# Calculations and References

This page describes the calculations used to convert greenhouse gas emission numbers into different types of equivalent units. Go to the equivalency calculator page for more information.

## Electricity Reductions (kilowatt-hours)

The Greenhouse Gas Equivalencies Calculator uses the Emissions & Generation Resource Integrated Database (eGRID) U.S. annual non-baseload $CO_2$ output emission rate to convert reductions of kilowatt-hours into avoided units of carbon dioxide emissions. Most users of the Equivalencies Calculator who seek equivalencies for electricity-related emissions want to know equivalencies for emissions **reductions** from energy efficiency or renewable energy programs. These programs are not generally assumed to affect baseload emissions (the emissions from power plants that run all the time), but rather non-baseload generation (power plants that are brought online as necessary to meet demand). For that reason, the Equivalencies Calculator uses a non-baseload emission rate.

**Emission Factor**

**$7.0555 \times 10^{-4}$ metric tons $CO_2$ / kWh**
(eGRID2012 Version 1.0, U.S. annual non-baseload $CO_2$ output emission rate, year 2009 data)

Notes:

This calculation does not include any greenhouse gases other than $CO_2$.
This calculation does not include line losses.
Individual subregion non-baseload emissions rates are also available on the eGRID Web site.
To estimate indirect greenhouse gas emissions from electricity use, please use Power Profiler or use eGRID subregion annual output emission rates as a default emission factor (see eGRID2012 Version 1.0 Year 2009 GHG Annual Output Emission Rates (PDF) (1 p, 312K, About PDF)).

**Sources**

(EPA 2012). eGRID2012 Version 1.0, U.S. annual non-baseload $CO_2$ output emission rate, year 2009 data, U.S. Environmental Protection Agency, Washington, DC.

## Gallons of gasoline consumed

To obtain the number of grams of $CO_2$ emitted per gallon of gasoline combusted, the heat content of the fuel per gallon is multiplied by the kg $CO_2$ per heat content of the fuel.

The average heat content per gallon of gasoline is 0.125 mmbtu/gallon and the average emissions per heat content of gasoline is 71.35 kg $CO_2$/mmbtu (EPA 2012). The fraction oxidized to $CO_2$ is 100 percent (IPCC 2006).

**Calculation**

Note: Due to rounding, performing the calculations given in the equations below may not return the exact results shown.

0.125 mmbtu/gallon × 71.35 kg $CO_2$/mmbtu × 1 metric ton/1,000 kg = **8.92 × $10^{-3}$ metric tons $CO_2$/gallon of gasoline**

**Sources**

EPA (2012). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010. Annex 2 (Methodology for estimating $CO_2$ emissions from fossil fuel combustion), Table A-35 and P. A-71. U.S. Environmental Protection Agency, Washington, DC. U.S. EPA #430-R-12-001 (PDF) (389 pp, 10.6MB, About PDF)
IPCC (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Intergovernmental Panel on Climate Change, Geneva, Switzerland.

## Passenger vehicles per year

Passenger vehicles are defined as 2-axle 4-tire vehicles, including passenger cars, vans, pickup trucks, and sport/utility vehicles.

In 2010, the weighted average combined fuel economy of cars and light trucks combined was 21.5 miles per gallon (FHWA 2012). The average vehicle miles traveled in 2010 was 11,493 miles per year.

In 2010, the ratio of carbon dioxide emissions to total greenhouse gas emissions (including carbon dioxide, methane, and nitrous oxide, all expressed as carbon dioxide equivalents) for passenger vehicles was 0.985 (EPA 2012).

The amount of carbon dioxide emitted per gallon of motor gasoline burned is 8.92 × $10^{-3}$ metric tons, as calculated in the "Gallons of gasoline consumed" section above.

To determine annual greenhouse gas emissions per passenger vehicle, the following methodology was used: vehicle miles traveled (VMT) was divided by average gas mileage to determine gallons of gasoline consumed per vehicle per year. Gallons of gasoline consumed was multiplied by carbon dioxide per gallon of gasoline to determine carbon dioxide emitted per vehicle per year. Carbon dioxide emissions were then divided by the ratio of carbon dioxide emissions to total vehicle greenhouse gas emissions to account for vehicle methane and nitrous oxide emissions.

