Code of Ethics Commitment

In this and all other ASHRAE meetings, we will act with honesty, fairness, courtesy, competence, inclusiveness and respect for others, which exemplify our core values of excellence, commitment, integrity, collaboration, volunteerism and diversity, and we shall avoid all real or perceived conflicts of interests.

Diversity Commitment

ASHRAE is committed to providing a welcoming environment. Our culture is one of inclusiveness, acknowledging the inherent value and dignity of each individual. We proactively pursue and celebrate diverse and inclusive communities understanding that doing so fuels better, more creative and more thoughtful ideas, solutions and strategies for the Society and for the communities our Society serves. We respect and welcome all people regardless of age, gender, ethnicity, physical appearance, thought styles, religion, nationality, socio-economic status, belief systems, sexual orientation or education.

ASHRAE Puget Sound Chapter does not endorse any of the products, services, or technologies demonstrated or presented in this meeting.

Building Codes

Thank You Sponsors!

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P2S INC

MacDonald-Miller
FACILITY SOLUTIONS

Meet the New Board!

Siddharth Premkumar

President

Lynndy Hedgcoth

Treasurer

Ty Wasserman,

Past-President

Kartik Tiwari

Secretary

Krishnan Gowri

President-Elect

Sierra Spitulski,

Governor

Meet the New Committee Chairs!

STUDENT ACTIVITIES	**Emily Osurman, Michelle Fouard**
MEMBERSHIP PROMOTION	**Miriam Miller, Stephen Fournier**
YOUNG ENGINEERS IN ASHRAE (YEA)	**Jack Roberts, Alex Amimoto**
RESEARCH PROMOTION	**Ty Wasserman**
CHAPTER TECHNOLOGY TRANSFER	**Krishnan Gowri, Ryan Mattis**
GOVERNMENT AFFAIRS	**Brad Lentz**

Building Codes

Upcoming Events

Georgetown Steam Plant Science Fair

Event Details

- **Date:** September 22, 2024 12:00 pm – 6:00 pm PDT
- **Venue:** Georgetown Steam Plant
- **Categories:** Students

UW Dawg Daze Engineering Launch

Event Details

- **Date:** September 24, 2024 4:30 pm – 7:00 pm PDT
- **Categories:** Students

October 2024 Chapter Meeting

Dr. David Chassin
Senior staff scientist
SLAC National Accelerator Laboratory
Stanford University

Event Details

- **Date:** October 23, 2024 5:30 pm – 7:30 pm PDT
- **Venue:** 515 MADISON STREET
- **Categories:** Chapter Meeting

Grid Impacts of Building Electrification: Load Modeling and Forecast for the Next 10 Years

Building Codes

Building Decarbonization

Upcoming Changes in Codes and Standards

Charles Eley, FASHRAE, FAIA, PE


Building Codes

A Jumble of Units are Used (pick one from each side)

GHG Emissions

- Pounds (lb)
- Short ton (2,000 lb)
- Metric ton (1,000 kg or 2,204 lb)
- **Kilogram** (2.2 lb or 1,000 grams)
- Gram
- More

Per Unit of Energy Use

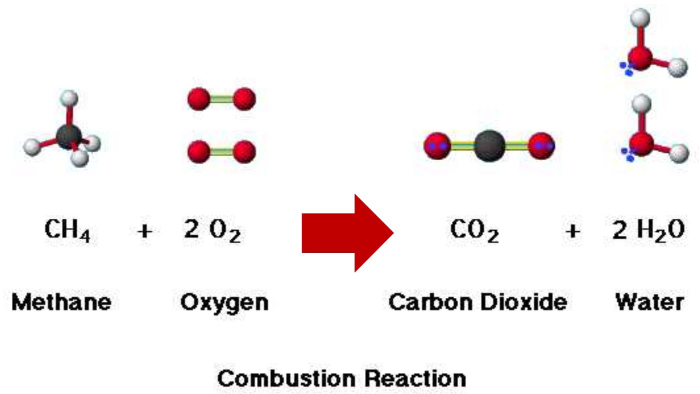
- Btu or kBtu (1,000 Btu)
- Therm (100,000 Btu)
- Cubic foot (natural gas)
- Joule, Megajoule Gigajoule
- kWh
- **MWh**
- More

I will use kg/MWh throughout this presentation for all emissions

Fossil Fuel Emissions = Combustion + Pre-Combustion

Combustion Emissions

Basic chemistry



Pre-Combustion Emissions

- Mining/extraction
- Refinement/processing
- Transportation/delivery

Methane leaks are most significant

Example Operational Emissions from Gas Plant (US fleet average)

