Conversion Factors used in the Taming Bigfoot Carbon Calculator: Documentation of Sources and Rationale

The conversion factors used in the Taming Bigfoot calculator estimate the net effect of the emitted greenhouse gases associated with each activity included in the calculator. The effect is expressed in pounds of "carbon dioxide equivalent" (CO_2e) which attempts to equate the additional impact of all greenhouse-enhancing gases with the amount of CO_2 necessary to cause the same greenhouse enhancement.

Many of the conversion factors must account for supporting infrastructure that often varies geographically. Groups that have organized a Taming Bigfoot competition can provide conversion factors that tailor the calculator to their participants. This customization makes the calculations more meaningful for the users in those regions with specific conversion factors. On the other hand, many other conversion factors do not vary, the result of chemical reactions that are universal.

The conversion factor of each item included in the Taming Bigfoot calculator is discussed below. Because the first Taming Bigfoot competition was held in Jefferson County, those conversion factors represent a default set, but wherever other regions substituted their own factors, those factors and the basis for the substitution are discussed. Wherever possible, references to the associated source documentation are provided.

ENERGY

Electricity

Jefferson County receives its power from the Bonneville Power Administration (BPA). The most recent data is for the year 2019, with an emissions rate of 0.0465 lbs. CO_2e/kWh, a slight increase from the 2015 value of 0.0442 lbs. CO_2e/kWh. (https://ww2.arb.ca.gov/mrr-acs).

The Edmonds and Seattle competitions use a factor of 0.907 lbs CO_2e per KWh that represents the value reported by the Climate Registry (https://www.theclimateregistry.org/) for power supplied within the NWPP region of the national power grid. (see https://www.theclimateregistry.org/wp-content/uploads/2014/11/2016-Climate-Registry-Default-Emission-Factors.pdf, Table 14.1)

The US-General value of 1.016 lbs CO_2e per KWh averages all the regions of the national power grid.

Natural gas

All regions use a conversion factor of 12.67 lbs. CO_2/ccf. The Climate Registry (https://www.theclimateregistry.org/) has published a conversion factor for Canadian markets (https://www.theclimateregistry.org/wp-content/uploads/2014/11/2016-Climate-Registry-Default-Emission-Factors.pdf, Table 12.2). The heat content (therm) of a volume of natural gas varies slightly with temperature, but these variations are ignored.

Heating oil

All regions use a conversion factor of 24.28 lbs. CO_2/lb. The Climate Registry (https://www.theclimateregistry.org/) has published that this refers to #6 Oil at 11.27 kgs CO_2 per gallon (https://www.theclimateregistry.org/wp-content/uploads/2014/11/2016-Climate-Registry-Default-Emission-Factors.pdf, Table 13.1).

Propane

Jefferson County uses a conversion factor of 12.59 lbs. CO_2e/gal. taken from http://www.carbonfootprint.com/calculator.aspx.

Edmonds, Seattle and US-General use a slightly different value of 12.61 lbs. CO_2e/gal. taken from the Climate Registry (https://www.theclimateregistry.org/wp-content/uploads/2014/11/2016-Climate-Registry-Default-Emission-Factors.pdf)

Wood

The Jefferson County Emissions Inventory states (p. 10 footnote): (1.035 lbs CO_2 per lb wood) x (2,737 lbs wood per cord of Douglas fir) = 2833 lbs. CO_2 per cord of wood. This equals 22.13 lbs CO_2/cu ft. Cord stacking causes cord density to be less than the pure wood density. Cedar is less dense and maple more dense than Douglas fir so it is a good average for this region. Moisture content matters as burning wet wood is inefficient because more of the heat must be used to evaporate the excess water in the wood. Air dried lumber generally can't be dried beyond 18%. Densities of various woods at 20% moisture content can be found at http://www.engineeringtoolbox.com/weigt-wood-d_821.html.