**Calculation**

Note: Due to rounding, performing the calculations given in the equations below may not return the exact results shown.

8.92 × $10^{-3}$ metric tons $CO_2$/gallon gasoline × 11,493 $VMT_{\text{car/truck average}}$ × 1/21.5 miles per $\text{gallon}_{\text{car/truck average}}$ × 1 $CO_2$, $CH_4$, and $N_2O$/0.985 $CO_2$ = **4.8 metric tons $CO_2E$ /vehicle/year**

**Sources**

EPA (2012). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010. Chapter 3 (Energy), Tables 3-12, 3-13, and 3-14. U.S. Environmental Protection Agency, Washington, DC. U.S. EPA #430-R-12-001 (PDF) (481 pp, 16.6MB, About PDF)

FHWA (2012). Highway Statistics 2010. Office of Highway Policy Information, Federal Highway Administration. Table VM-1.

## Therms of natural gas

Carbon dioxide emissions per therm are determined by multiplying heat content times the carbon coefficient times the fraction oxidized times the ratio of the molecular weight ratio of carbon dioxide to carbon (44/12).

The average heat content of natural gas is 0.1 mmbtu per therm (EPA 2012). The average carbon coefficient of natural gas is 14.47 kg carbon per mmbtu (EPA 2012). The fraction oxidized to $CO_2$ is 100 percent (IPCC 2006).

Note: When using this equivalency, please keep in mind that it represents the $CO_2$ equivalency for natural gas **burned** as a fuel, not natural gas released to the atmosphere. Direct methane emissions released to the atmosphere (without burning) are about 21 times more powerful than $CO_2$ in terms of their warming effect on the atmosphere.

#### Calculation

Note: Due to rounding, performing the calculations given in the equations below may not return the exact results shown.

0.1 mmbtu/1 therm × 14.47 kg C/mmbtu × 44 g $CO_2$/12 g C × 1 metric ton/1,000 kg = **0.005306 metric tons $CO_2$/therm**

#### Sources

EPA (2012). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010. Annex 2 (Methodology for estimating $CO_2$ emissions from fossil fuel combustion), P. A-85. U.S. Environmental Protection Agency, Washington, DC. U.S. EPA #430-R-12-001 (PDF) (389 pp, 10.6MB, About PDF).
IPCC (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Intergovernmental Panel on Climate Change, Geneva, Switzerland.

## Barrels of oil consumed

Carbon dioxide emissions per barrel of crude oil are determined by multiplying heat content times the carbon coefficient times the fraction oxidized times the ratio of the molecular weight of carbon dioxide to that of carbon (44/12).

The average heat content of crude oil is 5.80 mmbtu per barrel (EPA 2012). The average carbon coefficient of crude oil is 20.31 kg carbon per mmbtu (EPA 2012). The fraction oxidized is 100 percent (IPCC 2006).

#### Calculation

Note: Due to rounding, performing the calculations given in the equations below may not return the exact results shown.

5.80 mmbtu/barrel × 20.31 kg C/mmbtu × 44 g $CO_2$/12 g C × 1 metric ton/1,000 kg = **0.43 metric tons $CO_2$/barrel**

**Sources**

EPA (2012). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010. Annex 2 (Methodology for estimating $CO_2$ emissions from fossil fuel combustion), P. A-68, Table A-44. U.S. Environmental Protection Agency, Washington, DC. U.S. EPA #430-R-12-001 (PDF) (389 pp, 10.6MB, About PDF).
IPCC (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Intergovernmental Panel on Climate Change, Geneva, Switzerland.

## Tanker trucks filled with gasoline

Carbon dioxide emissions per barrel of gasoline are determined by multiplying the heat content times the carbon dioxide coefficient times the fraction oxidized times the ratio of the molecular weight ratio of carbon dioxide to carbon (44/12). A barrel equals 42 gallons. A typical gasoline tanker truck contains 8,500 gallons.

The average heat content of conventional motor gasoline is 0.125 mmbtu/gallon (EPA 2012). The average carbon coefficient of motor gasoline is 71.35 kg $CO_2$/mmbtu (EPA 2012). The fraction oxidized to $CO_2$ is 100 percent (IPCC 2006).

