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Emerald Eco-Label: Methods for Correctness Checks

Data Analysis and Approach to Data Entry Verifications

Prepared for the National Asphalt Pavement Association
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Executive Summary

In order to reduce operator error during plant-specific data entry into the Emerald Eco-Label Tool, correctness checks were instituted by Trisight at NAPA's request. Realistic limits for energy and electricity use per short ton were determined by analyzing the LCA performed by Dr. Mukherjee. Plants with energy usages below 96,700 or above 476,000 BTU / short ton or electricity use outside 0.04 - 8.25 kWh / short ton are now flagged for error checking by the user. The user may also confirm that the data entry is correct and that their plant operates outside of the normal bounds for energy usage. This flags the plant for further review by site administrators.

Introduction

The National Asphalt Pavement Association (NAPA) has asked Trisight, LLC, to update the Emerald Eco-Label Tool with additional data correctness checks, to maintain the high quality of data in the outputs of the tool. Trisight performed the following tasks:

1. Determine an appropriate benchmark for data checks using the LCA performed by Dr. Mukherjee in 2016.
2. Add to the Emerald Eco-Label tool a background data check to compare data entered into the tool against the benchmarks.
3. Update the user work flow to include notices to the users when their data are outside of the expected parameters.

Background

In April of 2017, the Emerald Eco-Label site went live in a soft rollout. Manufacturers have slowly but steadily been creating EPDs, with usage ramping up, and an additional impetus coming from CalTrans piloting the requirement for EPDs in pavement procurement.

The tool was created with a number of basic data entry verifications (i.e. total tonnage from a plant ≠ 0), as well as several more advanced checks, like the mass balance checker for mix design. But as more manufacturers utilize the tool, there is a need for a more advanced check to eliminate much of the hands-on data verification. This is being accomplished by verifying that the total energy and electricity use per short ton of asphalt is within an appropriate range of the energy use per ton identified during the original life cycle assessment (LCA) underlying the tool.

Methods

Analysis of the LCA Data for Energy Use

The Emerald Eco-Label engine (or the EPD Tool for short) is based on the LCA performed by Dr. Amlan Mukherjee titled "Life Cycle Assessment of Asphalt Mixtures in Support of an Environmental Product Declaration" and released in June of 2016. Data were gathered and analyzed from 50 plants that acted as a representative set for the North American asphalt manufacturing industry. These data were obtained (with identifying meta-data removed) from Dr. Mukherjee and analyzed by Trisight to determine the population curve for BTU / short ton asphalt.

This was chosen as the main point of comparison because it reflects the fundamental operation of asphalt manufacturing, which follow the basic process of aggregate + binder + heat energy = asphalt. It also roughly follows a normal distribution, simplifying analysis.

Determining LCA Data Distribution

A basic data cleaning was performed, and plants missing essential data were not included in the analysis. This left a total of 43 plants for analysis in the LCA Data set. All fuel sources were separated by their usage. The portion used in equipment like loaders and trucks and electrical generation were eliminated, leaving the portion used in burners and hot oil heaters. These fuel sources were multiplied by their energy density to determine the total BTU usage. The energy density factors used are given in Table 1.

Table 1: Energy Density Factors

Fuel Type	Fuel Units	Conversion Factor
Natural Gas	MCF	1019890 BTU/MCF
Liquid Propane	Gal	87006 BTU/Gal
Diesel	Gal	130490 BTU/Gal
Recycled Fuel Oil	Gal	130490 BTU/Gal

The total BTU usage was then divided by total tonnage, and the outputs tested for normality. First a visual inspection via histogram was performed, shown in Figure 1.