Some carbon calculators set wood burning for energy as carbon neutral noting that wood from quick-growing trees recapture the carbon emitted by burning. By harvesting subsequent wood fuel from those trees, the cycle is repeated. However, a number of factors lead us to include the direct carbon emissions of wood burning in our calculator. Foremost among these factors is the time scale of this cycle: even one of the fastest-growing, quickest carbon-sequestering trees that sprouts up today would require 50 years or more to absorb the carbon emitted by burning a single cord of wood (about the amount in a foot-thick 40-foot-long log). Also, the production

of slash from the harvesting process leads to reintroduction of much of the sequestered carbon back into the environment when it is burned. Finally, trees sequester carbon from all sources, not only from wood burning, making it more legitimate to include a carbon sink "credit" for tree-growth efforts, rather than limit the carbon offset effect to wood-burning alone.

Seattle and US-General have adopted this Jefferson County conversion factor; Edmonds has chosen to set this conversion factor to zero.

Wood pellets

Jefferson County's conversion factor of 0.054 lbs. CO_2/lb. is taken from http://www.carbonfootprint.com/calculator.aspx.

Seattle and US-General have adopted this Jefferson County conversion factor; Edmonds has chosen to set this conversion factor to zero.

WATER

The calculation is limited to those on municipal water networks. Those with private wells pay for water supply through electricity expended by well pumps. Private septic systems are similarly accounted for through electricity usage.

The Jefferson County Emissions Inventory provides a conversion factor of 0.00039452 lbs. CO_2e/gallon for supplied domestic water. From the same document, the ratio of wastewater to supplied water is 81.68% and the conversion factor of wastewater treatment is 0.004477 lbs. CO_2e/gallon. The higher value for wastewater reflects the additional energy required to treat wastewater. Water usage is required in CCF (100 cubic feet); 1 CCF is equivalent to 748 gallons, so the Jefferson County conversion factors are 0.2951 lbs. CO_2e/CCF for municipal supply water and 3.3488 lbs. CO_2e/CCF for wastewater.

Data including all the major reservoirs used to supply water to Seattle yield a conversion factor of 0.5835 lbs. CO_2e/CCF for domestic supply water. Wastewater volume was assumed to be the same 81.6% of supply water and a wastewater conversion factor of 1.32158 lbs. CO_2e/CCF. Edmonds, Seattle and US-General all use these latter set of conversion factors.

NON-RECYCLED GARBAGE

The 2018 Jefferson County Emissions Inventory (referenced earlier, pg. 34-35), reported that 20,672 metric tons of solid waste generated 3553 metric tons of CO2e (from a combination of unrecovered methane at the landfill site and transportation of the waste). The ratio of these two quantities results in a conversion factor of 0.172 lbs. CO_2e/lb. waste and is applied to

Jefferson County entries. This is close to the value of 0.166 lbs. CO_2e/lb. waste based on 2005 data from Jefferson County.

The Seattle Public Utility reported 0.79 metric tons of greenhouse gases emitted per ton of garbage disposed. This results in a conversion factor of 0.871 lbs. CO_2e/lb. waste. Edmonds, Seattle and US-General use this latter conversion factor.

PERSONAL TRANSPORTATION

Gasoline

19.64 lbs. CO_2 are produced by burning a gallon of gasoline that does not contain ethanol. Fuel with 10% ethanol reduces the CO_2 emission to 18.95 lbs. CO_2/gal. [Source: U.S. Energy Information Administration http://eia.gov]. In Jefferson County, most fuel sold is 10% ethanol so the lower conversion factor is used.

In Edmonds, Seattle and US-General, a slightly higher value of 19.35 lbs. CO_2/gal. is used, corresponding to a lower fraction of 10% ethanol fuel being consumed, in accordance with the Climate Registry (https://www.theclimateregistry.org/) document (https://www.theclimateregistry.org/wp-content/uploads/2014/11/2016-Climate-Registry-Default-Emission-Factors.pdf, Table 13.1).

