Chapter 11
Greenhouse Gas Emissions

Summary Statistics from Tables/Figures in this Chapter

Source			
Table 11.1	Carbon dioxide emissions (million metric tonnes)	1990	2014
	United States	*4,989*	*5,361*
	OECD Europe	*4,149*	*4,050*
	China	*2,293*	*9,595*
	Russia	*2,393*	*1,633*
	Japan	*1,054*	*1,245*
	Non-OECD Europe and Eurasia	*4,246*	*2,726*
	India	*573*	*1,808*
Table 11.5	Transportation share of U.S. carbon dioxide emissions from fossil fuel consumption		
	1990		*31.8%*
	2005		*33.2%*
	2013		*33.6%*
Table 11.7	Motor gasoline share of transportation carbon dioxide emissions		61.9%
Table 11.11	Average annual carbon footprint (metric tons of CO_2)		
	Cars		*6.1*
	Light trucks		*8.4*

The U.S. accounted for 23.2% of the World's carbon dioxide emissions in 1990 and 16.2% in 2005 and 2014. Nearly half (42%) of the U.S. carbon emissions are from oil use.

Table 11.1
World Carbon Dioxide Emissions, 1990, 2005, and 2014

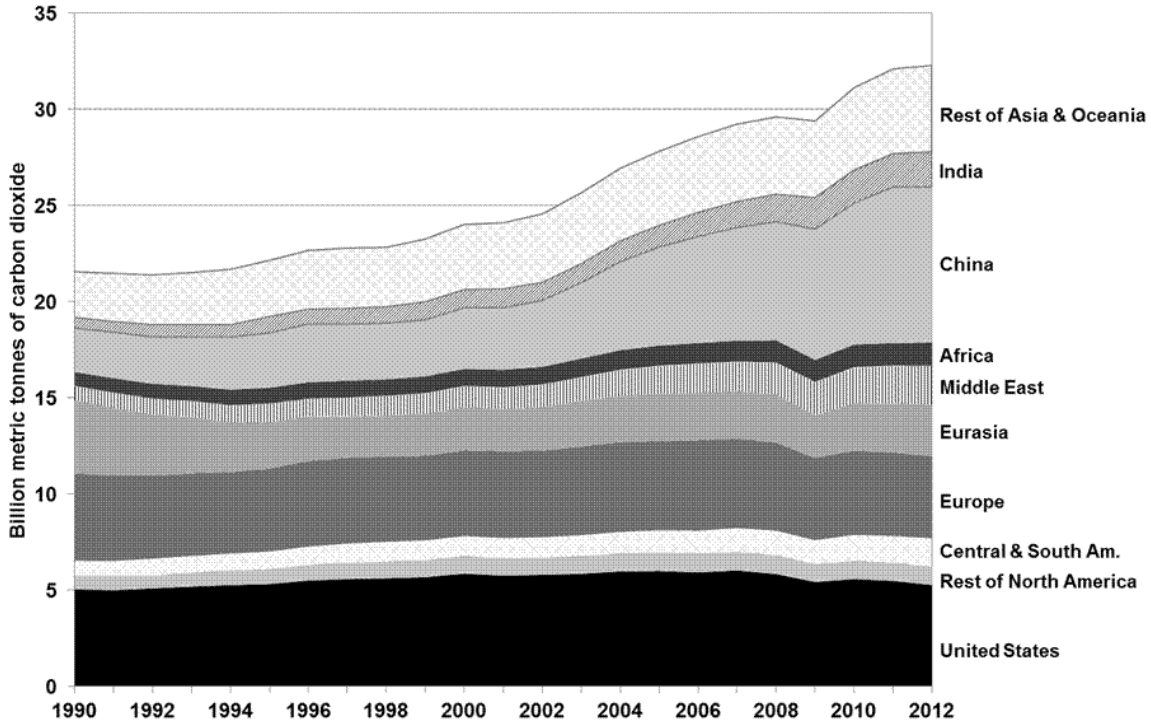
	1990		2005		2014	
Country/Region	million metric tons	Percent of emissions from oil use	million metric tons	Percent of emissions from oil use	million metric tons	Percent of emissions from oil use
OECD[a] Americas						
United States	4,989	44%	5,985	44%	5,361	42%
Canada	471	48%	620	49%	552	52%
Mexico/Chile	302	77%	461	66%	534	60%
Total	5,762	46%	7,066	46%	6,447	44%
OECD[a] Europe	4,149	45%	4,488	49%	4,050	45%
OECD[a] Asia						
Japan	1,054	65%	1,241	52%	1,245	44%
Australia/New Zealand	298	38%	438	55%	441	36%
Other	243	59%	494	30%	594	38%
Total	1,595	59%	2,173	47%	2,280	41%
Non-OECD Europe & Eurasia						
Russia	2,393	33%	1,548	25%	1,633	24%
Other	1,853	32%	1,120	26%	1,093	34%
Total	4,246	32%	2,668	25%	2,726	28%
Non-OECD Asia						
China	2,293	15%	5,490	16%	9,595	14%
India	573	28%	1,182	27%	1,808	25%
Other	811	57%	1,665	53%	1,953	48%
Total	3,677	26%	8,337	25%	13,356	21%
Other Non-OECD						
Middle East	704	70%	1,333	59%	1,924	56%
Africa	659	46%	978	43%	1,105	44%
Central & South America	695	76%	1,011	72%	1,298	70%
Total	2,058	64%	3,322	58%	4,327	57%
Total World	21,487	42%	28,054	40%	33,186	35%

Source:
U.S. Department of Energy, Energy Information Administration, *International Energy Statistics Databases*, Washington, DC, May 2015. (Additional resources: www.eia.doe.gov)

[a] OECD is the Organization for Economic Cooperation and Development. See Glossary for included countries.

