Public Review Draft

Proposed Addendum ab to Standard 189.1-2023

Standard for the Design of High-Performance Green Buildings

Except Low-Rise Residential Buildings

First Public Review (January, 2026)
(Draft Shows Proposed Changes to Current Standard)

This draft has been recommended for public review by the responsible project committee. To submit a comment on this proposed standard, go to the ASHRAE website at www.ashrae.org/standards-research--technology/public-review-drafts and access the online comment database. The draft is subject to modification until it is approved for publication by the Board of Directors and ANSI. Until this time, the current edition of the standard (as modified by any published addenda on the ASHRAE website) remains in effect. The current edition of any standard may be purchased from the ASHRAE Online Store at www.ashrae.org/bookstore or by calling 404-636-8400 or 1-800-727-4723 (for orders in the U.S. or Canada).

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(This foreword is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

Foreword

This proposal updates in Normative Appendix D, the hourly long range marginal emission rates (LRMER) based upon the 2024 NREL Cambium database and selection of the mid-case scenario for a 20 year period of analysis starting in 2025. These emission rates are applied when the performance compliance jurisdictional option in Section 7.6.2.2 is adopted by a jurisdiction. This proposal also updates *Table J11 – Cambium Assumptions Used for Long-Run Marginal Emission Rate* and the source Cambium spreadsheet in Informative Appendix J *Derivation of Source Energy Conversion Factors and CO_2e Emission Factors.*

[Note to Reviewers: This addendum makes proposed changes to the current standard. These changes are indicated in the text by underlining (for additions) and ~~strikethrough~~ (for deletions) except where the reviewer instructions specifically describe some other means of showing the changes. Highlights are added to show the changes. Only these changes to the current standard are open for review and comment at this time. Additional material is provided for context only and is not open for comment except as it relates to the proposed changes.]

Addendum ab to 189.1-2023

Replace Appendix D in its entirety. This updates Appendix D in its entirety. Everything here replaces the existing Appendix. The LRMER data are updated to be consistent with the Cambium data for 2024

NORMATIVE APPENDIX D

LONG-RUN MARGINAL EMISSION RATES

Normative Appendix D contains the long-run marginal emission rates for use with Section 7.6.2.2. LRMERs, based on a 20-year CO_2e time horizon, are provided for the Cambium Generation and Emission Assessment Regions shown in Figure D-1. Where comparing or combining CO_2e values, a consistent GWP time-horizon shall be used for all estimates of CO_2e.

Informative Notes:

1. The Cambium regions are similar, but not quite identical to the EPA eGRID subregions. New York state, for example, is one region for Cambium.
2. Long-run emissions rates based on a 100-year CO_2e time-horizon can be generated using the NREL Cambium Database "~~Cambium21_LRMER_GEAregions.xlsx,~~ Cambium24_workbook.xlsx~~"~~ which can be downloaded at ~~https:// data.nrel.gov/submissions/183~~ https://data.nrel.gov/submissions/289. The 100-year time-horizon data should be used whenever the results of this analysis are combined with or compared to 100-year CO_2e results in a whole building *life-cycle assessment*.

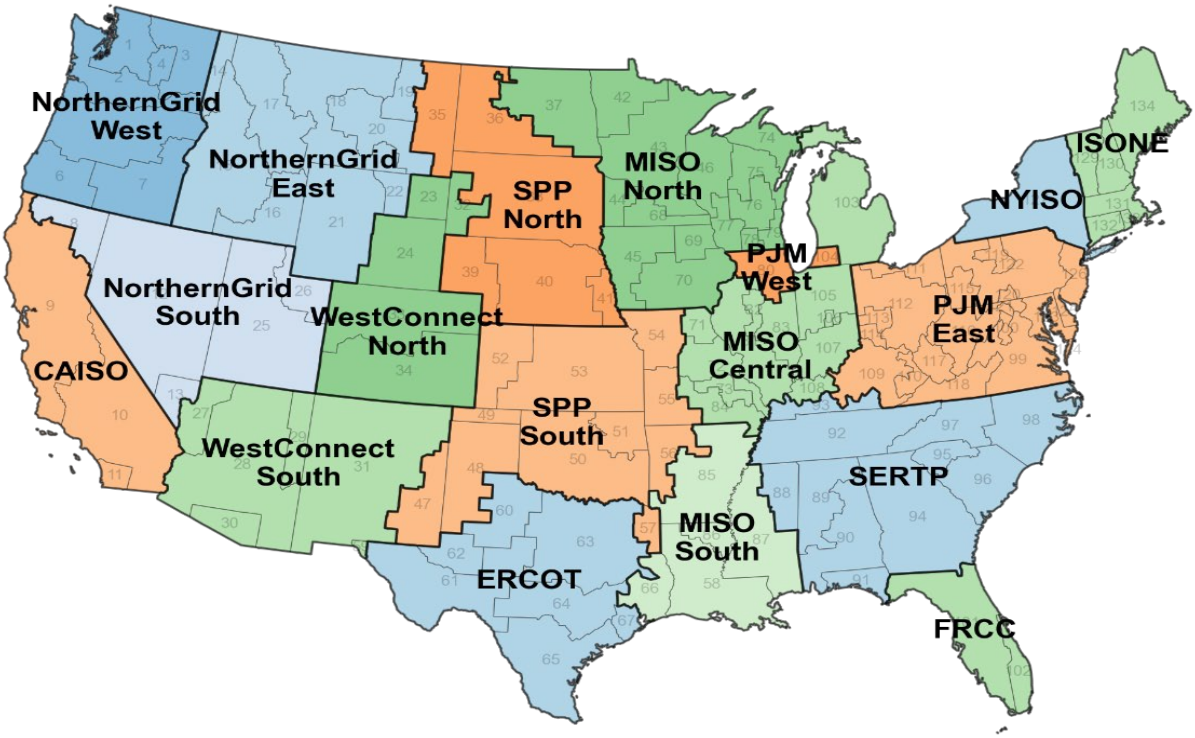

Figure D-1 – Cambium Generation and Assessment Regions

Note from Cambium: "For mappings of ZIP codes and counties to GEA regions, see the County Mapping and ZIP Mapping tabs. For the time zone that each GEA region is reported in, see the Timezones tab".

