

Chapter 3 Greenhouse Gas Emissions

Summary Statistics from Tables in this Chapter

Source		1990	1996
Table 3.1	Greenhouse gas emissions (million metric tonnes)		
	<i>France</i>	557	562
	<i>Germany</i>	1,209	1,091
	<i>United Kingdom</i>	757	717
	<i>Japan</i>	1,222	1,352 ^a
	<i>United States</i>	5,999	6,557
Table 3.6	Transportation share of U.S. carbon dioxide emissions from fossil fuel consumption		
	<i>1984</i>		30.5%
	<i>1990</i>		32.1%
	<i>1997</i>		31.2%
Table 3.7	Carbon dioxide emissions from U.S. transportation energy use, 1997		
	<i>Motor gasoline</i>		61.0%
	<i>Liquified petroleum gas</i>		0.1%
	<i>Jet fuel</i>		13.4%
	<i>Distillate fuel</i>		19.4%
	<i>Residual fuel</i>		3.4%
	<i>Lubricants</i>		0.4%
	<i>Aviation gas</i>		0.1%
	<i>Natural gas</i>		2.2%
	<i>Electricity</i>		0.1%

^a1995 data are the latest available.



Table 3.1
International Man-Made Emissions of All Greenhouse Gases, 1990-96*
(CO₂ equivalent)

	1990 (million metric tonnes)	1991	1992	1993	1994	1995	1996
		(percentage relative to 1990, 1990=100)					
Australia	415.66	100	101	101	102	105	107
Austria ^b	77.27	106	98	97	97	102	104
Belgium ^b	138.94	103	101	100	104	104	109
Canada	598.10	99	101	103	106	109	112
Czech Republic ^{bc}	192.13	92	85	82	78	79	80
Denmark ^{bc}	71.66	115	108	110	115	110	129
France	557.04	104	102	97	97	98	101
Germany	1,209.11	96	92	91	90	89	90
Greece	105.24	100	101	102	104	107	109
Ireland ^{bd}	56.86	99	100	100	103	104	105
Japan	1,221.71	102	104	103	109	111	^e
Latvia ^{bc}	35.67	82	72	62	54	54	51
Monaco ^b	0.11	116	123	125	128	125	131
Netherlands	217.11	103	102	103	104	108	112
New Zealand	72.42	100	101	101	100	100	103
Norway	55.06	96	93	97	101	102	107
Slovakia ^{''}	72.50	88	81	77	72	75	76
Sweden ^{bc}	65.10	99	101	101	104	103	112
Switzerland&	53.75	103	101	98	97	98	99
United Kingdom	757.85	100	97	94	93	92	95
United States	5,999.12	99 [']	101	103	105	106	109

Source:

United Nations Framework Convention on Climate Change, FCCC/CP/1998/INF.9, October 1998.

(Additional resources: <http://www.unfccc.de>)

^aExcluding land-use change and forestry.

^bAs estimates for HFCs, PFCs and SF₆ were not provided, or not provided for all years, estimates given here are for CO₂, CH₄ and N₂O only.

^cAs estimates for 1990-1995 were not provided in the inventory submission, data from the second national communication are used in this table.

^dAs estimates for 1990-1994 were not provided in the inventory submission, data from the second national communication are used in this table.

^eData are not available.



Table 3.2
International Man-Made Emissions of Carbon Dioxide, 1990-96^a

	1990 (million metric tonnes)	1991	1992	1993	1994	1995	1996
		(percentage relative to 1990, 1990=100)					
Australia	275.34	101	102	103	104	108	112
Austria	62.10	108	98	96	97	102	105
Belgium	116.09	103	102	100	104	105	111
Canada	460.90	98	101	101	103	107	110
Czech Republic ^b	165.49	93	85	81	77	78	80
Denmark ^b	52.28	120	110	114	121	114	140
France	390.7 1	107	105	99	99	101	104
Germany	1,014.16	96	91	91	89	88	90
Greece	85.35	100	102	102	104	106	108
Ireland ^c	30.72	103	105	104	108	111	113
Japan	1,124.53	102	103	102	108	109	110
Latvia ^b	24.77	78	66	58	48	49	45
Monaco	0.11	116	123	125	128	125	131
Netherlands	161.36	103	102	104	104	110	115
New Zealand	25.24	102	110	107	107	107	115
Norway	35.46	95	97	101	107	108	116
Slovakia ^b	60.03	88	81	77	72	76	77
Sweden ^b	55.45	100	101	101	106	105	114
Switzerland ^b	45.07	104	101	98	96	98	100
United Kingdom	583.17	101	98	95	95	93	97
United States	4,943.30	99	100	103	104	105	109

Source:

United Nations Framework Convention on Climate Change, FCCC/CP/1998/INF.9, October 1998.