Pre-Combustion

CO_2e = 210 kg/MWh

CO_2e N_2O CH_4

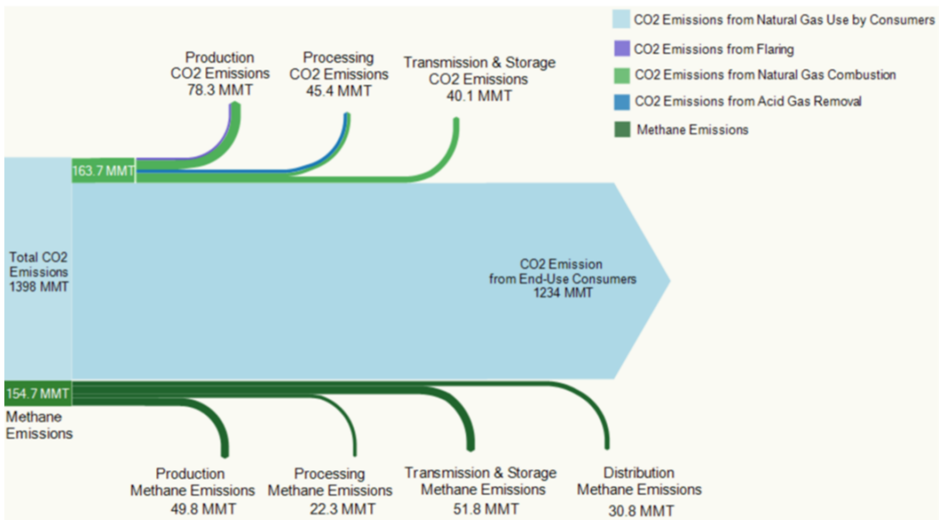
+

Combustion

CO_2e = 415 kg/MWh

CO_2e N_2O CH_4

= 625 kg/MWh



Heat Rate of Power Plants

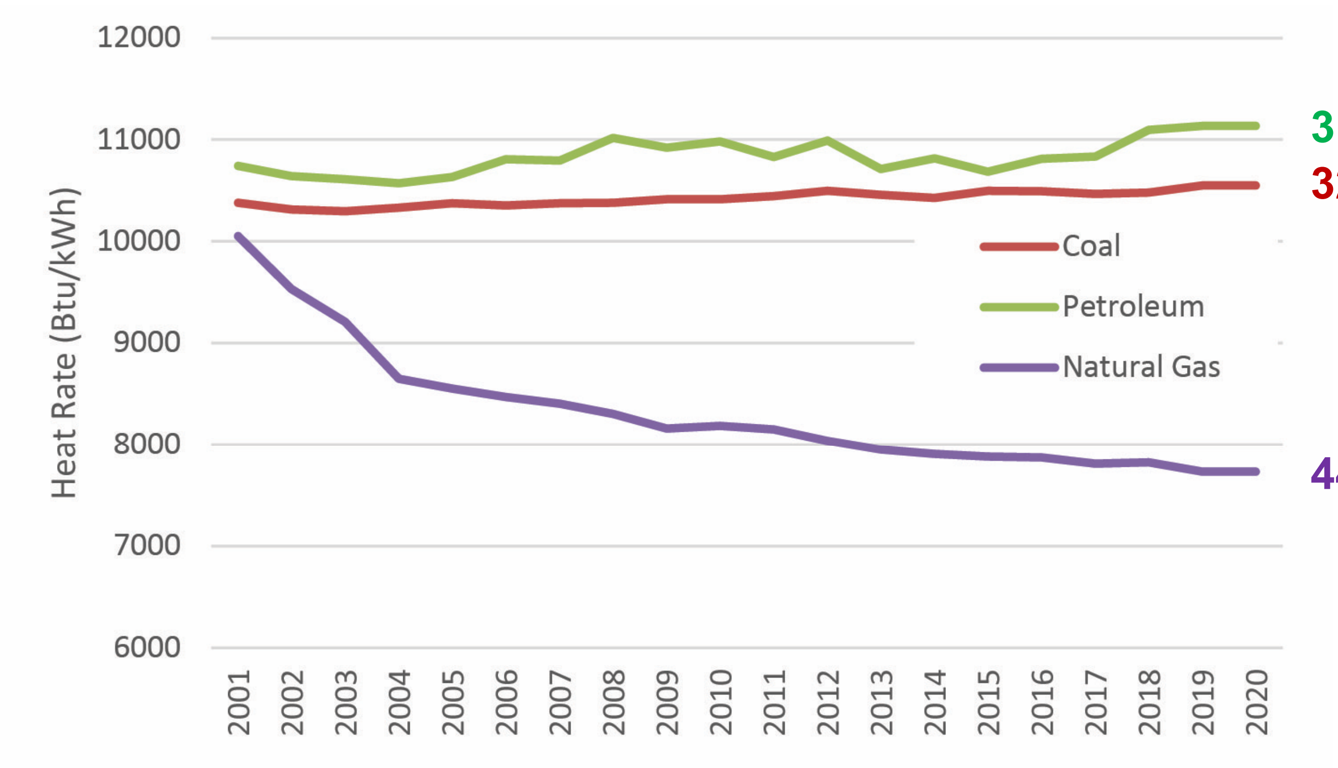


Figure 2 – Heat Rate of Coal, Petroleum and Natural Gas Generators

Source: Energy Information Agency, Monthly Energy Review, Table A6

31% Efficiency in 2020

32% Efficiency in 2020

44% Efficiency in 2020

Transmission and Distribution Losses

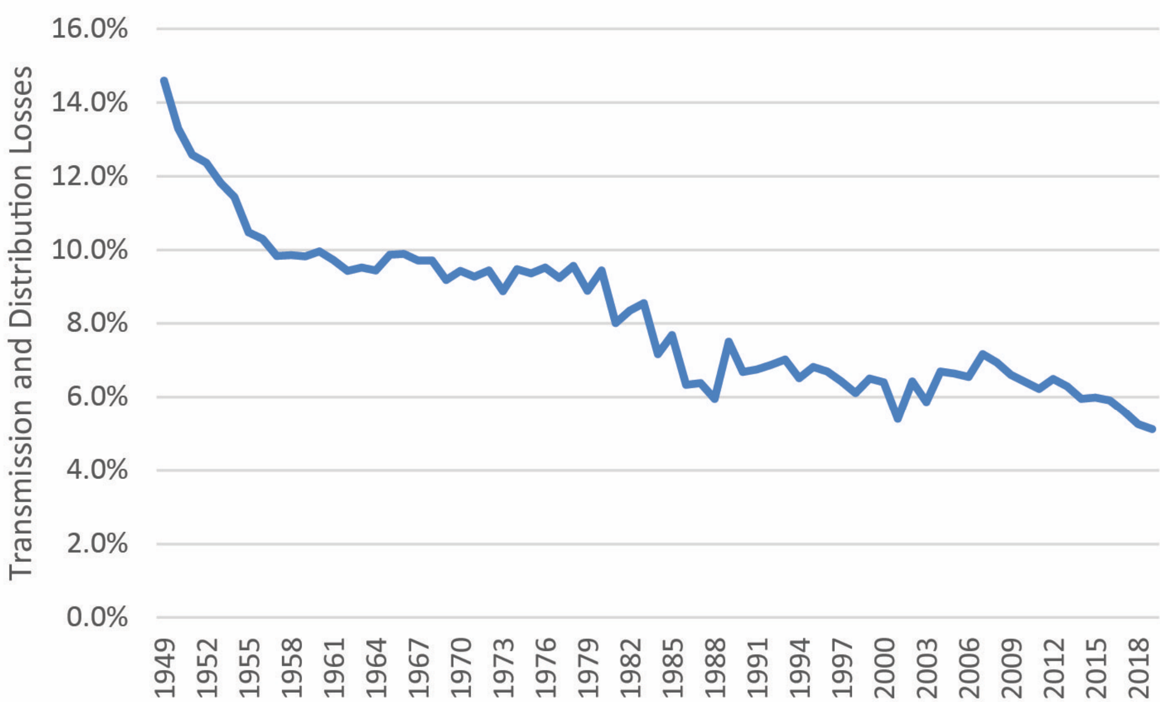


Figure 3 – Transmission and Distribution Losses

Source: Energy Information Agency, Monthly Energy Review, Table 7-1

5.3% in 2019

GHG Emissions from Fossil Fuels

Table 1 – GHG Emissions in kg per MWh of Fuel Burned

Source: NREL LCI Database, except for pre-combustion CH_4 emissions which are based on methane leaks of 1.09%. When two values are provided, the first is for a 20-year GWP and the second is for a 100-year GWP.

Fuel	Stage	CO_2	CH_4	N_2O	Total
		Unweighted Mass of Emissions (kg/MWh)			
Coal 1 MWh = 354 lb	Pre-Combustion	7.39	0.5233	0.0001	335
	Combustion	326.90	0.0385	0.0056	
Petroleum 1 MWh = 25 gal	Pre-Combustion	35.94	0.5573	0.0006	298
	Combustion	261.44	0.0109	0.0022	
Natural Gas 1 MWh = 35 therms	Pre-Combustion	16.48	0.7350	0.0001	201
	Combustion	183.64	0.0035	0.0003	
		Carbon Dioxide Equivalent (CO_2e) Emissions (kg/MWh) – 20-year / 100-year GWP			
Coal 1 MWh = 354 lb	Pre-Combustion	7	43/16	0.03	382/353
	Combustion	327	3.18/1.15	2	
Petroleum 1 MWh = 25 gal	Pre-Combustion	36	46/17	0.17	345/315
	Combustion	261	0.90/0.32	0.59	
Natural Gas 1 MWh = 35 therms	Pre-Combustion	16	61/22	0.02	261/222
	Combustion	184	0.29/0.10	0.09	
		Global Warming Potential			
GWP	100-year	1	29.8	273	
	20-year	1	82.5	273	

Source: https://eley.com/node/47

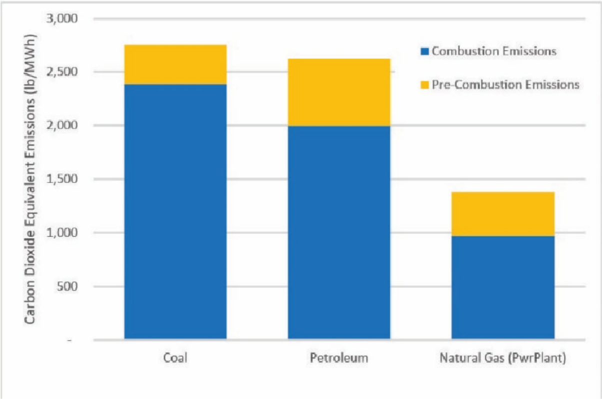
Fossil Fuel Power Plant Emissions

$$\text{Emissions per unit of electricity delivered to customers (kg/MWh)} = \frac{\text{Pre-combustion emissions per unit of fuel burned (kg/MWh)} + \text{Combustion emissions per unit of fuel burned (kg/MWh)}}{\text{Power plant efficiency} \times \text{Grid delivery efficiency}}$$

Table 2 – GHG Emissions from Coal, Oil and Natural Gas Power Plants (kg/MWh)

Source: Calculated using the procedures in this blog. Based on 20-year GWP.

Power Plant Type	*Heat Rate (Btu/kWh)*	*Power Plant Efficiency*	*Delivery Efficiency*	*Combustion Emissions*	*Pre-Combustion Emissions*	*Total Emissions*
Coal	10,551	32%	94.9%	1,083	165	1,248
Petroleum	11,135	31%	94.9%	906	283	1,189
Natural Gas	7,732	44%	94.9%	440	185	625



Source: https://eley.com/node/47

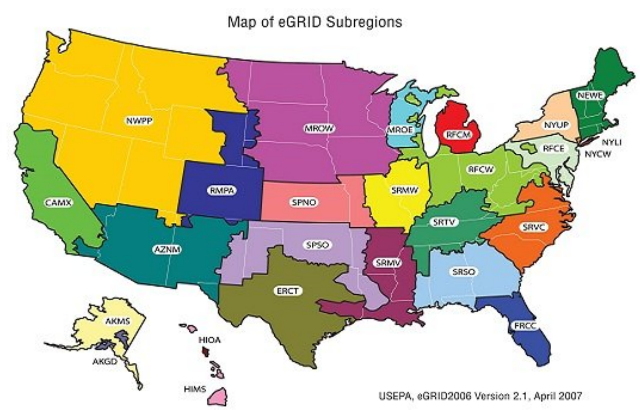
Retrospective and Average GHG Emissions (20-y GWP)

Table 3 – GHG Emissions from Coal, Oil and Natural Gas Power Plants (lb/MWh)

These data are calculated based on a 20-year time horizon and 1.08% methane leaks to power plants.

		CO_2e Emissions (kg/MWh)	
eGRID Subregion	*Combustion*	*Pre-Combustion*	*Total*
AKGD - ASCC Alaska Grid	514	159	673
AKMS - ASCC Miscellaneous	289	93	383
AZNM - WECC Southwest	444	121	565
CAMX - WECC California	255	88	343
ERCT - ERCOT All	431	126	558
FRCC - FRCC All	442	155	596
HIMS - HICC Miscellaneous	681	211	892
HIOA - HICC Oahu	895	233	1128
MROE - MRO East	770	150	920
MROW - MRO West	534	94	628
NEWE - NPCC New England	287	96	383
NWPP - WECC Northwest	349	76	426
NYCW - NPCC NYC/Westchester	269	110	379
NYLI - NPCC Long Island	481	169	650
NYUP - NPCC Upstate NY	132	48	180
PRMS - Puerto Rico Miscellaneous	731	214	944
RFCE - RFC East	350	106	456
RFCM - RFC Michigan	594	133	727
RFCW - RFC West	532	113	645
RMPA - WECC Rockies	580	120	699
SPNO - SPP North	515	93	608
SPSO - SPP South	460	123	583
SRMV - SERC Mississippi Valley	418	137	555
SRMW - SERC Midwest	779	134	913
SRSO - SERC South	496	133	629
SRTV - SERC Tennessee Valley	473	104	577
SRVC - SERC Virginia/Carolina	360	97	456
Average for Entire United States	436	111	547

Table 7.6.3 Standard 189.1-2023



Source: https://eley.com/node/47

Informative Appendix I, Standard 189.1-2023

- Documents the assumptions and methodology used to develop the GHG emission rates discussed here
- Provides guidance on how to adapt the results for special cases
  - Different mix of electric generators
  - Liquified natural gas
  - Imported Coal

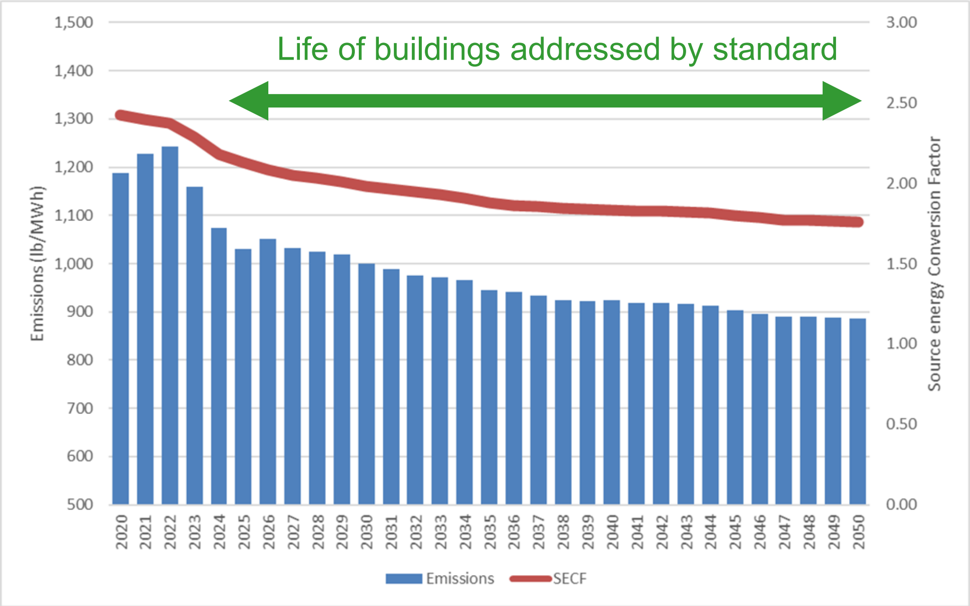
Source: Standard 189.1-2023, Appendix J

Building Codes

[illegible]	[illegible]	113	83	80	84	144	229	210	193	278	270
297	223	120	91	80	94	147	239	233	201	283	287
301	226	124	89	88	98	158	242	243	209	293	287
293	219	123	89	85	93	159	249	245	209	284	285
280	209	114	88	86	100	156	250	242	205	270	289
264	196	108	81	64	61	95	175	217	194	263	273
247	185	89	63	56	52	83	104	126	93	218	252
184	109	60	57	53	52	75	107	124	87	140	159
112	103	57	54	53	54	74	102	119	93	125	126
110	99	55	54	54	53	73	106	114	95	129	124
111	99	55	53	53	52	70	109	120	83	128	126
109	100	53	53	54	52	68	114	123	80	134	128
111	99	53	55	52	54	72	116	118	79	135	133
107	102	54	56	51	53	71	114	107	79	138	138
115	107	56	56	51	54	72	108	105	79	138	155
150	105	58	56	53	53	76	106	102	95	183	201
245	167	79	67	63	55	83	110	132	140	246	257
236	188	82	71	68	55	87	130	167	150	241	248
233	185	77	72	75	77	102	141	158	142	239	241
234	181	78	71	73	70	93	126	156	138	237	243
237	184	77	73	73	65	94	125	155	135	240	243
242	186	87	79	85	66	120	156	173	150	246	246
253	185	99	84	73	63	130	184	176	159	247	248
269	198	107	83	82	73	155	218	190	184	262	259