Table D-1 CAISO (kg CO2e per MWh of electricity consumption)

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
0	346	244	207	184	158	175	272	337	351	304	340	386	277
1	358	255	215	181	143	195	275	337	364	316	343	365	280
2	361	264	222	182	159	176	260	352	378	324	340	364	283
3	347	254	214	170	142	184	251	361	390	326	344	360	280
4	343	246	217	165	140	139	265	367	367	320	334	366	274
5	340	233	212	127	23	28	87	177	315	310	332	376	212
6	312	211	117	53	8	20	54	90	90	132	261	363	142
7	190	96	53	46	7	11	38	82	67	86	147	197	85
8	121	69	45	37	5	14	38	60	53	77	114	152	65
9	107	69	37	34	5	16	39	71	50	73	111	127	61
10	113	76	35	26	7	16	46	82	60	76	107	136	64
11	111	69	46	37	5	17	51	77	61	69	109	138	65
12	117	66	37	33	6	19	39	63	68	84	94	138	62
13	114	73	39	36	4	21	36	71	58	75	109	147	63
14	121	71	43	39	5	24	49	86	64	77	126	162	70
15	158	79	45	40	7	18	43	98	71	98	239	313	96
16	317	189	130	75	19	11	52	163	224	250	307	372	170
17	317	234	207	159	109	100	171	259	292	272	309	372	233
18	313	219	202	168	134	154	218	310	293	266	312	370	249
19	315	219	196	167	128	154	226	305	292	263	307	367	247
20	316	221	210	169	130	151	222	302	303	271	311	375	249
21	315	231	207	191	141	153	232	293	310	281	318	365	253
22	325	234	214	188	138	157	236	327	322	282	322	371	260
23	328	244	210	193	142	163	247	342	326	277	336	393	268

Table D-2 ERCOT (kg CO2e per MWh of electricity consumption)

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
0	288	328	260	223	304	359	338	369	358	264	286	321	312
1	277	314	251	224	300	348	350	361	355	253	284	296	304
2	281	316	231	219	290	360	354	361	357	242	280	305	303
3	278	317	239	232	291	369	351	360	361	251	291	302	307
4	285	333	251	228	313	367	349	376	371	270	296	308	315
5	290	335	273	238	302	341	361	389	396	274	295	307	319
6	308	325	260	188	210	251	303	315	309	237	283	317	277
7	266	305	195	139	166	217	261	255	234	152	178	264	221
8	184	244	181	138	169	205	253	252	228	161	144	204	200
9	164	212	152	140	163	219	263	262	217	151	138	204	195
10	163	196	140	128	167	233	274	262	218	152	131	199	195
11	152	153	129	146	179	237	271	261	236	164	135	196	197
12	141	143	129	137	187	239	280	268	248	167	137	183	198
13	141	150	132	141	187	236	282	276	259	169	136	190	202
14	137	144	141	154	192	238	298	284	257	175	141	193	207
15	158	171	144	158	195	247	288	287	284	188	180	227	220
16	257	226	160	174	209	257	311	313	310	276	307	332	265
17	327	339	263	266	276	308	338	359	395	357	341	353	328
18	312	339	321	320	348	439	420	456	436	328	322	331	371
19	306	345	283	283	334	374	414	401	384	322	314	332	346
20	313	340	266	280	315	362	385	391	362	329	312	353	338
21	304	328	267	296	322	371	377	398	371	326	313	343	339
22	318	320	254	252	341	362	383	400	367	294	311	331	332
23	308	327	263	236	327	363	361	401	359	271	305	309	323

Table D-3 FRCC (kg CO2e per MWh of electricity consumption)

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
0	585	595	602	599	650	658	641	645	655	641	574	606	624
1	588	612	605	595	628	672	653	667	668	630	599	614	631
2	593	608	603	600	618	646	673	676	663	621	586	615	629
3	595	606	601	595	613	631	659	667	629	618	587	611	620
4	592	603	599	597	616	633	649	670	643	613	581	613	620
5	576	597	588	576	553	589	619	672	659	636	586	603	607
6	551	569	465	290	269	353	322	354	410	474	531	600	428
7	391	380	226	224	234	313	273	302	281	290	254	360	294
8	250	264	218	206	223	286	251	277	268	264	241	279	253
9	236	256	207	209	228	270	253	278	270	265	245	261	249
10	234	252	209	208	225	282	263	298	277	273	229	267	254
11	233	240	210	202	228	286	270	278	279	258	219	260	250
12	232	244	206	212	236	273	273	305	275	303	219	271	258
13	223	252	209	213	250	292	286	303	309	296	229	257	265
14	227	252	212	223	261	301	294	314	314	320	239	280	275
15	243	286	221	238	286	346	323	354	343	347	244	320	302
16	375	341	260	269	336	388	364	417	423	460	429	488	379
17	522	511	438	412	451	461	448	511	526	561	491	548	488
18	507	511	464	475	545	537	536	569	550	557	482	548	526
19	497	509	465	471	526	531	537	569	550	560	487	550	524
20	514	518	461	487	555	558	563	574	555	573	487	555	536
21	535	536	519	513	577	565	555	568	573	587	526	570	554
22	554	559	539	518	590	578	566	594	590	605	550	583	571
23	556	559	539	518	616	588	595	613	609	620	544	598	582

Table D-4 ISONE (kg CO2e per MWh of electricity consumption)