(Additional resources: <http://www.unfccc.de>)

^aExcluding land-use change and forestry.

^bAs estimates for 1990-1995 were not provided in the inventory submission, data from the second national communication are used in this table.

^cAs estimates for 1990-1994 were not provided in the inventory submission, data from the second national communication are used in this table.



Table 3.3
International Man-Made Emissions of Carbon Dioxide by Source Category, 1990 and 1996^a

	Energy (excl transport)				Transport				Industrial processes				Total	
	1990		1996		1990		1996		1990		1996		1990	1996
	(MMT)	%	(MMT)	%	(MMT)	%	(MMT)	%	(MMT)	%	(MMT)	%	(MMT)	(MMT)
Australia	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	58.2	14	22.4	16	24.2	13	20.5	11	16.8	62	65
Belgium	86	74.0	94	72.9	20	17.2	22	17.4	9	7.9	11	8.8	116	129
Canada	275	59.6	300	59.1	147	31.9	167	32.8	32	6.9	39	7.7	461	509
Czech Republic ^b	152	91.9	120	90.3	8	4.8	10	7.5	5	3.3	2	1.9	165	133
Denmark ^b	41	77.8	60	82.0	10	20.0	12	16.0	1	1.9	1	1.9	52	73
France	241	61.8	248	61.1	123	31.5	135	33.3	21	5.4	17	4.3	391	407
Germany	824	81.3	712	78.2	162	16.0	173	19.0	28	2.7	25	2.7	1,014	910
Greece	62	72.7	66	72.1	15	17.8	17	18.8	8	9.1	8	8.8	85	92
Ireland ^b	24	78.6	26	76.1	5	15.9	7	18.8	2	5.3	2	5.0	31	35
Japan	846	75.2	904	73.2	207	18.4	249	20.1	59	5.2	61	4.9	1,125	1,235
Latvia ^b	18	74.2	9	83.7	6	23.5	2	14.6	563	2.3	185	1.7	25	11
Monaco	67	61.6	91	64.4	39	36.5	47	33.1	—	—	—	—	108	141
Netherlands	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	15	52.7	9	34.2	11	37.8	2	9.5	3	9.5	25	29
Norway	15	41.5	18	44.4	14	39.2	16	37.8	7	18.9	7	17.4	35	41
Slovakia ^b	51	85.6	39	84.5	5	8.6	4	9.0	3	5.7	3	6.5	60	46
Sweden ^b	33	59.0	40	62.9	19	33.6	20	30.9	4	6.8	4	5.9	55	63
Switzerland ^b	26	57.1	26	58.8	15	32.5	15	33.2	3	7.5	2	4.9	45	45
United Kingdom	453	77.6	429	76.2	116	19.9	122	21.6	14	2.4	12	2.1	583	563
United States	3,390	68.6	3,699	68.6	1,499	30.3	1,631	30.2	55	1.1	63	1.2	4,943	5,394

Source:

United Nations Framework Convention on Climate Change, FCC/CP/1998/INF.9, October 1998.

(Additional resources: <http://www.unfccc.de>)

^aExcluding land-use change and forestry.

^bAs estimates for 1990 were not provided in the inventory submission, data from the second national communication are used in this table.

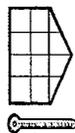


Table 3.4
International Man-Made Emissions of Nitrous Oxide, 1990-96

	1990 (million metric tonnes)	1991	1992	1993	1994	1995	1996
		(percentage relative to 1990, 1990=100)					
Australia	0.075	101	101	103	103	106	105
'Austria	0.009	103	103	105	108	109	109
Belgium	0.031	100	97	99	105	113	114
Canada	0.190	100	100	105	116	116	121
Czech Republic ^c	0.026	91	87	82	83	84	113
Denmark ^a	0.034	100	100	97	97	97	100
France	0.309	99	95	91	93	95	96
Germany	0.226	97	100	96	97	98	101
Greece	0.030	100	96	96	97	94	98
Ireland ^b	0.029	86	87	87	88	89	89
Japan	0.061	96	96	99	100	103	^c
Latvia ^c	0.023	88	85	77	75	72	72
Monaco ^d	-0						
Netherlands	0.064	103	106	106	110	113	113
New Zealand	0.037	99	99	100	101	101	101
Norway	0.018	100	83	94	94	94	100
Slovakia ^b	0.013	87	72	57	58	61	63
Sweden ^c	0.009	100	96	100	103	100	110
Switzerland ^c	0.012	101	102	103	103	103	103
United Kingdom	0.215	97	86	81	88	85	88
United States	1.136	101	103	102	110	106	108

Source:

United Nations Framework Convention on Climate Change, FCCC/CP/1998/INF.9, October 1998.