**Calculation**

Note: Due to rounding, performing the calculations given in the equations below may not return the exact results shown.

0.125 mmbtu/gallon × 71.35 kg $CO_2$/mmbtu × 1 metric ton/1,000 kg = $8.92 \times 10^{-3}$ metric tons $CO_2$/gallon

$8.92 \times 10^{-3}$ metric tons $CO_2$/gallon × 8,500 gallons/tanker truck = **75.82 metric tons $CO_2$/tanker truck**

**Sources**

EPA (2012). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010. Annex 2 (Methodology for estimating $CO_2$ emissions from fossil fuel combustion), Table A-35 and P. A-71. U.S. Environmental Protection Agency, Washington, DC. U.S. EPA #430-R-12-001 (PDF) (389 pp, 10.6MB, About PDF)
IPCC (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Intergovernmental Panel on Climate Change, Geneva, Switzerland.

## Home electricity use

In 2009, there were 113.6 million homes in the United States; of those, 71.8 million were single-family detached homes and 6.7 million were single-family attached homes for a total 78.5 million single-family homes* nationally (EIA 2012). On average, each single-family home consumed 11,319 kWh of delivered electricity (EIA 2012). The national average carbon dioxide output rate for electricity generated in 2009 was 1,216 lbs $CO_2$ per megawatt-hour (EPA 2012), which translates to about 1,301 lbs $CO_2$ per megawatt-hour for delivered electricity (assuming 7 percent in transmission and distribution losses).

Annual single-family home electricity consumption was multiplied by the carbon dioxide emission rate (per unit of electricity delivered) to determine annual carbon dioxide emissions per home.

**Calculation**

Note: Due to rounding, performing the calculations given in the equations below may not return the exact results shown.

11,319 kWh per home × 1,301.31 lbs $CO_2$ per megawatt-hour delivered × 1 mWh/1,000 kWh × 1 metric ton/2,204.6 lb = **6.68 metric tons $CO_2$/home.**

*A single-family home is defined in the U.S. Department of Energy's Residential Energy Consumption Survey as follows: A housing unit, detached or attached, that provides living space for one home or family. Attached houses are considered single-family houses as long as they are not divided into more than one housing unit and they have independent outside entrance. A single-family house is contained within walls extending from the basement (or the ground floor, if there is no basement) to the roof. A mobile home with one or more rooms added is classified as a single-family home. Townhouses, rowhouses, and duplexes are considered single-family attached housing units, as long as there is no home living above another one within the walls extending from the basement to the roof to separate the units.

**Sources**

EIA (2012). 2009 Residential Energy Consumption Survey. Table CE2.6, Household Fuel Consumption in the U.S., Totals and Averages, 2009, Physical Units, Preliminary.
EPA (2012). eGRID2012 Version 1.0. U.S. Environmental Protection Agency, Washington, DC.

## Home energy use

In 2009, there were 113.6 million homes in the United States; of those, 71.8 million were single-family detached homes and 6.7 million were single-family attached homes for a total 78.5 million single-family homes* nationally (EIA 2012). On average, each single-family home consumed 11,319 kWh of delivered electricity, 66,000 cubic feet of natural gas, 464 gallons of liquid petroleum gas, 551 gallons of fuel oil, and 108 gallons of kerosene (EIA 2012).

The national average carbon dioxide output rate for generated electricity in 2009 was 1,216 lbs $CO_2$ per megawatt-hour (EPA 2012), which translates to about 1,301 lbs $CO_2$ per megawatt-hour for delivered electricity (assuming 7 percent in transmission and distribution losses).

The average carbon dioxide coefficient of natural gas is 0.0544 kg $CO_2$ per cubic foot (EPA 2012a). The fraction oxidized to $CO_2$ is 100 percent (IPCC 2006).

The average carbon dioxide coefficient of distillate fuel oil is 429.61 kg $CO_2$ per 42-gallon barrel (EPA 2012b). The fraction oxidized to $CO_2$ is 100 percent (IPCC 2006).

The average carbon dioxide coefficient of liquefied petroleum gases is 219.3 kg $CO_2$ per 42-gallon barrel (EPA 2010b). The fraction oxidized is 100 percent (IPCC 2006).