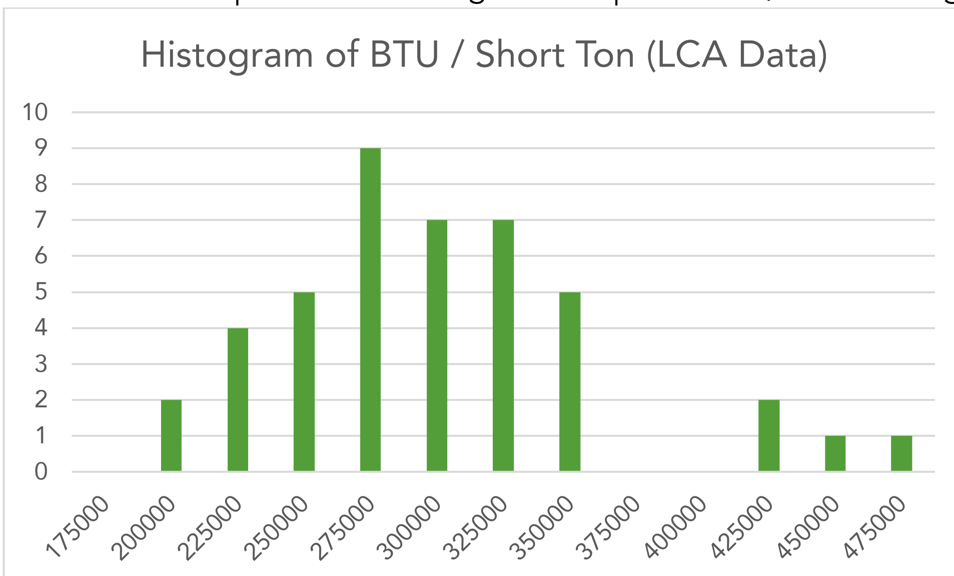

Figure 1: Distribution of Energy Usage from LCA

A slight skewness to the right was observed so a Chi-square test was performed using the typical testing parameters of α= 0.5 and H_0 = the data are normally distributed. The X^2 calculated was 15.48 which was less than $X^2(\alpha= 0.5, n=12)$ = 21.03 so the data were determined to follow a normal distribution. This significantly simplified the rest of the analysis.

Characterizing the LCA Data & Applying to EPD Tool Data

A simple mean and standard deviation analysis of the LCA data were performed and found to be

$$\text{BTU / short ton} = 2.86*10^5 \pm 6.32*10^4$$

Or written another way, this is an average of 286,000 BTU / short ton with a standard deviation of 63,200 BTU / short ton. This results in a 3σ range of 96,700 – 476,000 BTU / short ton. These numbers were then used to evaluate the plant data already entered by users into the EPD tool using a basic Z-test, where X is the observed value, χ is the sample mean, and σ is the standard deviation, such that

$$Z = ABS(X - \chi) / \sigma$$

$$Z = ABS(X - 2.86*10^5) / 6.32*10^4$$

So a Z value of 1.0 indicates that the data point is one standard variation (or 1.0σ) away from the mean. Data where Z > 3 were flagged. Of forty-five plant data points, three were more than three standard deviations from the mean, with values of 35,400 (Z = 4.0), 41,300 (Z = 3.9) and 495,000 (Z = 3.3) BTU / short ton.

Characterizing the EPD Tool Data

To see how the EPD Tool population differed from the LCA data, the same process of determining the population distribution was used on the EPD Tool data as had been used on the LCA data. The histogram of total BTU / short ton is shown in Figure 2.

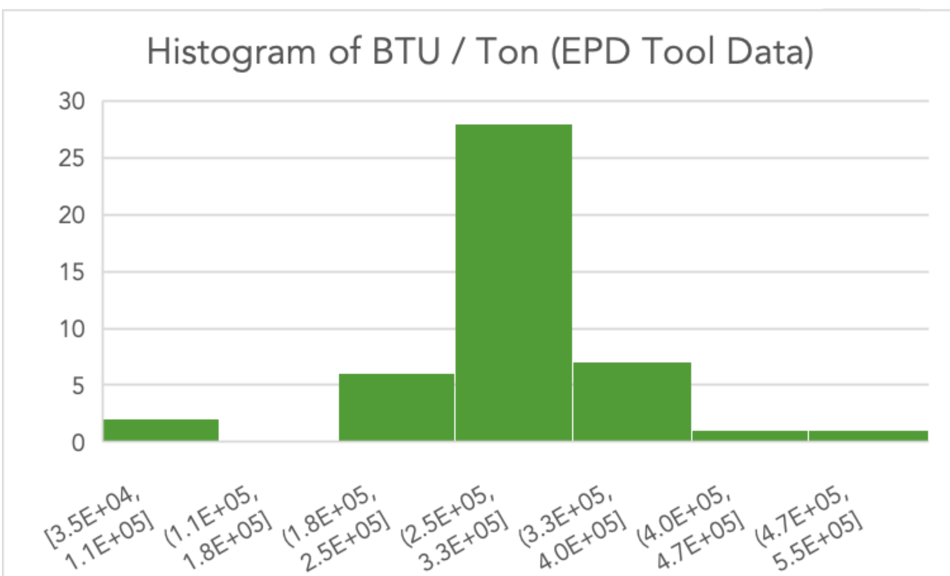

Figure 2: Distribution of Energy Usage from EPD Tool

A visual inspection of the histogram revealed a normal distribution. The mean and standard deviation of the EPD Tool Data were found to be

$$\text{BTU / short ton} = 2.90*10^5 \pm 7.39*10^4$$

Or in plain text, this is an average of 290,000 BTU / short ton with a standard deviation of 73,900 BTU / short ton. This mean is nearly identical to that of the LCA data (χ = 286,000 BTU / short ton), but the EPD Tool population has a larger variance than the LCA data (σ = 63,200 BTU / short ton).