Diesel

Jefferson County uses a value of 22.38 lbs. CO_2 produced by burning a gallon of diesel. [Source: U.S. Energy Information Administration http://eia.gov].

Edmonds, Seattle and US-General use 22.503 lbs. CO_2/gal. (https://www.theclimateregistry.org/wp-content/uploads/2014/11/2016-Climate-Registry-Default-Emission-Factors.pdf, Table 13.2).

Bio-diesel

All regions use a value of 20.79 lbs. CO_2/gal. bio-diesel (https://www.theclimateregistry.org/wp-content/uploads/2014/11/2016-Climate-Registry-Default-Emission-Factors.pdf, Table 13.2).

PUBLIC/SHARED TRANSPORTATION

Carpooling

Because fuel efficiency varies so widely among vehicles, a default mileage efficiency of 25 miles per gallon is assigned and the conversion factors for gasoline (see above) are altered to a conversion factor in units of lbs.CO_2/mile: Jefferson County, 0.758 lbs.CO_2/mile and for

Edmonds, Seattle and US-General, 0.774 lbs.CO_2/mile. This factor is adjusted automatically if the user specifies a mpg efficiency different than 25 mpg when inputting transportation data.

Business vans/shuttle

Diesel fuel is assumed along with an average fuel efficiency of 10 mpg for these vehicles which are typically larger and carry more passengers. Using the diesel conversion factors presented above results in conversion factors of 2.24 lbs. CO_2/mile for Jefferson County and 2.25 lbs. CO_2/mile for Edmonds, Seattle and US-General.

Bus

The emission conversion factor for bus travel varies depending on type of fuel used, service area (urban or rural) and number of passengers. http://www.carbonfund.org references **EPA Climate Leaders** (table 3, page 5) with an average emission factor for bus travel of 0.107kgs CO_2/passenger mile (or 0.236 lbs. CO_2/passenger mile) but this works out to an average busload of 19 passengers. On the other hand, http://www.fta.dot.gov/documents/PublicTransportationsRoleInRespondingToClimateChange.pdf (page 2) gives a national average of 0.653 lbs. CO_2/passenger mile and a specific value for King County, WA of 0.492 lbs. CO_2/passenger mile (page 10). The middle (King County) value, which also is close to the average of all three values, is used by all regions.

Urban light rail

Seattle data of 345.83 Btu/Seat Mile come from https://www.soundtransit.org/sites/default/files/documents/pdf/projects/seis/final_6-05/chapters/4-6_energy.pdf**.** Using a conversion of 3412 Btu per kWh and the Climate Registry (https://www.theclimateregistry.org/wp-content/uploads/2014/11/2016-Climate-Registry-Default-Emission-Factors.pdf) conversion factor for electricity (0.907 lbs. CO_2e/kWh, see above), produces a resulting urban light rail conversion factor of 0.0919 lbs. CO_2e/Seat Mile. All regions use this value.

Train

From http://www.carbonfund.org, the CO_2 emissions for rail travel vary by distance of the trip. On average, commuter rail emits 0.175 kgs CO_2e per passenger mile and subway trains emit 0.159 kgs CO_2e per passenger mile, and long distance trains (i.e., intercity rail) emit 0.145 kgs CO_2 per passenger mile (Source: *EPA Climate Leaders*, table 2, page 5). These factors may overestimate emissions in Washington State but are used in lieu of more regionally specific data. An average value of 0.16 kgs CO_2e/passenger mile (0.353 lbs. CO_2e/passenger mile) is used by all regions.

Ferry

In 2009, Washington State Ferries transported 22.4 million passengers over 9 routes totaling 85.5 nm in 167,355 sailings while using 17 million gallons of biodiesel [Source: http://www.wsdot.wa.gov/ferries/]. Using these data to derive network-wide averages, the average route is 9.5 nm. (11mi.) and the total distance travelled is 1,829,190 miles with a fuel efficiency of 0.108 miles per gallon. Biodiesel produces 22lbs. CO_2e/gal, so the emission rate is 204 lbs. CO_2e/mile. This is distributed among all passengers: 134 per sailing. The net result is a carbon emission factor of 1.525 lbs. CO_2e/mile used by Jefferson County.