(Additional resources: <http://www.unfccc.de>)

^aAs estimates for 1990-1995 were not provided in the inventory submission, data from the second national communication are used in this table.

^bAs estimates for 1990-1994 were not provided in the inventory submission, data from the second national communication are used in this table.

^cData are not available.

^dThe trend in emissions is not shown here as estimates reported were approximately zero from 1990 to 1996.



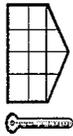


Table 3.5
Estimated U.S. Emissions of Greenhouse Gases, 1990-97

Greenhouse gas	Unit of measure ^a	1990	1991	1992	1993	1994	1995	1996	1997
Carbon dioxide	million metric tons of gas	4,971.7	4,916.3	4,988.8	5,109.8	5,183.9	5,236.4	5,422.3	5,503.0
	million metric tons of carbon	1,356.0	1,341.0	1,361.0	1,394.0	1,414.0	1,428.0	1,479.0	1,501.0
Methane	million metric tons of gas	30.2	30.4	30.4	29.7	29.9	30.0	29.1	29.1
	million metric tons of carbon (gwp) ^b	173.0	174.0	174.0	170.0	171.0	172.0	167.0	167.0
Nitrous oxide	million metric tons of gas	1.0	1.0	1.0	1.0	1.1	1.0	1.0	1.0
	million metric tons of carbon (gwp) ^b	82.0	83.0	85.0	86.0	91.0	88.0	86.0	85.0
Carbon monoxide	million metric tons of gas	87.6	89.3	86.3	86.4	90.4	81.4	80.6	^c
Nitrogen oxide	million metric tons of gas	21.6	21.5	21.9	22.2	22.5	21.7	21.3	^c
Nonmethane VOCs ^d	million metric tons of gas	19.0	19.1	18.8	19.0	19.5	18.7	17.3	^c
CFC-11,12,113 ^d	million metric tons of gas	0.2	0.2	0.2	0.1	0.1	0.1	0.1	^c
HCFC-22 ^d	million metric tons of gas	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
HCFC-23 and PFCs ^d	million metric tons of carbon (gwp) ^b	22.0	22.0	23.0	23.0	26.0	31.0	35.0	38.0

Source:

U.S. Department of Energy, Energy Information Administration, *Emissions of Greenhouse Gases in the United States, 1997*, Washington, DC, October 1998, p. ix, x. (Additional resources: <http://www.eia.doe.gov>)
 Criteria pollutants (CO, NO_x, VOC) – U.S. Environmental Protection Agency, *National Air Pollutant Emission Trends, 1900-1996, 1997*, pp. A-6, A-1 1, A-18. (Additional resources: <http://www.epa.gov/oar/oaqps>)

^aGases 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.

^bBased on global warming potential.

^cData are not available.

^dVOC=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 3.6
U.S. Carbon Dioxide Emissions from Fossil Energy Consumption
by End-Use Sector, 1984-97^a
 (million metric tons of carbon)

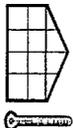
End use	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Energy consumption sectors														
Residential	241.1	245.8	244.0	251.0	264.8	267.5	253.1	257.2	256.0	271.8	268.4	270.3	285.6	286.5
Commercial	188.8	189.6	190.4	197.2	207.6	210.1	206.8	206.4	205.5	212.1	213.9	217.9	226.0	237.2
Industrial	434.4	424.1	409.0	422.7	444.1	450.4	454.1	442.7	459.2	458.8	467.4	465.0	478.3	482.9
Transportation	379.0	384.4	399.1	411.1	427.5	432.7	432.1	424.5	431.4	436.7	449.5	458.5	470.7	473.1
Percentage	30.5%	30.9%	32.1%	32.1%	31.8%	31.8%	32.1%	31.9%	31.9%	31.7%	32.1%	32.5%	32.2%	32.0%
Total energy	1,243.3	1,243.9	1,242.5	1,282.0	1,344.0	1,360.9	1,346.1	1,330.8	1,352.1	1,379.3	1,399.1	1,411.7	1,460.6	1,479.6
Electric utility sector														
Electric utility ^b	427.9	438.9	435.4	452.6	475.9	484.0	476.9	473.5	473.0	490.7	494.1	495.3	513.3	532.4

Source:

U.S. Department of Energy, Energy Information Administration, *Emissions of Greenhouse Gases in the United States, 1997*, Washington, DC, October 1998, p. 21, and annual. (Additional resources: <http://www.eia.doe.gov>)

^aIncludes energy from petroleum, coal, and natural gas. Electric utility emissions are distributed across consumption sectors.

^bDoes not include estimates of carbon dioxide emissions from the use of flue gas desulfurization.