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
0	214	211	166	122	178	205	275	296	193	178	191	203	206
1	201	206	148	122	183	190	266	284	181	176	176	196	197
2	196	216	159	111	181	188	265	286	183	173	169	186	196
3	204	210	155	133	170	180	264	278	186	170	165	177	193
4	209	219	153	123	160	164	251	285	182	169	183	185	193
5	218	227	158	112	155	162	234	269	184	179	191	206	193
6	229	223	153	113	163	172	230	266	188	177	206	223	197
7	235	220	151	112	175	176	222	271	186	177	200	228	198
8	227	212	164	112	173	182	247	289	193	186	205	225	204
9	229	216	163	110	175	191	258	296	192	177	212	230	207
10	226	208	161	117	176	189	274	303	207	191	213	238	212
11	230	209	157	113	172	186	277	307	208	190	217	237	213
12	229	202	161	109	175	184	279	307	211	190	213	238	213
13	225	196	156	109	177	189	281	306	207	184	208	234	212
14	222	190	160	102	179	192	283	305	208	192	222	237	213
15	224	209	163	105	177	193	288	307	213	204	238	255	220
16	233	224	194	127	188	202	300	324	235	217	235	258	234
17	235	234	207	139	208	232	326	333	239	217	235	261	244
18	239	236	206	143	213	238	324	330	233	219	238	261	245
19	237	232	205	140	207	245	324	330	234	217	236	256	242
20	235	232	203	149	214	231	327	332	234	208	233	258	242
21	228	230	202	138	211	234	322	330	234	200	229	258	239
22	222	223	189	135	202	234	307	323	226	198	220	245	231
23	216	218	184	127	175	215	291	304	218	174	204	229	217

Table D-5 MISO Central (kg CO2e per MWh of electricity consumption)

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
0	293	290	171	186	213	226	357	399	311	204	297	311	275
1	299	302	177	182	220	237	368	407	313	189	296	301	278
2	302	303	178	184	226	225	361	398	312	181	299	315	277
3	310	316	176	186	230	225	363	408	301	187	312	320	281
4	320	321	178	187	218	202	349	396	294	190	329	327	278
5	336	322	190	163	177	177	302	304	270	183	335	345	261
6	331	311	162	155	173	175	283	261	216	163	312	355	245
7	287	268	157	152	173	171	256	255	211	158	262	308	224
8	258	249	150	151	161	169	251	243	200	164	256	305	215
9	255	246	151	145	155	165	243	239	193	175	254	323	214
10	250	237	152	143	156	164	247	223	186	169	252	324	211
11	243	226	149	141	160	169	247	225	200	165	257	321	210
12	242	230	149	144	161	172	245	223	202	172	257	311	211
13	240	225	151	150	166	176	257	227	202	173	259	323	214
14	245	240	157	148	159	185	262	237	206	172	281	342	221
15	277	258	155	155	161	184	281	254	213	177	353	365	238
16	300	310	180	178	189	194	311	316	295	222	353	364	270
17	308	310	213	218	239	245	388	422	327	215	359	346	304
18	296	302	201	210	250	301	446	445	308	198	323	346	308
19	292	297	185	186	231	261	419	417	292	201	314	340	292
20	287	302	186	192	205	248	384	402	285	191	309	348	283
21	291	286	177	191	230	249	388	391	296	193	293	338	282
22	302	292	171	181	218	237	391	393	300	192	302	327	280
23	296	280	186	179	217	236	383	384	304	197	309	299	276

Table D-6 MISO North (kg CO2e per MWh of electricity consumption)

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
0	319	322	210	169	224	248	386	347	276	210	268	368	282
1	324	326	213	180	223	240	381	335	271	198	274	363	280
2	318	339	230	179	221	239	365	325	285	207	277	353	280
3	304	349	232	174	233	250	365	328	284	212	278	369	284
4	321	365	259	181	232	230	360	352	291	227	307	385	294
5	336	377	256	172	187	199	327	329	282	229	323	394	286
6	343	374	226	157	181	220	328	295	229	221	323	413	278
7	332	339	214	146	167	221	320	288	211	207	297	392	264
8	293	300	209	148	159	228	318	296	223	193	282	358	253
9	288	297	212	139	163	219	309	288	222	200	269	367	250
10	282	281	207	142	160	214	310	281	225	200	276	364	248
11	280	283	190	137	163	213	314	279	226	190	270	375	246
12	281	285	191	136	162	214	313	277	223	199	260	377	246
13	289	276	180	134	159	219	311	282	221	193	269	377	246
14	278	277	180	139	159	223	312	286	222	204	281	383	248
15	297	289	187	144	171	229	322	303	237	227	320	415	264
16	337	339	230	170	184	240	332	334	302	279	328	425	294
17	344	360	293	228	252	290	387	415	363	270	332	414	332
18	329	350	287	251	290	333	440	434	343	259	321	421	342
19	336	342	276	233	265	328	417	412	305	251	314	412	328
20	338	349	270	221	255	317	410	386	316	251	320	413	324
21	330	337	242	215	247	296	390	377	302	239	308	421	312
22	330	330	226	195	238	281	384	372	283	222	299	413	302
23	320	334	215	188	220	253	385	362	302	218	260	376	289

Table D-7 MISO South (kg CO2e per MWh of electricity consumption)

