Data and assumptions used to calculate consequences of different shopping choices

CO_2-equivalent to Trees
In order to convert units of CO_2 into something easier to visualize we convert it into "trees". Everyone knows that trees absorb CO_2 and that planting trees is a strategy for taking CO_2 out of the atmosphere.

Different species of tree and different ages of tree absorb different amounts of CO_2. A high estimate for absorption is as much as 48 pounds or 22 kg CO_2 for mature trees (https://projects.ncsu.edu/project/treesofstrength/treefact.htm). Since that is an upper limit, and most forests are of mixed age, we arbitrarily used a more modest rate of 10 kg/year for a hypothetical well-managed forest that is planted for the purpose of CO2 sequestration. To put this 10 kg/year in perspective for our sequestration forest, note that the estimated sequestration rates per urban tree (combining all kinds and all ages) are 5.9 kg/year in Boston, and 4 kg/year in New York City (Nowak & Crane. 2002. Carbon storage for urban trees in the USA. Environmental Pollution, 116: 381-389).

Shopping Choices in CO_2-equivalents

Should I buy my beer in aluminum cans or in glass bottles?

To calculate the differences between emissions from beer cans versus beer bottles, we first used emission estimates detailed in the study by Amienyo & Azapagic (2016), where CO_2 equivalents by beer packaging is as follows: glass bottle = 842 g CO2-eq/L; aluminum = 575 g CO2-eq/L; steel can = 510 g CO2-eq/L. We then assumed an average person drinks a six-pack of beer a week, or 52 six-packs a year and that each can or bottle is 12 fl. oz. or 0.35 L.

How to calculate CO_2-eq. from beer in glass bottles for one year per person:

$$\frac{0.842\ kg\ CO_2 eq.}{33.814\ fl.oz.of\ bottled\ beer} \times \frac{72\ fl.oz.of\ beer}{one\ six\ pack\ of\ beer\ per\ week} X \frac{52\ weeks}{year} = \frac{93.2\ kg\ CO_2 eq.}{per\ person\ per\ year}$$

How to calculate CO_2-eq. from canned beer for one year per person:

$$\frac{0.575\ kg\ CO_2 eq.}{33.814\ fl.oz.of\ canned\ beer} \times \frac{72\ fl.oz.of\ beer}{one\ six\ pack\ of\ beer\ per\ week} X \frac{52\ weeks}{year} = \frac{63.7\ kg\ CO_2 eq.}{per\ person\ per\ year}$$

Reduction in CO_2-eq. per person if canned beer is chosen over beer in bottles:

$$\frac{93.2\ kg\ CO_2 eq.}{bottled\ beer\ in\ one\ year} - \frac{63.7\ kg\ CO_2 eq.}{canned\ beer\ in\ one\ year} = \frac{29.5\ kg\ CO_2 eq.}{per\ person\ per\ year}$$

I am not willing to give up meat, but how much difference does it make if I give up beef and substitute chicken?

For the choice between beef or chicken, we used CO_2 equivalent estimates in the study by Pelletier & Tyedmers (2010). According to this study, beef emits 15 kg CO_2-eq/kg whereas poultry emits 1.5 kg CO_2-eq/kg. We also used a 2014 report by USDA for consumption rates, where it states that Americans consume 23.36 kg of beef per year and 26.63 kg of poultry per year.

How to calculate CO_2-eq. from beef for one year per person:

$$\frac{15\ kg\ CO_2 eq.}{kg\ of\ beef} \times \frac{23.36\ kg\ of\ beef\ consumed}{year} = \frac{350.4\ kg\ CO_2 eq.}{per\ person\ per\ year}$$

How to calculate CO_2-eq. from chicken for one year per person:

$$\frac{1.5\ kg\ CO_2 eq.}{kg\ of\ chicken} \times \frac{26.63\ kg\ of\ chicken\ consumed}{year} = \frac{39.95\ kg\ CO_2 eq.}{per\ person\ per\ year}$$

Reduction in CO_2-eq. per person if chicken is chosen over beef:

$$\frac{350.4\ kg\ CO_2 eq.}{beef\ for\ one\ year} - \frac{39.95\ kg\ CO_2 eq.}{chicken\ for\ one\ year} = \frac{310.45\ kg\ CO_2 eq.}{per\ person\ per\ year}$$

Eggs from cage-free chickens are very popular because of animal welfare, but what about emissions?