Retrospective vs. Forward-Looking

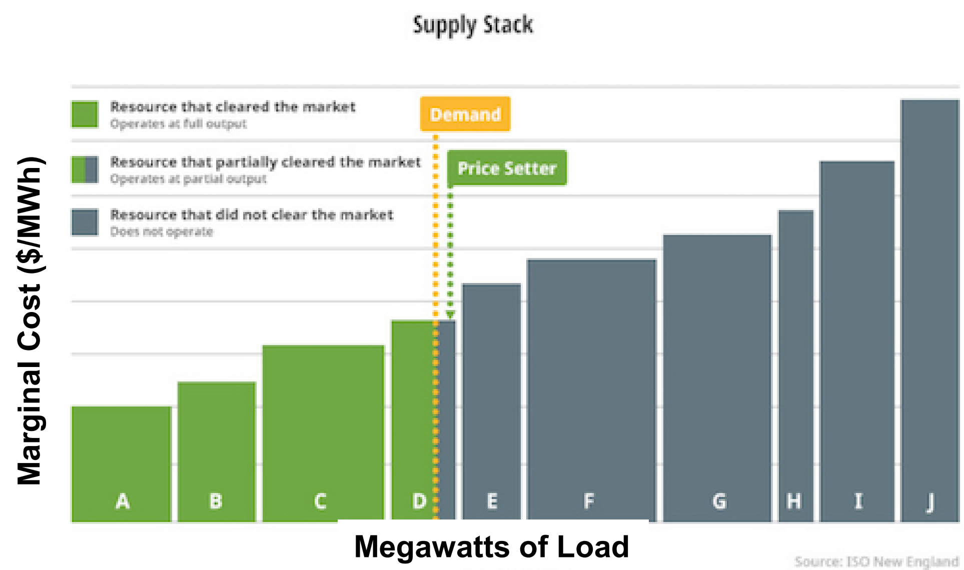
- Buildings addressed by building codes will not be constructed until several years from now.
- Once constructed they will use energy for decades beyond the date of the certificate-of-occupancy.



Projections are <u>annual average</u> emission rates based on the reference case and projected generation mix from from EIA's Annual Energy Outlook (similar data not available by eGRID subregion)

Average vs. Marginal Carbon Emissions

- New buildings new add load to the electric grid that will be supplied by the “marginal generator”.
- The “marginal generator” is the generator that would increase or reduce its supply in response to an incremental increase or reduction in load.
- Design decisions for new buildings should be based on marginal emissions.
- Carbon accounting for benchmarking programs is typically based on retrospective average emissions.



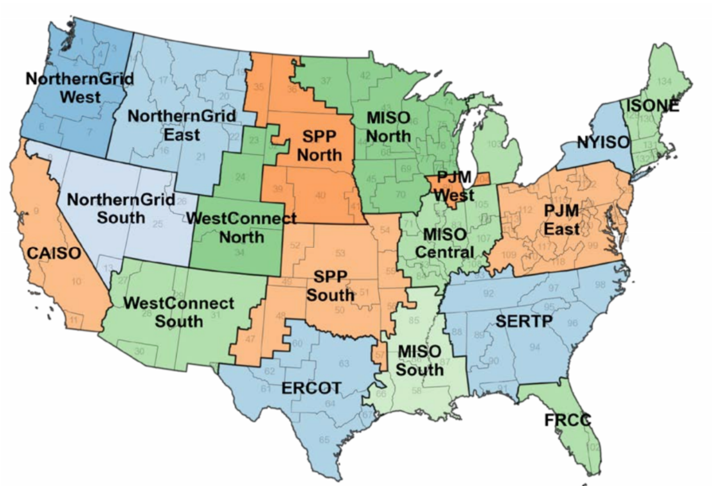
Average emissions are the weighted average of the emissions from generators A, B, C and part of D.

Marginal emissions are the emissions of generator D, the marginal generator.

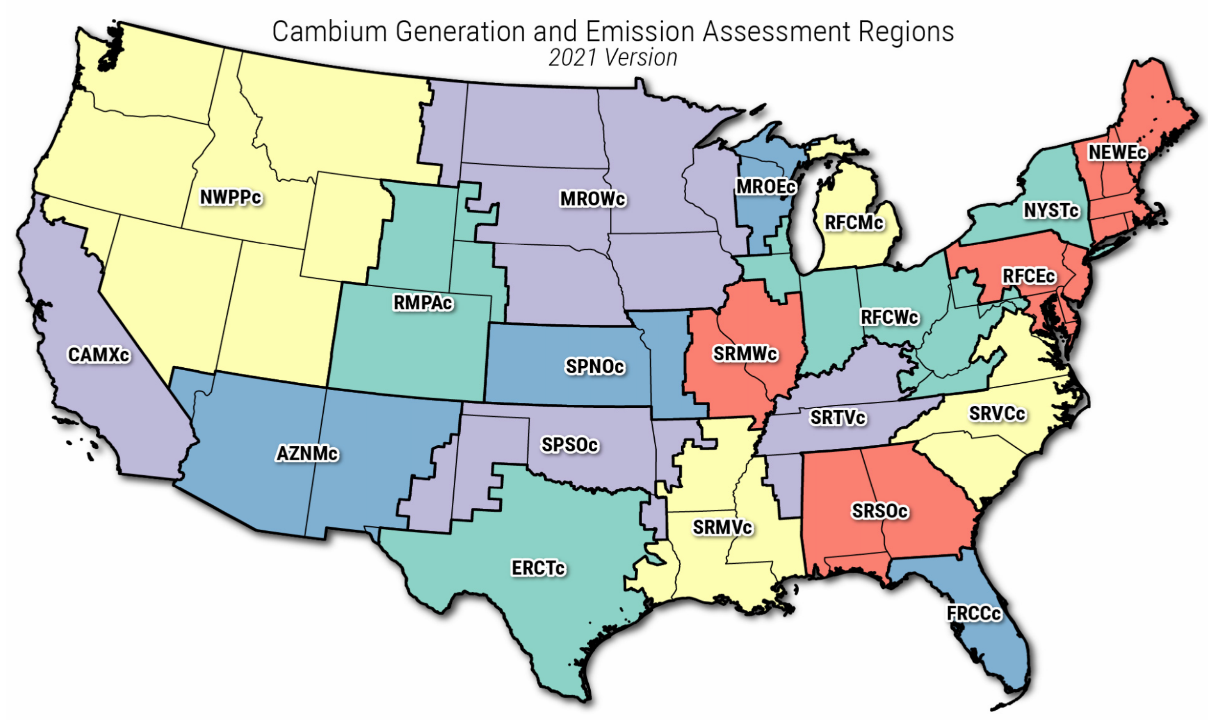
Charles Eley, FAIA, FASHRAE, PE

Space Granularity

- Separate emission rates for GEA regions
- 2021 map is similar (but not identical) to eGRID subregions

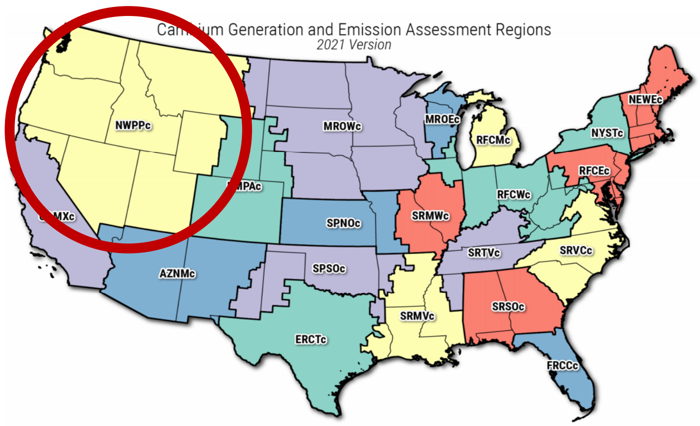


Revised Cambium GEA Regions – 2023



Time Granularity (two choices)

- **Month-hour data** (288 bins)
- **Year-hour data** (24 bins)



NWPPc	7 Hoffset												
Emissions Signature (kg/MWh)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
0	230	208	179	128	137	173	187	198	236	207	248	229	197
1	231	213	175	126	140	173	191	203	245	208	250	226	199
2	236	215	172	123	133	180	188	209	251	206	251	222	199
3	233	215	174	127	135	171	188	206	250	209	244	220	198
4	228	209	168	122	130	156	176	204	239	206	240	224	192
5	229	201	154	111	105	123	148	174	233	199	231	221	178
6	227	190	146	100	96	119	141	145	193	169	225	216	165
7	203	150	110	91	96	115	133	139	187	150	196	194	148
8	170	144	105	93	92	114	123	133	180	153	195	175	140
9	171	141	100	90	93	111	121	128	170	153	198	177	138
10	174	143	103	89	90	107	113	128	158	145	198	176	136
11	177	143	99	90	91	103	113	122	155	149	197	179	135
12	175	141	100	91	87	100	107	126	148	149	201	190	135
13	167	142	103	89	87	96	108	120	142	141	197	183	131
14	173	143	102	92	87	101	104	117	143	143	205	192	134
15	201	150	114	92	89	104	113	128	149	167	231	217	147
16	235	189	150	109	102	113	124	142	190	193	235	224	168
17	231	196	153	120	120	140	144	163	218	192	239	223	180
18	235	193	146	121	128	155	162	174	208	193	240	225	183
19	232	194	147	121	130	157	162	169	209	193	234	222	182
20	231	195	151	120	131	159	164	170	214	196	237	226	184
21	231	193	154	117	138	166	168	179	222	197	240	225	187
22	225	198	166	117	131	166	169	177	227	202	243	224	188
23	227	203	172	123	138	166	176	187	233	207	245	226	193

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Example Calculation (SRSO, Medium Office)

ASHRAE

Consumption Signature

0.0007	0.0006	0.0006	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0006	0.0007
0.0006	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
0.0006	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
0.0006	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
0.0006	0.0006	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
0.0006	0.0006	0.0005	0.0005	0.0005	0.0005	0.0006	0.0008	0.0005	0.0005	0.0005	0.0005
0.0014	0.0010	0.0015	0.0017	0.0022	0.0031	0.0038	0.0046	0.0031	0.0019	0.0008	0.0008
0.0063	0.0039	0.0029	0.0022	0.0027	0.0036	0.0042	0.0050	0.0034	0.0029	0.0022	0.0039
0.0083	0.0055	0.0034	0.0034	0.0049	0.0067	0.0075	0.0085	0.0056	0.0037	0.0032	0.0060
0.0066	0.0047	0.0034	0.0037	0.0054	0.0074	0.0083	0.0090	0.0061	0.0037	0.0032	0.0046
0.0054	0.0039	0.0034	0.0040	0.0060	0.0080	0.0088	0.0096	0.0065	0.0040	0.0030	0.0037
0.0047	0.0036	0.0036	0.0044	0.0065	0.0088	0.0095	0.0105	0.0071	0.0045	0.0031	0.0033
0.0043	0.0035	0.0039	0.0045	0.0065	0.0088	0.0094	0.0103	0.0072	0.0048	0.0034	0.0032
0.0046	0.0038	0.0040	0.0048	0.0069	0.0092	0.0100	0.0111	0.0077	0.0052	0.0037	0.0034
0.0040	0.0034	0.0042	0.0050	0.0069	0.0093	0.0099	0.0111	0.0077	0.0053	0.0038	0.0032
0.0036	0.0033	0.0043	0.0051	0.0072	0.0096	0.0103	0.0115	0.0079	0.0055	0.0039	0.0031
0.0037	0.0033	0.0045	0.0053	0.0075	0.0098	0.0106	0.0117	0.0081	0.0056	0.0039	0.0032
0.0037	0.0034	0.0037	0.0039	0.0055	0.0076	0.0083	0.0091	0.0060	0.0039	0.0037	0.0033
0.0037	0.0028	0.0026	0.0027	0.0038	0.0055	0.0060	0.0067	0.0042	0.0027	0.0030	0.0030
0.0042	0.0030	0.0024	0.0024	0.0034	0.0049	0.0053	0.0060	0.0037	0.0026	0.0025	0.0027
0.0041	0.0029	0.0023	0.0022	0.0031	0.0041	0.0045	0.0052	0.0032	0.0022	0.0021	0.0025
0.0041	0.0027	0.0021	0.0021	0.0030	0.0037	0.0042	0.0047	0.0031	0.0021	0.0018	0.0024
0.0042	0.0028	0.0012	0.0008	0.0008	0.0008	0.0010	0.0009	0.0008	0.0008	0.0017	0.0025
0.0009	0.0008	0.0007	0.0006	0.0007	0.0007	0.0007	0.0007	0.0006	0.0007	0.0008	0.0008