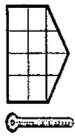


Table 3.7
U.S. Carbon Dioxide Emissions from Energy Use in the Transportation Sector, 1980-97
(million metric tons of carbon)

Fuel	1980		1985		1990		1995		1997	
	Emissions	Percentage								
Petroleum										
Motor gasoline	238.1	62.9%	245.1	63.8%	260.9	60.4%	279.9	61.1%	288.3	61.0%
LPG ^a	0.3	0.1%	0.5	0.1%	0.4	0.1%	0.3	0.1%	0.3	0.1%
Jet fuel	42.0	11.1%	48.0	12.5%	60.1	13.9%	60.0	13.1%	63.3	13.4%
Distillate fuel	55.3	14.6%	63.3	16.5%	75.7	17.5%	85.1	18.6%	91.6	19.4%
Residual fuel	30.0	7.9%	16.7	4.3%	21.9	5.1%	19.7	4.3%	15.9	3.4%
Lubricants	1.8	0.5%	1.6	0.4%	1.8	0.4%	1.7	0.4%	1.7	0.4%
Aviation gas	1.2	0.3%	0.9	0.2%	0.8	0.2%	0.7	0.2%	0.7	0.1%
Total	368.7	97.4%	376.1	97.8%	421.5	97.5%	447.4	97.6%	461.9	97.8%
Other energy										
Natural gas	9.4	2.5%	7.5	2.0%	9.8	2.3%	10.4	2.3%	10.5	2.2%
Electricity	0.3	0.1%	0.7	0.2%	0.7	0.2%	0.6	0.1%	0.7	0.1%
Total	378.4	100.0%	384.4	100.0%	432.1	100.0%	458.5	100.0%	473.1	100.0%

Source:

U.S. Department of Energy, Energy Information Administration, *Emissions of Greenhouse Gases in the United States, 1997*, Washington, DC, October 1998, p. 23, and annual. (Additional resources: <http://www.eia.doe.gov>)

^aLiquified 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 3.8
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 1997*, Washington, DC, October 1998, p. 8. Original source: Intergovernmental Panel on Climate Change. (Additional resources: <http://www.eia.doe.gov>, <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

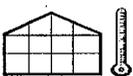
The energy in greenhouse gas estimates of the most recent version (Version 1.4) of the GREET model are displayed in the next two tables. The model estimates the full fuel-cycle emissions and energy use associated with various transportation fuels and advanced transportation technologies for light-duty 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, contact:

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Acronyms Used on Tables 3.9 and 3.10

Emissions acronyms

GHGs	greenhouse gases
CH ₄	methane
N ₂ O	nitrous oxide
c o 2	carbon dioxide

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)
ES5	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)
G C	grid-connected
GI	grid-independent
GHGs	g r e e n h o u s e g a s e s
GV	gasoline vehicle
H ₂	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
NE	northeast
NG	natural gas
RFD	reformulated diesel
SI	spark ignition
SIDI	spark-ignition, direct-injection
WB	woody biomass



Table 3.9
Near-Term Technology
Changes in Per-Mile, Fuel-Cycle Energy Use and Greenhouse Gas Emissions for Passenger Cars
(Percentage relative to conventional gasoline vehicles fueled with conventional gasoline)

	GV: FRFG2, MTBE	GV: CARFG2, ETBE	GV: CARFG2, EtOH	CIDI: CD	Bi-fuel CNGV	Dedi. CNGV	Dedi. LPGV: crude	Dedi. LPGV: NG	M85 FFV: NG
Total energy	0.0%	0.8%	0.4%	-29.7%	6.7%	3.3%	-8.6%	-9.6%	14.5%
Fossil fuels	0.0%	-3.1%	-2.6%	-29.6%	5.7%	2.3%	-8.6%	-9.3%	15.0%
Petroleum	-11.0%	-10.1%	-2.5%	-26.7%	-99.4%	-99.4%	-3.4%	-98.2%	-72.6%
CH4	18.2%	18.8%	-2.4%	-38.8%	211.0%	205.1%	-5.7%	2.8%	1.0%
N2O	0.4%	62.5%	32.4%	-42.6%	-38.4%	-19.4%	-1.8%	-1.8%	1.6%
CO2	1.2%	-0.9%	-5.1%	-25.8%	-13.9%	-16.7%	-12.6%	-14.3%	-4.7%
GHGs	1.6%	0.7%	-4.4%	-26.5%	-8.2%	-10.7%	-12.2%	-13.6%	-4.4%