In the case of choosing between eggs from caged or free-range chicken, we based our CO_2 emission estimates from a U.K. study by Leinonen et al. (2012). In the study, the global warming potential (1,000 kg of CO_2, 100-yr timescale) for the two different systems per 1,000 kg of eggs was as follows: caged = 2.92 and free-range = 3.38. We also assumed that each egg is a size large with a minimum USDA mass per large egg of 56.7 g (USDA, 2016) and that average egg consumption per year was about 250 eggs or ~ 14 kg (USDA, 2009).

How to calculate CO_2 from free-range eggs for one year per person:

$$\frac{3.38\ \times 1000\ kg\ CO_2}{1000\ kg\ of\ free\ range\ eggs} \times \frac{14\ kg\ of\ eggs}{year} = \frac{47.32\ kg\ CO_2}{person\ per\ year}$$

How to calculate CO_2-eq. from eggs from caged chickens for one year per person:

$$\frac{2.92\ \times 1000\ \ kg\ CO_2}{1000\ kg\ of\ eggs\ from\ caged\ chickens} \times \frac{14\ kg\ of\ eggs}{year} = \frac{40.88\ kg\ CO_2}{per\ person\ per\ year}$$

Reduction in CO_2 per person if caged is chosen over free-range chicken eggs:

$$\frac{47.32\ kg\ CO_2}{person\ per\ year} - \frac{40.88\ kg\ CO_2}{per\ person\ per\ year} = \frac{6.4\ kg\ CO_2}{year}$$

What about your weekly salmon dinner – wild-caught versus farm-raised?

Based on a study by Tyedmers (2000), farmed salmon contribute to 6.5 - 8 t CO_2-eq/t of salmon, while wild-caught salmon add 1.8 - 2.9 t CO_2-eq/t of salmon. We assumed that an average person consumes about 200 g of salmon per week.

How to calculate CO_2-eq. from wild-caught salmon for one year per person:

$$\frac{1800\ kg\ CO_2 eq.}{1000\ kg\ of\ wild\ caught\ salmon} \times \frac{10.4\ kg\ of\ wild\ caught\ salmon}{year} = \frac{18.72\ kg\ CO_2 eq.}{person\ per\ year}$$

How to calculate CO_2-eq. from eggs from farmed-raised salmon for one year per person:

$$\frac{6500\ kg\ CO_2 eq.}{1000\ kg\ of\ farmed\ salmon} \times \frac{10.4\ kg\ of\ farmed\ salmon}{year} = \frac{67.6\ kg\ CO_2 eq.}{person\ per\ year}$$

Reduction in CO_2 per person if wild-caught is chosen over farmed-raised salmon:

$$\frac{67.6\ kg\ CO_2 eq.}{person\ per\ year} - \frac{18.72\ kg\ CO_2 eq.}{person\ per\ year} = \frac{48\ kg\ CO_2 eq.}{year}$$

How much do we reduce emissions if we choose organic wine as opposed to non-organic wine?

Based on a study by Vázquez-Rowe, et al. (2013), the carbon footprint of a wine farm by appellation per 750 mL bottle of wine in grams of CO_2-eq. is as follows: Chianti Colli Senesi (red, organic) = 112.8; Cannonau di Sardegna (red, organic) = 351.0; Mixed (Red/White) = 213.1; Rías Baixasa (white) = 376.5; Ribeiro (white)= 1612.6; Vermentino di Sardegna (white) = 240.6. We assumed that a person consumes 2 bottles of wine a week.