×

LRMER Emissions Signature

483	445	373	341	394	436	608	606	479	441	455	506
483	448	409	391	445	470	631	585	487	468	460	515
490	449	434	411	480	501	618	575	492	469	461	516
485	446	433	390	483	506	606	568	495	477	454	514
476	432	390	354	463	497	609	569	493	436	442	515
457	427	357	316	414	444	593	590	460	374	429	508
452	422	337	257	297	278	383	439	368	349	420	480
437	388	274	175	209	197	261	310	264	252	359	448
335	300	210	141	181	167	214	244	200	184	260	347
267	258	176	130	162	163	183	214	176	162	226	277
242	242	169	130	157	164	164	193	166	162	211	261
246	230	167	127	165	154	163	171	157	159	207	260
257	223	165	131	167	151	166	160	145	156	209	257
251	228	164	131	171	153	168	160	151	156	204	255
258	231	161	131	183	166	173	170	156	167	205	265
267	241	174	133	201	189	188	174	168	166	220	283
304	255	186	147	217	212	212	195	197	204	277	362
404	348	258	173	261	243	261	272	281	288	408	455
440	404	322	241	313	305	336	356	345	324	418	464
439	412	341	269	357	360	383	403	361	323	414	466
440	414	335	262	350	360	395	393	353	323	414	470
442	419	328	246	330	352	389	379	378	330	411	473
461	429	331	254	333	390	400	460	419	342	427	495
487	450	359	289	352	427	490	565	477	379	448	520

= Annual LRMER

Year-Hour Method

0.0069	464
0.0062	483
0.0062	491
0.0062	488
0.0062	473
0.0067	447
0.0260	373
0.0431	298
0.0666	232
0.0659	199
0.0663	188
0.0695	184
0.0696	182
0.0745	183
0.0738	189
0.0755	200
0.0774	231
0.0622	304
0.0468	356
0.0430	377
0.0384	376
0.0359	373
0.0183	395
0.0086	437

(first column) × (second column) = Annual LRMER

Impact on Purchased Renewable Electricity

NWPPc 7 Hoffset

Emissions Signature (kg/MWh)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
0	230	208	179	128	137	173	187	198	236	207	248	229	197
1	231	213	175	126	140	173	191	203	245	208	250	226	199
2	236	215	172	123	133	180	188	209	251	206	251	222	199
3	233	215	174	127	135	171	188	206	250	209	244	220	198
4	228	209	168	122	130	156	176	204	239	206	240	224	192
5	229	201	154	111	105	123	148	174	233	199	231	221	178
6	227	190	146	100	96	119	141	145	193	169	225	216	165
7	203	150	110	91	96	115	133	139	187	150	196	194	148
8	170	144	105	93	92	114	123	133	180	153	195	175	140
9	171	141	100	90	93	111	121	128	170	153	198	177	138
10	174	143	103	89	90	107	113	128	158	145	198	176	136
11	177	143	99	90	91	103	113	122	155	149	197	179	135
12	175	141	100	91	87	100	107	126	148	149	201	190	135
13	167	142	103	89	87	96	108	120	142	141	197	183	131
14	173	143	102	92	87	101	104	117	143	143	205	192	134
15	201	150	114	92	89	104	113	128	149	167	231	217	147
16	235	189	150	109	102	113	124	142	190	193	235	224	168
17	231	196	153	120	120	140	144	163	218	192	239	223	180
18	235	193	146	121	128	155	162	174	208	193	240	225	183
19	232	194	147	121	130	157	162	169	209	193	234	222	182
20	231	195	151	120	131	159	164	170	214	196	237	226	184
21	231	193	154	117	138	166	168	179	222	197	240	225	187
22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	202	243	224	188
23	227	203	172	123	138	166	176	187	233	207	245	226	193

Grid Emissions Signature

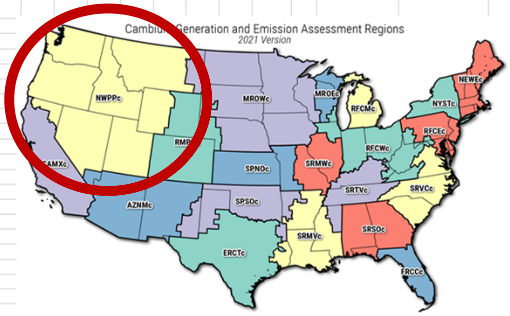
Avoided Emissions from Offsite Purchases (kg/MWh)

Solar	Wind	Hydro	Other
128	170	167	167

Set these values in "Cambium21_LRMER_GEAregions.xlsx"

User Inputs

0-1	Emission	CO2e
1-2	Emission stage	Combined
	Start year	2023
	Evaluation period (years)	20
	Discount rate (real)	0.03
	Scenario	Low RE Costs
	Global Warming Poten	20-year (AR5)
	Location	End-use
	2050 Fraction	0.00
	Min	87
	Avg	167
	Max	251



Avoided Emissions (kg/MWh)

Solar	128
Wind	170
Hydro	167

Solar | NWPPc | Avoided 128 kg/MWh | ##### | 11% | 143

Sum of Selected / Column Labels

Row Labels	1	2	3	4	5	6	7	8	9	10	11	12	Avg
0	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
3	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
4	0.00%	0.00%	0.00%	0.01%	0.12%	0.21%	0.11%	0.01%	0.00%	0.00%	0.00%	0.00%	0.46%
5	0.00%	0.00%	0.02%	0.24%	0.58%	0.66%	0.53%	0.33%	0.16%	0.03%	0.00%	0.00%	2.55%
6	0.00%	0.06%	0.32%	0.65%	0.98%	0.95%	0.92%	0.79%	0.61%	0.38%	0.11%	0.01%	5.78%
7	0.19%	0.33%	0.65%	0.86%	1.14%	1.09%	1.05%	1.02%	0.89%	0.76%	0.39%	0.17%	8.53%
8	0.45%	0.55%	0.83%	0.94%	1.17%	1.11%	1.10%	1.10%	0.98%	0.86%	0.52%	0.38%	10.01%
9	0.55%	0.62%	0.86%	0.97%	1.17%	1.12%	1.11%	1.11%	0.98%	0.84%	0.54%	0.42%	10.29%
10	0.55%	0.63%	0.88%	0.99%	1.15%	1.12%	1.12%	1.10%	0.96%	0.80%	0.54%	0.43%	10.27%
11	0.54%	0.60%	0.84%	0.97%	1.11%	1.12%	1.09%	1.07%	0.95%	0.78%	0.53%	0.41%	10.01%
12	0.54%	0.62%	0.81%	0.93%	1.13%	1.12%	1.05%	0.99%	0.96%	0.78%	0.52%	0.39%	9.83%
13	0.55%	0.62%	0.78%	0.87%	1.09%	1.12%	1.01%	0.95%	0.97%	0.79%	0.53%	0.40%	9.68%
14	0.49%	0.59%	0.76%	0.86%	1.05%	1.09%	0.99%	0.95%	0.93%	0.73%	0.41%	0.29%	9.16%
15	0.19%	0.42%	0.61%	0.76%	0.98%	1.00%	0.93%	0.85%	0.80%	0.43%	0.10%	0.05%	7.12%
16	0.01%	0.07%	0.25%	0.48%	0.74%	0.86%	0.78%	0.64%	0.37%	0.07%	0.01%	0.00%	4.29%
17	0.00%	0.00%	0.02%	0.11%	0.31%	0.48%	0.46%	0.26%	0.05%	0.00%	0.00%	0.00%	1.69%
18	0.00%	0.00%	0.00%	0.01%	0.04%	0.11%	0.12%	0.03%	0.00%	0.00%	0.00%	0.00%	0.32%
19	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.02%
20	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
21	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
23	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Solar Signature