	E10 GV: corn	E85 FFV: corn	E85 FFV: WB	E85 FFV: HB	EV: US mix	EV: NE mix	EV: CA mix	GC SIDI HEV: ETBE, CA mix	GC SIDI HEV: EtOH, CA mix
Total energy	2.1%	17.9%	90.4%	79.1%	-14.7%	-14.0%	-16.9%	-35.9%	-36.0%
Fossil fuels	-3.4%	-41.8%	-81.8%	-72.7%	-34.7%	-46.0%	-68.6%	-52.9%	-52.7%
Petroleum	-6.3%	-73.8%	-71.2%	-73.2%	-98.4%	-96.9%	-99.5%	-64.9%	-62.0%
CH4	-1.5%	-14.3%	-62.9%	-48.9%	-15.5%	-23.5%	-49.2%	-34.3%	-42.5%
N2O	45.4%	500.3%	187.1%	607.8%	-89.9%	-90.2%	-92.9%	-4.9%	-16.6%
CO2	-2.9%	-36.4%	-113.1%	-85.5%	-24.3%	-42.8%	-70.7%	-50.4%	-51.9%
GHGs	-2.0%	-26.3%	-106.4%	-72.2%	-25.3%	-43.1%	-70.5%	-49.1%	-51.1%

Source:

Wang, Michael Q., GREET Model Results, Argonne National Laboratory, Argonne, IL, September 1998.

Note:

See page preceding table for acronym definitions.

Table 3.10
Long-Term Technology
Changes in Per-Mile, Fuel-Cycle Energy Use and Greenhouse Gas Emissions for Passenger Cars
(Percentage relative to conventional gasoline vehicles fueled with conventional gasoline)

Long term	Dedi. CNGV	Dedi. LNGV	Dedi. LPGV: crude	Dedi. LPGV: NG	Dedi. MeOHV: M90, NG	Dedi. MeOHV: M90, FG	Dedi. MeOHV: M90, LFG	Dedi. EtOHV: E90, corn	Dedi. EtOHV: E90, WB	Dedi. EtOHV: E90, HB	SIDI: FRFG2, MTBE
Total energy	-8.6%	-5.7%	-16.8%	-17.7%	8.8%	13.8%	-1.8%	10.0%	57.7%	44.4%	-20.0%
Fossil fuels	-9.5%	-5.1%	-16.9%	-17.4%	9.4%	-45.4%	-61.0%	-50.1%	-82.2%	-78.2%	-20.0%
Petroleum	-99.4%	-96.0%	-1.3%	-98.2%	-78.1%	-78.1%	-78.7%	-81.5%	-79.3%	-81.1%	-20.0%
CH4	84.4%	84.2%	-28.9%	-22.3%	-22.2%	-27.0%	-409.0%	-19.3%	-60.9%	-54.3%	-18.0%
N2O	-48.5%	-47.7%	-2.2%	-2.2%	-0.4%	-2.7%	0.4%	307.9%	91.3%	337.6%	-0.9%
c o 2	-26.9%	-27.0%	-21.3%	-22.9%	-11.6%	-77.3%	-146.8%	-49.4%	-107.1%	-88.7%	-20.0%
GHGs	-23.8%	-23.9%	-21.2%	-22.5%	-11.7%	-74.3%	-152.2%	-39.9%	-101.1%	-77.5%	-19.6%

	SIDI: FRFG2, ETBE	SIDI: FRFG2 EtOH	SIDI: C A R F G 2 , ETBE	SIDI: CARFG2, EtOH	Dedi. MeOH SIDI: NG	Dedi. MeOH SIDI: M90, FG	Dedi. MeOH SIDI: M90, LFG	Dedi. EtOH SIDI: corn	Dedi. EtOH SIDI: E90, WB	Dedi. EtOH SIDI: E90, HB	GI SIDI HEV: FRFG2, MTBE
Total energy	-20.0%	-20.0%	-20.0%	-20.0%	-6.7%	-2.3%	-16.1%	-3.2%	38.7%	27.1%	-47.4%
Fossil fuels	-20.0%	-20.0%	-19.0%	-19.3%	-6.2%	-68.4%	-68.1%	-56.1%	-84.4%	-80.8%	-47.4%
Petroleum	-20.0%	-20.0%	-17.2%	-19.2%	-82.1%	-82.1%	-82.6%	-83.7%	-81.8%	-83.4%	-47.4%
CH4	-18.0%	-17.6%	-18.0%	-17.6%	-35.3%	-39.5%	-375.7%	-26.8%	-63.5%	-57.6%	-42.6%
N2O	-7.2%	-4.7%	-7.2%	-4.7%	-1.5%	-3.5%	-0.7%	268.1%	77.5%	294.2%	-2.1%
c o 2	-20.0%	-19.7%	-20.0%	-19.8%	-24.7%	-82.5%	-143.7%	-55.3%	-106.2%	-90.0%	-47.4%
GHGs	-19.6%	-19.3%	-19.6%	-19.3%	-24.6%	-79.7%	-148.2%	-46.7%	-100.6%	-79.8%	-46.4%

Table continued on next page. See page preceding Table 3.9 for acronym definitions.

