

## Chapter 3 Greenhouse Gas Emissions

Summary Statistics from Tables in this Chapter

Source			
Table 3.1	Greenhouse gas emissions (million metric tonnes)	1990	1997
	<i>France</i>	554	550
	<i>Germany</i>	1,201	1,036
	<i>United Kingdom</i>	727	657
	<i>Japan</i>	1,175	1,280
	<i>United States</i>	5,903	6,514
Table 3.5	Transportation share of U.S. carbon dioxide emissions from fossil fuel consumption		
	<i>1984</i>		30.5%
	<i>1990</i>		32.2%
	<i>1998</i>		32.6%
Table 3.6	Carbon dioxide emissions from U.S. transportation energy use, 1998		
	<i>Motor gasoline</i>		60.8%
	<i>Liquified petroleum gas</i>		0.0%
	<i>Jet fuel</i>		13.2%
	<i>Distillate fuel</i>		20.0%
	<i>Residual fuel</i>		3.1%
	<i>Lubricants</i>		0.4%
	<i>Aviation gas</i>		0.2%
	<i>Natural gas</i>		2.2%
	<i>Electricity</i>		0.1%

**Table 3.1**  
**International Man-Made Emissions of Greenhouse Gases, 1990–97<sup>a</sup>**  
**(CO<sub>2</sub> equivalent)**

	1990 (million metric tonnes)	1991	1992	1993	1994	1995	1996	1997
		(percentage relative to 1990, 1990=100)						
Australia	410.80	100	101	102	103	106	108	<sup>b</sup>
Austria	73.73	106	98	97	99	101	103	105
Canada	590.55	99	102	103	106	109	112	114
Denmark	71.66	115	108	110	115	110	129	117
France	553.58	104	102	98	97	99	101	99
Germany	1,201.12	96	91	89	88	88	89	86
Greece	103.80	100	101	102	103	105	107	<sup>b</sup>
Ireland	56.86	99	100	100	103	104	105	<sup>b</sup>
Italy	532.89	<sup>b</sup>	<sup>b</sup>	<sup>b</sup>	97	102	<sup>b</sup>	<sup>b</sup>
Japan	1,175.02	102	103	102	108	108	109	109 <sup>b</sup>
Netherlands	208.31	103	102	103	103	107	111	<sup>b</sup>
New Zealand	71.89	100	101	101	101	101	103	105
Norway	47.13	97	97	102	106	107	113	114
Poland	459.05	<sup>b</sup>	96	<sup>b</sup>	96	<sup>b</sup>	95	93
Portugal	68.44	103	109	105	106	<sup>b</sup>	<sup>b</sup>	<sup>b</sup>
Russian Federation	2,998.77	<sup>b</sup>	<sup>b</sup>	<sup>b</sup>	70	<sup>b</sup>	<sup>b</sup>	<sup>b</sup>
Spain	301.43	100	103	100	104	108	<sup>b</sup>	<sup>b</sup>
Sweden	69.47	93	94	94	98	97	111	100
Switzerland	53.75	103	101	98	97	98	99	96
United Kingdom	726.64	100	97	93	93	91	94	90
United States	5,902.99	99	101	103	105	106	109	110

**Source:**

United Nations Framework Convention on Climate Change, Greenhouse Gas Inventory Database,  
[www.unfccc.de/resource](http://www.unfccc.de/resource), April 2000, October 1998. (Additional resources: [www.unfccc.de](http://www.unfccc.de))

<sup>a</sup>Includes National totals of CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O, excluding land-use change and forestry.

<sup>b</sup>Data are not available.

**Table 3.2**  
**International Man-Made Emissions of Carbon Dioxide, 1990–97<sup>a</sup>**

	1990 (million metric tonnes)	1991	1992	1993	1994	1995	1996	1997
		(percentage relative to 1990, 1990=100)						
Australia	275.34	101	102	103	104	108	112	<sup>b</sup>
Austria	62.04	107	98	96	98	101	103	106
Canada	461.25	98	101	101	104	107	110	113
Denmark	52.28	120	110	114	121	114	140	123
France	395.51	106	104	99	98	100	103	102
Germany	1,014.50	96	91	90	89	89	91	88
Greece	85.35	100	102	102	104	106	108	<sup>b</sup>
Ireland	30.72	103	105	104	108	111	113	<sup>b</sup>
Italy	432.61	<sup>b</sup>	<sup>b</sup>	<sup>b</sup>	96	101	<sup>b</sup>	<sup>b</sup>
Japan	1,124.53	102	103	102	108	108	110	109
Netherlands	40.40	103	106	110	107	110	113	0
New Zealand	25.24	102	110	107	107	107	115	120
Norway	35.20	95	97	102	108	109	117	118
Poland	380.70	<sup>b</sup>	98	<sup>b</sup>	98	<sup>b</sup>	98	95
Portugal	47.12	104	112	107	108	<sup>b</sup>	<sup>b</sup>	<sup>b</sup>
Russian Federation	2,372.30	<sup>b</sup>	<sup>b</sup>	<sup>b</sup>	70	<sup>b</sup>	<sup>b</sup>	<sup>b</sup>
Spain	226.42	100	104	100	105	109	<sup>b</sup>	<sup>b</sup>
Sweden	55.44	100	101	101	106	105	114	102
Switzerland	45.07	104	101	98	96	98	100	96
United Kingdom	584.17	101	98	96	95	94	97	93
United States	4,928.90	99	100	103	104	106	109	111

**Source:**

United Nations Framework Convention on Climate Change, Greenhouse Gas Inventory Database,  
[www.unfccc.de/resource](http://www.unfccc.de/resource), April 2000. (Additional resources: [www.unfccc.de](http://www.unfccc.de))

<sup>a</sup>Includes National totals of CO<sub>2</sub>, excluding land-use change and forestry.

