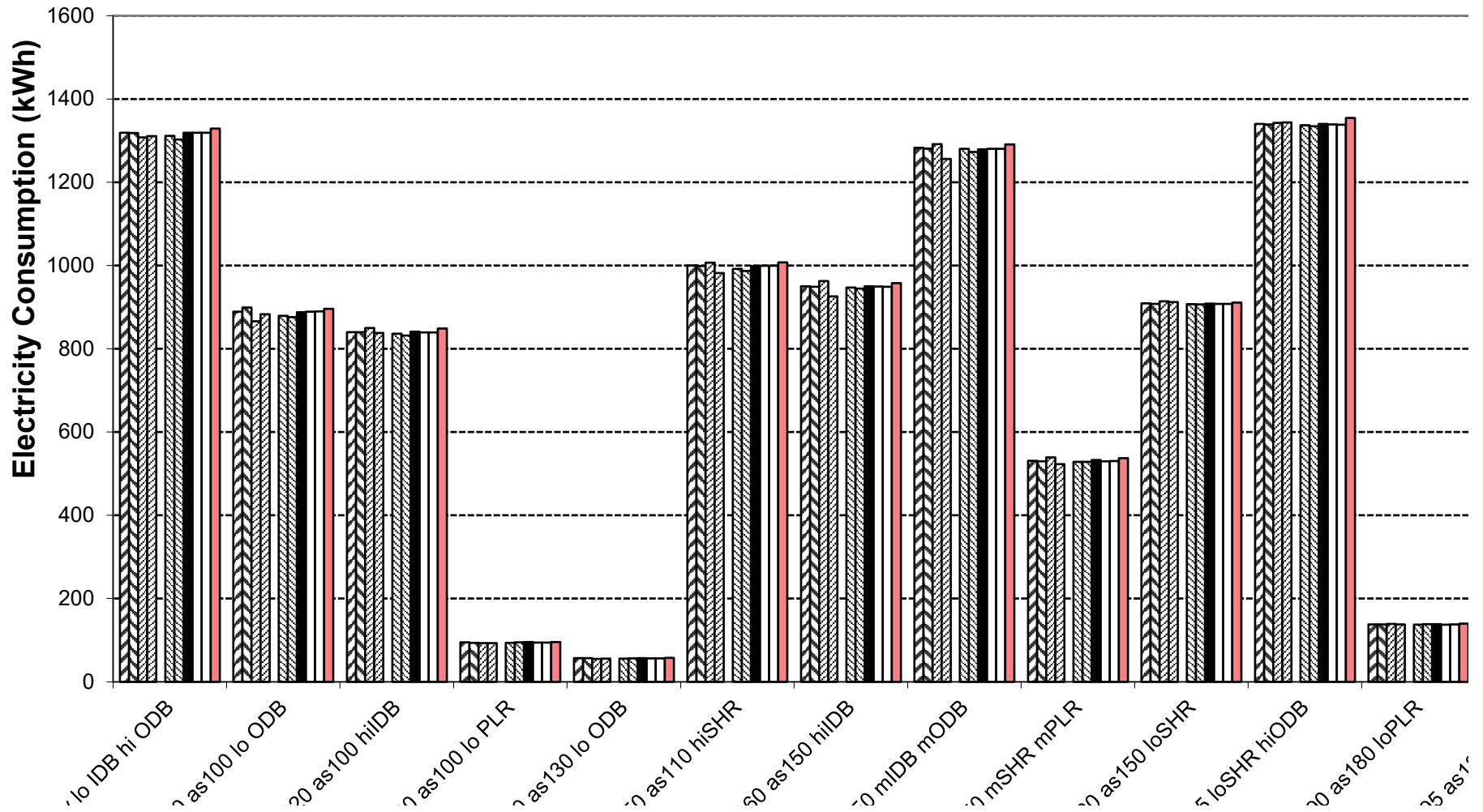


Figure B16.5.1-7.
HVAC BESTEST: Total Compressor Electricity Sensitivities