Wind | NWPPc | Avoided 170 kg/MWh | ##### | 0% | 170

Sum of Selected / Column Labels

Row Labels	1	2	3	4	5	6	7	8	9	10	11	12	Avg
0	0.47%	0.33%	0.48%	0.37%	0.35%	0.33%	0.30%	0.28%	0.19%	0.36%	0.40%	0.48%	4.35%
1	0.47%	0.33%	0.48%	0.37%	0.35%	0.32%	0.28%	0.27%	0.18%	0.36%	0.40%	0.48%	4.31%
2	0.47%	0.34%	0.48%	0.38%	0.35%	0.33%	0.28%	0.27%	0.18%	0.37%	0.40%	0.48%	4.33%
3	0.48%	0.34%	0.48%	0.38%	0.36%	0.32%	0.27%	0.27%	0.19%	0.36%	0.40%	0.47%	4.34%
4	0.48%	0.35%	0.48%	0.38%	0.35%	0.31%	0.24%	0.26%	0.20%	0.36%	0.40%	0.47%	4.28%
5	0.48%	0.35%	0.48%	0.36%	0.31%	0.26%	0.19%	0.21%	0.19%	0.36%	0.40%	0.47%	4.07%
6	0.48%	0.34%	0.46%	0.32%	0.29%	0.26%	0.15%	0.15%	0.16%	0.34%	0.40%	0.47%	3.82%
7	0.47%	0.32%	0.44%	0.32%	0.30%	0.27%	0.14%	0.14%	0.12%	0.30%	0.39%	0.46%	3.67%
8	0.44%	0.30%	0.44%	0.34%	0.32%	0.28%	0.14%	0.14%	0.12%	0.28%	0.37%	0.44%	3.61%
9	0.42%	0.30%	0.44%	0.35%	0.33%	0.29%	0.14%	0.14%	0.14%	0.29%	0.35%	0.43%	3.61%
10	0.41%	0.31%	0.45%	0.35%	0.34%	0.32%	0.15%	0.15%	0.16%	0.29%	0.35%	0.42%	3.69%
11	0.41%	0.30%	0.46%	0.35%	0.35%	0.35%	0.17%	0.16%	0.17%	0.31%	0.35%	0.42%	3.82%
12	0.42%	0.30%	0.47%	0.36%	0.36%	0.38%	0.20%	0.18%	0.17%	0.33%	0.35%	0.43%	3.96%
13	0.43%	0.31%	0.46%	0.36%	0.38%	0.39%	0.25%	0.19%	0.20%	0.33%	0.35%	0.44%	4.08%
14	0.43%	0.31%	0.47%	0.36%	0.39%	0.39%	0.26%	0.22%	0.20%	0.33%	0.35%	0.44%	4.13%
15	0.46%	0.32%	0.47%	0.36%	0.38%	0.41%	0.27%	0.23%	0.20%	0.32%	0.36%	0.46%	4.25%
16	0.47%	0.35%	0.48%	0.35%	0.38%	0.41%	0.27%	0.25%	0.21%	0.34%	0.38%	0.47%	4.36%
17	0.48%	0.36%	0.48%	0.36%	0.38%	0.41%	0.28%	0.27%	0.23%	0.35%	0.39%	0.48%	4.47%
18	0.48%	0.35%	0.48%	0.37%	0.38%	0.38%	0.29%	0.29%	0.24%	0.36%	0.39%	0.48%	4.48%
19	0.48%	0.36%	0.48%	0.37%	0.37%	0.38%	0.31%	0.31%	0.25%	0.36%	0.40%	0.48%	4.55%
20	0.48%	0.35%	0.48%	0.38%	0.37%	0.37%	0.31%	0.31%	0.23%	0.37%	0.40%	0.48%	4.54%
21	0.48%	0.35%	0.49%	0.37%	0.35%	0.36%	0.31%	0.31%	0.22%	0.37%	0.39%	0.47%	4.48%
22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.36%	0.29%	0.31%	0.21%	0.36%	0.39%	0.47%	4.43%
23	0.48%	0.35%	0.48%	0.36%	0.34%	0.34%	0.30%	0.29%	0.20%	0.37%	0.39%	0.48%	4.37%

Wind Signature

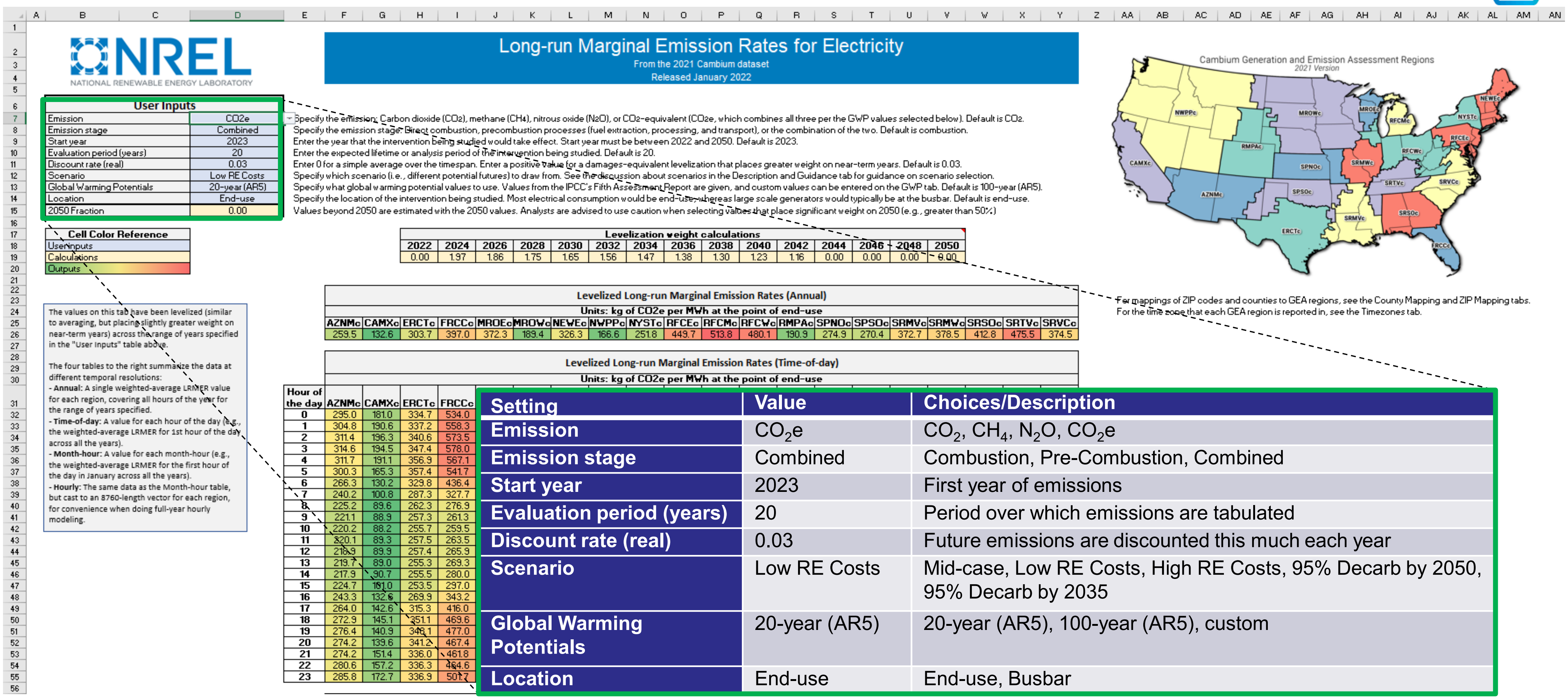
Hydro | NWPPc | Avoided 167 kg/MWh | ##### | 3% | 172

Sum of Selected / Column Labels

Row Labels	1	2	3	4	5	6	7	8	9	10	11	12	Avg
0	0.29%	0.28%	0.41%	0.40%	0.45%	0.42%	0.37%	0.35%	0.20%	0.21%	0.27%	0.25%	3.90%
1	0.27%	0.27%	0.40%	0.39%	0.44%	0.40%	0.36%	0.32%	0.18%	0.20%	0.26%	0.24%	3.74%
2	0.27%	0.27%	0.40%	0.39%	0.44%	0.40%	0.34%	0.31%	0.17%	0.19%	0.26%	0.23%	3.69%
3	0.27%	0.28%	0.41%	0.41%	0.44%	0.40%	0.35%	0.32%	0.17%	0.20%	0.27%	0.25%	3.77%
4	0.31%	0.31%	0.45%	0.43%	0.46%	0.39%	0.37%	0.33%	0.18%	0.23%	0.30%	0.28%	4.04%
5	0.37%	0.35%	0.50%	0.46%	0.41%	0.32%	0.30%	0.31%	0.19%	0.27%	0.34%	0.32%	4.15%
6	0.42%	0.40%	0.50%	0.37%	0.28%	0.26%	0.26%	0.26%	0.15%	0.21%	0.35%	0.37%	3.83%
7	0.40%	0.31%	0.36%	0.30%	0.26%	0.26%	0.27%	0.25%	0.14%	0.14%	0.28%	0.37%	3.33%
8	0.28%	0.23%	0.31%	0.27%	0.26%	0.28%	0.29%	0.27%	0.14%	0.14%	0.25%	0.32%	3.03%
9	0.26%	0.21%	0.28%	0.27%	0.27%	0.29%	0.32%	0.31%	0.14%	0.14%	0.25%	0.30%	3.04%
10	0.25%	0.19%	0.27%	0.26%	0.27%	0.30%	0.34%	0.35%	0.15%	0.14%	0.26%	0.31%	3.10%
11	0.24%	0.19%	0.27%	0.26%	0.27%	0.30%	0.35%	0.37%	0.15%	0.15%	0.26%	0.31%	3.12%
12	0.23%	0.19%	0.26%	0.26%	0.27%	0.30%	0.37%	0.40%	0.16%	0.15%	0.25%	0.30%	3.12%
13	0.22%	0.19%	0.26%	0.27%	0.27%	0.29%	0.37%	0.41%	0.17%	0.15%	0.25%	0.30%	3.15%
14	0.23%	0.19%	0.27%	0.27%	0.28%	0.31%	0.38%	0.43%	0.18%	0.18%	0.29%	0.33%	3.34%
15	0.32%	0.22%	0.30%	0.32%	0.32%	0.33%	0.39%	0.48%	0.26%	0.30%	0.40%	0.41%	4.05%
16	0.46%	0.37%	0.49%	0.46%	0.46%	0.43%	0.50%	0.56%	0.39%	0.41%	0.46%	0.46%	5.45%
17	0.50%	0.45%	0.55%	0.52%	0.54%	0.52%	0.58%	0.59%	0.45%	0.43%	0.47%	0.48%	6.07%
18	0.50%	0.46%	0.56%	0.53%	0.55%	0.53%	0.58%	0.59%	0.43%	0.43%	0.47%	0.46%	6.08%
19	0.47%	0.45%	0.55%	0.53%	0.56%	0.54%	0.58%	0.56%	0.42%	0.41%	0.44%	0.44%	5.97%
20	0.45%	0.43%	0.54%	0.52%	0.56%	0.54%	0.57%	0.55%	0.39%	0.38%	0.42%	0.42%	5.75%
21	0.41%	0.39%	0.50%	0.50%	0.54%	0.51%	0.53%	0.50%	0.35%	0.32%	0.38%	0.37%	5.31%
22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.48%	0.48%	0.44%	0.29%	0.27%	0.34%	0.33%	4.74%
23	0.31%	0.30%	0.43%	0.43%	0.47%	0.45%	0.41%	0.38%	0.24%	0.23%	0.30%	0.28%	4.23%

Hydro Signature

Cambium Database



Setting	Value	Choices/Description
Emission	CO_2e	CO_2, CH_4, N_2O, CO_2e
Emission stage	Combined	Combustion, Pre-Combustion, Combined
Start year	2023	First year of emissions
Evaluation period (years)	20	Period over which emissions are tabulated
Discount rate (real)	0.03	Future emissions are discounted this much each year
Scenario	Low RE Costs	Mid-case, Low RE Costs, High RE Costs, 95% Decarb by 2050, 95% Decarb by 2035
Global Warming Potentials	20-year (AR5)	20-year (AR5), 100-year (AR5), custom
Location	End-use	End-use, Busbar

Building Codes

ASHRAE Standard 189.1

History

- In 2010 standard was first published. The energy performance approach requires that buildings have lower carbon emissions based on a baseline building defined in Standard 90.1. The in 2010 version, a **single emissions rate** was published for electricity that applied to the whole country.
- In 2017, separate emission rates for electricity were published for each of the **eGRID subregions**. Emission were updated to be consistent with the latest EIA and EPA data.
- In 2020, Emission rates were updated to be consistent with the latest EIA and EPA data.
- In 2023, Emission rates were updated to be consistent with the latest EIA and EPA data. AND, a jurisdictional option was added to include hourly **long-run marginal emission rates (LRMER)**.

Possible Future

- For 2026, the committee is considering deleteing the performance metrics for cost and source energy, leaving carbon emissions as the sole performance metric.