<sup>b</sup>Data are not available.

**Table 3.3**  
**International Man-Made Emissions of Carbon Dioxide by Source Category, 1990 and 1997<sup>a</sup>**

	Energy (excl transport)				Transport				Industrial processes				Total	
	1990		1997		1990		1997		1990		1997		1990	1997
	(MMT)	%	(MMT)	%	(MMT)	%	(MMT)	%	(MMT)	%	(MMT)	%	(MMT)	(MMT)
Australia <sup>b</sup>	209	75.9	234	75.9	60	21.6	67	21.8	7	2.4	7	2.3	275	308
Austria	35	56.2	38	57.7	14	22.4	16	23.9	13	20.5	12	17.6	62	66
Canada	275	59.6	306	58.9	147	31.9	174	33.5	32	6.9	38	7.3	461	519
Denmark	41	77.8	51	78.7	10	20.0	12	18.8	1	1.9	2	2.4	52	64
France	241	61.8	241	59.8	123	31.5	138	34.3	21	5.4	18	4.4	391	402
Germany	824	81.3	694	77.6	162	16.0	175	19.6	28	2.7	25	2.8	1,014	894
Greece <sup>b</sup>	62	72.7	66	72.1	15	17.8	17	18.8	8	9.1	8	8.8	85	92
Ireland <sup>b</sup>	24	78.6	26	76.1	5	15.9	7	18.8	2	5.3	2	5.0	31	35
Italy <sup>b</sup>	307	70.9	303	69.1	96	22.1	110	25.1	28	6.4	23	5.2	433	438
Japan	846	75.2	899	73.1	207	18.4	251	20.4	59	5.2	60	4.8	1,125	1,231
Netherlands <sup>b</sup>	129	80.2	149	80.3	29	17.7	33	18.1	2	1.2	2	0.9	161	185
New Zealand	14	56.3	16	51.9	9	34.2	11	37.1	2	9.5	1	2.3	25	30
Norway	15	41.5	18	43.9	14	39.2	15	36.9	7	18.9	8	18.7	35	41
Poland	342	89.9	324	89.7	29	7.6	27	7.4	9	2.4	11	2.9	381	362
Portugal	29	62.3	30	59.6	14	29.8	17	33.1	3	7.3	3	6.7	47	51
Russian Federation <sup>b</sup>	2,326	98.0	1,619	97.5	–	0.0	–	0.0	46	2.0	24	1.4	2,372	1,660
Spain <sup>b</sup>	150	66.1	166	66.9	58	25.7	64	25.9	18	7.8	17	7.0	226	248
Sweden	33	59.0	33	58.8	19	33.6	20	34.6	4	6.8	4	6.6	55	56
Switzerland	26	57.1	24	56.5	15	32.5	15	35.2	3	7.5	2	5.1	45	43
United Kingdom	453	77.6	405	74.9	116	19.9	124	22.9	14	2.4	12	2.2	583	541
United States	3,390	68.6	3,756	68.8	1,499	30.3	1,635	30.0	55	1.1	65	1.2	4,943	5,456

**Source:**

United Nations Framework Convention on Climate Change, Greenhouse Gas Inventory Database, [www.unfccc.de/resource](http://www.unfccc.de/resource), April 2000.

(Additional resources: [www.unfccc.de](http://www.unfccc.de))

<sup>a</sup>National totals excluding land-use change and forestry.

<sup>b</sup>1997 data were not available. Australia, Greece, Ireland, and the Netherlands data are 1996; Italy and Spain data are 1995; and Russian Federation data are 1994.

**Table 3.4**  
**Estimated U.S. Emissions of Greenhouse Gases, 1990–98**

Greenhouse gas	Unit of measure <sup>a</sup>	1990	1991	1992	1993	1994	1995	1996	1997	1998
Carbon dioxide	million metric tons of gas	4,939.0	4,886.0	4,972.9	5,109.5	5,169.7	5,220.5	5,395.6	5,464.9	5,483.4
	million metric tons of carbon	1,347.0	1,333.0	1,356.0	1,389.0	1,410.0	1,424.0	1,472.0	1,490.0	1,495.0
Methane	million metric tons of gas	30.2	30.5	30.6	29.9	30.0	30.2	29.3	29.3	28.8
	million metric tons of carbon	173.0	174.0	175.0	171.0	172.0	173.0	168.0	168.0	165.0
Nitrous oxide	million metric tons of gas	1.2	1.2	1.2	1.2	1.3	1.3	1.2	1.2	1.2
	million metric tons of carbon	99.0	101.0	103.0	103.0	111.0	106.0	105.0	104.0	103.0
Carbon monoxide	million metric tons of gas	86.8	88.6	85.5	85.6	89.5	80.7	82.3	79.2	<sup>b</sup>
Nitrogen oxide	million metric tons of gas	21.2	21.3	21.6	21.8	22.1	21.5	21.3	21.4	<sup>c</sup>
Nonmethane VOCs <sup>c</sup>	million metric tons of gas	18.9	19.0	18.6	18.8	19.4	18.6	17.4	17.3	<sup>c</sup>
CFC-11,12,113 <sup>d</sup>	million metric tons of gas	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.0	0.0
HCFC-22 <sup>d</sup>	million metric tons of gas	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
HCFC-23 and PFCs <sup>d</sup>	million metric tons of carbon	22.0	22.0	23.0	24.0	26.0	32.0	36.0	38.0	40.0