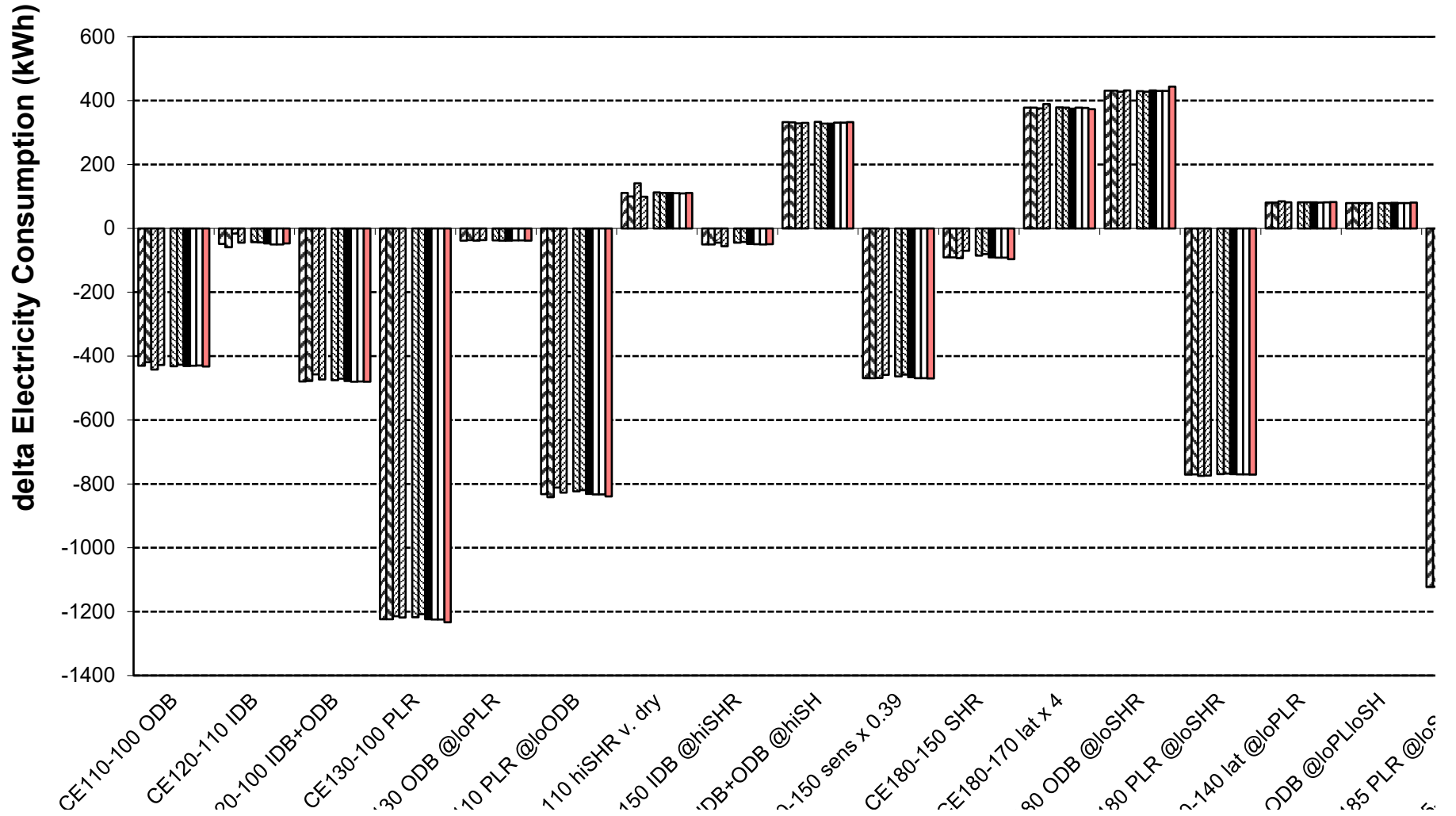


Figure B16.5.1-8.
HVAC BESTEST: Total Indoor (Supply) Fan Electricity Consumption