This distribution was used to evaluate the EPD Tool data, using a Z-test where

$$Z = ABS(X - 2.90*10^5) / 7.39*10^4$$

Again, data where Z > 3 were flagged. Of forty-five plant data points, two were more than three standard deviations from the mean, with values of 35,400 (Z = 3.4) and 41,300 (Z = 3.4) BTU / short ton. These were two of the three plants identified as outliers using the LCA data. Only the plant with an energy usage of 495,000 (Z = 2.8) BTU / short ton was not flagged using both the LCA data-based evaluation and the EPD Tool data-based evaluation.

To visualize this difference between the EPD Tool and LCA data sets, Figure 3 presents the EPD Tool data (in green) with the LCA data upper (blue) and lower bounds (red), and Figure 4 gives the same EPD Tool data (green) but with the EPD Tool upper (blue) and lower bounds (red). Notice the looser bounds in Figure 4 no longer catch the plant data point in the upper right of the scatter plot.

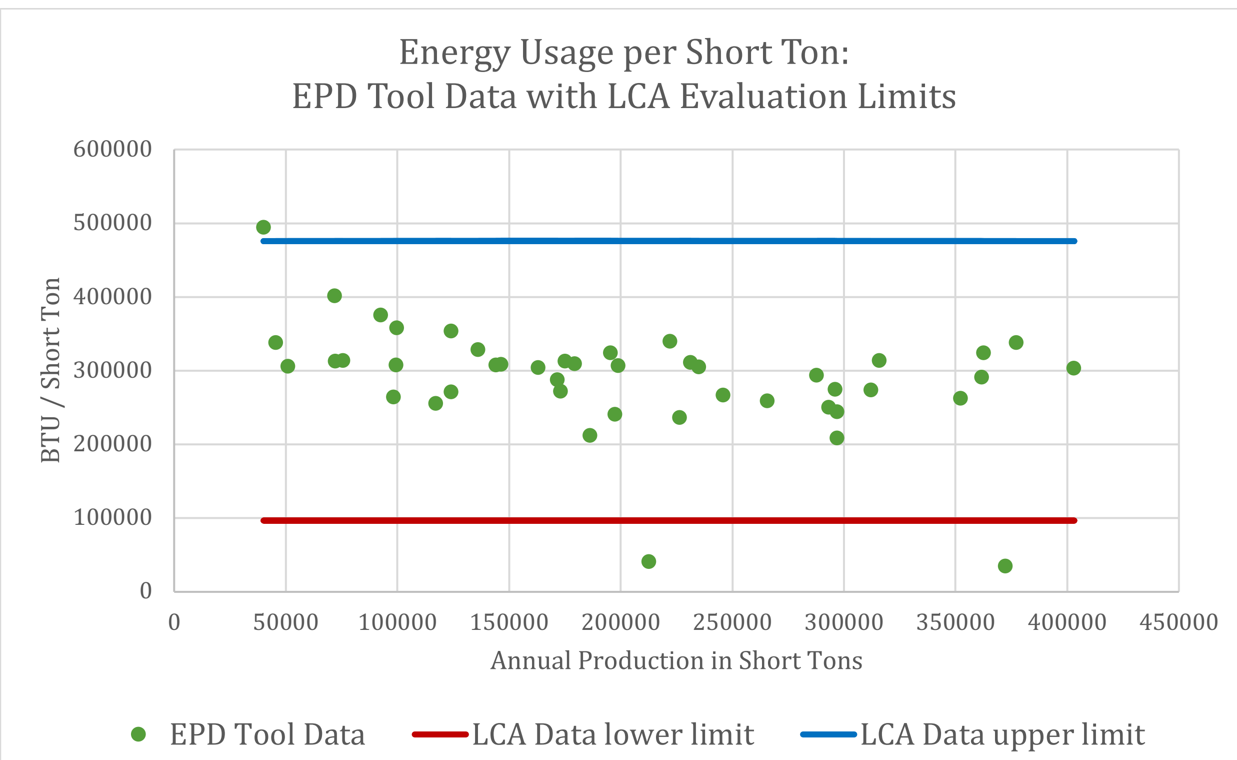

Figure 3: Scatter Plot of Energy Usage vs Annual Production from EPD Data with LCA-based limits