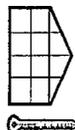


Table 3.10 (continued)
Long-Term Technology
Changes in Per-Mile, Fuel-Cycle Energy Use and Greenhouse Gas Emissions for Passenger Cars
(Percentage relative to conventional gasoline vehicles fueled with conventional gasoline)

	GI SIDI HEV: FRFG2, ETBE	GI SIDI HEV: FRFG2, EtOH	GI SI HEV: CNG	GI SI HEV: LNG	GI SI HEVs: LPG, crude	GI SI HEVs: LPG, NG	GI SIDI HEVs: M90, NG	GI SIDI HEVs: M90, FG	GI SIDI HEVs: M90 LFG	GI SIDI HEVs: E90, corn	GI SIDI HEVs: E90, WB
Total energy	-47.4%	-47.4%	-43.5%	-41.7%	-46.2%	-46.7%	-37.0%	-34.1%	-43.2%	-36.3%	-8.7%
Fossil fuels	-47.4%	-47.4%	-44.1%	-41.4%	-46.2%	-46.6%	-36.7%	-68.4%	-77.4%	-71.1%	-89.7%
Petroleum	-47.4%	-47.4%	-99.6%	-97.5%	-36.1%	-98.8%	-87.3%	-87.3%	-87.7%	-89.3%	-88.0%
CH4	-42.7%	-41.7%	33.0%	32.8%	-50.1%	-45.8%	-52.8%	-55.6%	-276.8%	-45.7%	-69.8%
N2O	-16.9%	-11.2%	-50.0%	-49.4%	-3.0%	-3.0%	-2.1%	-3.4%	-1.6%	168.3%	42.9%
c o 2	-47.4%	-47.2%	-55.0%	-55.0%	-49.1%	-50.1%	-48.8%	-86.9%	-127.1%	-70.3%	-103.8%
GHGs	-46.4%	-46.2%	-52.1%	-52.1%	-48.3%	-49.1%	-48.1%	-84.3%	-129.4%	-63.9%	-99.3%

	GC SIDI HEV: FRFG2, HEVs: E90, HB	GC SIDI HEV: FRFG2, MTBE, US mix	GC SIDI HEV: FRFG2, ETBE, US mix	GC SIDI HEV: FRFG2, EtOH, US mix	GC SIDI HEV: FRFG2, MTBE, CA mix	GC SIDI HEV: FRFG2, ETBE, CA mix	GC SIDI HEV: FRFG2, EtOH, CA mix	GC SI HEV: CNG, US mix	GC SI HEV: CNG, CA mix	GC SI HEV: LNG, US mix	GC SI HEV: LNG, CA mix
Total energy	-16.4%	-43.7%	-43.8%	-43.7%	-43.9%	-44.0%	-43.9%	-40.8%	-41.0%	-39.5%	-39.7%
Fossil fuels	-87.4%	-48.2%	-47.1%	-47.3%	-55.5%	-54.8%	-54.9%	-45.7%	-53.0%	-43.8%	-51.1%
Petroleum	-89.1%	-60.7%	-60.4%	-61.4%	-61.0%	-60.7%	-61.7%	-99.4%	-99.6%	-97.8%	-98.1%
CH4	-65.9%	-43.6%	-43.7%	-39.7%	-49.9%	-50.0%	-47.3%	10.2%	3.9%	10.1%	3.8%
N2O	185.5%	-28.2%	-39.4%	-35.0%	-29.9%	-40.5%	-36.4%	-61.7%	-63.4%	-61.3%	-63.0%
c o 2	-93.1%	-46.1%	-46.5%	-45.8%	-56.0%	-56.2%	-55.8%	-51.4%	-61.3%	-51.4%	-61.4%
GHGs	-85.6%	-45.6%	-46.3%	-45.4%	-55.3%	-55.6%	-55.1%	-49.6%	-59.3%	-49.7%	-59.3%

Table continued on next page. See page preceding Table 3.9 for acronym definitions.