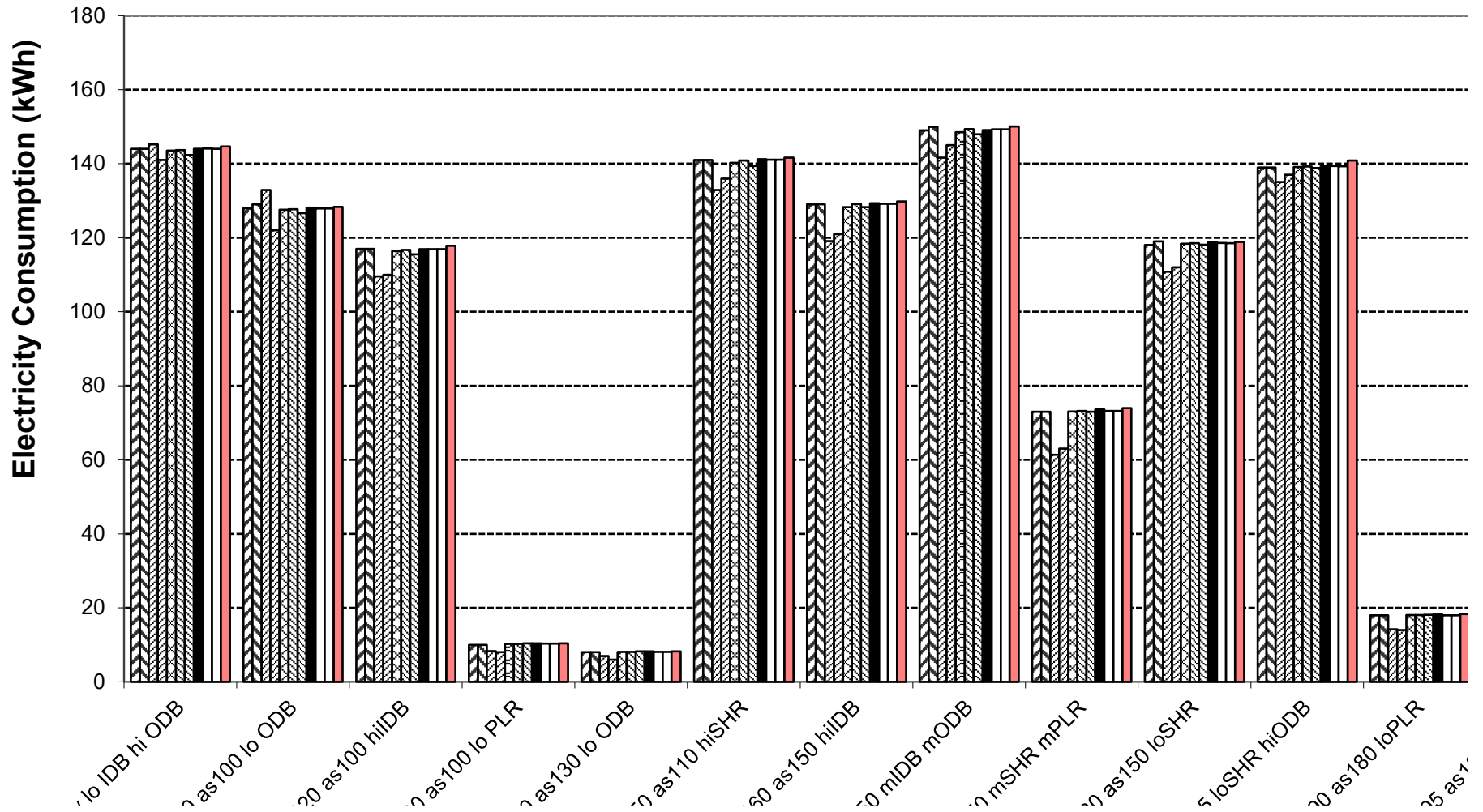


Figure B16.5.1-9.
HVAC BESTEST: Indoor (Supply) Fan Electricity Sensitivities

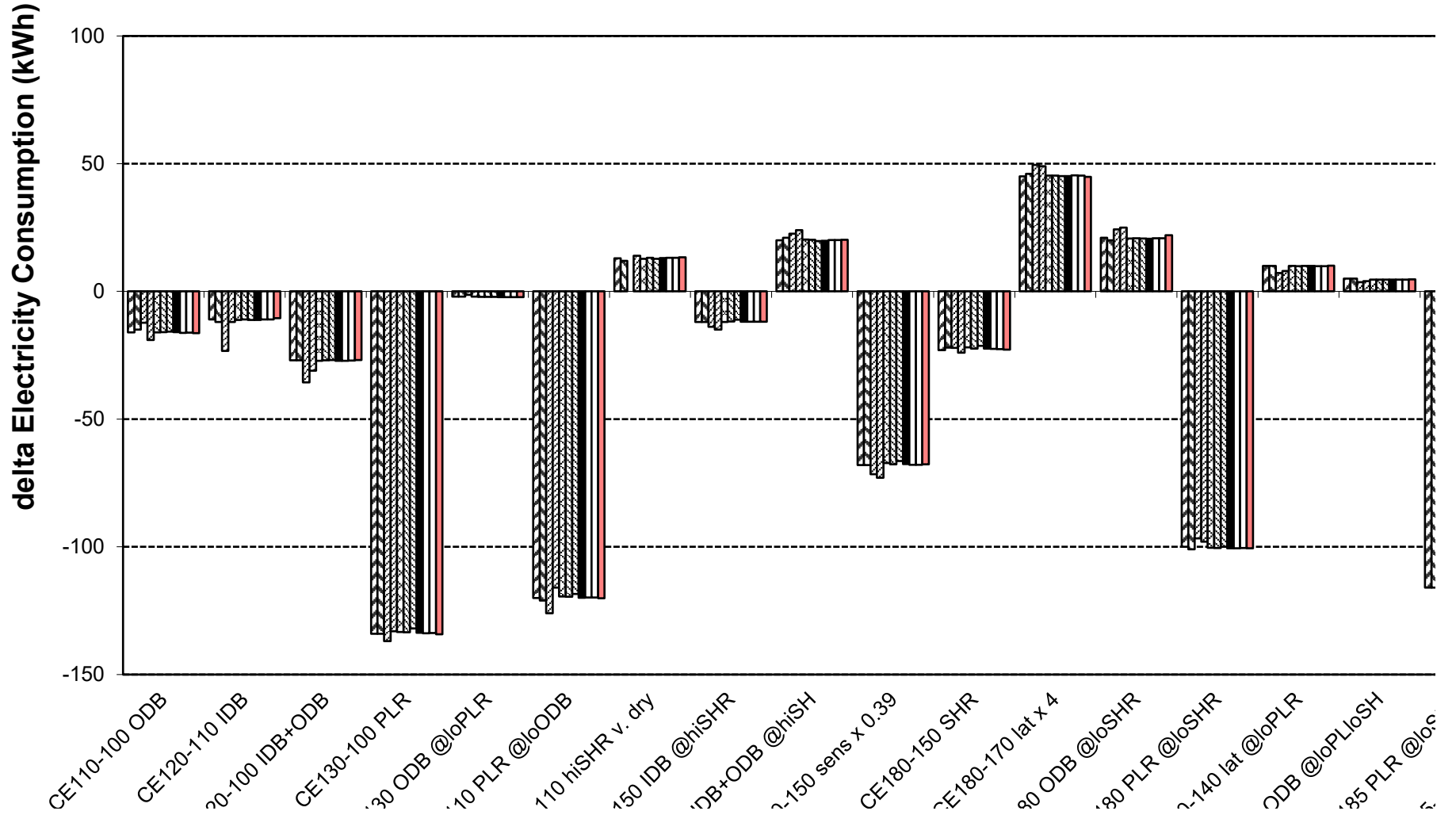


Figure B16.5.1-10.