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
0	426	444	364	381	450	458	552	518	484	431	468	455	456
1	427	444	362	375	470	476	517	499	479	424	460	444	451
2	429	446	369	375	476	474	510	499	488	424	467	452	453
3	420	450	380	383	487	465	523	511	474	423	471	458	456
4	440	438	394	397	497	466	527	516	496	433	483	465	465
5	435	437	385	358	344	341	443	470	478	436	465	487	424
6	431	447	312	253	256	279	348	334	310	304	436	490	351
7	355	384	264	226	252	267	331	309	294	251	283	380	301
8	308	329	254	215	245	262	321	298	286	245	263	319	280
9	292	314	246	213	252	270	332	311	297	247	250	314	280
10	298	310	241	216	260	278	329	312	304	246	245	324	283
11	297	306	236	213	265	260	317	309	296	241	243	334	278
12	304	305	239	215	270	267	327	301	274	233	243	326	277
13	288	303	243	215	266	267	318	298	278	237	244	332	276
14	286	300	246	217	269	269	326	301	286	238	243	326	278
15	289	295	249	222	279	285	340	324	300	250	283	363	292
16	409	380	276	250	316	310	380	353	387	375	471	458	360
17	407	448	355	339	396	374	429	428	455	405	448	448	411
18	406	446	351	374	438	433	478	462	447	395	434	442	428
19	407	443	347	347	430	410	467	451	436	388	429	441	418
20	406	435	341	336	424	405	448	441	437	389	446	453	415
21	420	442	343	338	449	419	484	466	460	408	466	448	431
22	431	452	363	350	462	475	539	513	495	443	490	446	458
23	421	438	383	389	474	495	551	539	489	445	486	454	467

Table D-8 Northern Grid East (kg CO2e per MWh of electricity consumption)

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
0	314	354	276	279	287	288	398	401	443	380	341	331	341
1	313	366	270	273	281	277	383	407	425	392	332	327	337
2	310	366	288	272	278	273	392	408	445	390	323	329	339
3	319	370	280	276	279	276	406	402	435	379	326	334	340
4	319	365	288	268	275	281	398	405	429	388	330	335	340
5	320	361	290	275	274	280	411	397	443	385	337	341	342
6	319	371	287	262	264	285	409	395	424	388	333	338	339
7	324	377	272	267	265	294	412	403	408	372	322	323	336
8	317	367	274	264	278	279	428	392	403	354	330	331	334
9	305	359	272	253	266	275	405	405	421	369	318	341	332
10	308	370	265	258	262	277	418	418	423	349	320	333	334
11	307	374	270	260	266	277	411	417	423	344	316	340	335
12	306	360	278	263	265	272	389	410	426	358	317	326	332
13	314	373	272	255	266	274	415	418	423	359	317	333	337
14	306	367	277	261	275	271	400	409	416	353	322	327	334
15	311	358	271	253	272	280	393	405	417	361	335	336	335
16	320	375	287	253	264	275	412	416	447	385	344	341	345
17	326	370	296	274	262	292	438	445	454	396	346	343	356
18	325	378	288	284	298	292	435	447	462	398	346	329	359
19	326	365	290	276	307	297	424	445	447	387	355	322	356
20	318	373	286	290	295	296	423	440	454	384	344	325	354
21	319	368	283	289	301	309	423	448	456	399	346	327	357
22	319	374	285	280	285	294	416	431	436	396	338	329	349
23	319	351	275	278	293	290	408	427	462	383	338	327	347

Table D-9 Northern Grid South (kg CO2e per MWh of electricity consumption)

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
0	420	441	355	350	382	388	455	491	501	453	448	495	433
1	432	430	358	354	381	388	464	519	501	454	441	500	437
2	423	433	374	345	377	413	477	533	515	463	446	483	442
3	423	446	359	352	388	410	484	539	532	466	444	478	445
4	408	429	364	339	391	416	494	527	525	473	448	469	442
5	408	437	367	349	304	269	433	530	529	488	453	476	421
6	416	448	361	241	202	209	245	288	392	466	448	488	350
7	425	413	224	186	167	181	230	197	206	229	327	470	273
8	293	268	179	166	163	183	215	181	177	191	251	355	219
9	231	240	175	178	166	184	210	184	174	184	227	290	204
10	230	229	181	177	180	206	207	179	179	187	239	276	206
11	225	233	183	152	193	214	202	184	189	193	233	274	206
12	225	229	199	191	181	204	204	193	188	200	229	274	209
13	217	220	185	174	185	190	208	200	197	192	221	278	205
14	236	226	177	175	183	191	220	212	202	193	244	300	213
15	255	233	186	192	178	201	216	229	202	209	286	341	225
16	350	278	210	190	166	190	238	294	251	299	433	464	275
17	409	440	366	263	207	187	291	396	411	436	452	478	355
18	419	447	399	359	360	338	420	480	465	439	444	476	421
19	423	445	399	368	378	391	462	506	463	442	440	474	435
20	413	447	395	366	387	394	468	497	455	446	434	471	433
21	411	435	373	351	385	387	468	497	457	436	432	472	428
22	433	444	396	356	372	376	455	491	471	444	454	488	433
23	421	443	374	348	374	373	457	503	481	449	443	489	431

Table D-10 Northern Grid West (kg CO2e per MWh of electricity consumption)

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
0	156	156	106	95	97	101	139	169	194	161	158	160	140
1	153	156	103	92	99	103	142	169	194	159	154	158	140
2	157	159	103	93	96	96	139	166	198	160	156	160	140
3	151	157	106	88	99	101	136	168	203	160	150	158	139
4	155	156	102	93	98	94	131	171	198	161	154	161	139
5	154	161	101	87	92	92	113	163	189	161	157	159	135
6	157	157	98	78	86	88	111	142	167	148	153	161	129
7	148	145	92	73	92	92	107	148	159	137	144	153	124
8	138	146	83	75	85	92	102	144	155	131	140	147	120
9	139	143	85	75	89	90	100	146	157	134	142	149	121
10	142	138	85	76	90	89	107	142	163	136	140	151	122
11	135	142	89	79	88	92	106	146	160	134	141	148	122
12	136	144	78	70	91	90	106	147	156	137	143	153	121
13	131	145	88	74	89	93	105	143	155	137	143	148	121
14	138	146	89	73	89	88	116	145	156	137	147	151	123
15	144	150	95	78	91	90	111	146	169	146	154	164	128
16	157	156	101	89	79	88	116	150	180	161	160	165	134
17	161	159	105	94	96	97	128	164	192	166	161	164	141
18	157	160	107	96	105	105	134	174	196	166	159	171	145
19	155	161	107	95	105	110	139	177	198	165	160	165	145
20	155	162	105	95	103	109	140	172	197	159	158	167	144
21	154	158	104	98	99	108	138	175	189	163	160	164	142
22	152	153	99	92	101	103	136	171	190	165	154	162	140
23	156	158	100	100	100	102	135	172	193	162	160	162	141