The average carbon dioxide coefficient of kerosene is 426.31 kg $CO_2$ per 42-gallon barrel (EPA 2012b). The fraction oxidized to $CO_2$ is 100 percent (IPCC 2006).

Total single-family home electricity, natural gas, distillate fuel oil, and liquefied petroleum gas consumption figures were converted from their various units to metric tons of $CO_2$ and added together to obtain total $CO_2$ emissions per home.

**Calculation**

Note: Due to rounding, performing the calculations given in the equations below may not return the exact results shown.

1. Delivered electricity: 11,319 kWh per home × 1,301.31 lbs $CO_2$ per megawatt-hour delivered × 1 mWh/1,000 kWh × 1 metric ton/2204.6 lb = 6.68 metric tons $CO_2$/home.

2. Natural gas: 66,000 cubic feet per home × 0.0544 kg $CO_2$/cubic foot × 1/1,000 kg/metric ton = 3.59 metric tons $CO_2$/home

3. Liquid petroleum gas: 464 gallons per home × 1/42 barrels/gallon × 219.3 kg $CO_2$/barrel × 1/1,000 kg/metric ton = 2.42 metric tons $CO_2$/home

4. Fuel oil: 551 gallons per home × 1/42 barrels/gallon × 429.61 kg $CO_2$/barrel × 1/1,000 kg/metric ton = 5.64 metric tons $CO_2$/home

5. Kerosene: 108 gallons per home × 1/42 barrels/gallon × 426.31 kg $CO_2$/barrel × 1/1,000 kg/metric ton = 1.10 metric tons $CO_2$/home

Total $CO_2$ emissions for energy use per single-family home: 6.68 metric tons $CO_2$ for electricity + 3.59 metric tons $CO_2$ for natural gas + 2.42 metric tons $CO_2$ for liquid petroleum gas + 5.64 metric tons $CO_2$ for fuel oil + 1.10 metric tons $CO_2$ for kerosene = **19.43 metric tons $CO_2$ per home per year**.

*A single-family home is defined in the U.S. Department of Energy's Residential Energy Consumption Survey as follows: A housing unit, detached or attached, that provides living space for one home or family. Attached houses are considered single-family houses as long as they are not divided into more than one housing unit and they have independent outside entrance. A single-family house is contained within walls extending from the basement (or the ground floor, if there is no basement) to the roof. A mobile home with one or more rooms added is classified as a single-family home. Townhouses, rowhouses, and duplexes are considered single-family attached housing units, as long as there is no home living above another one within the walls extending from the basement to the roof to separate the units.

**Sources**

EIA (2012). 2009 Residential Energy Consumption Survey. Table CE2.6, Household Fuel Consumption in the U.S., Totals and Averages, 2009, Physical Units, Preliminary.
EPA (2012a). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010. Annex 2 (Methodology for estimating $CO_2$ emissions from fossil fuel combustion), P. A-85. U.S. Environmental Protection Agency, Washington, DC. U.S. EPA #430-R-12-001 (PDF) (389 pp, 10.6MB, About PDF).
EPA (2012b). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010. Annex 2 (Methodology for estimating $CO_2$ emissions from fossil fuel combustion), P. A-68. U.S. Environmental Protection Agency, Washington, DC. U.S. EPA #430-R-12-001 (PDF) (389 pp, 10.6MB, About PDF).
EPA (2011). Inventory of U.S. Greenhouse Gas Emissions and Sinks: Fast Facts 1990-2009. Conversion Factors to Energy Units (Heat Equivalents) Heat Contents and Carbon Content Coefficients of Various Fuel Types. U.S. Environmental Protection Agency, Washington, DC. USEPA #430-F-11-007 (PDF) (2 pp, 430K, About PDF).
IPCC (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Intergovernmental Panel on Climate Change, Geneva, Switzerland.
EPA (2012). eGRID2012 Version 1.0. U.S. Environmental Protection Agency, Washington, DC.

