

Updating the Operational Emissions Score for Laboratories

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1. Overview

This memo describes an update to a previously developed system [1] for assigning laboratory buildings a score that reflects their operational greenhouse gas (GHG) emissions performance relative to their peers, primarily for use in the Laboratory Benchmarking Tool (LBT) [2]. The score was designed to rate a building's operational emissions performance based on its location, (i.e., electrical grid emissions rate), energy consumption, and fuel mix, while adjusting for factors it cannot control (i.e., functional requirements like lab use type, occupied hours, climate, etc.). This score is meant to evaluate location-based operational emissions (a market-based emissions score would require additional data that is not currently available in the LBT), and is meant to be complementary to the LBT's energy score.

Since the score was originally developed, significant efforts have been made to expand the LBT dataset through additional data collection. With the newly available data, we have re-evaluated the regression model underlying the scoring system, and have updated the score computations using the new model. We have also updated the scoring system to use the newest available GHG emissions factors.

This work was carried out by Lawrence Berkeley National Laboratory (LBNL) and the International Institute for Sustainable Laboratories (I2SL), and we received valuable feedback from several stakeholders and members of I2SL's Labs2Zero Operational Emissions Technical Advisory Committee (TAC).

2. Data Sources

The primary source of data for this analysis was the dataset underlying the Laboratory Benchmarking Tool (LBT) [2], which is the largest known collection of energy-related information on laboratory buildings. The database contains over 4000 records and 100 fields

describing various characteristics of each laboratory building (e.g., size, age, location, operating characteristics, installed systems, and energy consumption). See the full list of LBT data fields and their descriptions [3] for more information.

Since the score was originally developed, I2SL has made significant data outreach efforts to expand the LBT dataset, with the goal of increasing the amount of recent data and of specifically targeting some types of lab buildings that were previously under-represented. Based on discussions with the I2SL Energy Score TAC, the type-specific outreach focused on laboratory buildings with a large amount of vivarium space, on manufacturing facilities, and on facilities in cold-weather locations (ASHRAE Climate Zones 6 and higher). The outreach resulted in 323 buildings being added to the LBT dataset, including increases in the targeted categories (6 more vivarium-dominated buildings, 3 more manufacturing facilities, and 14 more cold-weather facilities).

We carefully inspected the data entered by users of the LBT and removed any data deemed to be unreliable (e.g., physically unrealistic) or otherwise not representative of laboratories in general (e.g., abnormally high or low values relative to other buildings), but acknowledge that some data errors may not have been detected. When developing the score, we utilized only the small subset of the dataset (572 out of 4929 total records) passing all of our data quality checks, which are now stricter than when the score was originally developed. In particular, we included only data from 2014 and later in the new subset. As for the first version of the score, we included only buildings located in the United States.

For each building in the LBT dataset, we computed source energy from energy consumption of each individual fuel using conversion factors in Figure 1 of the U.S. Environmental Protection Agency's (EPA) Technical Reference on Source Energy [4].

To compute GHG emissions from energy consumption of individual fuels, we used different sources for emissions factors, depending on the fuel.

For all fuels except grid electricity and district chilled water (i.e., natural gas, fuel oil #2, district hot water, and district steam), we used the factors in Figures 1 and 3 of the EPA's Technical Reference on GHG Emissions [5]. Buildings using fuels other than those listed in Figures 1 and 3 (i.e., fuels without known emissions factors) were excluded from the analysis.

For grid electricity, we first looked up each building's eGRID subregion from its ZIP code using the EPA's Power Profiler Emissions Tool [6]. We then computed GHG emissions due to grid electricity using Table 1 in the eGRID Summary Tables [7]. If ZIP code was not available, we used the state average emissions factor from Table 3. If neither ZIP code nor state was available, we used the national average factor from Table 3. Fewer than 1% of buildings did not have a ZIP code available in the dataset.