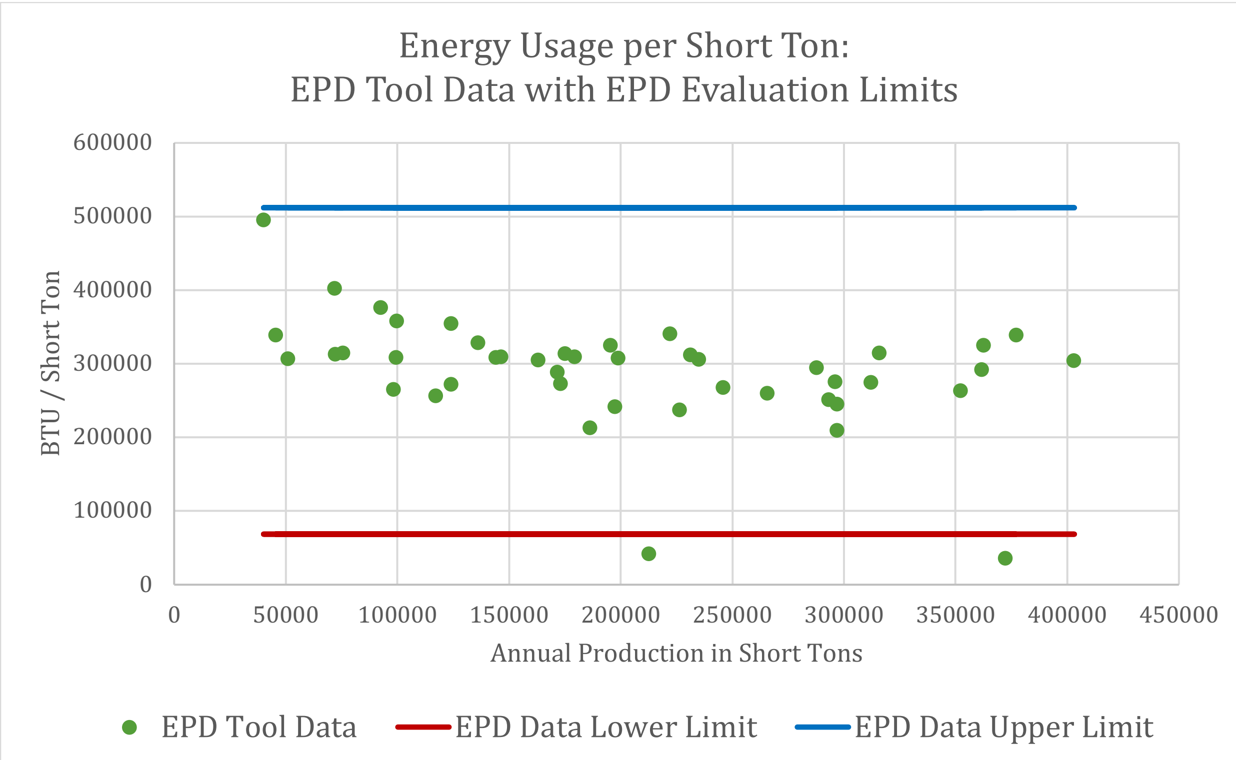

Figure 4: Scatter Plot of Energy Usage vs Annual Production from EPD Data with EPD Tool-based limits

The differences in the distributions may be due to the sub-set of users who are early adopters of the EPD Tool not being the same as the set of plants used to generate the LCA data. The LCA was designed to be a representative set of asphalt manufacturers at the time it was performed. Therefore, these data are being used to evaluate data entered into the EPD Tool. It may be interesting to see how the EPD Tool population characteristics change over time, but for now the LCA is the best characterization of the industry.

Developing Electricity Bounds From LCA Data

In Dr. Mukherjee's LCA, the mean energy usage per plant and 95% confidence interval is found to be 3.32 ± 0.5 kWh / short ton, from a sample size of 32 plants. To simplify the finding appropriate bounds for electricity usage, standard deviation was calculated using the following transformation:

$\sigma = \sqrt{(n-1)} * (\text{CI upper limit} - \text{CI lower limit}) / t_{\alpha,n-1}$

$\sigma = \sqrt{(31)} * (3.82 - 2.82) / 1.64$

Where CI is the confidence interval, and $t_{\alpha,n-1}$ is the t distribution value that corresponds to the sample size n and the significance value of α (which is 0.05 in this case). This gives us a standard deviation of σ = 1.64 kWh / short ton and an expected electricity usage of kWh / short ton = 3.32 ± 1.64.

Using the same Z = 3 test of viability as applied in the energy usage above (or in laymen's terms, a value within 3 standard deviations of the mean is acceptable) gives upper and lower limits of 8.35 and 0 kWh / short ton, respectively. Given the wide variance of the data, the decision was made to use a lower limit of 2 standard deviations, so that the limit would be non-zero (0.04 kWh / short ton).