How to calculate CO_2-eq. from organic Chianti Colli Senesi red wine for one year per person:

$$\frac{0.1128\ kg\ CO_2 eq.}{750\ ml\ bottle\ of\ wine} \times \frac{2\ \times 750\ ml\ bottle\ of\ wine}{week} \times \frac{52\ weeks}{year} = \frac{11.7\ kg\ CO_2 eq.}{person\ per\ year}$$

How to calculate CO_2-eq. from non-organic Ribeiro white wine for one year per person:

$$\frac{1.6126\ kg\ CO_2 eq.}{750\ ml\ bottle\ of\ wine} \times \frac{2\ \times 750\ ml\ bottle\ of\ wine}{week} \times \frac{52\ weeks}{year} = \frac{167.7\ kg\ CO_2 eq.}{person\ per\ year}$$

Reduction in CO_2 per person if organic wine is chosen over non-organic wine:

$$\frac{167.7\ kg\ CO_2 eq.}{person\ per\ year} - \frac{11.7\ kg\ CO_2 eq.}{person\ per\ year} = \frac{156\ kg\ CO_2 eq.}{year}$$

How much do we reduce emissions if we choose grass-fed beef as opposed to conventional beef?

According to a 2012 study by Capper, for every 1.0 x 10^9 kg of beef, conventional beef emits 15,989 x 10^3 t CO_2-eq. and grass-fed beef emits 26,785 × 10^3 t CO_2-eq. Conventional beef represents the characteristic beef production of most systems, where it ends in feedlots with growth-enhancing technology. We assumed that an average person consumes close to 52 lbs of beef a year based on a 2014 USDA report.

How to calculate CO_2-eq. from conventional beef for one year per person:

$$\frac{15{,}989\ x\ 10^3\ t\ CO_2 eq.}{10^9 kg\ of\ conventional\ beef} \times \frac{23.59\ kg\ conventional\ beef\ consumed}{year} = \frac{.377\ t\ CO_2 eq.}{year}$$

Then convert tons to kg,

$$\frac{0.377\ t\ CO_2 eq.}{year} \times \frac{1000\ kg}{t} = \frac{377\ kg\ CO_2 eq.}{year}$$

How to calculate CO_2-eq. from grass-fed beef for one year per person:

$$\frac{26{,}785\ x\ 10^3\ t\ CO_2 eq.}{10^9 kg\ of\ grass\ fed\ beef} \times \frac{23.59\ kg\ grass\ fed\ beef\ consumed}{year} = \frac{.632\ t\ CO_2 eq.}{year}$$

Then convert tons to kg,

$$\frac{0.632\ t\ CO_2 eq.}{year} \times \frac{1000\ kg}{t} = \frac{632\ kg\ CO_2 eq.}{year}$$

Reduction in CO_2 per person if conventional beef is chosen over grass-fed beef:

$$\frac{632\ kg\ CO_2 eq.}{year} - \frac{377\ kg\ CO_2 eq.}{year} = \frac{255\ kg\ CO_2 eq.}{year}$$

How much do we reduce emissions if we choose tap water as opposed to bottled water?

In a 2014 study by Fantin et al., 24 published studies of Life Cycle Assessment (LCA) of tap water and 33 published studies on LCA of bottled water were analyzed. They found that tap water contributed to 0.09 + 0.03 kg CO_2-eq./100 l whereas bottled water contributed to 16.24 + 0.92 kg CO_2-eq./100 l. We assumed that the average person adult drinks 58 gallons (219.554 liters) of water per year based on statistics on the average American by Beverage Digest (Hamblin, 2013).

How to calculate CO_2-eq. from tap water for one year per person:

$$\frac{0.09\ kg\ CO_2 eq.}{100\ l} \times \frac{219.554\ l}{year} = \frac{0.1976\ kg\ CO_2 eq.}{person\ per\ year}$$

How to calculate CO_2-eq. from bottled water for one year per person:

$$\frac{16.24\ kg\ CO_2 eq.}{100\ l} \times \frac{219.554\ l}{year} = \frac{35.66\ kg\ CO_2 eq.}{person\ per\ year}$$

Reduction in CO_2 per person if tap water is chosen over bottled water:

$$\frac{35.66\ kg\ CO_2 eq.}{person\ per\ year} - \frac{0.1976\ kg\ CO_2 eq.}{person\ per\ year} = \frac{35.5\ kg\ CO_2 eq.}{year}$$

How much do we reduce emissions if we choose instant black coffee as opposed to ground black coffee?