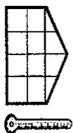


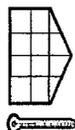
Table 3.10 (continued)
Long-Term Technology

Changes in Per-Mile, Fuel-Cycle Energy Use and Greenhouse Gas Emissions for Passenger Cars
(Percentage relative to conventional gasoline vehicles fueled with conventional gasoline)

	GC SI HEV: LPG, crude, US mix	GC SI HEV: LPG, NG, US mix	GC SI HEV: LPG, crude, CA mix	GC SI HEVs: LPG, NG, CA mix	GC SIDI HEV: M90, NG, US mix	GC SIDI HEV: M90, FG, US mix	GC SIDI HEV: M90, LFG, US mix	GC SIDI HEV: M90, NG, CA mix	GC SIDI HEV: M90, FG, CA mix	GC SIDI HEV: M90, LFG, CA mix	GC SIDI HEV: E90, corn, US mix
Total energy	-42.7%	-43.1%	-42.9%	-43.3%	-36.2%	-34.1%	-40.6%	-36.4%	-34.3%	-40.8%	-35.8%
Fossil fuels	-47.2%	-47.5%	-54.6%	-54.8%	-40.5%	-63.3%	-69.8%	-47.8%	-70.7%	-77.1%	-64.7%
Petroleum	-53.6%	-98.8%	-53.8%	-99.0%	-90.5%	-90.5%	290.7%	-90.8%	-90.8%	-91.0%	-91.9%
CH4	-49.5%	-45.8%	-55.2%	-52.1%	-50.8%	-52.8%	-211.8%	-57.1%	-59.1%	-218.1%	-42.8%
N2O	-28.5%	-28.9%	-30.5%	-30.5%	-28.3%	-29.2%	-27.9%	-29.9%	-30.9%	-29.5%	40.5%
c o 2	-47.2%	-47.9%	-57.1%	-57.8%	-47.1%	-74.4%	-103.4%	-57.1%	-84.4%	-113.3%	-62.4%
GHGs	-47.0%	-47.5%	-56.6%	-57.1%	-46.9%	-72.9%	-105.3%	-56.5%	-82.6%	-115.0%	-59.4%

	GCSIDI HEV: E90, WB, US mix	GCSIDI HEV: E90, HB, US mix	GCSIDI HEV: E90, corn, CA mix	GCSIDI HEV: E90, WB, CA mix	GCSIDI HEV: E90, HB, CA mix	CIDI: RFD	CIDI: DME, NG	CIDI: DME, FG	CIDI: FT50, NG	CIDI: FT50, FG	CIDI: BD20
Total energy	-15.9%	-21.5%	-36.0%	-16.1%	-21.7%	-35.1%	-17.7%	-14.4%	-21.3%	-13.2%	-31.4%
Fossil fuels	-78.1%	-76.4%	-72.3%	-85.7%	-84.0%	-35.0%	-17.2%	-67.4%	-21.1%	-38.6%	-31.6%
Petroleum	-91.0%	-91.8%	-92.2%	-91.3%	-92.0%	-25.0%	-97.9%	-97.9%	-59.9%	-59.9%	-36.7%
CH4	-60.1%	-57.3%	-50.4%	-67.7%	-64.9%	-51.9%	-50.0%	-49.9%	-52.1%	-51.6%	-53.9%
N2O	-49.6%	52.9%	39.2%	-51.0%	51.5%	-42.7%	-44.6%	-47.4%	-44.9%	-45.4%	-35.4%
c o 2	-86.5%	-78.8%	-72.5%	-96.5%	-88.8%	-32.3%	-35.7%	-94.6%	-31.6%	-61.2%	-40.1%
GHGs	-84.9%	-75.1%	-69.2%	-94.6%	-84.8%	-33.1%	-36.3%	-92.3%	-32.5%	-60.6%	-40.5%

Table continued on next page. See page preceding Table 3.9 for acronym definitions.



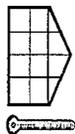


Table 3.10 (continued)
Long-Term Technology
Changes in Per-Mile, Fuel-Cycle Energy Use and Greenhouse Gas Emissions for Passenger Cars
(Percentage relative to conventional gasoline vehicles fueled with conventional gasoline)

	GC CIDI		GC CIDI		GC CIDI		GC CIDI		GC CIDI	GC CIDI	GC CIDI
	HEV: RFD	HEV: DME, NG	HEV: FT50, NG	HEV: FT50, FG	HEV: FT50, NG	HEV: FT50, FG	HEV: BD20	HEV: US mix	HEV: CA mix	HEV: DME, NG, US mix	HEV: DME, FG, NG, CA mix
Total energy	-57.7%	-46.3%	-44.2%	-43.3%	-48.7%	-55.3%	-53.5%	-53.3%	-42.2%	-40.7%	-42.4%
Fossil fuels	-57.6%	-46.0%	-78.7%	-43.1%	-57.6%	-55.4%	-65.2%	-57.8%	-46.5%	-70.5%	-53.9%
Petroleum	-51.1%	-98.6%	-98.6%	-73.8%	-73.8%	-58.7%	-67.3%	-67.1%	-98.6%	-98.6%	-98.9%
CH4	-68.1%	-66.3%	-66.3%	-67.9%	-68.2%	-69.4%	-69.6%	-63.3%	-60.1%	-60.1%	-66.4%
N2O	-43.5%	-44.8%	-46.6%	-45.3%	-45.0%	-38.8%	-59.0%	-57.3%	-58.1%	-59.5%	-59.8%
c o 2	-55.8%	-58.1%	-96.5%	-74.7%	-55.4%	-60.9%	-64.5%	-54.5%	-53.2%	-81.3%	-63.2%
GHGs	-56.0%	-58.1%	-94.6%	-74.0%	-55.6%	-60.7%	-64.5%	-54.8%	-53.5%	-80.2%	-63.2%