For district chilled water, we started with the emissions factor for an electric-driven chiller in Figure 3 of the EPA's Technical Reference [5], then scaled the factor using the ratio of each

particular building's electricity emissions factor to the national average factor (from Figure 5 in EPA's Technical Reference [5]).

For example, consider a building in ZIP code 60463. In the Technical Reference [5], the district chilled water factor from Figure 3 is 52.70 kgCO₂e/MBtu, and the national average electricity factor from Figure 5 is 109.99 kgCO₂e/MBtu. The Power Profiler [6] indicates eGRID subregion RFCW, and the Summary Tables [7] indicate an electricity emissions factor of 916.0 lbCO₂e/MWh = 121.77 kgCO₂e/MBtu. Thus, the district chilled water factor for this building would be computed as $52.70 \times 121.77 / 109.99 = 58.34$ kgCO₂e/MBtu.

3. Computing a Score

In order to quantify a building's operational emissions performance relative to its peers, we first predict the amount of energy a typical building with the same functional requirements is expected to use, then compute the GHG emissions a typical building would emit as a result of that energy use, then compare the building's actual GHG emissions to the expected emissions.

In order to predict expected energy use, we used the linear regression model developed as part of the LBT Energy Score methodology (see [8] for details). This model was constructed by identifying statistically significant relationships between source energy use intensity (EUI) and several variables deemed as functional requirements of laboratory buildings, thus reflecting typical energy use while adjusting for characteristics and operating behaviors necessary for a functioning laboratory. The model predicts source EUI (kBtu/sqft) with the following coefficients:

- Intercept: 227 kBtu/sqft
- Ducted Fume Hood Density [number of hoods per unit area of lab space]: 35.0 (kBtu/sqft) / (number of hoods / 1000 sqft)
- Occupied Hours: 0.447 (kBtu/sqft) / (hours/week)
- Lab Area Ratio [fraction of gross area that is lab space]: 280 (kBtu/sqft) / 100%
- HDD: 12.0 (kBtu/sqft) / (1000 degree-days)
- CDD: 54.4 (kBtu/sqft) / (1000 degree-days)
- Lab Type = Manufacturing: +107 kBtu/sqft
- Lab Type = Teaching: -127 kBtu/sqft
- Vivarium Lab Area [fraction of lab space that is vivarium]: 165 (kBtu/sqft) / 100%

Note that the previous version of the operational emissions scoring system used the previous version of the LBT Energy Score model, but this updated operational emissions scoring system uses the updated version of the LBT Energy Score model. See [8] for more detail on the differences between the previous and updated regression models.

We used the LBT database to learn the relationship between a typical laboratory building's energy consumption and its operational GHG emissions, based on the assumption that the LBT contains a representative sample of laboratories in the United States. This assumption is difficult to test, but since the LBT is the largest known collection of laboratory energy data, we believe it to be reasonable. For each peer building in the LBT database, we computed the ratio of GHG emissions intensity (GHGI) to source EUI, then computed the average of that ratio to be 36.492 kgCO₂e/MBtu. For each building, we multiply its predicted source EUI by this ratio to yield its predicted GHGI (interpreted as the GHGI of a typical laboratory building with similar functional requirements to the building in question).

To compare a building's operational emissions performance to that of its peers, we compute its GHGI ratio as its actual GHGI divided by its predicted GHGI. The resulting GHGI ratio represents the proportion of predicted GHGI that the building actually used. For example, a GHGI ratio of 0.75 means the building emitted 75% as much GHG as predicted for a building with the same functional requirements and a typical ratio of GHGI to source EUI (i.e., a typical fuel mix and typical emissions factors).

Following the methodology used for the LBT Energy Score [8], we fitted a gamma distribution to these GHGI ratios (see Figure 1), then used the fitted gamma distribution to generate a lookup table (see Table 1) that maps each range of GHGI ratios to the corresponding operational emissions score. The score represents the percentage of buildings performing worse than a given building (i.e., a score of 100 indicates highest performance and a score of 1 indicates lowest performance). For example, consider a building with a predicted GHGI of 28.17 kgCO₂e/sqft, and assume that this building's actual GHGI was 19.23 kgCO₂e/sqft. The GHGI ratio is computed as $19.23 / 28.17 = 0.6826$. According to Table 1, this ratio corresponds to a score of 70.