HVAC BESTEST: Outdoor (Condenser) Fan Electricity Consumption

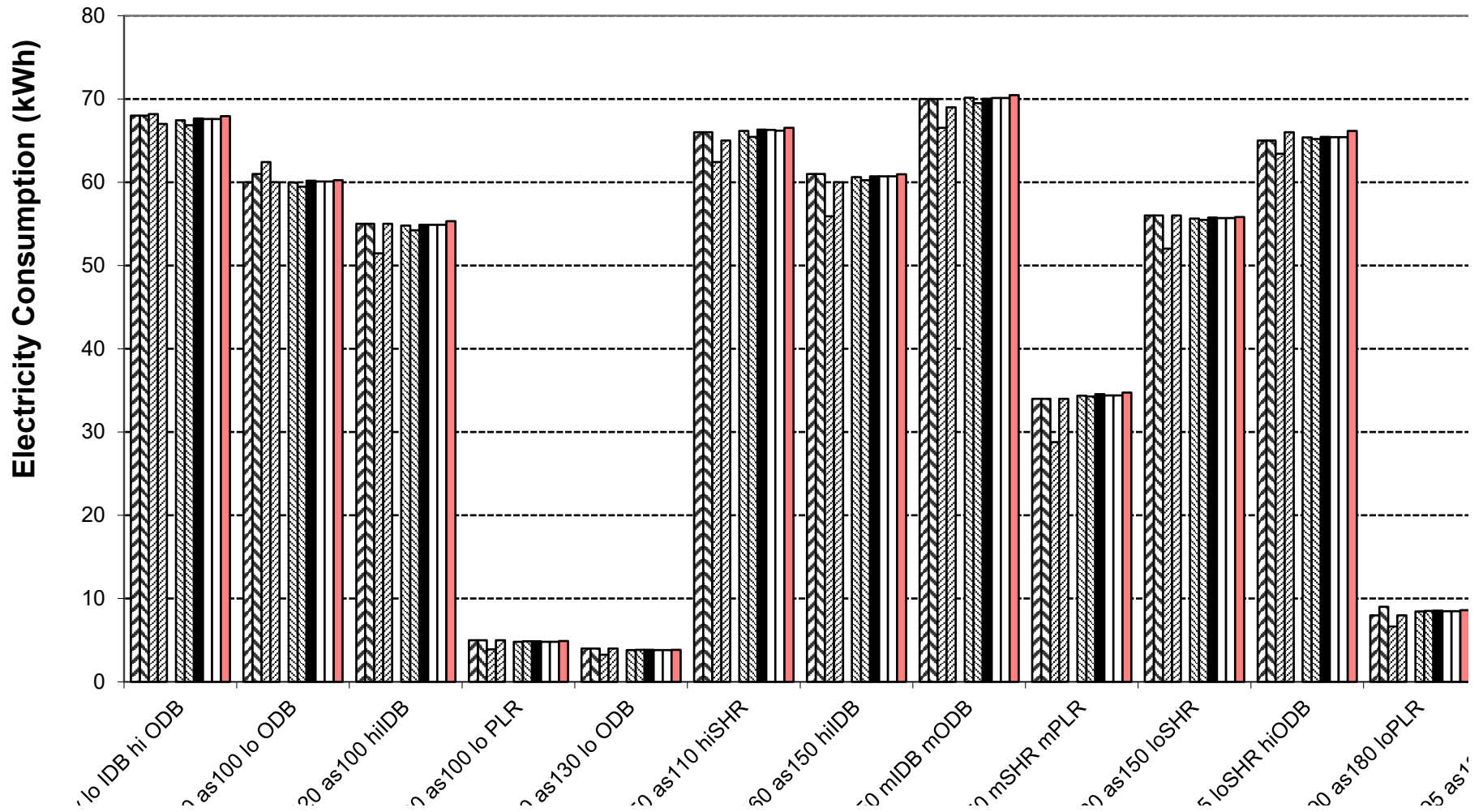


Figure B16.5.1-11.
HVAC BESTEST: Outdoor (Condenser) Fan Electricity Sensitivities

