Carbon Footprint

"A carbon footprint is the total greenhouse gas (GHG) emissions caused directly and indirectly by an individual, organization, event or product."[1] It is calculated by summing the emissions resulting from every stage of a product or service's lifetime (material production, manufacturing, use phase, and end-of-life disposal). Throughout a product's lifetime, or lifecycle, different greenhouse gases (GHGs) may be emitted, such as methane and nitrous oxide, each with a greater or lesser ability to trap heat in the atmosphere. These differences are accounted for by calculating the global warming potential (GWP) of each gas in units of carbon dioxide equivalents (CO_2e), giving carbon footprints a single unit for easy comparison. See the Center for Sustainable Systems' "Greenhouse Gases Factsheet" for more information on GWP.

Sources of Emissions

Food

- On average, U.S. household food consumption emits 8.1 metric tons of CO_2e each year. The production of food accounts for 83% of emissions, while its transportation accounts for 11%.[3]
- The emissions associated with food production consist mainly of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (NO_2), which result primarily from agricultural practices.[3]
- Meat products have larger carbon footprints per calorie than grain or vegetable products because of the inefficient transformation of plant energy to animal energy.[3]
- Ruminant animals such as cattle, sheep, and goats produced 170 million metric tons (mmt) in CO_2e of methane in the U.S. in 2016 through digestion.[4]
- Eating all locally grown food for one year could save the GHG equivalent of driving 1,000 miles, while eating a vegetarian meal one day a week could save the equivalent of driving 1,160 miles.[3]
- A vegetarian diet greatly reduces an individual's carbon footprint, but switching to less carbon intensive meats can have a major impact as well. For example, replacing all beef consumption with chicken for one year leads to an annual carbon footprint reduction of 882 pounds CO_2e.[5]
- Organic food typically requires 30-50% less energy during production but requires one-third more hours of human labor compared to typical farming practices, making it more expensive.[6]
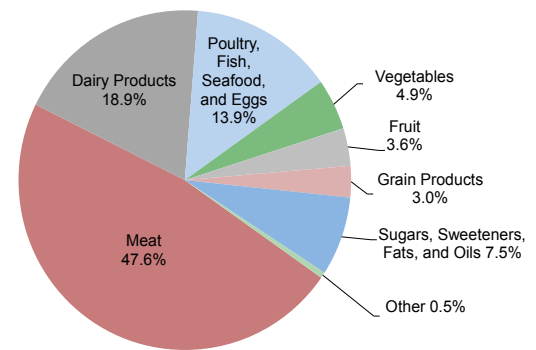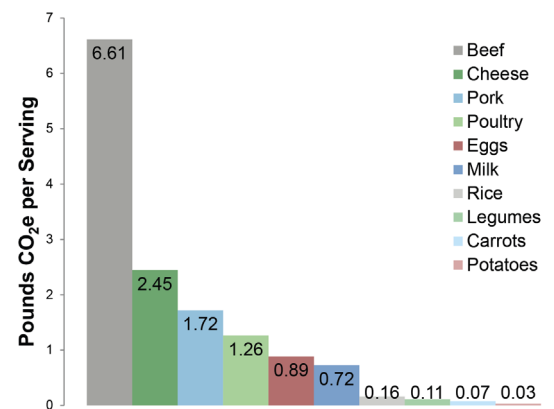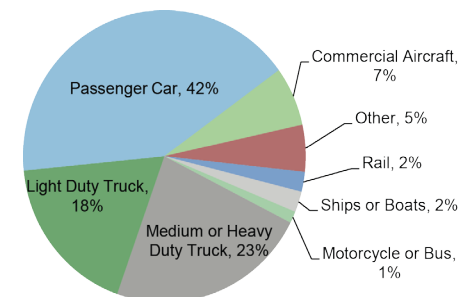
Household Emissions

- For each kilowatt hour generated in the U.S., an average of 0.954 pounds of CO_2 is released at the power plant.[7] Coal releases 2.2 pounds, petroleum releases 2.0 pounds, and natural gas releases 0.9 pounds. Nuclear, solar, wind, and hydroelectric release no CO_2 when they produce electricity, but emissions are released during upstream production activities (e.g., solar cells, nuclear fuels, cement production).[4,8]
- Residential electricity use in 2016 emitted 667.5 mmt CO_2e, 10.3% of U.S. total.[4]
- Heating and cooling account for about 53% of the energy use in a typical U.S. home.[9] Space heating with wood emits the least CO_2e (31.4 tons per million BTU) followed by 64.2 for natural gas, with the highest being 210.5 for electric heaters.[10]
- Refrigerators are one of the largest users of household appliance energy; in 2015, an average of 726.9 pounds of CO_2e per household was due to refrigeration.[11]
- Washing clothes on 'cold' reduces CO_2 emissions by 1.2-14.9 pounds per laundry load, depending on washing machine type, hot water temperature, and electricity source.[12]