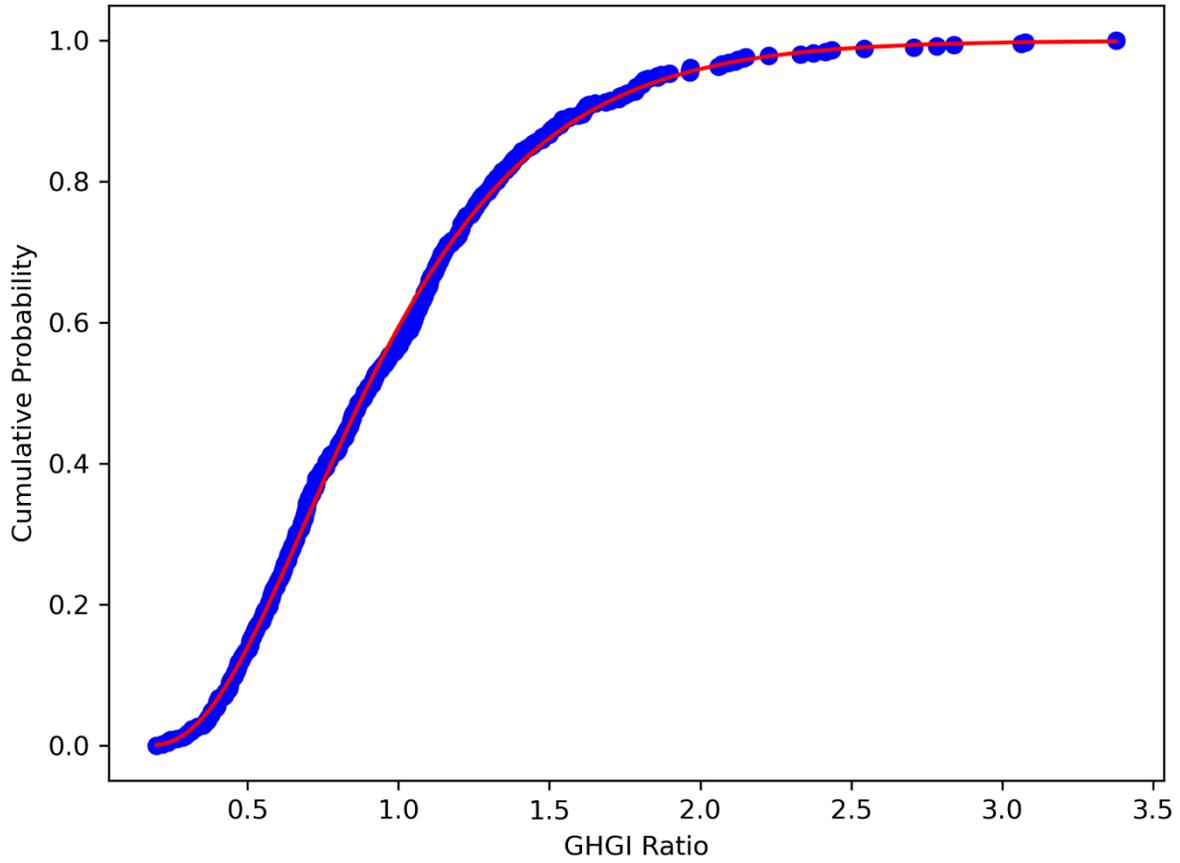


Figure 1: Cumulative distribution function for GHGI ratio. The blue circles represent the ratios computed from the dataset. The red line represents the gamma distribution fitted to the computed ratios.