Since 1990, China shows the greatest increase of carbon dioxide (CO_2) emissions. The Americas, Europe and Eurasia have about the same (CO_2) emissions in 2012 as in 1990.

Figure 11.1. World Carbon Dioxide Emissions, 1990–2012



Source:

U.S. Department of Energy, Energy Information Administration, *International Energy Statistics*, Total Carbon Dioxide Emissions from the Consumption of Energy, www.eia.doe.gov/cfapps/ipdbproject/IEDIndex3.cfm, July 2015. (Additional resources: www.eia.doe.gov)

Global Warming Potentials (GWP) were developed to allow comparison of the ability of each greenhouse gas to trap heat in the atmosphere relative to carbon dioxide. Extensive research has been performed and it has been discovered that the effects of various gases on global warming are too complex to be precisely summarized by a single number. Further understanding of the subject also causes frequent changes to estimates. Despite that, the scientific community has developed approximations, the latest of which are shown below. Most analysts use the 100-year time horizon.

Table 11.2
Numerical Estimates of Global Warming Potentials Compared with Carbon Dioxide
(kilogram of gas per kilogram of carbon dioxide)

Gas	Lifetime (years)	Global warming potential direct effect for time horizons of 20 years	100 years
Carbon Dioxide (CO_2)	5-200[a]	1	1
Methane (CH_4)[b]	12.4	86	34
Tetrafluoroethane (HFC-134a)	13.4	3,790	1,550
Trichlorofluoromethane (CFC-11)	45	7,020	5,350
Nitrous Oxide (N_2O)	121	268	298
Perfluoromethane (CF_4)	50,000	4,950	7,350

Note: Includes climate-carbon feedbacks.

Source:
Myhre, G., D. Shindell, F.-M. Breon, W. Collins, J. Fuglestvedt, J. Huang, D. Koch, J.-F. Lamarque, D. Lee, B. Mendoza, T. Nakajima, A. Robock, G. Stephens, T. Takemura and H. Zhang, 2013: Anthropogenic and Natural Radiative Forcing. In: *Climate Change 2013: The Physical Science Basis*. Contribution of Working Group 1 to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, R.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Zia, V. Bex and P.M. Midgley (eds)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[a] No single lifetime can be defined for carbon dioxide due to different rates of uptake by different removal processes.

[b] These values do not include carbon dioxide from methane oxidation. Perturbation lifetime is used in the calculation of metrics.

Carbon dioxide emissions in 2013 were 7% higher than in 1990, but down from the highest annual emissions of this data series in 2007. Carbon dioxide accounts for the majority (82%) of greenhouse gases.

Table 11.3
U.S. Emissions of Greenhouse Gases, Based on Global Warming Potential, 1990–2013
(million metric tonnes carbon dioxide equivalent[a])

Year	Carbon dioxide	Methane	Nitrous oxide	High GWP gases[b]	Total
1990	5,090.0	745.3	329.8	101.9	6,267.0
1991	5,034.9	748.8	354.7	92.9	6,231.3
1992	5,141.5	753.4	345.4	97.4	6,337.7
1993	5,254.0	743.6	366.6	98.0	6,462.2
1994	5,344.6	758.4	352.6	101.9	6,557.5
1995	5,410.0	750.1	371.3	122.3	6,653.7
1996	5,598.3	750.7	393.7	134.6	6,877.3
1997	5,671.8	731.3	376.4	143.3	6,922.8
1998	5,712.2	720.7	358.0	159.3	6,950.2
1999	5,784.8	715.6	353.0	157.2	7,010.6
2000	5,956.6	715.9	334.9	159.0	7,166.4
2001	5,852.6	706.0	352.8	146.2	7,057.6
2002	5,895.4	703.2	346.7	154.4	7,099.7
2003	5,935.4	707.1	334.0	144.7	7,121.2
2004	6,049.1	698.1	355.4	152.2	7,254.8
2005	6,076.1	707.9	355.5	152.7	7,292.2
2006	5,995.1	720.2	353.7	154.1	7,223.1
2007	6,082.9	724.2	376.8	163.4	7,347.3
2008	5,887.6	727.8	364.0	162.8	7,142.2
2009	5,453.2	709.5	355.8	156.7	6,675.2
2010	5,654.2	667.2	359.9	167.1	6,848.4
2011	5,525.5	660.7	371.5	175.1	6,732.8
2012	5,316.3	647.6	365.3	173.8	6,503.0
2013	5,470.6	636.3	355.0	176.6	6,638.5

Note: This greenhouse gas emissions inventory includes fossil fuel combustion, use of fluorinated gases and other transportation categories.

Source:
U.S. Environmental Protection Agency, *Inventory of U. S. Greenhouse Gas Emissions and Sinks: 1990-2013.* April 15, 2015, EPA430-R-15-004, www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2015-Main-Text.pdf

[a] Carbon dioxide equivalents are computed by multiplying the weight of the gas being measured by its estimated Global Warming Potential (See Table 11.2).

[b] GWP = Global warming potential. Includes HFC-hydrofluorocarbons; PFC-perfluorocarbons; and SF_6-sulfur hexaflouride.

The transportation sector accounts for the largest share of total greenhouse gas emissions, due to the high share of carbon dioxide emissions. The industrial sector accounts for nearly the same amount of total greenhouse gas emissions as the transportation sector.