**Source:**

U.S. Department of Energy, Energy Information Administration, *Emissions of Greenhouse Gases in the United States, 1998*, Washington, DC, October 1999, p. ix, x. (Additional resources: [www.eia.doe.gov](http://www.eia.doe.gov))

Criteria pollutants (CO, NO<sub>x</sub>, VOC) – U.S. Environmental Protection Agency, *National Air Pollutant Emission Trends, 1900-1997*, 1998, pp. A-6, A-11, A-18. (Additional resources: [www.epa.gov/oar/oaqps](http://www.epa.gov/oar/oaqps))

<sup>a</sup>Gases that contain carbon can be measured either in terms of the full molecular weight of the gas or just in terms of their carbon content. See Appendix B, Table B.5 for details.

<sup>b</sup>Data are not available.

<sup>c</sup>VOC=volatile organic compounds. CFC=chlorofluorocarbons. HCFC=hydrochlorofluorocarbons. HFC=hydrofluorocarbons. PFC=perfluorocarbons.

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 content. The ratio of the weight of carbon to carbon dioxide is 0.2727.

**Table 3.5**  
**U.S. Carbon Dioxide Emissions from Fossil Energy Consumption**  
**by End-Use Sector, 1984–98<sup>a</sup>**  
**(million metric tons of carbon)**

End use	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
<b>Energy consumption sectors</b>															
Residential	241.1	245.8	244.0	251.0	264.8	267.5	253.1	257.1	255.9	271.7	268.3	270.3	285.9	284.8	284.5
Commercial	188.8	189.6	190.4	197.2	207.6	210.1	206.7	206.4	205.4	211.3	213.8	217.9	226.0	238.0	238.4
Industrial	434.4	424.1	409.0	422.7	444.1	450.4	453.7	442.2	459.8	458.9	467.1	466.0	480.0	483.7	477.7
Transportation	379.0	384.4	399.1	411.1	427.5	432.7	432.8	424.3	431.1	436.4	449.1	457.6	468.7	473.4	484.9
Percentage	30.5%	30.9%	32.1%	32.1%	31.8%	31.8%	32.2%	31.9%	31.9%	31.7%	32.1%	32.4%	32.1%	32.0%	32.6%
<b>Total energy</b>	<b>1,243.3</b>	<b>1,243.9</b>	<b>1,242.5</b>	<b>1,282.0</b>	<b>1,344.0</b>	<b>1,360.9</b>	<b>1,345.2</b>	<b>1,330.0</b>	<b>1,351.3</b>	<b>1,378.2</b>	<b>1,398.3</b>	<b>1,411.7</b>	<b>1,460.5</b>	<b>1,478.0</b>	<b>1,485.4</b>
<b>Electric utility sector</b>															
Electric utility <sup>b</sup>	427.9	438.9	435.4	452.6	475.9	484.0	476.7	473.3	472.8	490.5	494.0	495.2	513.0	532.8	549.8

**Source:**

U.S. Department of Energy, Energy Information Administration, *Emissions of Greenhouse Gases in the United States, 1998*, Washington, DC, October 1999, p. 22, and annual. (Additional resources: [www.eia.doe.gov](http://www.eia.doe.gov))

<sup>a</sup>Includes energy from petroleum, coal, and natural gas. Electric utility emissions are distributed across consumption sectors.

<sup>b</sup>Does not include estimates of carbon dioxide emissions from the use of flue gas desulfurization.

**Table 3.6**  
**U.S. Carbon Dioxide Emissions from Energy Use in the Transportation Sector, 1980–98**  
**(million metric tons of carbon)**

Fuel	1980		1985		1990		1995		1998	
	Emissions	Percentage								
<b>Petroleum</b>										
Motor gasoline	238.1	62.9%	245.1	63.8%	260.9	60.4%	279.9	61.1%	294.6	60.8%
LPG <sup>a</sup>	0.3	0.1%	0.5	0.1%	0.4	0.1%	0.3	0.1%	0.2	0.0%
Jet fuel	42.0	11.1%	48.0	12.5%	60.1	13.9%	60.0	13.1%	64.2	13.2%
Distillate fuel	55.3	14.6%	63.3	16.5%	75.7	17.5%	85.1	18.6%	96.9	20.0%
Residual fuel	30.0	7.9%	16.7	4.3%	21.9	5.1%	19.7	4.3%	14.9	3.1%
Lubricants	1.8	0.5%	1.6	0.4%	1.8	0.4%	1.7	0.4%	1.8	0.4%
Aviation gas	1.2	0.3%	0.9	0.2%	0.8	0.2%	0.7	0.2%	0.7	0.2%
<b>Total</b>	<b>368.7</b>	<b>97.4%</b>	<b>376.1</b>	<b>97.8%</b>	<b>421.5</b>	<b>97.5%</b>	<b>447.4</b>	<b>97.6%</b>	<b>473.4</b>	<b>97.6%</b>
<b>Other energy</b>										
Natural gas	9.4	2.5%	7.5	2.0%	9.8	2.3%	10.4	2.3%	10.8	2.2%
Electricity	0.3	0.1%	0.7	0.2%	0.7	0.2%	0.6	0.1%	0.7	0.1%
<b>Total</b>	<b>378.4</b>	<b>100.0%</b>	<b>384.4</b>	<b>100.0%</b>	<b>432.1</b>	<b>100.0%</b>	<b>458.5</b>	<b>100.0%</b>	<b>484.9</b>	<b>100.0%</b>

**Source:**

U.S. Department of Energy, Energy Information Administration, *Emissions of Greenhouse Gases in the United States, 1998*, Washington, DC, October 1999, p. 24, and annual. (Additional resources: [www.eia.doe.gov](http://www.eia.doe.gov))

<sup>a</sup>Liquified petroleum gas.