Table D-11 NYISO (kg CO2e per MWh of electricity consumption)

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
0	167	168	122	109	154	177	266	266	174	142	164	153	176
1	154	158	124	118	163	174	268	249	168	141	168	147	173
2	149	165	113	108	161	169	258	254	172	134	155	164	170
3	159	172	117	117	175	173	258	252	166	136	165	141	172
4	147	173	125	125	157	170	270	268	178	144	155	154	175
5	157	194	135	123	167	171	256	258	185	153	158	160	178
6	187	191	142	120	175	188	274	270	192	167	194	185	193
7	180	181	137	123	188	188	284	267	201	160	197	196	194
8	174	179	148	122	192	191	300	278	206	163	182	181	196
9	176	177	142	114	186	193	298	290	214	168	187	178	198
10	177	175	150	108	175	195	296	288	205	165	175	182	196
11	172	175	143	104	182	189	294	290	206	164	170	181	195
12	168	172	144	109	183	190	273	289	209	166	179	180	194
13	162	174	143	99	186	187	268	283	215	162	179	177	192
14	167	178	142	105	188	187	271	279	208	161	180	177	193
15	171	171	139	104	183	176	276	280	205	172	192	192	194
16	178	167	144	111	183	194	281	279	220	165	203	177	198
17	183	167	143	113	198	205	294	297	204	162	205	191	202
18	180	177	145	117	183	202	283	281	206	157	205	189	198
19	182	177	139	118	182	196	278	278	197	157	199	191	195
20	178	177	135	114	179	196	272	265	183	153	194	191	190
21	178	179	128	102	173	196	273	258	187	153	191	185	188
22	180	172	125	98	167	200	270	257	181	142	185	184	184
23	156	162	114	103	145	181	273	266	171	128	179	168	175

Table D-12 PJM East (kg CO2e per MWh of electricity consumption)

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
0	389	406	329	303	392	380	470	483	425	354	398	405	397
1	385	400	334	301	382	382	470	487	416	350	395	401	395
2	389	405	329	304	380	383	471	485	418	353	394	402	395
3	381	406	337	315	396	376	470	487	423	353	398	411	398
4	397	417	354	332	411	390	472	493	428	363	411	417	408
5	405	432	368	339	392	357	461	487	432	366	422	429	409
6	417	437	364	296	352	331	447	454	394	359	429	442	396
7	410	415	317	273	348	320	429	431	361	313	395	434	374
8	381	392	292	259	338	324	422	424	360	316	366	418	361
9	375	379	278	246	337	326	423	418	359	316	370	418	358
10	366	377	274	230	326	327	428	414	361	313	371	421	355
11	366	367	275	227	322	322	423	419	362	316	369	415	353
12	365	364	267	217	321	324	423	418	364	321	361	415	352
13	358	359	274	225	320	326	423	421	362	323	356	415	352
14	354	359	270	228	323	334	425	423	370	320	358	419	354
15	374	370	268	238	327	344	435	431	378	343	404	440	368
16	402	409	319	253	361	359	450	446	414	383	442	458	396
17	419	441	381	336	405	399	474	479	454	395	434	457	426
18	418	438	390	362	438	438	504	512	458	386	434	454	440
19	415	433	383	358	438	452	506	511	454	382	429	456	438
20	414	430	378	350	429	436	497	500	454	381	425	449	432
21	407	426	370	337	424	430	492	500	448	367	421	444	426
22	403	421	351	323	413	417	484	489	438	352	412	434	415
23	398	420	333	304	401	403	479	487	424	344	408	413	404

Table D-13 PJM West (kg CO2e per MWh of electricity consumption)

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
0	379	358	176	140	186	235	395	397	345	172	306	369	294
1	364	348	181	149	182	222	409	395	322	140	307	356	287
2	360	358	180	143	183	221	425	383	330	151	311	359	289
3	371	369	187	147	207	238	426	401	320	176	313	372	299
4	383	374	205	166	223	222	402	431	335	202	339	389	309
5	413	383	214	159	207	225	369	363	321	210	346	409	305
6	409	387	205	166	208	248	397	369	270	186	321	432	304
7	371	368	216	141	193	230	437	397	285	199	298	381	299
8	311	370	190	153	181	239	440	405	292	183	310	389	295
9	346	358	193	147	182	228	436	418	296	184	314	414	300
10	331	328	168	139	176	228	428	413	310	184	325	424	296
11	316	311	177	137	183	229	415	405	282	171	322	450	291
12	308	309	182	142	181	224	410	393	293	178	324	436	289
13	297	305	184	133	187	215	417	397	278	184	314	445	288
14	309	335	181	137	181	214	416	410	305	184	327	440	294
15	362	331	191	143	188	217	441	402	331	212	393	442	312
16	383	377	225	169	211	259	470	458	386	251	377	409	340
17	389	373	252	204	266	303	534	515	415	239	358	399	364
18	367	368	242	200	286	341	554	515	394	231	336	405	363
19	357	368	247	167	261	308	506	524	388	223	333	388	348
20	360	368	230	174	250	295	541	502	409	214	321	383	346
21	388	369	213	183	255	296	480	460	398	210	321	408	339
22	391	346	211	140	226	266	470	453	379	176	322	416	324
23	371	349	197	138	212	280	435	402	372	178	312	348	306