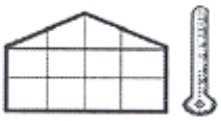
Table 11.4
Total U.S. Greenhouse Gas Emissions by End-Use Sector, 2013
(million metric tonnes carbon dioxide equivalent[a])

	Carbon dioxide	Methane	Nitrous oxide	Hydroflurocarbons, perflurocarbons, sulfur hexafluoride	Total greenhouse gas emissions
Residential	1,074.7	5.2	10.5	38.9	1,129.3
Commercial	937.6	132.8	13.8	42.6	1,126.8
Agricultural	122.3	240.6	286.4	0.2	649.5
Industrial	1,604.8	256.0	27.5	34.4	1,922.7
Transportation	1,731.2	1.7	16.8	60.5	1,810.2
Transportation share of total	31.6%	0.3%	4.7%	34.3%	27.3%
Total greenhouse gas emissions	5,470.6	636.3	355.0	176.6	6,638.5

Note: Totals may not sum due to rounding.

Source:
U.S. Environmental Protection Agency, *Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990-2013*. April 2015. (Additional resources: www.epa.gov/climatechange/emissions/usinventoryreport.html)

[a] Carbon dioxide equivalents are computed by multiplying the weight of the gas being measured by its estimated Global Warming Potential (See Table 11.2).



Gases which contain carbon can be measured in terms of the full molecular weight of the gas or just in terms of their carbon content. This table presents carbon dioxide gas. The ratio of the weight of carbon to carbon dioxide is 0.2727. The transportation sector accounts for approximately one-third of carbon emissions.

Table 11.5
U.S. Carbon Emissions from Fossil Fuel Consumption
by End-Use Sector, 1990–2013[a]
(million metric tonnes of carbon dioxide)

	End use sector				Transportation	CO_2 from
	Residential	Commercial	Industrial	Transportation	percentage	all sectors
1990	931.4	755.4	1,529.2	1,496.8	31.8%	4,712.8
1991	949.1	762.1	1,497.0	1,450.6	31.1%	4,658.8
1992	945.2	758.0	1,557.0	1,499.8	31.5%	4,760.0
1993	998.0	782.3	1,565.1	1,535.4	31.5%	4,880.8
1994	988.8	794.7	1,588.3	1,580.4	31.9%	4,952.2
1995	994.6	812.3	1,586.6	1,613.2	32.2%	5,006.7
1996	1,055.3	843.2	1,644.1	1,657.7	31.9%	5,200.3
1997	1,045.1	882.9	1,662.2	1,673.6	31.8%	5,263.8
1998	1,049.5	901.1	1,639.4	1,710.2	32.3%	5,300.2
1999	1,070.4	912.7	1,619.0	1,764.7	32.9%	5,366.8
2000	1,133.1	972.1	1,643.6	1,809.3	32.6%	5,558.1
2001	1,124.8	980.6	1,578.4	1,793.7	32.7%	5,477.5
2002	1,151.6	978.7	1,553.1	1,834.7	33.2%	5,518.1
2003	1,181.5	989.3	1,572.1	1,827.2	32.8%	5,570.1
2004	1,179.6	1,007.7	1,597.9	1,872.4	33.1%	5,657.6
2005	1,214.1	1,026.7	1,564.4	1,892.5	33.2%	5,697.7
2006	1,151.8	1,007.2	1,564.1	1,889.2	33.7%	5,612.3
2007	1,204.5	1,047.3	1,562.9	1,894.7	33.2%	5,709.4
2008	1,190.2	1,039.3	1,499.5	1,800.3	32.6%	5,529.3
2009	1,122.6	976.7	1,329.5	1,724.8	33.5%	5,153.6
2010	1,174.8	993.2	1,416.5	1,736.5	32.6%	5,321.0
2011	1,117.9	959.1	1,398.8	1,715.8	33.0%	5,191.6
2012	1,008.4	897.4	1,377.0	1,704.6	34.2%	4,987.4
2013	1,070.2	933.3	1,399.8	1,722.4	33.6%	5,125.7
	Average annual percentage change					
1990–2013	0.6%	0.9%	-0.4%	0.6%		0.4%
2003–2013	-1.1%	-0.6%	-1.2%	-0.6%		-0.8%

Note: The CO_2 from all sectors does not match Table 11.3 since it is only from fossil fuel consumption and does not include the use of fluorinated gases and other transportation categories.

Source:
U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990-2013*. April 15, 2015. (Additional resources: www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2015-Main-Text.pdf)

[a] Includes energy from petroleum, coal, and natural gas. Electric utility emissions are distributed across consumption sectors.

This report has typically displayed carbon and carbon dioxide data from the Environmental Protection Agency (EPA). However, the Energy Information Administration's (EIA's) Monthly Energy Review *also includes carbon dioxide emission data. The differences in the two data series have been about 3-4%, but as high as 7% in 1991. According to EIA, the difference in the data comes from differences in carbon factors and other adjustments.*

Table 11.6
Transportation Sector Carbon Dioxide Emissions from Energy Consumption, 1973-2014
(million metric tons of carbon dioxide)