*Global Warming Potentials (GWP) were developed to allow comparison of each greenhouse gas' ability 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, which are shown below. Most analysts use the 100-year time horizon.*

**Table 3.7**  
**Numerical Estimates of Global Warming Potentials Compared With Carbon Dioxide**  
**(kilogram of gas per kilogram of carbon dioxide)**

Gas	Lifetime (years)	Direct effect for time horizons of		
		20 years	100 years	500 years
Carbon Dioxide	Variable	1	1	1
Methane	12 ± 3	56	21	7
Nitrous Oxide	120	280	310	170
HFCs, PFCs, and other gases				
HFC-23	264	9,200	12,100	9,900
HFC-125	33	4,800	3,200	11
HFC-134a	15	3,300	1,300	420
HFC-152a	2	460	140	42
HFC-227ea	37	4,300	2,900	950
Perfluoromethane	50,000	4,400	6,500	10,000
Perfluoroethane	10,000	6,200	9,200	14,000
Sulfur hexafluoride	3,200	16,300	23,900	34,900

**Source:**

U.S. Department of Energy, Energy Information Administration, *Emissions of Greenhouse Gases in the United States 1998*, Washington, DC, October 1999, p. 8. Original source: Intergovernmental Panel on Climate Change. (Additional resources: [www.eia.doe.gov](http://www.eia.doe.gov), [www.ipcc.ch](http://www.ipcc.ch))

**Note:**

The typical uncertainty for global warming potentials is estimated by the Intergovernmental Panel on Climate Change at ± 35 percent.

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

The energy in greenhouse gas estimates of the most recent version (Version 1.5a) of the GREET model are displayed in the next two tables. The model estimates the full fuel-cycle emissions and energy use associated with various transportation fuels and advanced transportation technologies for light-duty vehicles. It calculates fuel-cycle emissions of **three greenhouse gases** (carbon dioxide, methane, and nitrous oxide) and five criteria pollutants (volatile organic compounds, carbon monoxide, nitrogen oxides, sulfur oxides, and particulate matter measuring 10 microns or less). **See Chapter 4 for the criteria pollutant data from GREET.** The model also calculates the total fuel-cycle energy consumption, fossil fuel consumption, and petroleum consumption using various transportation fuels. The fuel cycles that are included in the GREET model are:

- petroleum to conventional gasoline, reformulated gasoline, conventional diesel, reformulated diesel, liquefied petroleum gas, and electricity via residual oil;
- natural gas to compressed natural gas, liquefied natural gas, liquefied petroleum gas, methanol, Fischer-Tropsch diesel, dimethyl ether, hydrogen, and electricity;
- coal to electricity;
- uranium to electricity;
- renewable energy (hydropower, solar energy, and wind) to electricity;
- corn, woody biomass, and herbaceous biomass to ethanol;
- soybeans to biodiesel; and
- landfill gases to methanol.

*Near-term* technologies are ones which may be applied to 2000 model-year cars and *Long-term* technologies are ones which may be applied to 2010 model-year cars.

For additional information about the GREET model, see *GREET 1.5 – Transportation Fuel-Cycle Model, Volume 1: Methodology, Development, Use and Results*, ANL/ESD-39, Vol. 1, August 1999, or contact:

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<p>GREET Web Site: <a href="http://www.transportation.anl.gov/ttrdc/greet/">http://www.transportation.anl.gov/ttrdc/greet/</a></p>
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### Acronyms Used on Tables 3.8 and 3.9

#### Emissions acronyms

CO <sub>2</sub>	carbon dioxide
GHGs	greenhouse gases

#### Geographical acronyms

CA	California
NE	northeast
US	United States

#### Technologies acronyms

BD20	mixture of 20% biodiesel and 80% conventional diesel (by volume)
CARFG2	California Phase 2 reformulated gasoline
CD	conventional diesel
CIDI	compression ignition, direct injection
CNG	compressed natural gas
CNGV	compressed natural gas vehicle
Dedi.	dedicated
DME	dimethyl ether
E10	mixture of 10% ethanol and 90% gasoline (by volume)
E85	mixture of 85% ethanol and 15% gasoline (by volume)
E90	mixture of 90% ethanol and 10% gasoline (by volume)
ETBE	ethyl tertiary butyl ether
EtOH	ethanol
EtOHV	ethanol vehicle
EV	electric vehicle
FCV	fuel-cell vehicle
FFV	flexible fuel vehicle
FRFG2	Federal Phase 2 reformulated gasoline
FG	flared gas
FT50	mixture of 50% Fischer-Tropsch diesel and 50% conventional diesel (by volume)
FT100	100% Fischer-Tropsch diesel
GC	grid-connected
GI	grid-independent
GHGs	greenhouse gases
GV	gasoline vehicle
H <sub>2</sub>	hydrogen
HB	herbaceous biomass
HEV	hybrid electric vehicle
LFG	land-fill gas
LNG	liquefied natural gas
LNGV	liquefied natural gas vehicle
LPG	liquefied petroleum gas
LPGV	liquefied petroleum gas vehicle
M85	mixture of 85% methanol and 15% gasoline by volume
M90	mixture of 90% methanol and 10% gasoline by volume
MeOH	methanol
MeOHV	methanol vehicle
MTBE	methyl tertiary butyl ether
NG	natural gas
RFD	reformulated diesel
SI	spark ignition
SIDI	spark-ignition, direct-injection
WB	woody biomass