Table D-14 SERTP (kg CO2e per MWh of electricity consumption)

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
0	432	445	360	409	443	444	505	518	473	452	439	469	451
1	422	435	367	388	436	445	496	529	477	437	440	456	446
2	440	440	367	361	447	456	492	530	475	412	436	455	445
3	434	450	373	362	445	466	492	535	470	414	441	456	447
4	427	444	381	371	460	463	489	545	480	410	432	463	449
5	434	434	383	385	450	416	483	541	475	427	419	458	443
6	427	431	363	338	345	361	407	435	410	406	438	477	405
7	417	408	317	316	340	343	388	400	367	335	370	455	374
8	367	369	308	316	340	344	373	393	374	329	343	408	356
9	364	369	311	311	335	336	361	375	353	332	347	393	350
10	371	360	307	308	337	325	361	375	346	325	341	392	347
11	369	358	305	319	322	324	365	373	354	331	345	389	347
12	366	360	311	315	322	317	368	372	348	338	351	404	348
13	370	361	305	319	328	325	373	376	345	332	344	403	349
14	373	366	311	316	331	329	382	375	347	337	359	412	354
15	373	366	304	322	331	335	387	383	351	340	359	435	358
16	401	391	316	329	343	344	420	413	376	387	427	473	385
17	433	434	358	371	379	382	453	457	433	418	434	480	420
18	429	435	361	391	414	414	490	493	449	414	425	477	436
19	426	430	352	379	429	434	500	501	437	409	426	474	437
20	425	428	350	384	403	411	496	486	436	415	433	476	431
21	432	435	355	389	411	432	496	486	448	416	424	478	436
22	426	438	355	389	412	419	495	492	448	418	432	463	435
23	436	440	354	393	430	423	507	507	468	417	428	474	442

Table D-15 SPP North (kg CO2e per MWh of electricity consumption)

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
0	383	417	268	233	282	368	540	525	434	310	385	504	397
1	383	429	266	237	290	350	539	496	424	287	381	494	390
2	390	451	264	236	297	348	534	514	411	290	395	497	393
3	385	472	291	241	312	350	526	519	429	288	410	509	401
4	392	457	302	250	338	369	549	518	436	332	409	511	411
5	396	468	333	264	305	355	558	510	446	338	404	517	414
6	440	457	331	241	298	369	494	504	421	320	426	540	409
7	420	435	310	254	292	341	502	483	392	311	407	537	396
8	371	417	306	249	289	325	503	482	409	317	380	517	386
9	375	399	308	232	286	332	484	456	389	314	363	546	380
10	380	402	298	216	290	329	476	451	410	311	360	529	377
11	377	370	273	224	280	334	506	462	408	306	356	531	377
12	383	378	276	227	287	331	494	457	398	308	356	545	378
13	387	358	275	222	294	345	506	468	387	301	371	520	379
14	380	365	271	234	309	361	501	467	406	303	374	524	383
15	399	410	270	240	304	369	496	490	409	319	395	572	398
16	428	450	300	255	316	364	488	512	414	398	443	572	418
17	455	463	377	311	346	404	528	573	509	393	430	593	455
18	434	470	388	351	390	467	581	581	509	382	445	566	471
19	444	476	352	310	381	441	575	553	494	364	420	559	456
20	439	464	322	294	369	408	568	512	451	341	413	562	438
21	434	433	342	265	346	402	575	535	437	343	413	558	434
22	428	421	318	255	346	369	559	522	433	327	415	534	420
23	395	429	298	245	334	392	540	515	441	320	380	498	408

Table D-16 SPP South (kg CO2e per MWh of electricity consumption)

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
0	356	421	279	256	297	350	440	458	441	324	353	390	368
1	358	420	299	255	299	337	436	464	447	288	361	366	365
2	362	418	296	256	299	341	439	482	468	308	372	371	372
3	359	460	305	280	326	360	444	486	477	320	375	386	384
4	371	448	326	270	344	361	457	482	478	332	394	372	389
5	383	468	314	269	314	347	422	483	492	342	393	411	389
6	382	460	285	234	273	334	384	407	415	321	382	434	362
7	390	417	250	233	284	315	373	414	351	263	306	381	335
8	326	393	231	236	277	297	376	384	353	264	272	360	318
9	285	363	233	215	288	310	369	393	335	275	290	350	314
10	302	361	221	218	280	316	395	383	353	273	287	351	318
11	301	335	230	217	288	308	388	378	352	272	288	364	316
12	298	342	231	232	289	315	390	379	347	265	274	354	316
13	290	305	232	227	278	326	398	385	351	260	268	348	314
14	295	304	220	230	278	331	397	385	358	259	260	341	314
15	312	337	220	238	273	330	397	398	372	303	309	393	330
16	380	379	229	241	295	335	406	426	408	338	400	449	361
17	424	450	326	325	315	359	457	486	488	397	425	454	411
18	403	467	365	355	425	467	530	557	516	391	404	437	450
19	408	446	324	336	414	449	505	520	479	374	384	444	430
20	396	435	291	302	379	401	482	474	455	353	372	421	402
21	394	417	289	285	370	378	462	472	446	352	372	433	394
22	389	417	285	265	370	363	467	483	455	321	353	414	387
23	359	429	300	249	346	368	451	463	423	304	355	404	376

Table D-17 West Connect North (kg CO2e per MWh of electricity consumption)