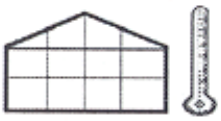
Year	Energy Information Administration's *Monthly Energy Review*	Environmental Protection Agency's Greenhouse Gas Inventory Report	Percentage difference
1973	1,315.2	[a]	[a]
1975	1,291.6	[a]	[a]
1980	1,400.2	[a]	[a]
1985	1,421.2	[a]	[a]
1986	1,472.1	[a]	[a]
1987	1,519.0	[a]	[a]
1988	1,579.0	[a]	[a]
1989	1,591.2	[a]	[a]
1990	1,587.7	1,505.6	5.2%
1991	1,567.9	1,458.2	7.0%
1992	1,591.6	1,507.6	5.3%
1993	1,607.2	1,543.4	4.0%
1994	1,647.4	1,588.7	3.6%
1995	1,681.3	1,621.4	3.6%
1996	1,725.2	1,665.6	3.5%
1997	1,744.2	1,682.0	3.6%
1998	1,782.0	1,719.1	3.5%
1999	1,828.0	1,773.7	3.0%
2000	1,872.5	1,817.9	2.9%
2001	1,852.0	1,801.1	2.7%
2002	1,892.5	1,842.2	2.7%
2003	1,892.1	1,833.0	3.1%
2004	1,958.6	1,878.1	4.1%
2005	1,985.6	1,898.0	4.4%
2006	2,013.7	1,894.6	5.9%
2007	2,021.0	1,899.9	6.0%
2008	1,897.9	1,805.1	4.9%
2009	1,831.6	1,728.9	5.6%
2010	1,849.0	1,741.5	5.8%
2011	1,817.5	1,720.5	5.3%
2012	1,780.2	1,709.1	4.0%
2013	1,808.7	1,727.2	4.5%
2014	1,832.3	[a]	[a]

Sources:

U.S. Department of Energy, Energy Information Administration, *Monthly Energy Review*, July 2015, Washington, DC, Table 12.5.

U.S. Environmental Protection Agency, U.S. Greenhouse Gas Inventory Report: 1990-2013, April 2015, Washington, DC, Table 2-12.

[a] Data are not available.



Most U.S. transportation sector carbon dioxide emissions come from petroleum fuels (97%). Motor gasoline has been responsible for about two-thirds of U.S. carbon dioxide emissions over the last twenty years.

Table 11.7
U.S. Carbon Emissions from Fossil Fuel Combustion in the Transportation End-Use Sector, 1990–2013
(million metric tonnes of carbon dioxide equivalent)

	Motor gasoline	LPG[a]	Jet fuel	Distillate fuel	Residual fuel	Aviation gas	Natural gas	Electricity[b]	Total
1990	983.5	1.4	184.2	262.9	22.6	3.1	36.0	3.0	1,496.7
1991	969.7	1.3	215.2	266.2	77.0	2.9	32.9	3.0	1,568.2
1992	992.8	1.2	213.4	281.9	80.3	2.8	32.2	3.0	1,607.6
1993	1,010.9	1.2	215.1	298.5	67.7	2.7	34.2	3.0	1,633.3
1994	1,022.9	2.1	223.9	318.6	66.3	2.6	37.6	3.1	1,677.1
1995	1,042.4	1.1	222.1	333.5	68.4	2.7	38.4	3.1	1,711.7
1996	1,063.6	1.0	235.6	348.6	63.9	2.6	39.1	3.1	1,757.5
1997	1,075.6	0.9	238.9	364.4	53.4	2.7	41.4	3.1	1,780.4
1998	1,107.5	1.1	242.4	378.2	50.6	2.5	35.3	3.2	1,820.8
1999	1,128.0	0.9	250.0	396.8	50.0	2.7	35.8	3.2	1,867.4
2000	1,136.2	0.7	257.0	408.9	66.6	2.5	35.6	3.4	1,910.9
2001	1,149.6	0.8	246.1	406.0	44.0	2.4	34.9	3.6	1,887.4
2002	1,174.8	0.9	239.9	420.0	50.8	2.3	37.0	3.5	1,929.2
2003	1,177.4	1.1	234.5	430.0	42.9	2.1	33.2	4.3	1,925.5
2004	1,194.3	1.2	242.9	448.3	55.5	2.2	31.9	4.5	1,980.8
2005	1,183.9	1.7	189.3	458.1	19.3	2.4	33.1	4.7	1,892.5
2006	1,172.0	1.7	242.6	479.1	68.0	2.3	33.1	4.5	2,003.3
2007	1,166.3	1.4	241.0	484.5	74.6	2.2	35.2	5.1	2,010.3
2008	1,109.4	2.5	229.2	460.7	69.5	2.0	36.7	4.7	1,914.7
2009	1,101.7	1.7	154.1	409.0	13.9	1.8	37.9	4.5	1,724.6
2010	1,092.7	1.8	151.5	425.5	20.4	1.9	38.1	4.5	1,736.4
2011	1,069.0	2.1	146.6	433.7	19.4	1.9	38.9	4.3	1,715.9
2012	1,064.9	2.3	143.4	431.3	15.8	1.7	41.3	3.9	1,704.6
2013	1,065.8	2.5	147.1	437.6	15.0	1.5	48.8	4.0	1,722.3
				Average annual percentage change					
1990-2013	0.4%	2.6%	-1.0%	2.2%	-1.8%	-3.1%	1.3%	1.3%	0.6%
2003-2013	-1.0%	8.6%	-4.6%	0.2%	-10.0%	-3.3%	3.9%	-0.7%	-1.1%

Source:
U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990-2013*. April 15, 2015. (Additional resources: www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2015-Main-Text.pdf)

[a] Liquified petroleum gas.
[b] Share of total electric utility carbon dioxide emissions weighted by sales to the transportation sector.

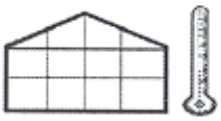
Highway vehicles are responsible for the majority of greenhouse gas emissions in the transportation sector.