ASHRAE Standard 90.1

History

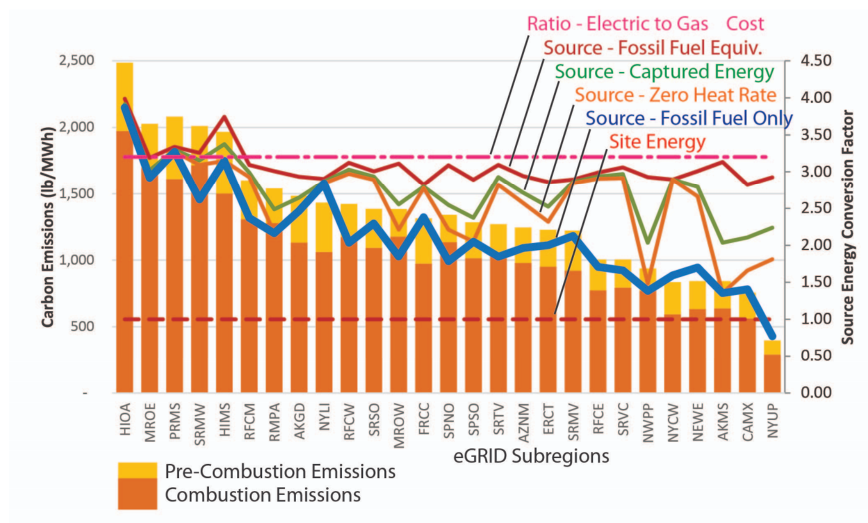
- Prior to 2022, the standard did not directly address carbon emissions or climate change. Energy cost was the sole performance metric.
- In 2022,
  - Informative Appendix I was added that provides a optional procedure for local governments to adopt other metrics such as site energy, source energy and GHG emissions. Uses 189.1 emission rates.
  - Appendix L added a Total Systems Performance Ratio (TSPR) which includes an informative note that GHG emissions can be substituted for cost.

Possible Future

- Informative Appendix N to 90.1-2022. Net Zero Operational Energy Emissions (NZOEE). Contains table that show how much renewable energy must be either installed or purchased to achieve NZOEE. The procedure includes credits for more efficient equipment, etc.
- A prescriptive pathway to NZOEE is being considered in another proposal.

California Building Energy Efficiency Standards

- Legal counsel advised the California Energy Commission that to comply with federal law, state-adopted energy standards must be based on either cost or energy.
- Their opinion is that to base an energy standard on GHG emissions could be a violation of the preemption clauses in federal law.
- To address this issue, the California standards use hourly source energy as the metric for evaluating energy performance, but they define hourly source energy in such a way that it tracks GHG emissions very closely; the source energy from both nuclear and renewable energy generators are assumed to be zero.
- The graph at the right is from a blog I wrote that compares various metrics for each of the eGRID subregions.



Source: https://eley.com/node/82

ICC and the IECC

- The ICC Board of Directors are recommending a revised scope and intent that **explicitly prohibits ICC energy standards from directly addressing climate change** measures such as EV charging, solar, batteries and probably demand-response.
- The revised scope and intent has a shady history:
  - The consensus committees for both the residential and commercial updates to the IECC for 2024 voted for and approved a number of requirements to address climate change, including on-site solar, batteries, and EV chargers.
  - Appeals were filed by power players in the building industry.
  - The ICC Board agreed with appellants and made all requirements related to EV charging, batteries, solar, etc. optional (move to appendices).
  - In doing so, the ICC Board violated its own rules to only consider appeals that address process or procedure issues.
- However, an optional Appendix CC requires that renewable energy be installed or purchased in quantities sufficient to achieve zero. First adopted for 2020 and updated for 2023. Not mandatory.

Washington State and Seattle

- No direct requirements on GHG emissions (that I know of)
- For new construction and electrification, WA and Seattle energy codes now have the "fossil fuel compliance path" to work around the Berkeley court decision. Fossil fuel space heating and water heating is allowed only if applicants qualify for "additional efficiency credits“.
- The Seattle Energy Code requires that fossil fuel heating and water heating equipment in existing buildings be replaced with heat pumps, but includes some broad exceptions permitting partial or delayed compliance. Any project not doing full electrification must provide a "future decarbonization plan."

ASHRAE Standard 242P

Future

- This standard is under development and aims to establish one set of GHG emission factors that would be used in all ASHRAE standards.


Building Codes

Washington State – Clean Buildings Performance Standard

- First enacted in 2019
- Sets **EUI targets** aimed at reducing the energy use of the worst-performing half of the building stock to the average
- Applies to commercial buildings with staggered implementation based on floor area
  - Over 220,000 square feet by June 2026
  - Over 90,000 square feet by June 2027
  - Over 50,000 square feet by June 2028.
- Compliance options
  - Direct compliance – show you meet the targets
  - Investment criteria path – do an ASHRAE Level 2 audit and implementation what's cost-effective
- Financial incentives offered for early adopters
  - $0.85 per square foot for buildings that are 15 EUI points above the target and achieve compliance before the deadlines

Seattle Building Emissions Performance Standards

- Adds GHG emission targets as a layer on top of the Washington State Clean BPS
- Sets targets requiring all covered buildings to achieve to zero GHG emissions over the next couple of decades (see table to the right)
- Includes emission factors (see table below)

BEPS Greenhouse Gas Intensity Targets (GHGITs)

Table A for 22.925.070: Building activity type greenhouse gas intensity targets (GHGITs)

	GHGITs (KGCO2e/SF/YR) by compliance interval			
Building Activity Type	2031-2035	2036-2040[1]	2041-2045[1, 2]	2046-2050[1, 3]
College/University	2.69	*1.57*	*0.00*	*0.00*
Entertainment/Public Assembly	1.18	*0.69*	*0.00*	*0.00*
Fire/Police Station	2.23	*1.30*	*0.00*	*0.00*
Hospital	4.68	*2.73*	*0.00*	*0.00*
Hotel	2.06	*1.20*	*0.00*	*0.00*
K-12 School	0.95	*0.56*	*0.00*	*0.00*
Laboratory	*6.30*	*3.68*	*0.00*	*0.00*
Multifamily Housing[3,4]	0.89	*0.63*	*0.37*	*0.00*
Non-Refrigerated Warehouse	0.77	*0.45*	*0.00*	*0.00*
Office	0.81	*0.47*	*0.00*	*0.00*
Other	2.48	*1.45*	*0.00*	*0.00*
Recreation	3.22	*1.88*	*0.00*	*0.00*
Refrigerated Warehouse	0.98	*0.57*	*0.00*	*0.00*
Residence Hall/Dormitory	1.16	*0.68*	*0.00*	*0.00*
Restaurant	5.73	*3.34*	*0.00*	*0.00*
Retail Store	1.03	*0.60*	*0.00*	*0.00*
Self-Storage Facility	0.31	*0.18*	*0.00*	*0.00*
Senior Living Community	2.11	*1.23*	*0.00*	*0.00*
Services	1.36	*0.79*	*0.00*	*0.00*
Supermarket/Grocery Store	3.42	*2.00*	*0.00*	*0.00*
Worship Facility	1.20	*0.70*	*0.00*	*0.00*

1 – Targets may be revised by future rule, per subsection 925.070.A.
2 – Net-zero emissions by 2041-2045 for nonresidential.
3 – Net-zero emissions by 2046-2050 for multifamily housing.
4 – Pursuant to Section 22.925.110, owners of low-income housing, human service use, and low-rent housing may receive an extension from meeting the GHGITs in 2031-2035 but still must meet benchmarking verification and all other reporting obligations for 2031-2035.

Table B for 22.925.070: Greenhouse gas emissions factors

	Emissions factors (kgCO2e/kBtu)	
Energy source	For baseline GHGI (2019-2028)	For compliance GHGI (2031 – 2035) (Provisional)
Seattle City Light electricity	.0058	.0029
Puget Sound Energy natural gas	.053	.053
CenTrio district thermal energy	.081	.081

Other fossil fuels: Emission factors for fuels such as heating oil, propane, etc. will reference the US EPA.[4]

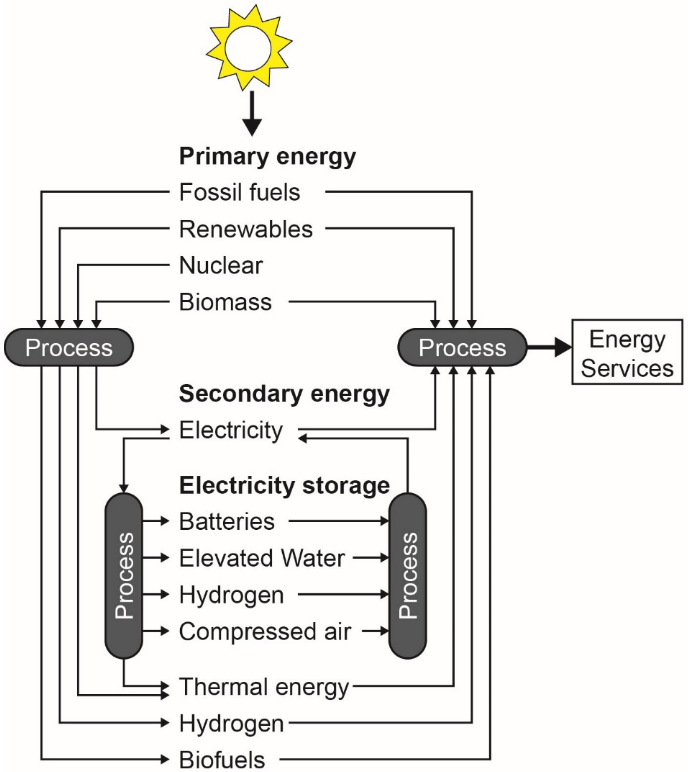
Other Cities

- New York City: Local Law 97 sets carbon emission limits for buildings over 25,000 square feet.
- Boston: Has a BPS that targets energy use reductions in large buildings.
- St. Louis: Enacted a BPS focusing on energy performance in buildings over 50,000 square feet.
- Washington, D.C.: Implemented a BPS that requires buildings to meet specific energy performance targets.
- Reno, Nevada: Adopted BPS to enhance building energy efficiency.
- Chula Vista, California: Has also enacted BPS to address building energy performance.