## Number of tree seedlings grown for 10 years

A medium growth coniferous tree, planted in an urban setting and allowed to grow for 10 years, sequesters 23.2 lbs of carbon. This estimate is based on the following assumptions:

- The medium growth coniferous trees are raised in a nursery for one year until they become 1 inch in diameter at 4.5 feet above the ground (the size of tree purchased in a 15-gallon container).
- The nursery-grown trees are then planted in a suburban/urban setting; the trees are not densely planted.
- The calculation takes into account "survival factors" developed by U.S. DOE (1998). For example, after 5 years (one year in the nursery and 4 in the urban setting), the probability of survival is 68 percent; after 10 years, the probability declines to 59 percent. For each year, the sequestration rate (in lbs per tree) is multiplied by the survival factor to yield a probability-weighted sequestration rate. These values are summed for the 10-year period, beginning from the time of planting, to derive the estimate of 23.2 lbs of carbon per tree.

Please note the following caveats to these assumptions:

- While most trees take 1 year in a nursery to reach the seedling stage, trees grown under different conditions and trees of certain species may take longer: up to 6 years.
- Average survival rates in urban areas are based on broad assumptions, and the rates will vary significantly depending upon site conditions.
- Carbon sequestration is dependent on growth rate, which varies by location and other conditions.
- This method estimates only direct sequestration of carbon, and does not include the energy savings that result from buildings being shaded by urban tree cover.

To convert to units of metric tons $CO_2$ per tree, multiply by the ratio of the molecular weight of carbon dioxide to that of carbon (44/12) and the ratio of metric tons per pound (1/2,204.6).

#### Calculation

Note: Due to rounding, performing the calculations given in the equations below may not return the exact results shown.

23.2 lbs C/tree × (44 units $CO_2$ ÷ 12 units C) × 1 metric ton ÷ 2,204.6 lbs = **0.039 metric ton $CO_2$ per urban tree planted**

#### Sources


U.S. DOE (1998). Method for Calculating Carbon Sequestration by Trees in Urban and Suburban Settings. Voluntary Reporting of Greenhouse Gases, U.S. Department of Energy, Energy Information Administration (16 pp, 111K, About PDF)


## Acres of U.S. forests storing carbon for one year

Growing forests accumulate and store carbon. Through the process of photosynthesis, trees remove $CO_2$ from the atmosphere and store it as cellulose, lignin, and other compounds. The rate of accumulation is equal to growth minus removals (i.e., harvest for the production of paper and wood) minus decomposition. In most U.S. forests, growth exceeds removals and decomposition, so the amount of carbon stored nationally is increasing overall.

**Calculation for U.S. Forests**

The *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010* (EPA 2012) provides data on the net change in forest carbon stocks and forest area. Net changes in carbon attributed to harvested wood products are not included in the calculation.

Annual Net Change in Carbon Stocks per Area in Year n = (Carbon $Stocks_{(t+1)}$ - Carbon $Stocks_t$) ÷ Area of land remaining in the same land-use category

**Step 1: Determine the carbon stock change between years** by subtracting carbon stocks in year t from carbon stocks in year (t+1). (This includes carbon stocks in the above-ground biomass, below-ground biomass, dead wood, litter, and soil organic carbon pools.)

**Step 2: Determine the annual net change in carbon stocks (i.e., sequestration) per area** by dividing the carbon stock change in U.S. forests from Step 1 by the total area of U.S. forests remaining in forests in year n+1 (i.e., the area of land that did not change land-use categories between the time periods).

Applying these calculations to data developed by the USDA Forest Service for the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010* yields a result of 150 metric tons of carbon per hectare (or 61 metric tons of carbon per acre) for the carbon stock density of U.S. forests in 2010, with an annual net change in carbon stock per area in 2010 of 0.82 metric tons of carbon sequestered per hectare per year (or 0.33 metric tons of carbon sequestered per acre per year). These values include carbon in the five forest pools: above-ground biomass, below-ground biomass, deadwood, litter, and soil organic carbon, and are based on state-level Forest Inventory and Analysis (FIA) data. Forest carbon stocks and carbon stock change are based on the stock difference methodology and algorithms described by Smith, Heath, and Nichols (2010).

**Conversion Factor for Carbon Sequestered Annually by 1 Acre of Average U.S. Forest**

Note: Due to rounding, performing the calculations given in the equations below may not return the exact results shown.

-0.33 metric ton C/acre/year* (44 units $CO_2$ ÷ 12 units C) = **-1.22 metric ton $CO_2$ sequestered annually by one acre of average U.S. forest.**

*Negative values indicate carbon sequestration.