Table 11.8
Transportation Carbon Dioxide Emissions by Mode, 1990–2013
(Million metric tonnes of carbon dioxide equivalent)

Year	Passenger Vehicles	Heavy Trucks	Highway Total	Water	Air	Rail	Pipeline	Total
1990	952.2	238.3	1,190.5	44.3	187.3	38.5	36.0	1,496.6
1991	937.2	233.0	1,170.2	39.5	171.7	36.4	32.9	1,450.7
1992	968.8	243.4	1,212.2	48.5	169.4	37.4	32.2	1,499.7
1993	988.4	256.5	1,244.9	47.1	170.9	38.3	34.1	1,535.3
1994	1,002.3	273.4	1,275.7	47.7	178.1	41.2	37.5	1,580.2
1995	1,015.6	284.1	1,299.7	57.8	174.9	42.7	38.2	1,613.3
1996	1,038.1	296.4	1,334.5	53.7	187.1	43.4	38.9	1,657.6
1997	1,051.7	310.6	1,362.3	39.4	187.2	43.6	41.2	1,673.7
1998	1,083.0	324.0	1,407.0	33.4	190.9	44.0	35.0	1,710.3
1999	1,116.5	342.7	1,459.2	29.3	195.1	45.5	35.5	1,764.6
2000	1,113.9	356.9	1,470.8	60.2	197.4	45.5	35.2	1,809.1
2001	1,124.8	354.6	1,479.4	42.0	192.0	45.8	34.4	1,793.6
2002	1,150.6	367.9	1,518.5	46.7	187.6	45.4	36.4	1,834.6
2003	1,164.4	364.9	1,529.3	36.8	181.4	47.1	32.5	1,827.1
2004	1,182.9	380.3	1,563.2	39.6	188.8	49.7	31.1	1,872.4
2005	1,166.0	407.6	1,573.6	44.6	191.8	50.3	32.2	1,892.5
2006	1,154.5	417.8	1,572.3	47.6	184.6	52.3	32.3	1,889.1
2007	1,124.5	448.6	1,573.1	54.2	181.7	51.7	34.2	1,894.9
2008	1,066.7	430.0	1,496.7	45.0	175.1	47.9	35.6	1,800.3
2009	1,062.2	390.7	1,452.9	38.3	155.9	40.7	36.7	1,724.5
2010	1,054.5	403.9	1,458.4	44.1	153.4	43.5	37.1	1,736.5
2011	1,035.5	403.2	1,438.7	45.9	148.5	45.1	37.8	1,716.0
2012	1,031.7	404.2	1,435.9	39.6	145.1	43.7	40.3	1,704.6
2013	1,032.0	410.8	1,442.8	38.8	148.6	44.4	47.7	1,722.3
			Average annual percentage change					
1990-2013	0.4%	2.4%	0.8%	-0.6%	-1.0%	0.6%	1.2%	0.6%
2003-2013	-1.2%	1.2%	-0.6%	0.5%	-2.0%	-0.6%	3.9%	-0.6%

Note: Emissions from U.S. Territories are not included. Passenger vehicles includes cars, light trucks and motorcycles. Heavy trucks includes medium and heavy trucks and buses.

Source:
U.S. Environmental Protection Agency, *Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2013*, Table 3-12, April 2015. (Additional resources: www.epa.gov/climatechange/ghgemissions/usinventoryreport.html)

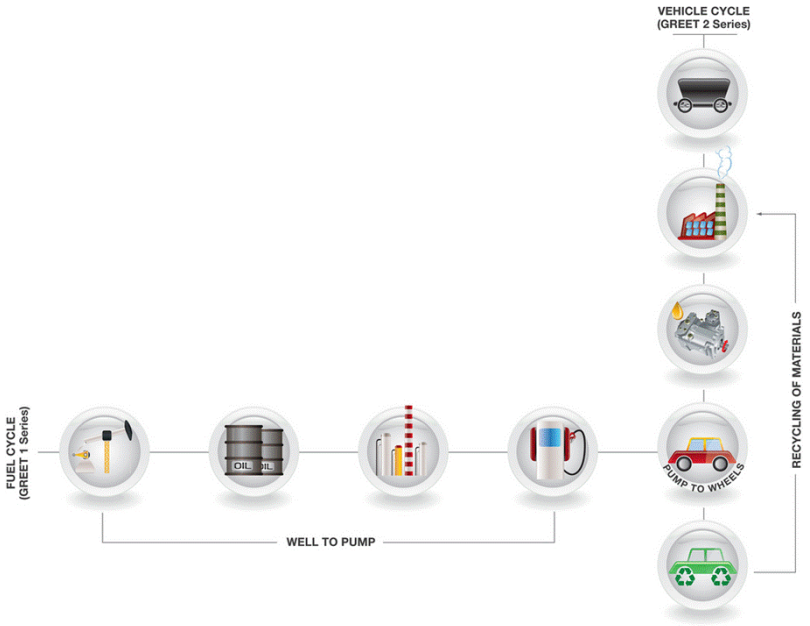


The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model

greet.es.anl.gov

Sponsored by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE), Argonne has developed a full life-cycle model called GREET™ (Greenhouse gases, Regulated Emissions, and Energy use in Transportation). It allows researchers and analysts to evaluate energy and emission impacts of various vehicle and fuel combinations on a full fuel-cycle/vehicle-cycle basis. The first version of GREET was released in 1996. Since then, Argonne has continued to update and expand the model. The most recent GREET versions are GREET 1 2013 version for fuel-cycle analysis and GREET 2 2013 version for vehicle-cycle analysis.