Building Codes

Building Codes

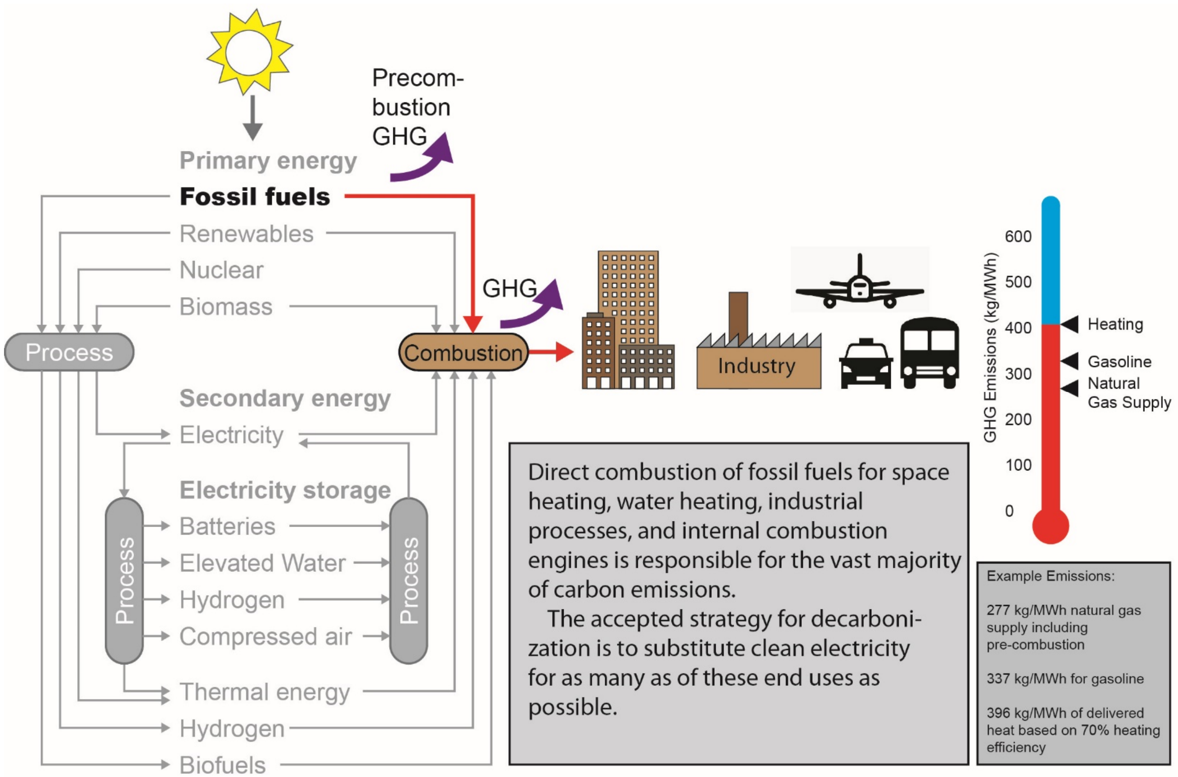
Base Diagram



- Primary energy is originates from the sun
- Secondary energy is created from primary energy
- Virtually all GHG emissions originate from fossil fuels or biomass
- This diagram will be used to illustrate GHG for various forms of energy

Source: https://eley.com/node/87

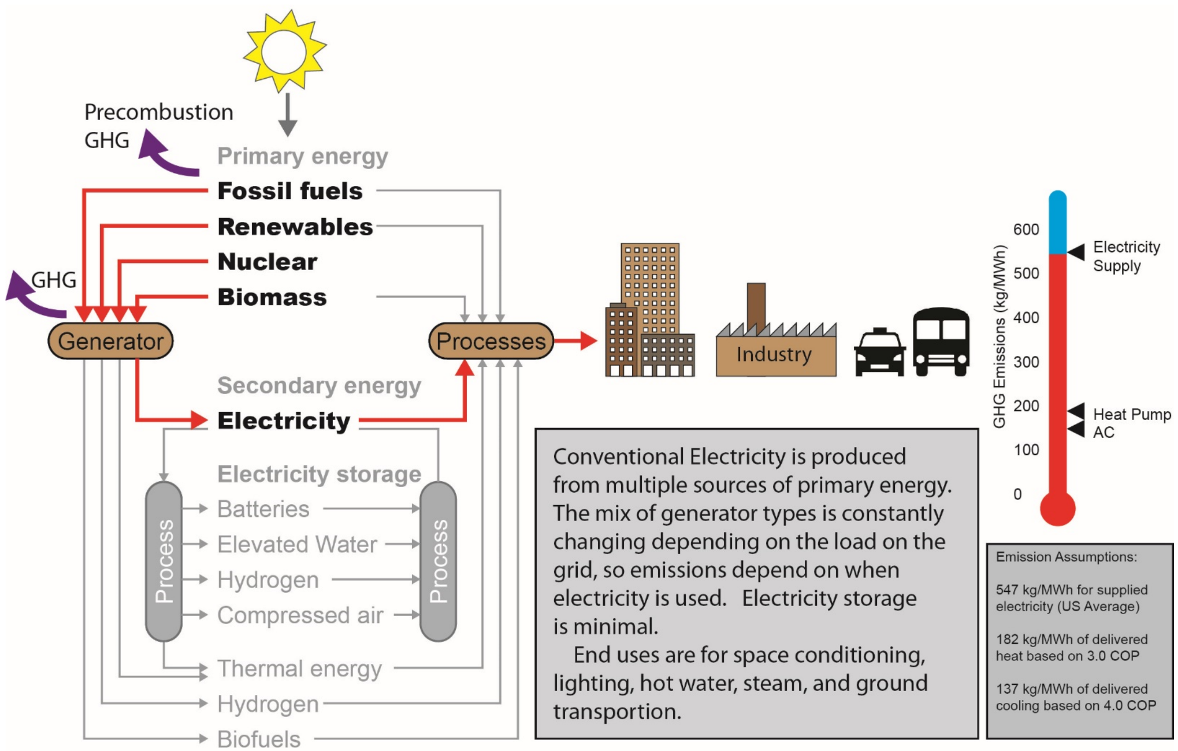
Fossil Fuel Use



- Fossil fuel is extracted from the earth and delivered to buildings or industry where it is burned
- It is used to power buildings, industry and transportation
- Emissions include both pre-combustion and combustion

Source: https://eley.com/node/87

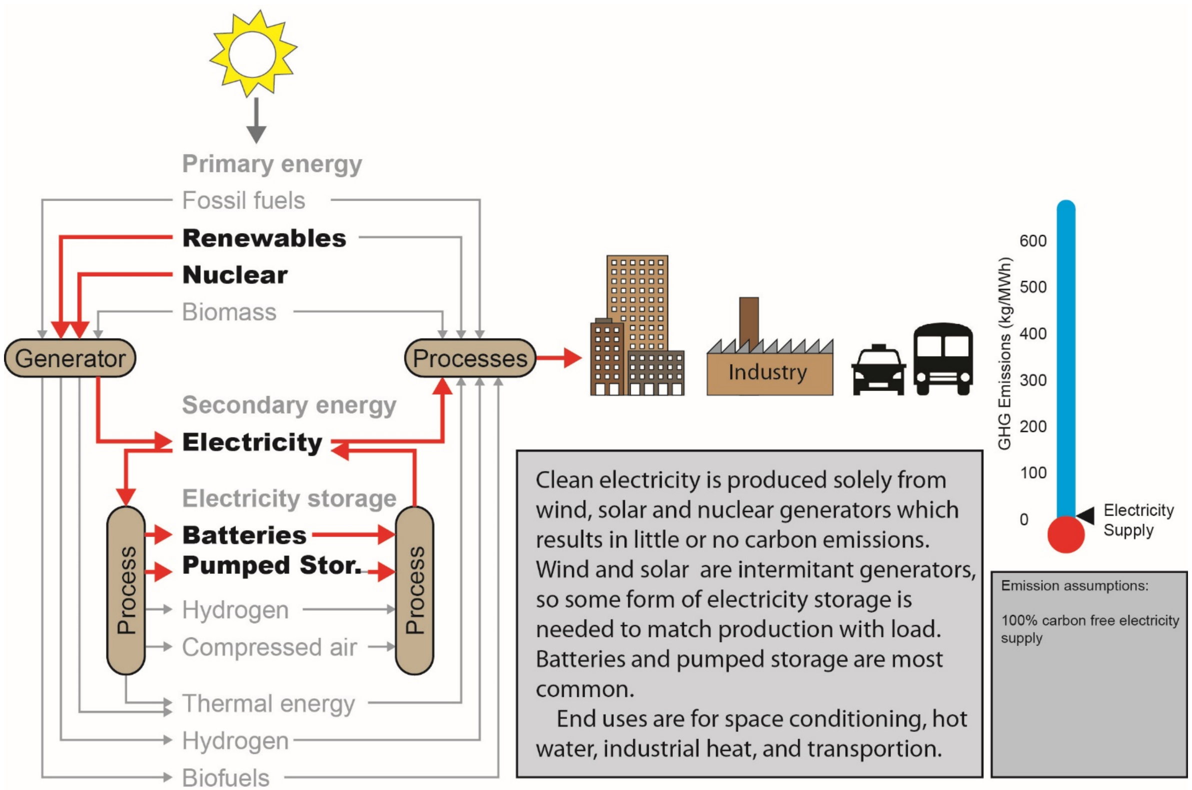
Conventional Electricity



- Conventional electricity is generated from a variety of generators
- The mix is very different by state or country and changes hourly depending on load

Source: https://eley.com/node/87

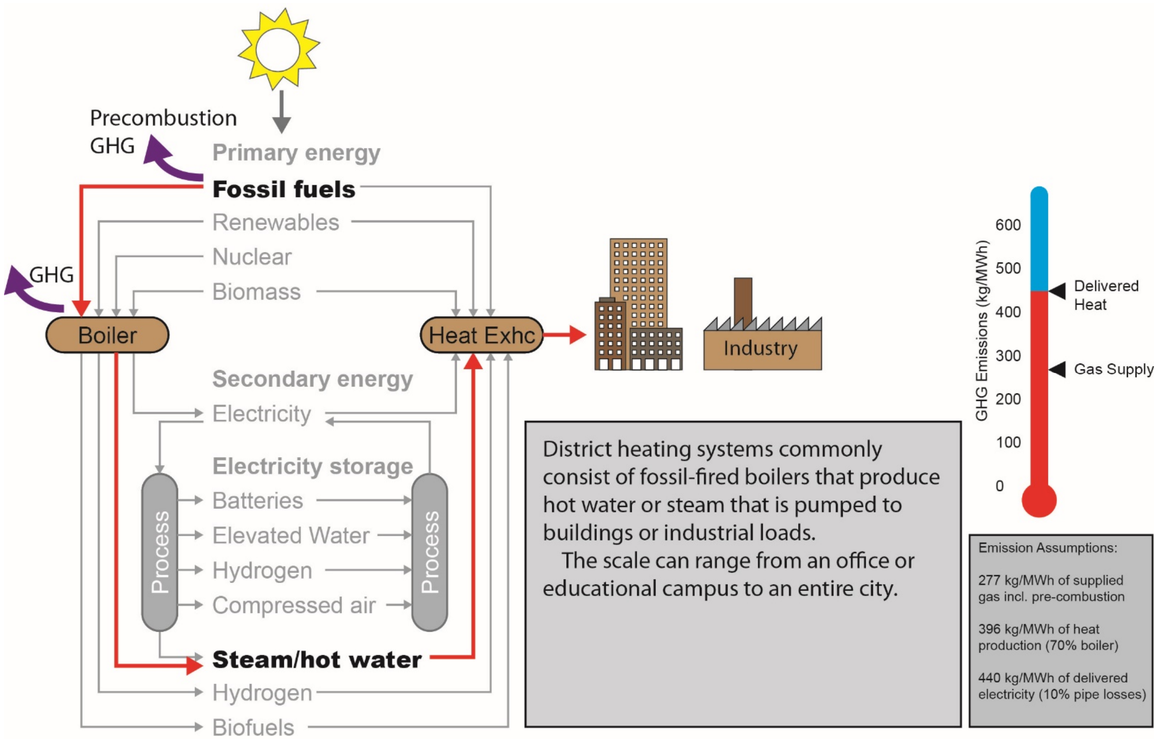
Clean Electricity



- Clean electricity is generated solely from renewable energy or nuclear
- This is our goal
- Solar and wind are variable so clean energy requires some means of electricity storage