Please note that this is an estimate for "average" U.S. forests in 2010; i.e., for U.S. forests as a whole in 2010. Significant geographical variations underlie the national estimates, and the values calculated here might not be representative of individual regions or states. To estimate carbon sequestered for additional acres in one year, simply multiply the number of acres by 1.22 mt $CO_2$ acre/year. From 2000–2010 the average annual sequestration per area was 0.73 metric tons C hectare/year (or 0.30 metric tons C acre/year) in the United States, with a minimum value of 0.36 metric tons C hectare/year (or 0.15 metric tons C acre/year) in 2000, and a maximum value of 0.83 metric tons C hectare/year (or 0.34 metric tons C acre/year) in 2006.

**Sources**

EPA (2012). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010. U.S. Environmental Protection Agency, Washington, DC. U.S. EPA #430-R-12-001 (PDF) (481 pp, 16.6MB, About PDF)

IPCC (2006). Guidelines for National Greenhouse Gas Inventories. Volume 4. Agriculture, Forestry and Other Land Use. Task Force on National Greenhouse Gas Inventories.
Smith, J., Heath, L., & Nichols, M. (2010). *U.S. Forest Carbon Calculation Tool User's Guide: Forestland Carbon Stocks and Net Annual Stock Change. General Technical Report NRS-13 revised*, U.S. Department of Agriculture Forest Service, Northern Research Station.

## Acres of U.S. forest preserved from conversion to cropland

Based on data developed by the USDA Forest Service for the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010*, the carbon stock density of U.S. forests in 2010 was 150 metric tons of carbon per hectare (or 61 metric tons of carbon per acre) (EPA 2012). This estimate is composed of the five carbon pools: aboveground biomass (52 metric tons C/hectare), belowground biomass (10 metric tons C /hectare), dead wood (9 metric tons C/hectare), litter (17 metric tons/C hectare), and soil organic carbon (62 metric tons C/hectare).

The *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010* estimates soil carbon stock changes using U.S.-specific equations and data from the USDA Natural Resource Inventory and the Century biogeochemical model (EPA 2012). When calculating carbon stock changes in biomass due to conversion from forestland to cropland, the IPCC guidelines indicate that the average carbon stock change is equal to the carbon stock change due to removal of biomass from the outgoing land use (i.e., forestland) plus the carbon stocks from one year of growth in the incoming land use (i.e., cropland), or the carbon in biomass immediately after the conversion minus the carbon in biomass prior to the conversion plus the carbon stocks from one year of growth in the incoming land use (i.e., cropland) (IPCC 2006). The carbon stock in annual cropland biomass after one year is 5 metric tons C per hectare, and the carbon content of dry aboveground biomass is 45 percent (IPCC 2006). Therefore, the carbon stock in cropland after one year of growth is estimated to be 2.25 metric tons C per hectare (or 0.91 metric tons C per acre).

The averaged reference soil carbon stock (for high-activity clay, low-activity clay, and sandy soils for all climate regions in the United States) is 40.83 metric tons C/hectare (EPA 2012). Carbon stock change in soils is time-dependent, with a default time period for transition between equilibrium soil organic carbon values of 20 years for mineral soils in cropland systems (IPCC 2006). Consequently, it is assumed that the change in equilibrium mineral soil organic carbon will be annualized over 20 years to represent the annual flux. The IPCC (2006) guidelines indicate that there are insufficient data to provide a default approach or parameters to estimate carbon stock change from dead organic matter pools or below-ground carbon stocks in perennial cropland (IPCC 2006).

**Calculation for Converting U.S. Forests to U.S. Cropland**

**Annual Change in Biomass Carbon Stocks on Land Converted to Other Land-Use Category**

$$\Delta CB = \Delta C_G + C_{Conversion} - \Delta C_L$$

**Where:**

**$\Delta CB$ =** annual change in carbon stocks in biomass on land converted to another land-use category

**$\Delta C_G$ =** annual increase in carbon stocks in biomass due to growth on land converted to another land-use category (i.e., 2.25 metric tons C/hectare)

**$C_{Conversion}$ =** initial change in carbon stocks in biomass on land converted to another land-use category. The sum of the carbon stocks in aboveground, belowground, deadwood, and litter biomass (-88.47 metric tons

C/hectare). Immediately after conversion from forestland to cropland, biomass is assumed to be zero, as the land is cleared of all vegetation before planting crops)

**$\Delta C_L$ =** annual decrease in biomass stocks due to losses from harvesting, fuel wood gathering, and disturbances on land converted to other land-use category (assumed to be zero)

**Therefore**: $\Delta CB = \Delta C_G + C_{Conversion} - \Delta C_L$ = -86.22 metric tons C/hectare/year of biomass carbon stocks are lost when forestland is converted to cropland.