Figure 11.2. GREET Model



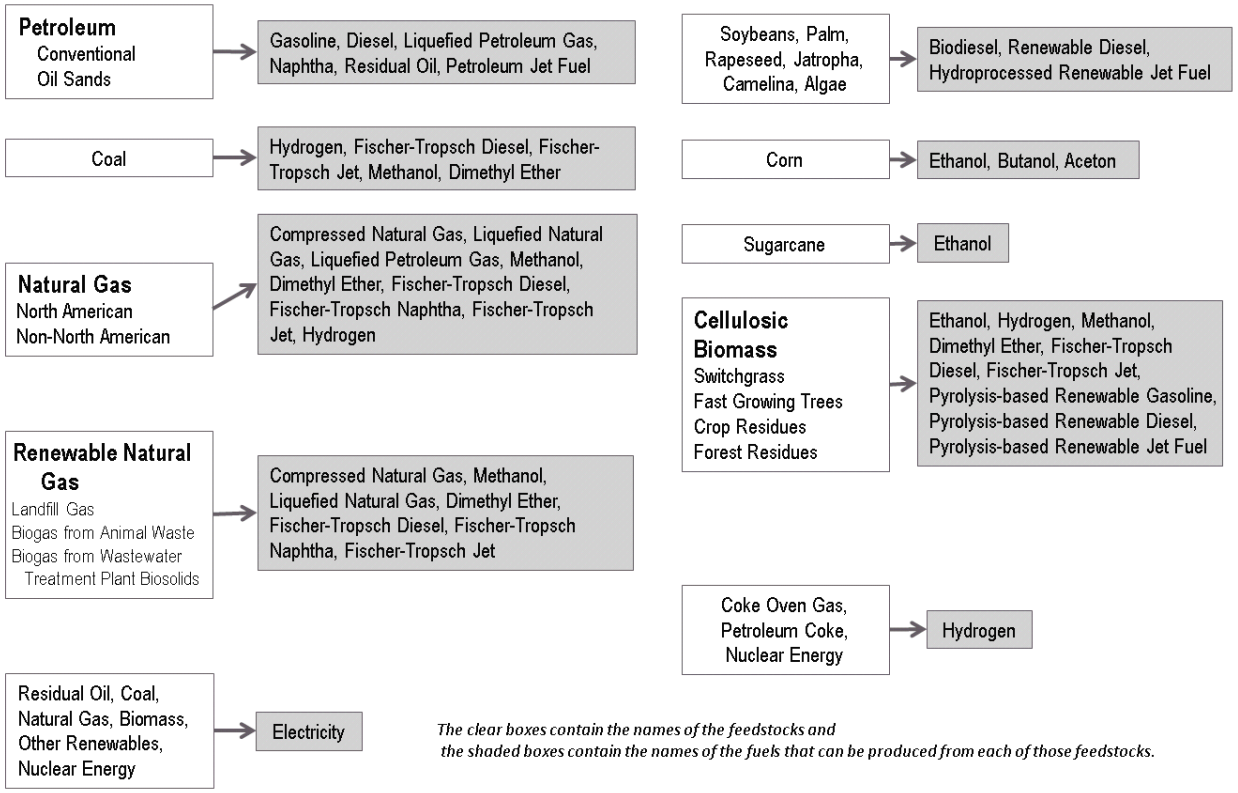
For a given vehicle and fuel system, GREET separately calculates the following:

- Consumption of total energy (energy in non-renewable and renewable sources), fossil fuels (petroleum, natural gas, and coal together), petroleum, coal and natural gas.
- Emissions of CO_2-equivalent greenhouse gases - primarily carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).
- Emissions of six criteria pollutants: volatile organic compounds (VOCs), carbon monoxide (CO), nitrogen oxide (NOx), particulate matter with size smaller than 10 micron (PM_{10}), particulate matter with size smaller than 2.5 micron ($PM_{2.5}$),and sulfur oxides (SOx).

GREET includes more than 100 fuel production pathways and more than 80 vehicle/fuel systems. These vehicle/fuel systems cover all major vehicle technologies in the market and R&D arena: conventional spark-ignition engine vehicles; spark-ignition, direct-injection engine vehicles; compression-ignition, direct-injection engine vehicles; hybrid electric vehicles; plug-in hybrid electric vehicles; battery-powered electric vehicles; and ffuel-cell vehicles.

Recently, GREET was expanded to include air and marine modes as well.

Figure 11.3. GREET Model Feedstocks and Fuels



To address technology improvements over time, GREET simulates vehicle/fuel systems over the period from 1990 to 2035, in five-year intervals.

For additional information about the GREET model, see the GREET website, or contact:

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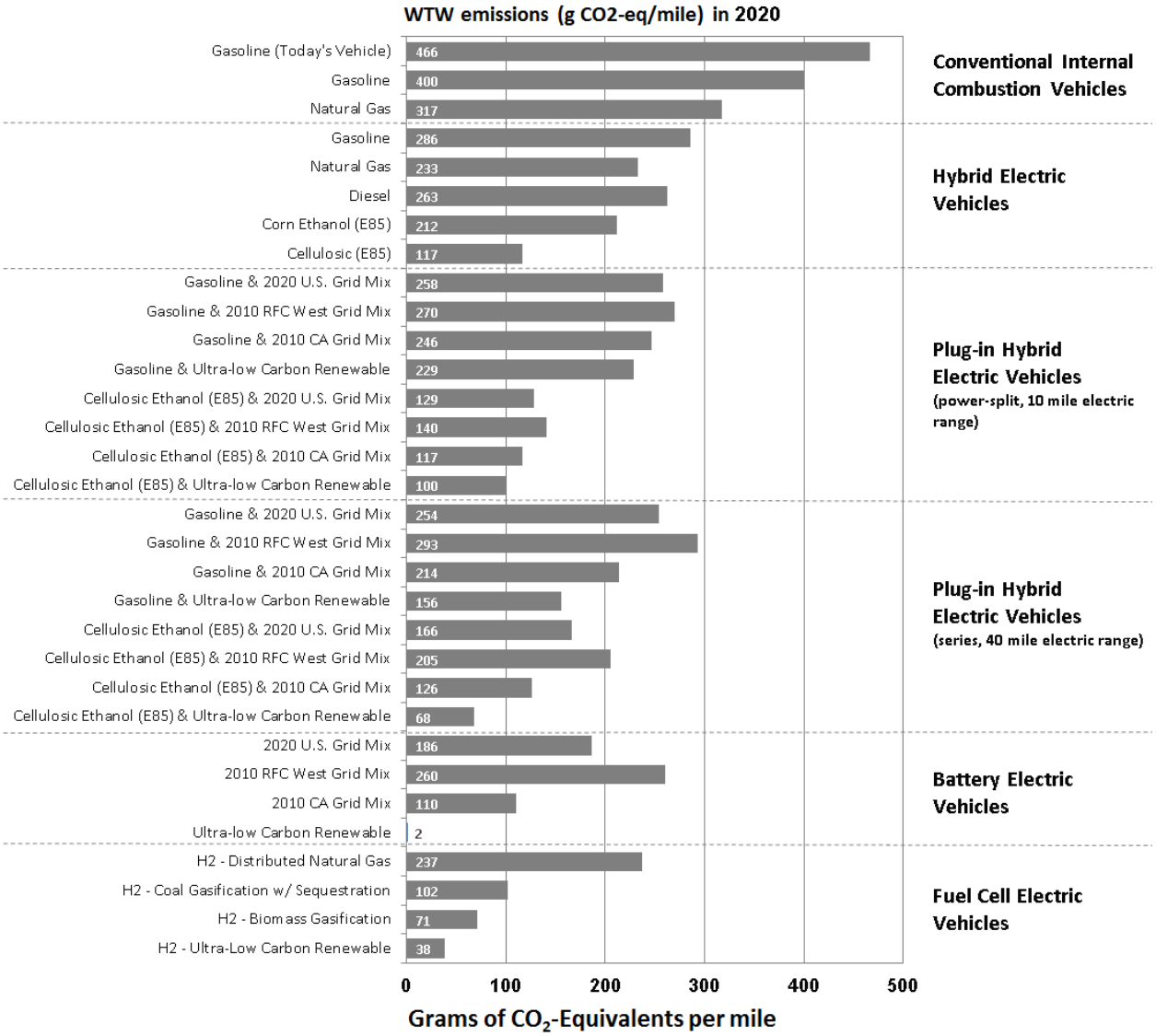
These are results from the GREET model (see preceding pages for description). For electricity, three different grid mixes are compared—the U.S., California, and RFC West. California's (CA) grid mix was chosen due to the high renewable energy mix in that state. The RFC West is an electricity grid subregion that includes Indiana, Ohio, West Virginia, and parts of Illinois, Pennsylvania, Virginia, Kentucky, and Wisconsin. The RFC West uses a high amount of coal to produce electricity.

Figure 11.4. Well-to-Wheel Emissions for Various Fuels and Vehicle Technologies



Note: H2 = hydrogen.

Source: Argonne National Laboratory, GREET 1 2013 Model.

Carbon Footprint

The carbon footprint measures a vehicle's impact on climate change in tons of carbon dioxide (CO_2) emitted annually. The following three tables show the carbon footprint for various vehicle classes. The sales-weighted average fuel economy rating for each vehicle class, based on 45% highway and 55% city driving, is used to determine the average annual carbon footprint for vehicles in the class. An estimate of 15,000 annual miles is used for each vehicle class and for each year in the series. The equation to calculate carbon footprint uses results of the GREET model version 1.8.

$$CarbonFootprint = \left(CO_2 \times LHV \times \frac{AnnualMiles}{CombinedMPG}\right) + \left(CH_4 + N_2O\right) \times AnnualMiles$$

where:

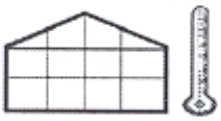
CO_2 = (Tailpipe CO_2 + Upstream Greenhouse Gases) in grams per million Btu

LHV = Lower (or net) Heating Value in million Btu per gallon

CH_4 = Tailpipe CO_2 equivalent methane in grams per mile

N_2O = Tailpipe CO_2 equivalent nitrous oxide in grams per mile

Note: The Environmental Protection Agency publishes tailpipe emissions in the *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2014,* www.epa.gov/otaq/fetrends.htm.



The production-weighted average annual carbon footprint for cars and car SUVs declined by an average of 2% annually between 1975 and 2014.

Table 11.9
Production-Weighted Annual Carbon Footprint of New Domestic and Import Cars
Model Years 1975–2014[a]
(metric tons of CO_2)

Model Year	Car	Car SUV
1975	12.6	15.2
1980	8.5	11.6
1981	7.9	11.5
1982	7.6	8.6
1983	7.7	8.2
1984	7.6	8.8
1985	7.4	8.4
1986	7.1	8.9
1987	7.1	8.7
1988	7.0	8.8
1989	7.2	8.9
1990	7.3	9.0
1991	7.2	9.3
1992	7.3	9.5
1993	7.2	9.9
1994	7.3	9.4
1995	7.2	9.5
1996	7.3	9.2
1997	7.3	8.8
1998	7.3	9.3
1999	7.4	9.1
2000	7.4	9.5
2001	7.4	9.0
2002	7.3	8.8
2003	7.3	8.5
2004	7.3	8.5
2005	7.2	8.4
2006	7.3	8.3
2007	7.0	8.2
2008	7.0	8.0
2009	6.7	7.7
2010	6.5	7.4
2011	6.5	7.2
2012	6.1	7.2
2013	6.0	6.9
2014	5.9	7.0
	Average annual percentage change	
1975–2014	-1.9%	-2.0%
2004–2014	-2.1%	-1.9%

Source:
Calculated using fuel economy from the U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 Through 2014*, October 2014. See page 11-12 for details. (Additional resources: www.epa.gov/fueleconomy/fetrends/1975-2014/420r14023a.pdf)

[a] Annual carbon footprint is based on 15,000 miles of annual driving. Includes tailpipe plus upstream emissions.