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
0	293	337	262	245	264	251	317	306	329	293	327	367	300
1	285	312	253	233	269	237	303	319	316	292	311	383	294
2	294	331	267	230	275	236	318	325	332	295	318	359	299
3	309	328	254	232	284	238	307	322	345	293	314	346	298
4	295	324	263	237	271	235	306	319	333	299	315	348	296
5	283	324	259	228	238	220	294	313	347	299	310	343	289
6	287	324	248	225	214	216	254	266	293	276	294	337	271
7	263	290	215	214	201	207	253	244	238	249	272	319	248
8	248	278	200	208	195	218	253	234	218	245	247	292	237
9	232	268	207	218	205	206	267	252	239	244	228	274	237
10	244	257	216	193	194	208	246	238	239	234	247	275	233
11	235	264	208	203	209	207	259	234	235	245	246	270	235
12	251	275	212	213	210	212	260	249	236	252	246	278	242
13	244	268	212	207	216	203	255	255	247	252	245	292	242
14	235	289	208	211	214	213	247	246	249	245	249	277	240
15	271	291	218	223	213	209	248	264	254	266	311	328	258
16	299	318	235	220	211	211	262	292	324	341	346	385	286
17	303	339	285	258	254	261	311	331	378	341	353	369	315
18	300	334	276	284	304	267	322	331	357	327	331	351	315
19	303	323	272	274	277	270	306	330	344	321	316	354	308
20	292	330	272	267	272	253	322	325	348	319	315	351	306
21	282	333	259	264	274	272	327	337	344	310	323	347	306
22	300	329	277	252	259	273	299	316	324	322	322	350	302
23	287	319	264	259	268	250	312	328	328	315	313	354	300

Table D-18 West Connect South (kg CO2e per MWh of electricity consumption)

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
0	382	405	349	362	359	373	468	517	487	374	385	420	412
1	395	401	343	372	377	393	474	525	506	377	415	418	422
2	386	400	345	371	378	380	485	534	500	379	407	409	420
3	395	401	347	370	397	376	460	511	498	382	394	406	416
4	388	386	343	358	390	394	494	516	512	369	401	404	418
5	402	397	352	348	316	283	433	509	502	382	396	406	397
6	404	409	318	279	206	214	276	322	336	318	368	406	321
7	353	321	225	213	182	200	276	299	269	206	274	352	266
8	246	253	203	196	182	184	252	287	251	190	217	246	227
9	214	239	202	194	177	196	242	264	260	195	219	220	220
10	213	233	193	205	192	193	258	260	269	209	213	202	222
11	218	253	200	188	192	202	260	260	278	222	201	212	226
12	202	232	200	220	185	202	266	277	285	209	213	206	228
13	194	240	195	206	204	183	260	292	297	233	210	220	232
14	189	252	196	212	191	192	270	311	298	252	213	201	236
15	241	233	198	205	183	189	265	316	298	267	293	254	247
16	337	282	225	212	154	195	295	351	346	329	381	401	288
17	386	390	345	280	198	230	344	433	452	380	385	416	350
18	385	394	353	352	384	378	442	498	499	390	387	401	411
19	385	396	370	388	398	387	459	498	497	382	383	412	418
20	384	388	354	376	407	388	439	495	484	383	376	410	412
21	377	385	355	371	399	382	458	489	480	366	367	402	408
22	400	401	348	370	374	394	451	504	497	382	380	408	414
23	392	402	356	373	364	381	462	499	483	388	379	411	412

Table D-19 Avoided Emissions from Off-Site Purchases of Renewable Energy (kg CO2e per MWh of electricity consumption)

GEA Region	Solar	Wind	Hydro	Average
CAISO	62	188	204	180
ERCOT	209	282	280	271
FRCC	272	472	488	444
ISONE	207	207	212	211
MISO Central	208	251	245	253
MISO North	244	283	287	279
MISO South	288	390	368	373
Northern Grid East	335	331	339	341
Northern Grid South	216	345	351	339
Northern Grid West	116	132	131	133
NYISO	195	175	185	184
PJM East	353	386	381	388
PJM West	283	296	303	305
SERTP	352	406	408	402
SPP North	377	399	413	399
SPP South	319	362	360	358
West Connect North	237	281	275	277
West Connect South	233	338	360	331

Update Table J11 in Informative Appendix J as follows, the rest of the text is unchanged outside of the MS Excel filename.
Note is Informative Appendix was updated in Addendum S to Std 189.1-2023

J5. LONG-RUN MARGINAL EMISSION RATES

The long-run marginal emission rates published in normative Appendix E were taken from the Cambium database as published in the **"**Cambium24_workbook.xlsx" workbook, and using the settings shown in Table J11

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Table J11 – Cambium Assumptions Used for Long-Run Marginal Emission Rate

User Input	Value	Description
Emission	CO2e	Specify the emission: CO_2, CH_4, N_2O, or CO_2-equivalent (CO_2e, which combines all three per the GWP values selected below). Default is CO_2.
Emission stage	Combined	Specify the emission stage: Direct combustion, precombustion processes (fuel extraction, processing, and transport), or the combination of the two. Default is combustion.
Start year	2025	Enter the year that the intervention being studied would take effect. Start year must be between 2025 and 2050. Default is 2025.
Evaluation period (years)	20	Enter the expected lifetime or analysis period of the intervention being studied. Default is 20.
Discount rate (real)	0.03	Enter 0 for a simple average over the timespan. Enter a positive value for a damages-equivalent levelization that places greater weight on near-term years.
Scenario	Mid-case	Specify which scenario (i.e., different potential futures) to draw from. See the Scenario Definitions tab for more information.
Global Warming Potentials	20-year (AR6)	Specify what global warming potential values to use. Default is 100-year from the IPCC's AR6, and custom values can be entered on the GWP tab.
Location	End-use	Specify the location of the intervention. Most electrical consumption would be end-use, whereas large scale generators would typically be at the busbar. Default is end-use.
2050 Fraction	0.00	Values beyond 2050 are estimated with the 2050 values. Analysts are advised to use caution when selecting values that place significant weight on 2050 (e.g., greater than 50%)

Avoided annual emissions in Table 7.6.2.2.1 and avoided monthly average hourly emissions in Normative Appendix D are based on the hourly signatures of electricity production for solar, wind and hydro, taken from the Cambium database. The avoided emissions for "other renewables" assume that the generators produce a constant amount of electricity for all hours of the year.