An alternative calculation that uses more recent data: 18,607,000 gallons of biodiesel to provide 191,526,928 passenger miles yields 2.14 lbs. CO2e per passenger mile. This higher value may include fuel used to reposition ferries, a factor that could be argued should be included in the emissions associated with passenger use of ferries. This conversion factor was used by Edmonds, Seattle and US-General.

Airplane

From http://www.carbonfund.org, an average carbon emission factor for air travel is 0.277 kgs CO_2/ passenger mile (0.61 lbs CO_2/passenger mile). Much like vehicle emissions, this number varies widely by the size of the airplane and the distance travelled as well as the number of stops (i.e., more fuel-hungry take-offs and landings). A good site to find this detail is http://blueskymodel.org/air-mile.

FOOD

Data for the greenhouse gas emissions associated with the production of various main entree selections come from two sources: http://www.greeneatz.com/foods-carbon-footprint.html and http://static.ewg.org/reports/2011/meateaters/pdf/methodology_ewg_meat_eaters_guide_to_health_and_climate_2011.pdf. By also adjusting for the relative amount of each food type consumed in the US, three categories of entree and their associated carbon footprint were derived. All regions use these conversion factors.

Beef/Lamb

6.80 lbs. CO_2e/4 oz. serving

Pork/Turkey

2.961 lbs. CO_2e/4 oz. serving

Chicken/Fish

1.725 lbs. CO_2e/4 oz. serving

Local source

The carbon calculator website http://www.carbonfootprint.com/calculator.aspx offers three options for the proportion of food purchased locally (all, most, none). For 0% locally sourced food the emission is 0.09 metric tons CO_2e (198 lbs.), while for 100% local food the emission is 0.02 metric tons CO_2e (44.2 lbs.). Based on a USDA Food Cost document (available at http://www.cnpp.usda.gov), the average annual food cost of a middle-age adult (moderate cost plan) is $3372 ($65/week). Thus, every dollar spent on non-local food has a footprint impact of 198/3372=0.0587 lbs.CO_2e/$, while a dollar spent on local food has a lower footprint impact of 44.2/3372=0.0131 lbs.CO_2e/$. When the user inputs a food shopping event of X dollars spent and a percentage of P of that purchase on local food, the carbon impact is then calculated as:

$$\text{Footprint} = X * [(100 - P) * 198/F + P * 44.2/F] ,$$

where F is the annual food cost provided as a conversion factor that can be different by region but all regions have adopted an annual food cost of $3372.

Organic fruits & vegetables

Similarly, from the same carbon calculator website, http://www.carbonfootprint.com/calculator.aspx, the annual carbon footprint for 0% organic produce was 66.15 lbs. CO_2e and 0 lbs. CO_2e for 100% organic produce. From a US Bureau of Labor Statistics document ("Consumer Expenditures in 2015"), produce purchases average about 20% of the food budget. Using the above value for the annual food budget, the average annual produce budget is set at $675. Using the same approach as above, the corresponding formula to calculate the carbon impact of Y dollars spent on produce where L is the organic fraction is:

$$\text{Footprint} = Y * (100 - P) * 66.15/D ,$$

where D is the annual food cost on organic produce provided as a conversion factor that can be different by region. All regions have chosen to use $675 as the annual amount spent on produce.

SHOPPING

Clothing

By inputting a wide range of dollars spent in the carbon footprint calculator http://coolclimate.berkeley.edu/calculator, a linear scaling coefficient of 1.2 lbs. CO_2e/dollar spent was derived and is used for all regions.

Paper reading material

By inputting a wide range of dollars spent in the carbon footprint calculator http://coolclimate.berkeley.edu/calculator, a linear scaling coefficient of 0.65 lbs. CO_2e/dollar spent was derived and is used for all regions.