Source: https://eley.com/node/87

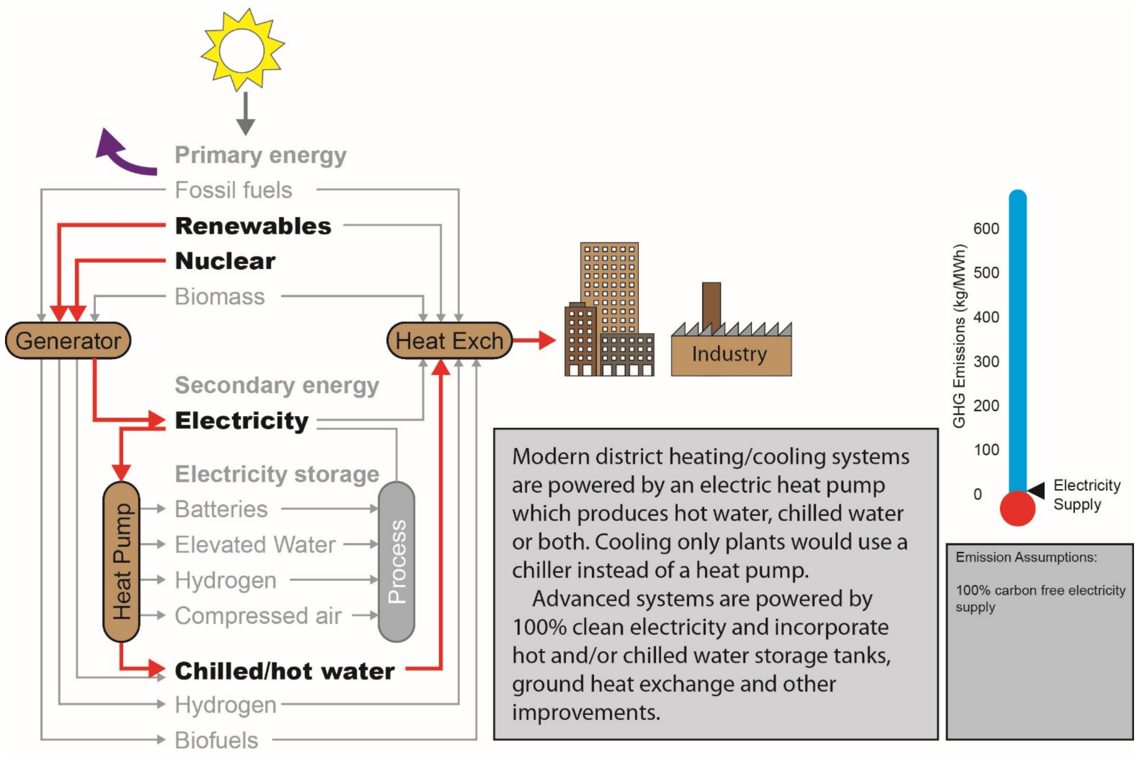
District Heat



- Typical of most district heating systems
- Boilers are often inefficient and pipe losses are significant

Source: https://eley.com/node/87

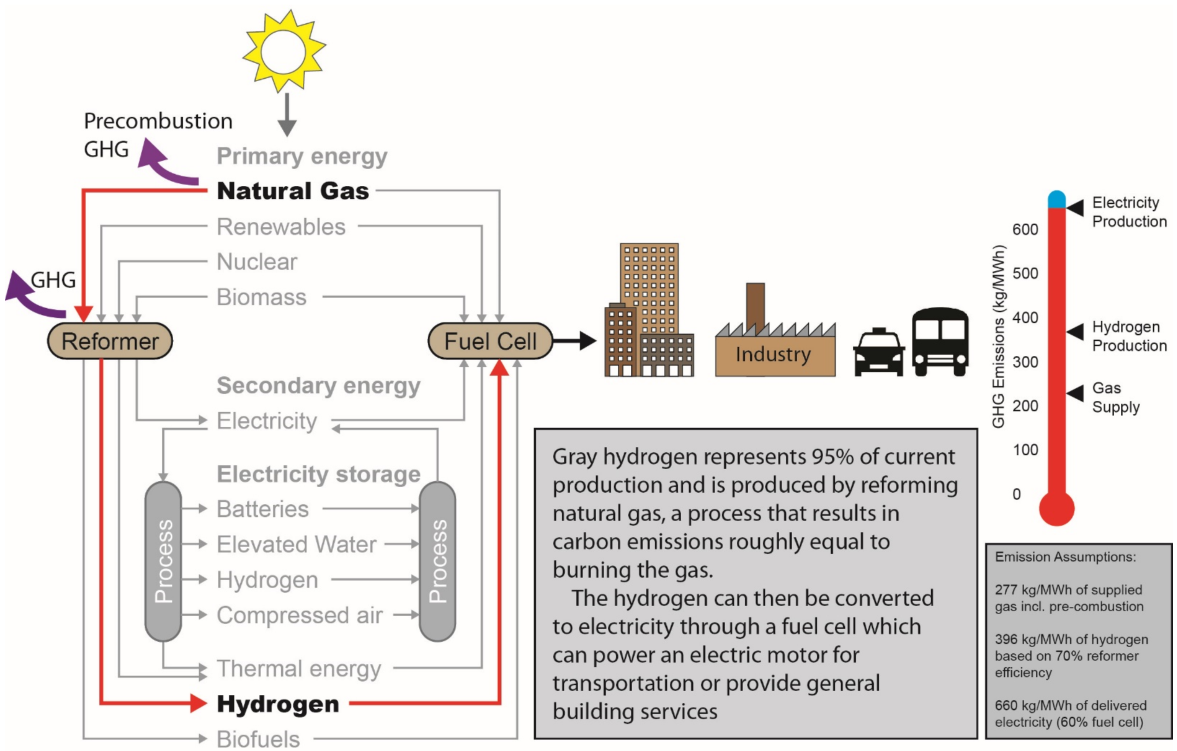
Zero-GHG District Heating and Cooling



- Stanford University and the Google Bay View campuses use systems like this

Source: https://eley.com/node/87

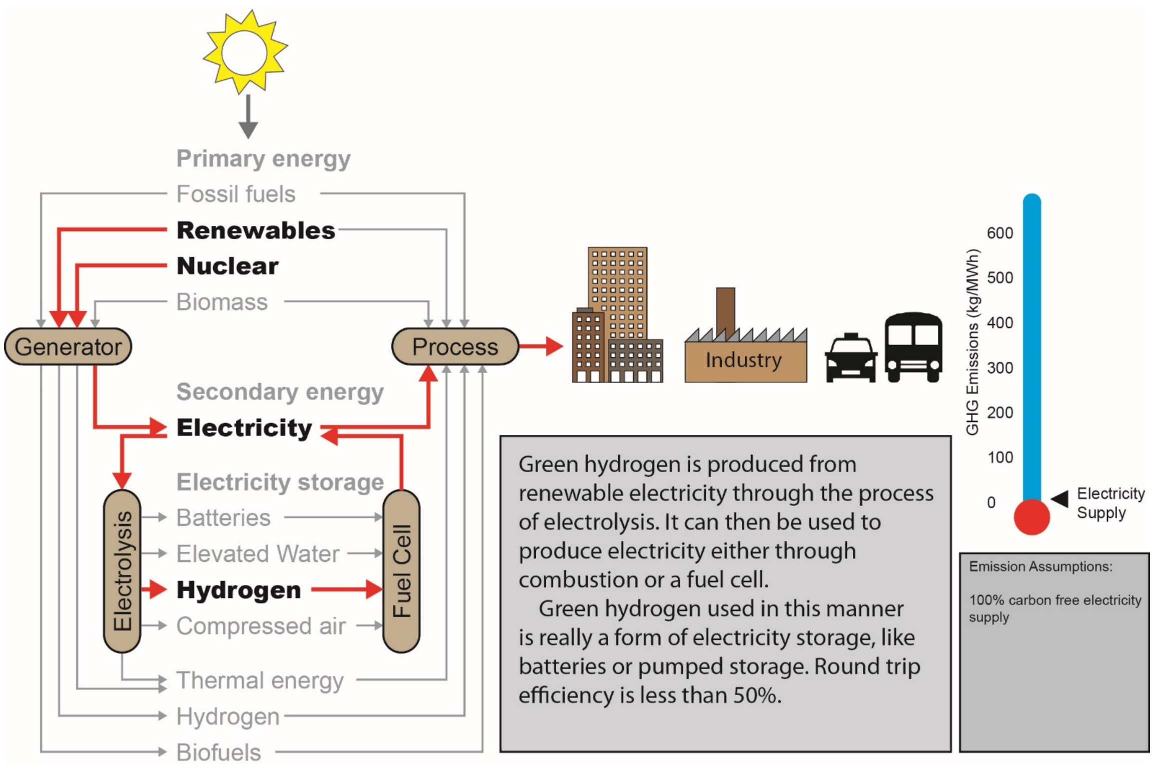
Gray Hydrogen



- About 95% of hydrogen is produced this way

Source: https://eley.com/node/87

Green Hydrogen



- Less than 1% of hydrogen production
- Is really a form of electricity storage

Source: https://eley.com/node/87

Biomass – It's Complicated

Possible Biomass Actions	*Counterfactual*	*Impact*
Methane is captured from feed lots or landfills and mixed with natural gas supplies or used to generate electricity. CO_2 is released to the atmosphere as the methane is burned..	Methane would be released to the atmosphere but at a slower rate. Methane has a global warming potential much greater than CO_2.so the climate damage could be greater	*Somewhat beneficial*. The global warming from the CO_2 release would generally be less than the slower release of methane.
Switchgrass, corn or sugar is grown and processed into ethanol. GHG would be released through farming, processing, delivery and finally from combustion of the ethanol.	The land would be used (or continue to be used) to grow, process and deliver food to consumers, a process which would also generate GHG.	*Depends.* The main difference between the action and the counterfactual is the combustion of the ethanol. This represents a burst of GHG as opposed to a slow release from digestion and food waste in landfills. Also, land that would otherwise be used to grow food would be repurposed to generate a biofuel.
Wood or waste is burned to make electricity. CO_2 and other pollutants are released to the atmosphere. This release would be near instantaneous in geologic time.	The wood or waste would release CO_2 and other GHG if it is left in the forest or land fill to decay. This process would be slow and last for decades	*Bad*. Wood/waste power plants are extremely dirty, producing more pollutants per MWh than even coal plants. While similar amounts of GHG would result from the counterfactual, the release would be spread over decades.
Timber is harvested to produce pellets that are processed and shipped overseas to make electricity. GHG is released from harvesting, transportation, processing the pellets, shipping them to the power plant and from combustion at the power plant.	The unharvested forest would continue absorb GHG from the atmosphere.	*Really Bad*. Significant GHG emissions would be released from the activities of making pellets, shipping them to a remote location, and burning them. The impact would be amplified as a carbon sink is eliminated.
Rain forests are burned to clear land for agriculture or grazing.	The rain forest would be maintained and nurtured as a major carbon sink.	*Worst*. A significant carbon sink is destroyed and massive carbon emissions result from the fire.

Source: https://eley.com/node/87