In an LCA study by Büsser, & Jungbluth (2009), they found the carbon footprint for different types of coffee as follows: white coffee is 180 g CO_2-eq./cup of coffee; white instant coffee is 130 g CO_2-eq./cup of coffee; black coffee is 128 g CO_2-eq/cup of coffee; espresso is 90 g CO_2-eq./cup of coffee; black instant coffee is 80 g CO_2-eq/cup of coffee. We assumed that an average person drinks about 3 cups of coffee a day based on statistics from American consumers in 2010 by the National Coffee Drinking Trends (Harvard, 2010).

How to calculate CO_2-eq. from instant black coffee for one year per person:

$$\frac{0.080\ kg\ CO_2eq.}{cup\ of\ coffee} \times \frac{3\ cups}{day} \times \frac{365\ days}{year} = \frac{87.6\ kg\ CO_2eq.}{person\ per\ year}$$

How to calculate CO_2-eq. from ground black coffee for one year per person:

$$\frac{0.128\ kg\ CO_2eq.}{cup\ of\ coffee} \times \frac{3\ cups}{day} \times \frac{365\ days}{year} = \frac{140.2\ kg\ CO_2eq.}{person\ per\ year}$$

Reduction in CO_2 per person if instant black coffee is chosen over ground black coffee:

$$\frac{140.2\ kg\ CO_2eq.}{person\ per\ year} - \frac{87.6\ kg\ CO_2eq.}{person\ per\ year} = \frac{52.6\ kg\ CO_2eq.}{year}$$

How much do we reduce emissions if we choose reusable bags as opposed to plastic or paper bags?

We used the assumptions and calculations in an LCA study by Lewis et al. (2010), where the functional unit is the number of shopping bags consumed by a household to carry 70-grocery items home from the supermarket each week for a year. The results were that in a year a single-use 100% virgin HDPE plastic bags contributed to 7.52 kg CO_2-eq, single-use paper bags contributed to 44.74 kg CO_2-eq, and reusable woven polypropylene (PP) bag contributed to 5.43 kg CO_2-eq.

Reduction in CO_2 per person if reusable bags are chosen over plastic:

$$\frac{7.52\ kg\ CO_2eq.}{person\ per\ year} - \frac{5.43\ kg\ CO_2eq.}{person\ per\ year} = \frac{2.09\ kg\ CO_2eq.}{year}$$

Reduction in CO_2 per person if reusable bags are chosen over paper bags:

$$\frac{44.74\ kg\ CO_2eq.}{person\ per\ year} - \frac{5.43\ kg\ CO_2eq.}{person\ per\ year} = \frac{39.3\ kg\ CO_2eq.}{year}$$

How much do we reduce emissions if we choose homemade meals as opposed to frozen ready-made meals?

In the study by Rivera & Azapagic (2016), the life cycle costs and environmental impacts of different homemade and frozen ready-made meals were assessed. The results were 1.99 kg CO_2-eq. per homemade meal consisting of British conventional chicken and vegetables and Spanish conventional tomato paste, where the pre-processing was fresh (chilled) and manufacturing and distribution was fresh (chilled), and consumption consisted of chicken roasted in electric oven and vegetables and ready-made tomato sauce cooked in microwave; for the frozen ready-made meal, it was 2.41 kg CO_2-eq. per meal consisting of British conventional chicken and vegetables and Spanish conventional tomato paste, where pre-processing was fresh (chilled), manufacturing and distribution was frozen, and was heated in a microwave. We assumed that on average a person eats three frozen meals a week.