Score	GHGI Ratio Min	GHGI Ratio Max
100	0	0.2707
99	0.2707	0.3056
98	0.3056	0.3319
97	0.3319	0.3538
96	0.3538	0.3732
95	0.3732	0.3908
94	0.3908	0.4071
93	0.4071	0.4224
92	0.4224	0.4369
91	0.4369	0.4508
90	0.4508	0.4641
89	0.4641	0.4770
88	0.4770	0.4895
87	0.4895	0.5017
86	0.5017	0.5136

85	0.5136	0.5252
84	0.5252	0.5367
83	0.5367	0.5480
82	0.5480	0.5591
81	0.5591	0.5700
80	0.5700	0.5809
79	0.5809	0.5916
78	0.5916	0.6023
77	0.6023	0.6128
76	0.6128	0.6233
75	0.6233	0.6338
74	0.6338	0.6442
73	0.6442	0.6545
72	0.6545	0.6649
71	0.6649	0.6752
70	0.6752	0.6855
69	0.6855	0.6958
68	0.6958	0.7061
67	0.7061	0.7164
66	0.7164	0.7267
65	0.7267	0.7371
64	0.7371	0.7474
63	0.7474	0.7578
62	0.7578	0.7683
61	0.7683	0.7788
60	0.7788	0.7893
59	0.7893	0.8000
58	0.8000	0.8106
57	0.8106	0.8214
56	0.8214	0.8322
55	0.8322	0.8431
54	0.8431	0.8541
53	0.8541	0.8652
52	0.8652	0.8764
51	0.8764	0.8878
50	0.8878	0.8992
49	0.8992	0.9108
48	0.9108	0.9225
47	0.9225	0.9343
46	0.9343	0.9463
45	0.9463	0.9585
44	0.9585	0.9708

43	0.9708	0.9834
42	0.9834	0.9961
41	0.9961	1.0090
40	1.0090	1.0221
39	1.0221	1.0355
38	1.0355	1.0491
37	1.0491	1.0630
36	1.0630	1.0772
35	1.0772	1.0916
34	1.0916	1.1064
33	1.1064	1.1215
32	1.1215	1.1370
31	1.1370	1.1529
30	1.1529	1.1691
29	1.1691	1.1858
28	1.1858	1.2030
27	1.2030	1.2207
26	1.2207	1.2390
25	1.2390	1.2579
24	1.2579	1.2774
23	1.2774	1.2976
22	1.2976	1.3186
21	1.3186	1.3405
20	1.3405	1.3633
19	1.3633	1.3872
18	1.3872	1.4122
17	1.4122	1.4385
16	1.4385	1.4663
15	1.4663	1.4958
14	1.4958	1.5272
13	1.5272	1.5609
12	1.5609	1.5971
11	1.5971	1.6365
10	1.6365	1.6796
9	1.6796	1.7273
8	1.7273	1.7809
7	1.7809	1.8420
6	1.8420	1.9135
5	1.9135	1.9999
4	1.9999	2.1097
3	2.1097	2.2617
2	2.2617	2.5158

1	2.5158	inf
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Table 1: Lookup table mapping each range of GHGI ratios to the corresponding operational emissions score.

4. Next Steps

We computed emissions scores for each of the buildings in the LBT dataset (including several buildings entered into the LBT solely for the purpose of testing the emissions score), and confirmed the desired behavior of the score. For example:

- An all-electric building with a typical site EUI located in a region with a very dirty electric grid received a very low emissions score.
- An all-electric building with a typical site EUI located in a region with a very clean electric grid received a very high emissions score.
- A building with a typical site EUI, relatively little electric use, and located in a region with a dirty grid received a relatively high emissions score.
- A building with a typical site EUI and fuel mix, but located in a region with a very dirty grid received a moderately low emissions score.
- A building with a typical site EUI and fuel mix, but located in a region with a very clean grid received a moderately high emissions score.