**Table 3.8**  
**NEAR-TERM Technology (for MY 2000 vehicles)**

**Fuel-Cycle Energy and Greenhouse Gas Emission Changes of Alternative Transportation Fuels and Advanced Vehicle Technologies**

(percentage relative to conventional gasoline vehicles fueled with conventional gasoline)

	<b>GV: FRFG2, MTBE</b>	<b>GV: FRFG2, EtOH</b>	<b>CIDI: CD</b>	<b>Bi-Fuel CNGV on CNG</b>	<b>Dedi. CNGV</b>	<b>Dedi. LPGV: NG</b>	<b>Dedi. LPGV: Crude</b>	<b>M85 FFV: NG</b>	<b>E85 FFV: Corn</b>
<b>Total Emissions:</b>									
<b>Total Energy</b>	0.0%	0.4%	-29.7%	8.6%	5.1%	-9.6%	-8.6%	15.3%	17.8%
<b>Fossil fuels</b>	0.0%	-3.5%	-29.6%	6.9%	3.4%	-9.2%	-8.6%	16.0%	-41.9%
<b>Petroleum</b>	-11.0%	-3.6%	-26.7%	-99.3%	-99.4%	-98.2%	-3.4%	-72.6%	-74.3%
<b>CO2</b>	1.8%	-5.0%	-23.5%	-9.9%	-12.8%	-11.6%	-9.8%	-1.9%	-36.3%
<b>GHGs</b>	2.2%	-4.2%	-24.3%	-4.1%	-6.7%	-11.0%	-9.6%	-1.7%	-25.8%

	<b>E10 GV: Corn</b>	<b>EV: US Mix</b>	<b>EV: NE US Mix</b>	<b>EV: CA Mix</b>	<b>GC SIDI HEV: CARFG2, EtOH, CA Mix</b>	<b>GI SIDI HEV: FRFG2, MTBE</b>	<b>GI SIDI HEV: FRFG2, EtOH</b>	<b>GI CIDI HEV: CD</b>
<b>Total Emissions:</b>								
<b>Total Energy</b>	2.0%	-13.7%	-14.2%	-17.0%	-35.8%	-47.4%	-47.2%	-52.5%
<b>Fossil fuels</b>	-3.4%	-39.1%	-46.4%	-69.0%	-52.6%	-47.4%	-49.2%	-52.5%
<b>Petroleum</b>	-6.3%	-98.2%	-96.8%	-99.6%	-61.7%	-53.2%	-49.3%	-50.6%
<b>CO2</b>	-2.9%	-25.5%	-41.5%	-70.3%	-54.0%	-46.5%	-50.0%	-48.4%
<b>GHGs</b>	-1.9%	-26.7%	-41.9%	-70.1%	-53.1%	-45.2%	-48.6%	-48.5%

**Source:**

Wang, Michael Q., GREET 1.5a Model Results, Argonne National Laboratory, Argonne, IL, April 2000.

**Note:** See page preceding Table 3.8 for acronym definitions.

**Table 3.9**  
***LONG-TERM Technology (for MY 2010 vehicles)***  
**Fuel-Cycle Energy and Greenhouse Gas Emission Changes of Alternative Transportation Fuels and Advanced Vehicle Technologies**  
 (percentage relative to gasoline vehicles fueled with reformulated gasoline)

	Dedi. CNGV	Dedi. LNGV: NG	Dedi. LNGV: FG	Dedi. LPGV: NG	Dedi. LPGV: Crude	Dedi. MeOHV: M90, NG	Dedi. MeOHV: M90, FG	Dedi. EtOHV: E90, Corn	Dedi. EtOHV: E90, WB
<b>Total Emissions:</b>									
<b>Total Energy</b>	-8.5%	-5.7%	-89.8%	-17.8%	-16.9%	10.5%	-77.5%	10.1%	90.7%
<b>Fossil fuels</b>	-9.4%	-5.2%	-90.0%	-17.5%	-16.9%	11.1%	-77.7%	-52.0%	-88.7%
<b>Petroleum</b>	-99.4%	-97.8%	-95.9%	-98.2%	-1.3%	-78.1%	-78.1%	-80.1%	-76.1%
<b>CO2</b>	-25.0%	-24.5%	-93.3%	-21.0%	-19.5%	-8.1%	-77.1%	-49.8%	-122.8%
<b>GHGs</b>	-22.0%	-21.5%	-90.0%	-20.7%	-19.4%	-8.2%	-75.5%	-40.3%	-115.4%

  