How to calculate CO_2-eq. from frozen ready-made meals for one year per person:

$$\frac{2.41\ kg\ CO_2eq.}{meal} \times \frac{3\ meals}{week} \times \frac{52\ weeks}{year} = \frac{375.96\ kg\ CO_2eq.}{person\ per\ year}$$

How to calculate CO_2-eq. from homemade meals for one year per person:

$$\frac{1.99\ kg\ CO_2eq.}{meal} \times \frac{3\ meals}{week} \times \frac{52\ weeks}{year} = \frac{310.44\ kg\ CO_2eq.}{person\ per\ year}$$

Reduction in CO_2 per person if homemade meals is chosen over frozen ready-made meals:

$$\frac{310.44\ kg\ CO_2eq.}{person\ per\ year} - \frac{375.96\ kg\ CO_2eq.}{person\ per\ year} = \frac{65.5\ kg\ CO_2eq.}{year}$$

How much do we reduce emissions if we choose whole wheat as opposed to white bread?

The carbon footprint of bread was studied in Espinoza-Orias et al. (2011), where they found that the carbon footprint of a white bread (medium slice in plastic bag) is 1100.17 g CO_2-eq./800 g loaf of bread, while wholegrain bread (medium slice in plastic bag) is 1029.77 g CO_2-eq./800 g loaf of bread. We assumed that a person eats 2 loaves (each 800 g) of bread per week.

How to calculate CO_2-eq. from whole grain bread for one year per person:

$$\frac{1.02977\ kg\ CO_2eq.}{meal} \times \frac{2\ loaves\ of\ bread}{week} \times \frac{52\ weeks}{year} = \frac{107.09\ kg\ CO_2eq.}{person\ per\ year}$$

How to calculate CO_2-eq. from white bread for one year per person:

$$\frac{1.10017\ kg\ CO_2eq.}{loaf\ of\ bread} \times \frac{2\ loaves\ of\ bread}{week} \times \frac{52\ weeks}{year} = \frac{114.41\ kg\ CO_2eq.}{person\ per\ year}$$

Reduction in CO_2 per person if whole wheat bread is chosen over white bread:

$$\frac{114.41\ \ kg\ CO_2 eq.}{person\ per\ year} - \frac{107.09\ kg\ CO_2 eq.}{person\ per\ year} = \frac{7.3\ kg\ CO_2 eq.}{year}$$

How much do we reduce emissions if we choose non-dairy milk as opposed to dairy milk?

We used the life cycle analysis by Smedman et al. (2010). According to this study, the carbon footprint for milk and dairy alternatives is the following: 99 g CO_2-eq. per 100 g of milk, 30 g CO_2-eq. per 100 g of soy milk, and 21 g CO_2-eq. per 100 g of oat milk. We assumed a person consumed 2 gallons of milk per month. One gallon is 3840 grams of milk.

How to calculate CO_2-eq. from dairy milk for one year per person:

$$\frac{.099\ kg\ CO_2 eq.}{100\ g\ of\ milk} \times \frac{7680\ g\ of\ milk}{month} \times \frac{12\ months}{year} = \frac{91.2\ kg\ CO_2 eq.}{person\ per\ year}$$

How to calculate CO_2-eq. from soy milk for one year per person:

$$\frac{.030\ kg\ CO_2 eq.}{100\ g\ of\ soy\ milk} \times \frac{7680\ g\ of\ soy\ milk}{month} \times \frac{12\ months}{year} = \frac{27.6\ kg\ CO_2 eq.}{person\ per\ year}$$

How to calculate CO_2-eq. from oat milk for one year per person:

$$\frac{.021\ kg\ CO_2 eq.}{100\ g\ of\ soy\ milk} \times \frac{7680\ g\ of\ soy\ milk}{month} \times \frac{12\ months}{year} = \frac{19.4\ kg\ CO_2 eq.}{person\ per\ year}$$

Reduction in CO_2 per person if soy milk is chosen over dairy milk:

$$\frac{91.2\ kg\ CO_2 eq.}{person\ per\ year} - \frac{27.6\ kg\ CO_2 eq.}{person\ per\ year} = \frac{63.6\ kg\ CO_2 eq.}{year}$$

Reduction in CO_2 per person if oat milk is chosen over dairy milk:

$$\frac{91.2\ kg\ CO_2 eq.}{person\ per\ year} - \frac{19.4\ kg\ CO_2 eq.}{person\ per\ year} = \frac{71.8\ kg\ CO_2 eq.}{year}$$

How much do we reduce emissions if we choose reusable cotton roll towels over paper towels?