Personal Transportation

- U.S. fuel economy (mpg) declined by 12% from 1988-2004, then improved by 31% from 2005-2017, reaching an average of 25.2 mpg in 2017.[13] Annual per capita miles driven increased 13% since 1991, to 9,646 miles in 2015.[14]
- Cars and light trucks emitted 1.1 billion metric tons CO_2e or 17% of the 2016 total U.S. greenhouse gas emissions.[4]
- Of the roughly 126,000 pounds of CO_2e emitted in a car's lifetime (assuming 120,000 miles for a 1995 mid-sized sedan), 86% is from burning fuel.[15]
- Gasoline releases 19.6 pounds of CO_2 per gallon when burned, compared to 22.4 pounds per gallon for diesel.[16] However, diesel has 11% more BTU per gallon, which improves its fuel economy.[17]

Greenhouse Gases from Average Food Consumption[2]

Dairy Products 18.9%
Poultry, Fish, Seafood, and Eggs 13.9%
Vegetables 4.9%
Fruit 3.6%
Grain Products 3.0%
Sugars, Sweeteners, Fats, and Oils 7.5%
Other 0.5%
Meat 47.6%

Pounds of CO_2e per Serving[2]
(4 oz. meat, 1/2 c. asparagus & carrots, 8 oz. liquids)

Beef 6.61
Cheese 2.45
Pork 1.72
Poultry 1.26
Eggs 0.89
Milk 0.72
Rice 0.16
Legumes 0.11
Carrots 0.07
Potatoes 0.03

Transportation Greenhouse Gases, 2016[4]

Passenger Car, 42%
Light Duty Truck, 18%
Medium or Heavy Duty Truck, 23%
Commercial Aircraft, 7%
Other, 5%
Rail, 2%
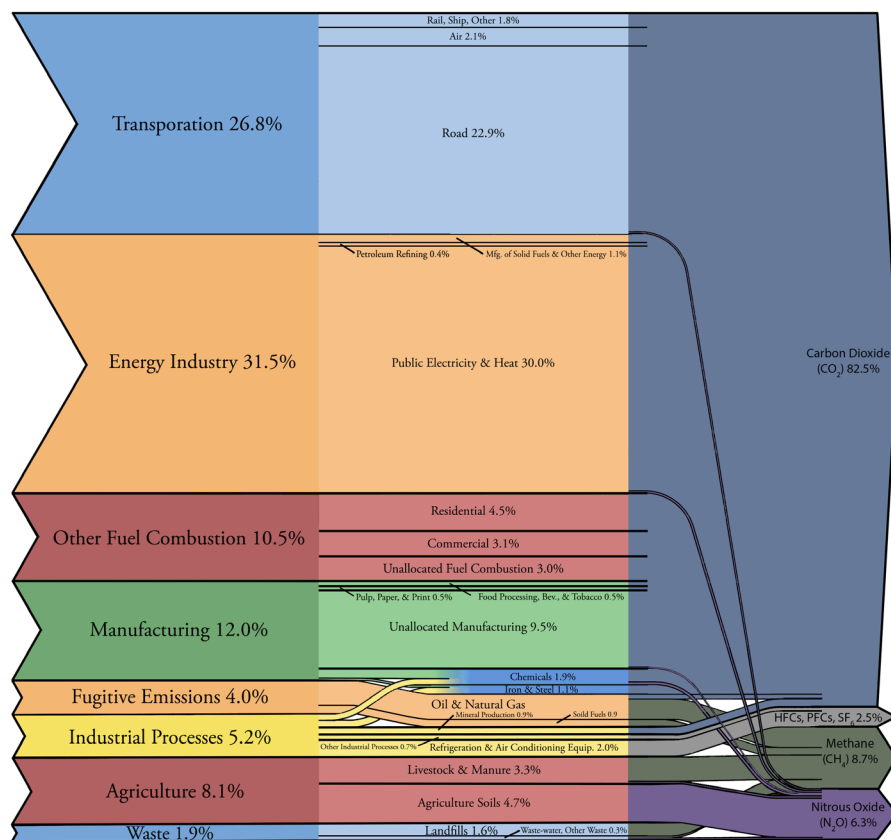Ships or Boats, 2%
Motorcycle or Bus, 1%

- The average passenger car emits 0.78 pounds of CO_2 per mile driven.[13]
- Automobile fuel economy can improve 7-14% by simply observing the speed limit. Every 5 mph increase in vehicle speed over 50 mph is equivalent to paying an extra \$0.20-\$0.40 per gallon.[18]
- Commercial aircraft GHG emissions vary according to aircraft type, the length of trip, occupancy rates, and passenger and cargo weight, but totaled 121.5 mmt CO_2e in 2016.[4] In 2016, the average domestic commercial flight emitted 0.39 pounds of CO_2e per passenger mile. Emissions per domestic passenger-mile decreased 44% from 1990-2016, due to increased occupancy and fuel efficiency.[4,19]
- On average, trains release 0.31 pounds of CO_2e per passenger mile, but this varies with occupancy and the length of the trip.[20]