	Dedi. EtOHV: E90, HB	SIDI: FRFG2, EtOH	Dedi. MeOH SIDI: M90, NG	Dedi. MeOH SIDI: M90, FG	Dedi. EtOH SIDI: E90, Corn	Dedi. EtOH SIDI: E90, WB	Dedi. EtOH SIDI: E90, HB	GI SIDI HEV: FRFG2, EtOH	GI SI HEV: CNG
<b>Total Emissions:</b>									
<b>Total Energy</b>	77.6%	-20.0%	-5.2%	-82.7%	-3.1%	67.8%	56.3%	-47.4%	-43.5%
<b>Fossil fuels</b>	-80.5%	-20.0%	-4.7%	-135.5%	-57.8%	-90.1%	-82.8%	-47.4%	-44.0%
<b>Petroleum</b>	-78.5%	-20.0%	-82.1%	-82.1%	-82.5%	-78.9%	-81.1%	-47.4%	-99.6%
<b>CO2</b>	-94.9%	-20.0%	-21.4%	-82.1%	-55.8%	-120.1%	-95.5%	-47.4%	-53.7%
<b>GHGs</b>	-80.7%	-19.5%	-21.2%	-80.5%	-47.2%	-113.3%	-82.8%	-46.3%	-51.0%

Table continued on next page. See page preceding Table 3.8 for acronym definitions.

Table 3.9 (continued)  
***LONG-TERM Technology (for MY 2010 vehicles)***  
**Fuel-Cycle Energy and Greenhouse Gas Emission Changes of Alternative Transportation Fuels and Advanced Vehicle Technologies**  
 (percentage relative to gasoline vehicles fueled with reformulated gasoline)

	GI SI HEV: LNG, NG	GI SI HEV: LNG, FG	GI SI HEV: LPG, NG	GI SI HEV: LPG, Crude	GI SIDI HEV: M90, NG	GI SIDI HEV: M90, FG	GI SIDI HEV: E90, Corn	GI SIDI HEV: E90, WB	GI SIDI HEV: E90, HB
<b>Total Emissions:</b>									
Total Energy	-41.8%	-93.7%	-46.8%	-46.2%	-54.0%	-54.1%	-36.3%	10.4%	2.8%
Fossil fuels	-41.4%	-93.8%	-46.6%	-46.3%	-35.7%	-121.7%	-72.2%	-93.5%	-88.7%
Petroleum	-98.7%	-97.5%	-98.8%	-36.1%	-87.3%	-87.3%	-88.5%	-86.1%	-87.5%
CO2	-53.4%	-95.9%	-48.9%	-47.9%	-46.8%	-86.8%	-71.0%	-113.3%	-97.1%
GHGs	-50.7%	-93.0%	-47.9%	-47.1%	-46.0%	-85.0%	-64.5%	-107.9%	-87.9%

  

	GC SIDI HEV: RFG2, EtOH, US Mix	GC SIDI HEV: RFG2, EtOH, NE US Mix	GC SIDI HEV: RFG2, EtOH, CA Mix	GC SI HEV: CNG, US Mix	GC SI HEV: CNG, NE US Mix	GC SI HEV: CNG, CA Mix	GC SI HEV: LNG, NG, US Mix	GC SI HEV: LNG, FG, US Mix	GC SI HEV: LNG, NG, NE US Mix
<b>Total Emissions:</b>									
Total Energy	-43.9%	-44.4%	-44.1%	-40.9%	-41.5%	-41.2%	-39.7%	-77.2%	-40.2%
Fossil fuels	-47.5%	-48.8%	-55.3%	-45.9%	-47.3%	-54.0%	-44.0%	-81.8%	-45.2%
Petroleum	-61.4%	-61.3%	-61.7%	-99.3%	-99.2%	-99.7%	-98.7%	-97.8%	-98.5%
CO2	-44.5%	-48.1%	-55.6%	-50.2%	-53.9%	-61.6%	-50.0%	-80.7%	-53.2%
GHGs	-44.1%	-47.5%	-54.9%	-48.6%	-52.0%	-59.6%	-48.4%	-78.9%	-51.3%

Table continued on next page. See page preceding Table 3.8 for acronym definitions.

**Table 3.9 (continued)**  
**LONG-TERM Technology (for MY 2010 vehicles)**  
**Fuel-Cycle Energy and Greenhouse Gas Emission Changes of Alternative Transportation Fuels and Advanced Vehicle Technologies**  
 (percentage relative to gasoline vehicles fueled with reformulated gasoline)

	GC SI HEV: LNG, FG, NE US Mix	GC SI HEV: LNG, NG, CA Mix	GC SI HEV: LNG, FG, CA Mix	GC SI HEV: LPG, NG, US. Mix	GC SI HEV: LPG, Crude, U.S. Mix	GC SI HEV: LPG, NG, NE US Mix	GC SI HEV: LPG, Crude, NE US Mix	GC SI HEV: LPG, NG, CA Mix	GC SI HEV: LPG, Crude, CA Mix
<b>Total Emissions:</b>									
Total Energy	-77.7%	-40.0%	-77.4%	-43.3%	-42.9%	-43.9%	-43.5%	-43.6%	-43.2%
Fossil fuels	-83.1%	-51.0%	-89.4%	-47.7%	-47.5%	-49.0%	-48.8%	-55.0%	-55.0%
Petroleum	-97.6%	-98.9%	-98.1%	-98.8%	-53.6%	-98.6%	-53.4%	-99.1%	-53.8%
CO2	-84.0%	-59.9%	-91.2%	-46.7%	-46.0%	-50.0%	-49.3%	-56.8%	-56.3%
GHGs	-82.1%	-57.9%	-89.1%	-46.4%	-45.8%	-49.4%	-48.9%	-56.1%	-55.8%

  