Based on a study by Gregory et al. (2013), where a life cycle assessment of different hand drying systems was performed, paper towels produce about 16 g of CO_2-eq. and cotton roll towels produce about 12 g of CO_2-eq. to dry a single pair of hands. We assumed that a person dries their hands at least 10 times a day.

How to calculate CO_2-eq. from paper towels for one year per person:

$$\frac{0.016\ kg\ CO_2 eq.}{paper\ towels\ used\ to\ dry\ a\ single\ pair\ of\ hands} \times \frac{10 \times 365\ days}{year} = \frac{58.5\ kg\ CO_2 eq.}{person\ per\ year}$$

How to calculate CO_2-eq. from reusable cotton roll towels for one year per person:

$$\frac{0.012\ kg\ CO_2 eq.}{paper\ towels\ used\ to\ dry\ a\ single\ pair\ of\ hands} \times \frac{10 \times 365\ days}{year} = \frac{43.8\ kg\ CO_2 eq.}{person\ per\ year}$$

Reduction in CO_2 per person if reusable cotton roll towels are chosen over paper towels:

$$\frac{58.5\ kg\ CO_2 eq.}{person\ per\ year} - \frac{43.8\ kg\ CO_2 eq.}{person\ per\ year} = \frac{14.6\ kg\ CO_2 eq.}{year}$$

How much do we reduce emissions if we choose a vegetarian lifestyle over the average diet?

We used results found in the study by Tilman and Clark (2014) that show that per person in one year, a vegetarian diet can emit about 200 kg of CO_2-C equivalents, a pescetarian diet can emit about 244 kg of CO_2-C equivalents, and an average global diet can emit about 340 kg of CO_2-C equivalents.

Reduction in CO_2 per person if a vegetarian diet is chosen over an average diet:

$$\frac{340\ kg\ CO_2 eq.}{person\ per\ year} - \frac{200\ kg\ CO_2 eq.}{person\ per\ year} = \frac{140\ kg\ CO_2 eq.}{year}$$

Reduction in CO_2 per person if a pescetarian diet is chosen over an average diet:

$$\frac{340\ kg\ CO_2 eq.}{person\ per\ year} - \frac{244\ kg\ CO_2 eq.}{person\ per\ year} = \frac{96\ kg\ CO_2 eq.}{year}$$

How much do we reduce emissions if we choose dark chocolate over milk chocolate?

We used the 2011 study by Nilsson et al., where the results show that for every kg of product, milk chocolate accounts for 0.9 kg of CO_2-eq. and dark chocolate accounts for 2.7 kg of CO_2-eq. We assumed that a person eats one regular chocolate bar (52.7 g) a day.

How to calculate CO_2-eq. from dark chocolate for one year per person:

$$\frac{0.9\ kg\ CO_2 eq.}{kg\ of\ dark\ chocolate} \times \frac{.0527\ kg\ of\ dark\ chocolate}{day} \times \frac{365\ days}{year} = \frac{17.31\ kg\ CO_2 eq.}{person\ per\ year}$$

How to calculate CO_2-eq. from milk chocolate for one year per person:

$$\frac{2.7\ kg\ CO_2 eq.}{kg\ of\ milk\ chocolate} \times \frac{.0527\ kg\ of\ milk\ chocolate}{day} \times \frac{365\ days}{year} = \frac{51.94\ kg\ CO_2 eq.}{person\ per\ year}$$

Reduction in CO_2 per person if dark chocolate is chosen over white chocolate:

$$\frac{51.94\ kg\ CO_2 eq.}{person\ per\ year} - \frac{17.31\ kg\ CO_2 eq.}{person\ per\ year} = \frac{34.63\ kg\ CO_2 eq.}{year}$$

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