The production-weighted average annual footprint of pickups, vans, and truck SUVs decreased from 1975 to 2014. Truck SUVs experienced the greatest decline.

Table 11.10
Production-Weighted Annual Carbon Footprint of New Domestic and Import Trucks
Model Years 1975–2014[a]
(metric tons of CO_2)

Model Year	Pickup	Van	Truck SUV
1975	14.2	15.2	15.3
1980	10.2	12.0	12.8
1985	9.3	10.2	10.2
1986	9.0	9.7	9.9
1987	8.9	9.6	9.8
1988	9.3	9.5	9.9
1989	9.5	9.5	10.2
1990	9.7	9.5	10.3
1991	9.3	9.4	10.1
1992	9.7	9.4	10.4
1993	9.6	9.3	10.4
1994	9.7	9.5	10.6
1995	10.0	9.4	10.6
1996	9.9	9.2	10.4
1997	10.0	9.3	10.5
1998	10.0	9.1	10.5
1999	10.4	9.3	10.5
2000	10.2	9.1	10.6
2001	10.6	9.4	10.3
2002	10.7	9.1	10.4
2003	10.5	8.9	10.3
2004	10.7	8.8	10.3
2005	10.7	8.8	10.1
2006	10.5	8.7	9.9
2007	10.5	8.7	9.6
2008	10.3	8.5	9.3
2009	10.0	8.4	8.8
2010	10.0	8.4	8.6
2011	9.8	8.1	8.5
2012	9.9	7.9	8.5
2013	9.7	8.0	8.1
2014	9.4	8.0	8.0
	Average annual percentage change		
1975–2014	-1.1%	-1.6%	-1.6%
2004–2014	-1.3%	-0.9%	-2.5%

Note: Includes light trucks of 8,500 lbs. or less.

Source:
Calculated using fuel economy from the U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 Through 2014*, October 2014. See page 11-12 for details. (Additional resources: www.epa.gov/fueleconomy/fetrends/1975-2014/420r14023a.pdf)

[a] Annual carbon footprint is based on 15,000 miles of annual driving. Includes tailpipe plus upstream emissions.

Between 1975 and 2014, the production-weighted average annual carbon footprint for light vehicles dropped dramatically. Cars experienced the greatest decrease at 51.5% while the carbon footprint for light trucks decreased by 42.0%.

Table 11.11
Average Annual Carbon Footprint by Vehicle Classification, 1975 and 2014[a]
(metric tons of CO_2)

	Production share		Carbon footprint		Percent change
Fuel	1975	2014	1975	2014	1975 - 2014
		Cars			
Car	80.6%	51.3%	12.6	5.9	-52.9%
Car SUV	0.1%	10.0%	15.2	7.0	-54.0%
Total cars	80.7%	61.3%	12.6	6.1	-51.5%
		Light trucks			
Van	4.5%	3.9%	15.2	8.0	-47.3%
Truck SUV	1.7%	23.3%	15.3	8.0	-47.7%
Pickup	13.1%	11.5%	14.2	9.4	-33.7%
Total light trucks	19.3%	38.7%	14.5	8.4	-42.0%

Source:
Calculated using fuel economy from the U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 Through 2014*, October 2014. See page 11-12 for details. (Additional resources: www.epa.gov/fueleconomy/fetrends/1975-2014/420r14023a.pdf)

[a] Annual carbon footprint is based on 15,000 miles of annual driving. Includes tailpipe and upstream emissions.

The amount of carbon dioxide released into the atmosphere by a vehicle is primarily determined by the carbon content of the fuel. However, there is a small portion of the fuel that is not oxidized into carbon dioxide when the fuel is burned. The Environmental Protection Agency (EPA) has published information on carbon dioxide emissions from gasoline and diesel which takes the oxidation factor into account and is based on the carbon content used in EPA's fuel economy analyses. The other fuels listed come from the Energy Information Administration.

Table 11.12
Direct Carbon Dioxide Emissions from a Gallon of Fuel[a]

	Grams per gallon	Kilograms per gallon	Pounds per gallon
Gasoline	8,887	8.9	19.6
Diesel	10,180	10.2	22.4
E85	1,340	1.3	3.0
B20	8,120	8.1	17.9
LPG	5,805	5.8	12.8
Propane	5,740	5.8	12.7
Aviation gasoline	8,320	8.3	18.3
Jet fuel	9,751	9.6	21.5
Kerosene	9,751	9.8	21.5
Residual fuel	11,791	11.8	26.0

Sources:
Gasoline and Diesel: U.S. Environmental Protection Agency, "Greenhouse Gas Emissions from a Typical Passenger Vehicle," December 2011. (Additional resources: www.epa.gov/otaq)
All others: Energy Information Administration, Voluntary Reporting of Greenhouse Gases Program, Fuel and Energy Source Codes and Emission Coefficients.

[a] Direct emissions are from the "tank-to-wheels" process. No upstream emissions are included.