In addition, we performed several checks for biases within the scoring system. We looked at buildings with very high scores and confirmed that the scores are deserved (e.g., an all-electric building in a very clean grid region), and likewise for very low scores. We also looked for relationships between emissions scores and laboratory characteristics (e.g., lab type, climate, grid region, electric to site ratio) and found no strong correlations. We also looked at buildings with abnormal combinations of energy scores (see [8]) and emissions scores, and confirmed that both scores are as expected (e.g., a building with a high energy score but a low emissions score has a low source EUI, but uses a lot of electricity and is located in a region with a dirty electric grid).

We checked how emissions scores have changed for particular buildings when changing from the old to the new scoring system. Overall, we found a small tendency towards lower emissions scores with the new scoring system, with a small portion of labs scoring significantly higher. Of the 1327 LBT peer buildings, 85% of the buildings had their score change by less than 15 points, and 43% of buildings had their score change by less than 5. We found that the changes in the emissions score are largely due to the changes in the underlying energy score regression model. For example, note that the previous energy score model did not include a coefficient for HDD, but the new model has a positive HDD coefficient. Labs with lower values of HDD tended to receive lower energy and emissions scores with the new scoring systems. We observed similar effects for other variables associated with changes in the new energy score model (e.g., score

increases for labs with a greater density of fume hoods and higher proportion of vivarium area, and score decreases for biological/chemical labs and for buildings with fewer fume hoods).

We are confident in the utility of this scoring system, but acknowledge that further scrutiny and refinement may be needed to achieve stakeholder buy-in and widespread adoption and use of the score. We will continue to check for indications that the score is treating any particular types of buildings unfairly (e.g., whether buildings of particular types or in particular locations tend to score abnormally higher or lower than their peers). If we identify any such biases, we will consider adjustments to the scoring methodology (potentially advised by additional data collection).

Lastly, as the LBT database grows and more information about the relationship between laboratory energy use and GHG emissions is available, we will consider updating the regression model used to predict expected source EUI, the factor used to convert predicted source EUI to GHGI, and the scoring methodology itself. As electrical grids change (e.g., as more renewables come online), we will also monitor updated emissions factors from the EPA and update our methodology when appropriate.

5. References

[1] T. Walter, J. Kace, and A. Farmer. "Development of an Operational Emissions Score for Laboratories". March 2024.

<https://lbt.i2sl.org/files/Development%20of%20an%20Operational%20Emissions%20Score%20for%20Laboratories.pdf>.

[2] International Institute for Sustainable Laboratories. "Laboratory Benchmarking Tool". 2025. <https://lbt.i2sl.org/>.

[3] International Institute for Sustainable Laboratories. "Laboratory Benchmarking Tool: Data Fields". May 2024. <https://lbt.i2sl.org/files/List%20of%20LBT%20Data%20Fields.pdf>.

[4] U.S. Environmental Protection Agency (EPA). "ENERGY STAR Portfolio Manager Technical Reference: Source Energy". August 2023. <https://portfoliomanager.energystar.gov/pdf/reference/Source%20Energy.pdf> (Accessed May 6, 2025).

[5] U.S. Environmental Protection Agency (EPA). "ENERGY STAR Portfolio Manager Technical Reference: Greenhouse Gas Emissions". August 2024. <https://portfoliomanager.energystar.gov/pdf/reference/Emissions.pdf> (Accessed May 6, 2025).

[6] U.S. Environmental Protection Agency (EPA). "Power Profiler Emissions Tool 2023". January 2025. https://www.epa.gov/system/files/documents/2025-01/power_profiler_zipcode_tool_v14.2.xlsx (Accessed May 9, 2025).

[7] U.S. Environmental Protection Agency (EPA). "eGRID Summary Tables". January 2025. https://www.epa.gov/system/files/documents/2025-01/egrid2023_summary_tables_rev1.xlsx (Accessed May 9, 2025).

[8] T. Walter, J. Kace, and A. Farmer. "Updating the Energy Score for Laboratories". May 2025. <https://lbt.i2sl.org/files/Updating%20the%20Energy%20Score%20for%20Laboratories.pdf>.