**Annual Change in Organic Carbon Stocks in Mineral Soils**

$$\Delta C_{Mineral} = (SOC_0 - SOC_{(0-T)}) \div D$$

**Where:**

**$\Delta C_{Mineral}$ =** annual change in carbon stocks in mineral soils

**$SOC_0$ =** soil organic carbon stock in last year of inventory time period (i.e., 40.83 mt/hectare)

**$SOC_{(0-T)}$ =** soil organic carbon stock at beginning of inventory time period (i.e., 62 mt C/hectare)

**D =** Time dependence of stock change factors which is the default time period for transition between equilibrium SOC values (i.e., 20 years for cropland systems)

**Therefore**: $\Delta C_{Mineral} = (SOC_0 - SOC_{(0-T)}) \div D = (40.83 - 62) \div 20 = -1.06$ metric tons C/hectare/year of soil organic C lost.

**Source**: **(IPCC 2006)**.

Consequently, the change in carbon density from converting forestland to cropland would be -86.22 metric tons of C/hectare/year of biomass plus -1.06 metric tons C/hectare/year of soil organic C, equaling a total loss of 87.28 metric tons C/hectare/ year (or -35.32 metric tons C/acre/year). To convert to carbon dioxide, multiply by the ratio of the molecular weight of carbon dioxide to that of carbon (44/12), to yield a value of -320.01 metric tons $CO_2$ hectare/year (or -129.51 metric tons $CO_2$ acre/year).

**Conversion Factor for Carbon Sequestered Annually by 1 Acre of Forest Preserved from Conversion to Cropland**

Note: Due to rounding, performing the calculations given in the equations below may not return the exact results shown.

-35.32 metric tons C/acre/year* (44 units $CO_2$ ÷ 12 units C) = **-129.51 metric tons $CO_2$/acre/year**

*Negative values indicate $CO_2$ that is NOT emitted.

To estimate $CO_2$ not emitted when an acre of forest is preserved from conversion to cropland, simply multiply the number of acres of forest not converted by -129.51 mt $CO_2e$/acre/year. Please note that this calculation method assumes that all of the forest biomass is oxidized during clearing (i.e., none of the burned biomass remains as charcoal or ash). Also note that this estimate only includes mineral soil carbon stocks, as most forests in the contiguous United States are growing on mineral soils. In the case of mineral soil forests, soil carbon stocks could be replenished or even increased, depending on the starting stocks, how the agricultural lands are managed, and the time frame over which lands are managed.

#### Sources

EPA (2012). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010. U.S. Environmental Protection Agency, Washington, DC. U.S. EPA #430-R-12-001 (PDF) (481 pp, 16.6MB, About PDF)
IPCC (2006). *Guidelines for National Greenhouse Gas Inventories. Volume 4. Agriculture, Forestry and Other Land Use.* Task Force on National Greenhouse Gas Inventories.

## Propane cylinders used for home barbecues

Propane is 81.7 percent carbon (EPA 2012). The fraction oxidized is 100 percent (IPCC 2006).

Carbon dioxide emissions per pound of propane were determined by multiplying the weight of propane in a cylinder times the carbon content percentage times the fraction oxidized times the ratio of the molecular weight of carbon dioxide to that of carbon (44/12). Propane cylinders vary with respect to size; for the purpose of this equivalency calculation, a typical cylinder for home use was assumed to contain 18 pounds of propane.

#### Calculation

Note: Due to rounding, performing the calculations given in the equations below may not return the exact results shown.