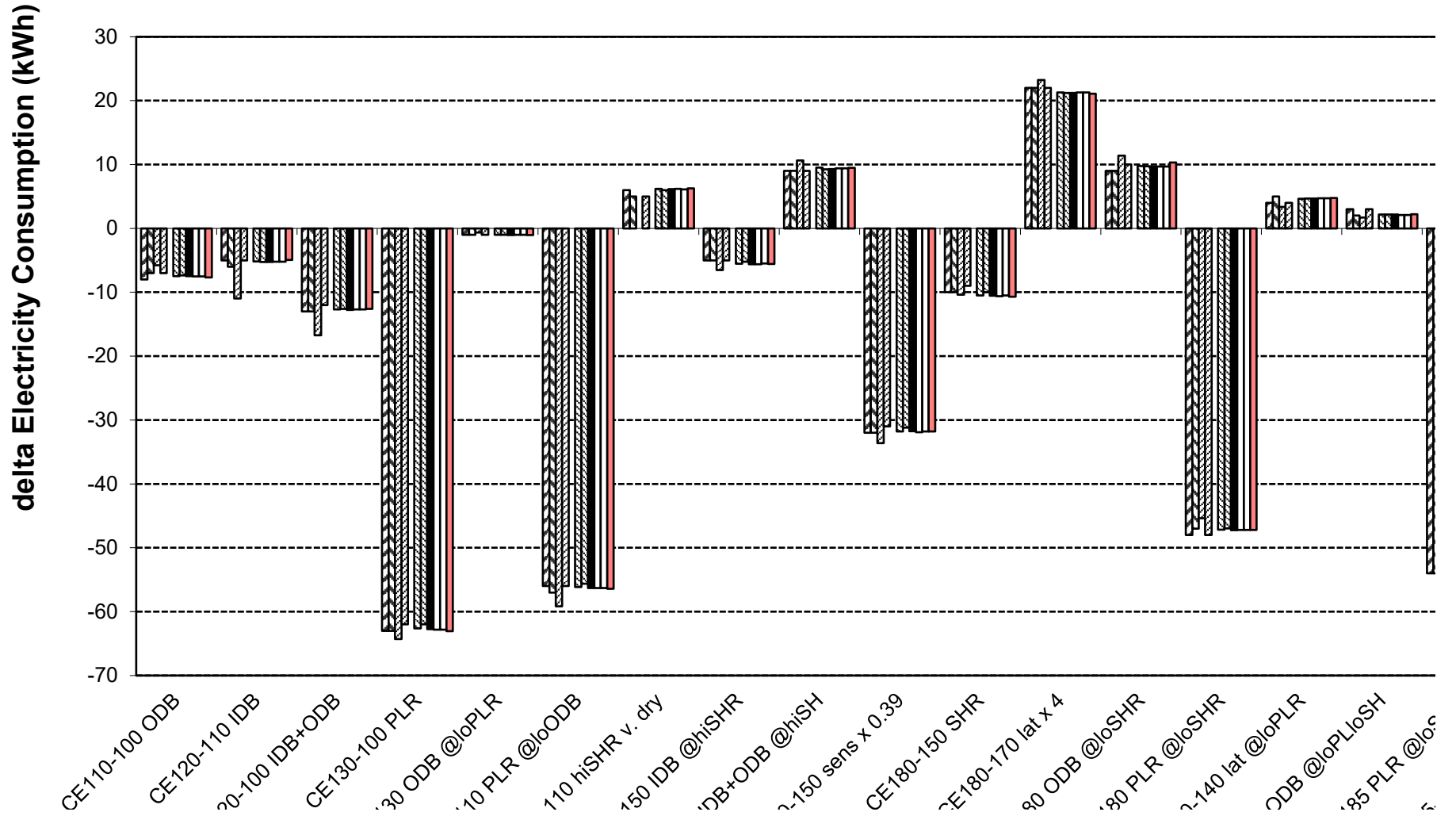


Figure B16.5.1-12.
HVAC BESTEST: Total Coil Load

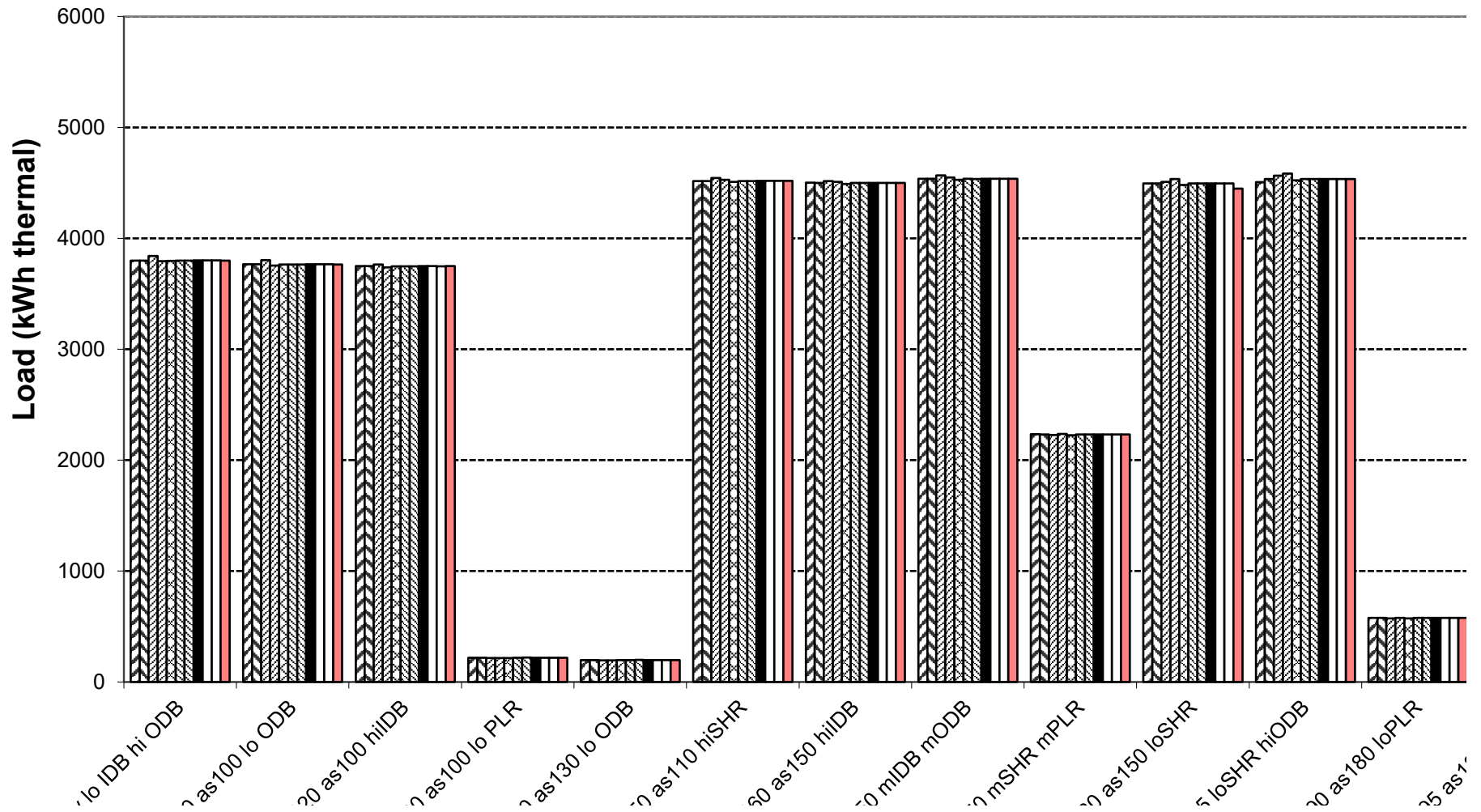
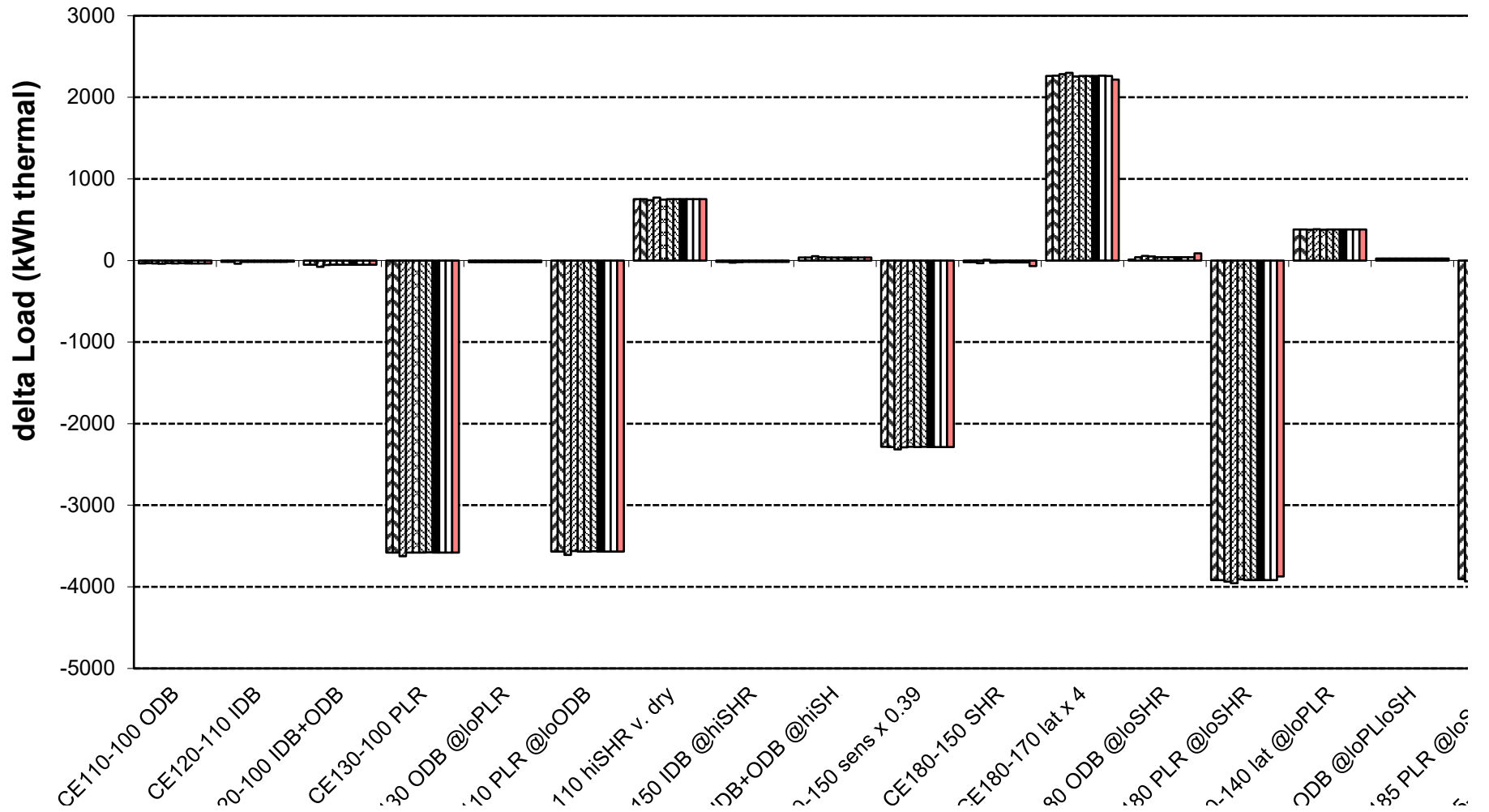
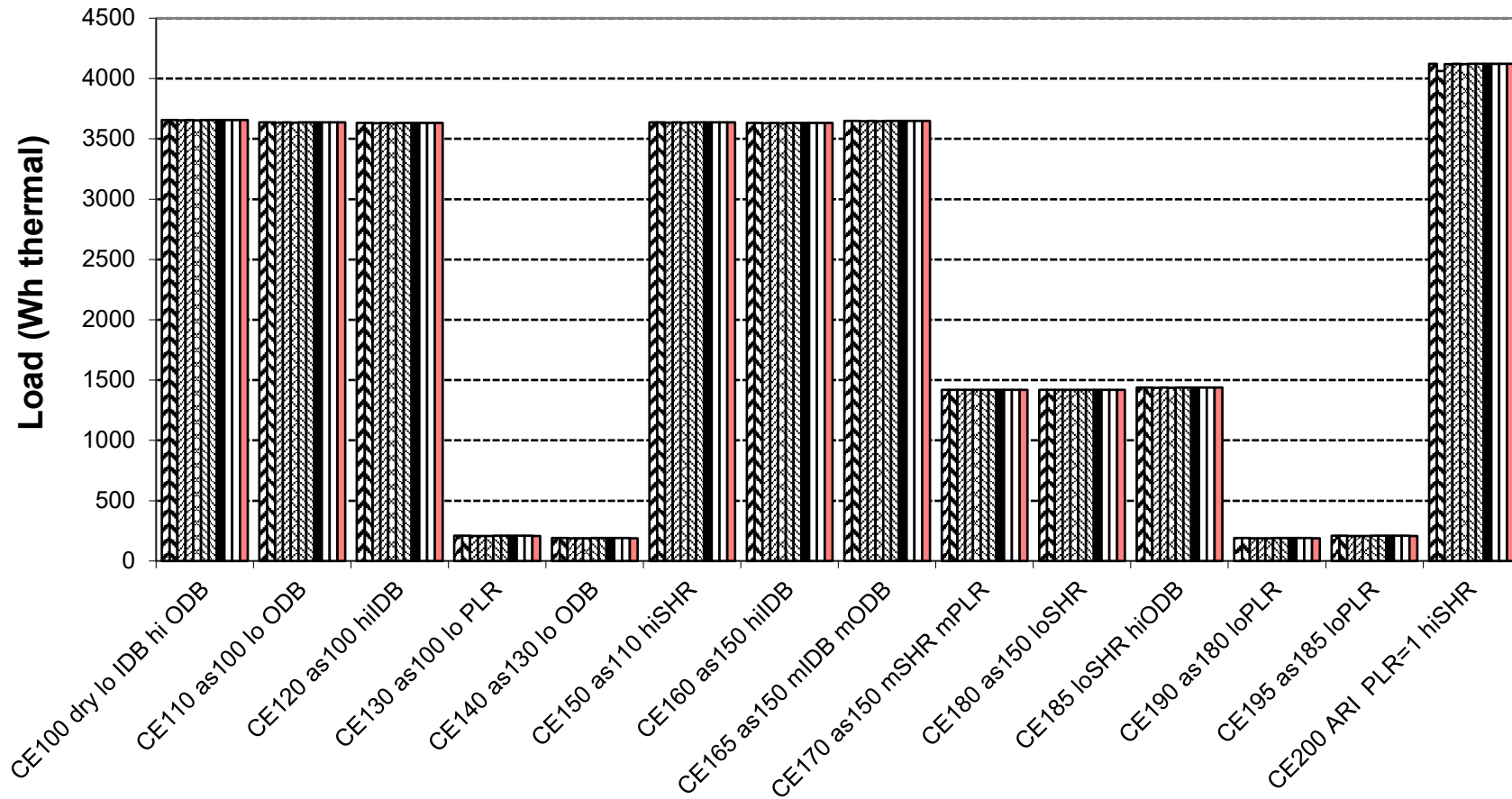


Figure B16.5.1-13.
HVAC BESTEST: Total Coil Load Sensitivities



ASHRAE Standard 140-2020 Test Results Comparison for Section 5.3 - HVAC Equipment Performance Tests CE100 through CE200
 TRNSYS 18.05.0001 (TRNSYS18) vs. Annex B16, Section B16.5.1 Example Results, by Thermal Energy System Specialists, LLC (TESS), 22-Mar-2

Figure B16.5.1-23.
HVAC BESTEST: Sensible Zone Load



CA-SIS/EDF	CLIM2000/EDF	DOE-2.1E/CIEMAT	DOE-2.1E/NREL	EnergyPlus/GARD	TRNSYS-ideal/TUD
TRNSYS-real/TUD	Analytical/TUD	Analytical/HTAL1	Analytical/HTAL2	TRNSYS18/TESS	

Figure B16.5.1-25.
HVAC BESTEST: Sensible Coil Load - Zone Load (Fan Heat)