	GC SIDI HEV: M90, NG, US Mix	GC SIDI HEV: M90, FG, US Mix	GC SIDI HEV: M90, NG, NE US Mix	GC SIDI HEV: M90, FG, NE US Mix	GC SIDI HEV: M90, NG, CA Mix	GC SIDI HEV: M90, FG, CA Mix	GC SIDI HEV: E90, Corn, US Mix	GC SIDI HEV: E90, WB, US Mix	GC SIDI HEV: E90, HB, US Mix
<b>Total Emissions:</b>									
Total Energy	-35.7%	-72.3%	-36.2%	-72.9%	-35.9%	-72.6%	-35.9%	-2.3%	-7.8%
Fossil fuels	-40.0%	-101.8%	-41.2%	-103.2%	-47.1%	-109.7%	-66.2%	-81.5%	-78.1%
Petroleum	-90.5%	-90.5%	-90.3%	-90.3%	-90.8%	-90.8%	-91.3%	-89.7%	-90.7%
CO2	-45.3%	-74.1%	-48.5%	-77.4%	-55.2%	-84.5%	-62.7%	-93.1%	-81.5%
GHGs	-45.1%	-73.1%	-48.1%	-76.3%	-54.6%	-83.2%	-58.4%	-89.6%	-75.2%

Table continued on next page. See page preceding Table 3.8 for acronym definitions.

Table 3.9 (continued)  
***LONG-TERM Technology (for MY 2010 vehicles)***  
**Fuel-Cycle Energy and Greenhouse Gas Emission Changes of Alternative Transportation Fuels and Advanced Vehicle Technologies**  
 (percentage relative to gasoline vehicles fueled with reformulated gasoline)

	GC SIDI HEV: E90, Corn, NE US Mix	GC SIDI HEV: E90, WB, NE US Mix	GC SIDI HEV: E90, HB, NE US Mix	GC SIDI HEV: E90, Corn, CA Mix	GC SIDI HEV: E90, WB, CA Mix	GC SIDI HEV: E90, HB, CA Mix	CIDI: RFD	CIDI: DME, NG	CIDI: DME, FG
<b>Total Emissions:</b>									
Total Energy	-36.4%	-2.6%	-8.2%	-36.1%	-2.5%	-8.0%	-35.1%	-17.1%	-94.8%
Fossil fuels	-67.5%	-82.4%	-79.2%	-73.7%	-86.6%	-84.6%	-35.1%	-16.6%	-148.4%
Petroleum	-91.2%	-89.5%	-90.5%	-91.6%	-89.8%	-90.9%	-25.0%	-97.9%	-97.9%
CO2	-66.0%	-95.4%	-84.4%	-73.0%	-100.4%	-90.6%	-30.7%	-33.5%	-94.5%
GHGs	-61.5%	-91.8%	-77.9%	-68.3%	-96.6%	-83.9%	-31.6%	-34.3%	-93.4%
	CIDI: FT100, NG	CIDI: FT100, FG	CIDI: BD20	GI CIDI HEV: RFD	GI CIDI HEV: DME, NG	GI CIDI HEV: DME, FG	GI CIDI HEV: FT100, NG	GI CIDI HEV: FT100, FG	GI CIDI HEV: BD20
<b>Total Emissions:</b>									
Total Energy	4.0%	-92.0%	-31.5%	-57.7%	-45.9%	-96.6%	-32.2%	-94.8%	-55.3%
Fossil fuels	4.7%	-145.6%	-31.7%	-57.7%	-45.6%	-131.6%	-31.7%	-129.8%	-55.5%
Petroleum	-97.5%	-97.5%	-36.7%	-51.1%	-98.6%	-98.6%	-98.4%	-98.4%	-58.7%
CO2	-20.9%	-87.7%	-38.9%	-54.8%	-56.7%	-96.5%	-48.4%	-92.0%	-60.2%
GHGs	-22.3%	-87.3%	-39.3%	-55.0%	-56.7%	-95.3%	-48.9%	-91.3%	-60.0%

Table continued on next page. See page preceding Table 3.8 for acronym definitions.

Table 3.9 (continued)  
***LONG-TERM Technology (for MY 2010 vehicles)***  
**Fuel-Cycle Energy and Greenhouse Gas Emission Changes of Alternative Transportation Fuels and Advanced Vehicle Technologies**  
 (percentage relative to gasoline vehicles fueled with reformulated gasoline)