Solutions and Sustainable Actions
Ways to Reduce Carbon Footprint

- Eat local, vegetarian, or organic foods. For non-vegetarians, replace some beef consumption with chicken.[2,3,6]
- Walk, bike, carpool, use mass transit, or drive a best-in-class vehicle.[21]
- Smaller homes use less energy. Average household energy use is highest in houses (82.3 million BTU), followed by mobile homes (59.8 million BTU), apartments with 2-4 units (53.5 million BTU), and apartments with 5+ units in the building (34.2 million BTU).[11]
- Using a low-flow shower head can save 350 pounds of CO_2e per year. Setting the temperature to 120°F can help improve a hot water heater's efficiency.[22]
- Turn off your TV, computer, and other electronics when not in use to reduce your carbon footprint by thousands of pounds of CO_2e each year. Unplug unused electronics to further reduce your footprint.[22]
- Choose energy-efficient lighting. If every home in the U.S. replaced their 5 most used light bulbs with Energy Star bulbs, the reduction in carbon emissions would be equivalent to removing 10 million cars from the road.[23]
- Recycling half a household's waste can save 2,400 pounds of CO2 per year. Buying products with minimal packaging also helps reduce waste. For every 10% of waste reduction, 1,200 pounds of CO2e are avoided.[22]

U.S. Greenhouse Gas Emissions, 2012[27]

- Shop smart and purchase items with a comparatively low carbon footprint when possible. Some manufacturers have begun assessing and publishing their products' carbon footprints.
- Replacing 80% of conditioned roof area on commercial buildings in the U.S. with solar reflective material would offset 125 mmt CO_2 over the structures' lifetime, equivalent to turning off 31 coal power plants for one year.[24,25]
- Replacing the global fleet of shipping containers' roof and wall panels with aluminum would save \$28 billion in fuel.[26]

Carbon Footprint Calculator

Use one of these tools to estimate your personal or household greenhouse gas emissions and explore the impact of different techniques to lower those emissions:
- Global Footprint Network: www.footprintnetwork.org/en/index.php/gfn/page/calculators/
- The Nature Conservancy: www.nature.org/greenliving/carboncalculator/
- U.S. Environmental Protection Agency: www3.epa.gov/carbon-footprint-calculator/

1. The Carbon Trust (2012) Carbon Footprinting.
2. Heller, M. and G. Keoleian. (2014) "Greenhouse gas emissions estimates of U.S. dietary choices and food loss." Journal of Industrial Ecology, 19 (3): 391-401.
3. Weber, C. and H. Matthews (2008) "Food miles and the Relative Climate Impacts of Food Choices in the United States." Environmental Science & Technology, 42(10): 3508-3513.
4. U.S. Environmental Protection Agency (EPA) (2018) Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 - 2016.
5. Fiala, N. (2009) How Meat Contributes to Global Warming. Scientific American.
6. Ziesemer, J. (2007) Energy Use in Organic Food Systems. Natural Resources Management and Environment Department, Food and Agriculture Organization of the United Nations.
7. U.S. EPA (2018) "Emissions & Generation Resource Integrated Database (eGRID)."
8. U.S. Energy Information Administration (EIA) (2018) Electric Power Monthly with Data from February 2018.
9. U.S. Department of Energy (DOE), Energy Efficiency and Renewable Energy (EERE) (2012) Buildings Energy Data Book 2011.
10. Houck, J., et al. (1998) Air Emissions from Residential Heating: The Wood Heating Option Put into Environmental Perspective.
11. U.S. EIA (2018) Residential Energy Consumption Survey 2015.
12. Sabaliunas, D., et al. (2006) "Residential Energy Use and Potential Conservation Through Reduced Laundering Temperatures in the United States and Canada." Integrated Environmental Assessment and

Management (2): 142-153.
13. U.S. EPA (2017) Light-Duty Automotive Technology and Fuel Economy Trends: 1975 Through 2017.
14. U.S. DOE, Oak Ridge National Lab (2017) Transportation Energy Data Book: Edition 36.1.
15. Keoleian, G., et al. (1998) LCI Modeling Challenges and Solutions for a Complex Product System: A Mid-Sized Automobile. CSS98-07.
16. U.S. EIA (2016) "How Much Carbon Dioxide is Produced by Burning Gasoline and Diesel Fuel."
17. U.S. DOE, Alternative Fuels Data Center (2015) "Fuel Properties Comparison Chart."
18. U.S. DOE, EERE (2018) "Driving More Efficiently."
19. U.S. Department of Transportation Bureau of Transportation Statistics (2018) National Transportation Statistics 2018.
20. U.S. EPA (2018) Emission Factors for Greenhouse Gas Inventories.
21. U.S. DOE, EERE (2009) "Gas Mileage Tips: Keeping Your Car In Shape."
22. Texas A&M University, College of Agriculture and Life Sciences (2008) 10 Simple Ways to Reduce your Carbon Footprint.
23. U.S. EPA (2009) "Climate Change – What You Can Do."
24. Levinson, R. (2012) The Case for Cool Roofs. Lawrence Berkeley National Laboratory, Heat Island Group.
25. U.S. EPA (2017) "Greenhouse Gas Equivalencies Calculator."
26. Buchanan, C., et al (2018) "Lightweighting shipping containers: Life cycle impacts on multimodal freight transportation." Transportation Research Part D 62:418-432.
27. U.S. EPA (2013) Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2012. CRF Tables.