18 pounds propane/1 cylinder × 0.817 pound C/pound propane × 0.4536 kilograms/pound × 44 kg $CO_2$/12 kg C × 1 metric ton/1,000 kg = **0.024 metric tons $CO_2$/cylinder**

#### Sources

EPA (2012). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010. Annex 2 (Methodology for estimating $CO_2$ emissions from fossil fuel combustion), P. A-75. U.S. Environmental Protection Agency, Washington, DC. U.S. EPA #430-R-12-001 (PDF) (389 pp, 10.6MB, About PDF).
IPCC (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Intergovernmental Panel on Climate Change, Geneva, Switzerland.

## Railcars of coal burned

The average heat content of coal in 2009 was 27.56 mmbtu per metric ton (EPA 2011). The average carbon coefficient of coal in 2009 was 25.34 kilograms carbon per mmbtu (EPA 2011). The fraction oxidized is 100 percent (IPCC 2006).

Carbon dioxide emissions per ton of coal were determined by multiplying heat content times the carbon coefficient times the fraction oxidized times the ratio of the molecular weight of carbon dioxide to that of carbon (44/12). The amount of coal in an average railcar was assumed to be 100.19 short tons, or 90.89 metric tons (Hancock 2001).

#### Calculation

Note: Due to rounding, performing the calculations given in the equations below may not return the exact results shown.

27.56 mmbtu/metric ton coal × 25.34 kg C/mmbtu × 44g $CO_2$/12g C × 90.89 metric tons coal/railcar × 1 metric ton/1,000 kg = **232.74 metric tons $CO_2$/railcar**

**Sources**

EPA (2011). Inventory of U.S. Greenhouse Gas Emissions and Sinks: Fast Facts 1990-2009. Conversion Factors to Energy Units (Heat Equivalents) Heat Contents and Carbon Content Coefficients of Various Fuel Types. U.S. Environmental Protection Agency, Washington, DC. USEPA #430-F-11-007 (PDF) (2 pp, 430K, About PDF).
EPA (2012). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010. Annex 2 (Methodology for estimating $CO_2$ emissions from fossil fuel combustion), P. A-31-A-32. U.S. Environmental Protection Agency, Washington, DC. U.S. EPA #430-R-12-001 (PDF) (389 pp, 10.6MB, About PDF).
Hancock (2001). Hancock, Kathleen and Sreekanth, Ande. *Conversion of Weight of Freight to Number of Railcars. Transportation Research Board*, Paper 01-2056, 2001.
IPCC (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Intergovernmental Panel on Climate Change, Geneva, Switzerland.

## Tons of waste recycled instead of landfilled

To develop the conversion factor for recycling rather than landfilling waste, emission factors from EPA's WAste Reduction Model (WARM) were used (EPA 2012). These emission factors were developed following a life-cycle assessment methodology using estimation techniques developed for national inventories of greenhouse gas emissions. According to WARM, the net emission reduction from recycling mixed recyclables (e.g., paper, metals, plastics), compared with a baseline in which the materials are landfilled, is 0.73 metric tons of carbon equivalent per short ton. This factor was then converted to metric tons of carbon dioxide equivalent by multiplying by 44/12, the molecular weight ratio of carbon dioxide to carbon.

**Calculation**

Note: Due to rounding, performing the calculations given in the equations below may not return the exact results shown.

0.73 metric tons of carbon equivalent/ton × 44 g $CO_2$/12 g C = **2.67 metric tons $CO_2$ equivalent /ton of waste recycled instead of landfilled**

**Sources**

EPA (2012). WAste Reduction Model (WARM). U.S. Environmental Protection Agency.

## Coal-fired power plant emissions for one year

In 2009, a total of 457 power plants used coal to generate at least 95% of their electricity (EPA 2012). These plants emitted 1,614,625,638.1metric tons of $CO_2$ in 2009.

Carbon dioxide emissions per power plant were calculated by dividing the total emissions from power plants whose primary source of fuel was coal by the number of power plants.

**Calculation**

Note: Due to rounding, performing the calculations given in the equations below may not return the exact results shown.

1,614,625,638.1 metric tons of $CO_2$ × 1/457 power plants = **3,533,098 metric tons $CO_2$/power plant**

http://www.epa.gov/cleanenergy/energy-resources/refs.html
Last updated on Thursday, April 25, 2013

**Sources**

EPA (2012). eGRID2012 Version 1.0, year 2009 data.