An additional check was created to address the plants that have a grid electricity usage of zero, as detailed in the next section on implementation in the software. Finally, a check to more precisely correlate generator fuel use with electrical use was developed by Joseph Shacat. The transformation factor is 0.075 gal fuel / kWh electricity and its development is detailed in Appendix A.

Correctness Check Implementation in the Software

Energy Use

Using the energy density factors given in Table 1, a calculation of BTU / short ton was added to the Emerald Eco-Label tool. During the plant information entry step, this value is calculated and compared against the LCA data, and if Z >3 (if the value is below 96,700 or above 476,000 BTU / short ton), the following actions occur:

1. The user is told that their energy usage per short ton is outside of normal bounds and is prompted to check the fuel use numbers entered and units selected.
2. The user is given the opportunity to affirm that the data they entered are correct, and to proceed forward. If this occurs, the data are flagged for review by Trisight.

Electricity Use

During the plant information entry step, the electricity use per short ton is calculated, and if it is outside the bounds of 0.04 – 8.35 kWh / short ton, the same actions occur as above, except the user is prompted to check / affirm their electricity data, instead of their fuel numbers. If the electricity from the grid is exactly zero, the tool checks that there is a value entered in either the generator or onsite solar fields, and if not, prompts the user to check their data entry. An additional check to more precisely correlate generator fuel use with electrical use was developed by Joseph Shacat. It uses a factor of 0.075 gal / kWh to transform fuel used in the generator to electrical use which is then added to the total electrical per short ton in the tool prior to the electrical check. This method is detailed in Appendix A.

Both the electricity and energy use data are only available for viewing by site administrators.

Appendix A. Onsite Generator Fuel Consumption

Asphalt plants typically purchase electrical power from the grid, but sometimes utilize an onsite generator for portable plants, remote locations where grid power is not available, or to supply emergency power. To include generator fuel consumption in the Emerald Eco-Label correctness check protocol for electricity consumption, a conversion factor of 0.075 gallons of fuel per kWh, or 13.33 kWh per gallon of fuel, was selected as a reasonable estimate for converting generator fuel consumption to electricity consumption. A description of how this conversion factor was selected is provided below.

Generators are typically rated by their power generation capacity (kW). For instance, a 500 kW genset operating at full capacity will generate 500 kWh in one hour of operation. Generator fuel consumption is typically indicated in terms of gal/hr as a function of generator rating (kW) and load (e.g., 25%, 50%, etc.). Table A-1 provides typical fuel consumption values for three select generator sizes that span the range of required capacities for most portable or remote asphalt plants.

Table A-1. Typical fuel consumption rates for select generator sizes1

Generator Rating (kW)	Generator Load			
	25%	50%	75%	100%
	Fuel Consumption (gal/hr)			
250	5.7	9.5	13.6	18
500	11	18.5	26.4	35.7
750	16.3	27.4	39.3	53.4

For each combination of generator rating and generator load in Table A-1, the electricity production during one hour of operation is simply the product of the generator rating and the load. For example, a 500 kW generator operating at 50% load will generate 250 kWh per hour. Therefore, the fuel consumption rate can be converted from gal/hr to gal/kWh by dividing the fuel consumption rate in gal/hr by

[1] https://www.generatorsource.com/Diesel_Fuel_Consumption.aspx

the product of the generator rating and the load. For the example of a 500 kW generator operating at 50% load, the fuel consumption rate is:

(18.5 gal/hr) ÷ (250 kWh/hr) = 0.070 gal/kWh

Using this approach, the fuel consumption rates in Table A-1 were converted to units of gal/kWh, as shown in Table A-2. It should be noted that this approach does not take power factors or transmission losses into account, but should be sufficient for purposes of identifying potential outliers in the user input fields for the Emerald Eco-Label software.

Based on the information in Table A-2, a conversion factor of 0.075 gallons of fuel per kWh, or 13.33 kWh per gallon of fuel was selected as a reasonable estimate for converting generator fuel consumption to electricity consumption.

Table A-2. Typical fuel consumption rates for select generator sizes, expressed in terms of gal/kWh

Generator Rating (kW)	Generator Load				
	25%	50%	75%	100%	Average
	Fuel Consumption (gal/kWh)				
250	0.091	0.076	0.073	0.072	0.078
500	0.088	0.074	0.070	0.071	0.076
750	0.087	0.073	0.070	0.071	0.075
Average	0.089	0.074	0.071	0.072	0.076