	GC CIDI HEV: RFD, US Mix	GC CIDI HEV: RFD, NE US Mix	GC CIDI HEV: RFD, CA Mix	GC CIDI HEV: DME, NG, US Mix	GC CIDI HEV: DME, FG, US Mix	GC CIDI HEV: DME, NG, NE US Mix	GC CIDI HEV: DME, FG, NE US Mix	GC CIDI HEV: DME, NG, CA Mix	GC CIDI HEV: DME, FG, CA Mix
<b>Total Emissions:</b>									
Total Energy	-50.7%	-51.3%	-51.0%	-42.1%	-79.2%	-42.7%	-79.8%	-42.4%	-79.5%
Fossil fuels	-55.2%	-56.6%	-62.7%	-46.4%	-109.3%	-47.7%	-110.7%	-53.5%	-117.3%
Petroleum	-63.8%	-63.6%	-64.1%	-98.6%	-98.6%	-98.5%	-98.5%	-98.9%	-98.9%
CO2	-50.5%	-53.8%	-60.7%	-51.9%	-81.0%	-55.0%	-84.3%	-61.7%	-91.4%
GHGs	-51.0%	-54.1%	-60.9%	-52.3%	-80.5%	-55.2%	-83.7%	-61.8%	-90.6%
	GC CIDI HEV: FT100, NG, US Mix	GC CIDI HEV: FT100, FG, US Mix	GC CIDI HEV: FT100, NG, NE US Mix	GC CIDI HEV: FT100, FG, NE US Mix	GC CIDI HEV: FT100, NG, CA Mix	GC CIDI HEV: FT100, FG, CA Mix	GC CIDI HEV: BD20, US Mix	GC CIDI HEV: BD20, NE US Mix	GC CIDI HEV: BD20, CA Mix
<b>Total Emissions:</b>									
Total Energy	-32.1%	-77.9%	-32.6%	-78.5%	-32.3%	-78.2%	-49.0%	-49.6%	-49.3%
Fossil fuels	-36.2%	-108.0%	-37.5%	-109.4%	-43.2%	-115.9%	-53.6%	-55.0%	-61.3%
Petroleum	-98.4%	-98.4%	-98.2%	-98.3%	-98.7%	-98.7%	-69.4%	-69.2%	-69.7%
CO2	-45.8%	-77.7%	-48.9%	-81.0%	-55.5%	-88.1%	-54.4%	-57.8%	-65.0%
GHGs	-46.6%	-77.6%	-49.5%	-80.7%	-56.0%	-87.6%	-54.7%	-57.9%	-64.9%

Table continued on next page. See page preceding Table 3.8 for acronym definitions.

Table 3.9 (continued)  
***LONG-TERM Technology (for MY 2010 vehicles)***  
**Fuel-Cycle Energy and Greenhouse Gas Emission Changes of Alternative Transportation Fuels and Advanced Vehicle Technologies**  
 (percentage relative to gasoline vehicles fueled with reformulated gasoline)

	Electric Vehicle, US Mix	Electric Vehicle, NE US Mix	Electric Vehicle, CA Mix	FCV: Gaseous H <sub>2</sub> , NG, Central	FCV: Gaseous H <sub>2</sub> , NG, Refueling Station	FCV: Gaseous H <sub>2</sub> , Solar	FCV: Liquid H <sub>2</sub> , NG	FCV: Liquid H <sub>2</sub> , FG	FCV: Liquid H <sub>2</sub> , Solar
<b>Total Emissions:</b>									
Total Energy	-39.0%	-40.9%	-39.9%	-53.8%	-48.3%	-62.6%	-38.9%	-86.9%	-71.9%
Fossil fuels	-54.0%	-58.4%	-79.0%	-55.8%	-49.8%	-91.4%	-39.4%	-87.1%	-71.7%
Petroleum	-98.7%	-98.2%	-99.6%	-99.6%	-96.5%	-99.8%	-99.1%	-99.2%	-98.5%
CO <sub>2</sub>	-45.3%	-56.3%	-79.7%	-62.3%	-58.3%	-90.5%	-51.4%	-90.1%	-99.1%
GHGs	-46.3%	-56.7%	-79.8%	-63.0%	-58.5%	-90.6%	-52.8%	-91.1%	-99.2%
	FCV: MeOH, NG	FCV: MeOH, FG	FCV: RFG2, EtOH	FCV: RFD	EtOH FCVs: Corn	EtOH FCVs: WB	EtOH FCVs: HB	NG FCV: CNG	FCV: LNG, NG
<b>Total Emissions:</b>									
Total Energy	-45.1%	-96.4%	-50.0%	-51.4%	-37.7%	13.9%	5.5%	-51.9%	-50.5%
Fossil fuels	-44.8%	-131.4%	-50.0%	-51.3%	-77.5%	-101.0%	-95.7%	-52.4%	-50.2%
Petroleum	-98.4%	-98.4%	-50.0%	-43.7%	-96.5%	-93.9%	-95.5%	-99.7%	-98.9%
CO <sub>2</sub>	-56.0%	-96.2%	-50.0%	-48.0%	-76.1%	-122.8%	-104.9%	-60.5%	-60.3%
GHGs	-56.5%	-95.8%	-50.7%	-49.5%	-70.8%	-118.9%	-96.7%	-59.6%	-59.3%

Table continued on next page. See page preceding Table 3.8 for acronym definitions.

**Table 3.9 (continued)**  
***LONG-TERM Technology (for MY 2010 vehicles)***  
**Fuel-Cycle Energy and Greenhouse Gas Emission Changes of Alternative Transportation Fuels and Advanced Vehicle Technologies**  
**(percentage relative to gasoline vehicles fueled with reformulated gasoline)**

	FCV: LNG, FG	FCV: LPG, NG	FCV: LPG, Crude
<b>Total Emissions:</b>			
<b>Total Energy</b>	<b>-94.7%</b>	<b>-54.8%</b>	<b>-54.3%</b>
<b>Fossil fuels</b>	<b>-94.7%</b>	<b>-54.6%</b>	<b>-54.3%</b>
<b>Petroleum</b>	<b>-97.9%</b>	<b>-99.0%</b>	<b>-96.9%</b>
<b>CO2</b>	<b>-96.4%</b>	<b>-56.5%</b>	<b>-55.7%</b>
<b>GHGs</b>	<b>-95.3%</b>	<b>-57.2%</b>	<b>-56.5%</b>

**Source:**

**Wang, Michael Q., GREET 1.5a Model Results, Argonne National Laboratory, Argonne, IL, April 2000.**

**Note: See page preceding Table 3.8 for acronym definitions.**