Background information for Std 189.1 committee members (to be deleted before published for public review).
Note:

I downloaded the Cambium 2024 workbook and used that data. The relevant data is on the Levelized LRMER tab. I have a second spreadsheet that I used to pull data from Cambium and produce the tables.

The Cambium GEA Regions are totally different from the 2021 regions that we previously used. Some regions like the Pacific Northwest have been subdivided. Other regions in the southeast have been consolidated. The previous regions were similar to the eGRID regions. The new ones are not. The new ones are better.

I selected the Mid-Case scenario. See the end of this document (and the table below) for other assumptions. This information should be added to the end of the Informative Appendix explaining the emission rates.

User Input	*Value*	*Description*
Emission	CO2e	Specify the emission: CO2, CH4, N2O, or CO2-equivalent (CO2e, which combines all three per the GWP values selected below). Default is CO2.
Emission stage	Combined	Specify the emission stage: Direct combustion, precombustion processes (fuel extraction, processing, and transport), or the combination of the two. Default is combustion.
Start year	2025	Enter the year that the intervention being studied would take effect. Start year must be between 2025 and 2050. Default is 2025.
Evaluation period (years)	20	Enter the expected lifetime or analysis period of the intervention being studied. Default is 20.
Discount rate (real)	0.03	Enter 0 for a simple average over the timespan. Enter a positive value for a damages-equivalent levelization that places greater weight on near-term years.
Scenario	**Mid-case**	Specify which scenario (i.e., different potential futures) to draw from. See the Scenario Definitions tab for more information.
Global Warming Potentials	20-year (AR6)	Specify what global warming potential values to use. Default is 100-year from the IPCC's AR6, and custom values can be entered on the GWP tab.
Location	End-use	Specify the location of the intervention. Most electrical consumption would be end-use, whereas large scale generators would typically be at the busbar. Default is end-use.
2050 Fraction	0.00	Values beyond 2050 are estimated with the 2050 values. Analysts are advised to use caution when selecting values that place significant weight on 2050 (e.g., greater than 50%)

Summary of the Eight Scenarios in Cambium 2024

1. Mid-case: Central estimates for inputs such as technology costs (2024 Annual Technology Baseline (ATB) moderate projections), fuel prices (Annual Energy Outlook 2023 (AEO2023) reference[a]), and demand growth (1.8% compound annual growth rate [CAGR])

2. Low Renewable Energy and Battery Costs: The same set of base assumptions as the first scenario but where renewable energy and battery costs are assumed to be lower and performance improvements greater

3. High Renewable Energy and Battery Costs: The same set of base assumptions as the first scenario but where renewable energy and battery costs are assumed to be higher and performance improvements lesser

4. High Demand Growth: The same set of base assumptions as the first scenario but where demand growth is assumed to average 2.8% from 2024 through 2050

5. Low Natural Gas Prices: The same set of base assumptions as the first scenario but where natural gas prices are assumed to be lower

6. High Natural Gas Prices: The same set of base assumptions as the first scenario but where natural gas prices are assumed to be higher

7. Low Renewable Energy and Battery Costs With High Natural Gas Prices: The same set of base assumptions as the first scenario but with higher natural gas prices and where renewable energy and battery costs are assumed to be lower and performance improvements greater

8. High Renewable Energy and Battery Costs With Low Natural Gas Prices: The same set of base assumptions as the first scenario but with lower natural gas prices and where renewable energy and battery costs are assumed to be higher and performance improvements lesser.

From NREL 2025. (Gagnon et al.) *Cambium 2024 Scenario Descriptions and Documentation*. National Renewable Energy Laboratory. NREL/TP-6A40-93005. April 2025 https://docs.nrel.gov/docs/fy25osti/93005.pdf

For the 2023 standard, I found wind, solar and hydro signatures that were used by Cambium. My definition of a signature is a 12x24 table that adds up to 1 and shows the month-hour pattern of electricity generation. These data are used in conjunction with the emissions signatures to calculate the avoided emissions shown in Table D-19. I was unable to find similar data for the 2024 Cambium data, so I mapped each of the new GEA Regions to one of the old GEA regions and used the old generation signatures. I doubt that the signatures will change much so I think this is a reasonable assumption. My mapping is shown below.

New Region	*Old*
CAISO	CAMXc
ERCOT	ERCTc
FRCC	FRCCc
ISONE	NEWEc
MISO Central	SRMWc
MISO North	MROWc
MISO South	SRMVc
Northern Grid East	NWPPc
Northern Grid South	NWPPc
Northern Grid West	NWPPc
NYISO	NYSTc
PJM East	RFCEc
PJM West	RFCWc
SERTP	SRSOc
SPP North	MROWc
SPP South	SPNOc
West Connect North	RMPAc
West Connect South	AZNMc

I use conditional formatting in my spreadsheets to assist data checking. I left the colors in the table, but previously, ASHRAE decided to remove the colors for publication. Your committee may find them useful.

This draft of Appendix D completely replaces the existing appendix. I did not bother with underlines strikethroughs, etc.

The following table is a summary of the results. I have not compared this to the old LRMERs. The units are all kg/MWh, or grams per kWh (same thing).

GEA Region	*Min*	*Avg*	*Max*
CAISO	4	180	393
ERCOT	128	271	456
FRCC	202	444	676
ISONE	102	211	333
MISO Central	141	253	446
MISO North	134	279	440
MISO South	213	373	552
Northern Grid East	253	341	462
Northern Grid South	152	339	539
Northern Grid West	70	133	203
NYISO	98	184	300
PJM East	217	388	512
PJM West	133	305	554
SERTP	304	402	545
SPP North	216	399	593
SPP South	215	358	557
West Connect North	193	277	385
West Connect South	154	331	534