	GC CIDI		GC CIDI		GCCIDI		GCCIDI		GCCIDI		H2 FCV: NG, C. gaseous
	HEV: DME, FG, NG, CA mix	HEVs: FT50, NG, US mix	HEVs: FT50, FG, NG, US mix	HEV: FT50, CA mix	HEV: FT50, FG, CA mix	HEV: BD20, US mix	HEV: BD20, CA mix	EV: US mix	EV: NE mix	EV: CA mix	
Total energy	-40.9%	-43.9%	-40.1%	-44.1%	-40.3%	-48.8%	-49.0%	-38.4%	-39.7%	-39.0%	-59.7%
Fossil fuels	-77.8%	-48.3%	-56.7%	-55.7%	-64.0%	-53.4%	-60.7%	-53.4%	-57.2%	-77.9%	-60.3%
Petroleum	-98.9%	-80.5%	-80.5%	-80.7%	-80.7%	-69.4%	-69.7%	-98.7%	-98.2%	-99.6%	-99.7%
CH4	-66.3%	-61.4%	-61.2%	-67.7%	-67.5%	-62.3%	-68.6%	-48.8%	-45.9%	-69.7%	-62.6%
N2O	-61.1%	-58.3%	-58.5%	-59.9%	-60.2%	-53.7%	-55.4%	-89.3%	-90.2%	-94.9%	-98.2%
c o 2	-91.3%	-51.2%	-65.4%	-61.2%	-75.4%	-55.3%	-65.2%	-46.3%	-56.7%	-79.4%	-68.6%
GHGs	-89.9%	-51.7%	-65.1%	-61.4%	-74.8%	-55.5%	-65.1%	-47.2%	-57.0%	-79.4%	-69.0%

Table continued on next page. See page preceding Table 3.9 for acronym definitions.

Table 3.10 (continued)
Long-Term Technology
Changes in Per-Mile, Fuel-Cycle Energy Use and Greenhouse Gas Emissions for Passenger Cars
(Percentage relative to conventional gasoline vehicles fueled with conventional gasoline)

	H2 FCV:		H2 FCV:		FCV:	F C V :
	NG, station gaseous	H2 FCV: solar gas	solar, liquid	H2 FCV: NG, liquid	MeOH, NG	MeOH, FG
Total energy	-53.2%	-65.5%	-71.8%	-58.8%	-52.3%	-49.7%
Fossil fuels	-52.9%	-93.1%	-98.3%	-58.5%	-52.0%	-80.3%
Petroleum	-99.7%	-99.9%	-98.1%	-97.8%	-98.6%	-98.6%
CH4	-47.1%	-86.9%	-98.8%	-63.3%	-68.0%	-70.5%
N2O	-96.7%	-98.1%	-99.4%	-97.8%	-79.2%	-80.4%
CO2	-63.7%	-93.4%	-98.3%	-67.7%	-62.8%	-96.7%
GHGs	-63.8%	-93.3%	-98.3%	-68.1%	-63.3%	-95.6%

	FCV:	FCV:	EtOH	EtOH	EtOH	NG
	MeOH, LFG		FRFG2	FCV: Corn	FCV: WB	FCV: HB
Total energy	-57.8%	-50.0%	-37.7%	-7.1%	-15.6%	-52.0%
Fossil fuels	-88.3%	-50.0%	-77.4%	-97.3%	-94.8%	-52.5%
Petroleum	-98.9%	-50.0%	-96.5%	-94.9%	-96.2%	-99.7%
CH4	-267.5%	-53.0%	-70.7%	-92.8%	-89.3%	-9.4%
N2O	-78.7%	-78.7%	182.0%	8.6%	205.8%	-79.0%
CO2	-132.5%	-50.0%	-76.4%	-113.1%	-101.4%	-61.6%
GHGs	-135.8%	-50.6%	-71.2%	-110.1%	-95.1%	-60.3%

Source:

Wang, Michael Q., GREET Model Results, Argonne National Laboratory, Argonne, IL, August 1999.

Note:

See page preceding Table 3.9 for acronym definitions.

