Table 12.1 – Renewable Energy Impacts Calculation

Conversion Formula:
Step 1 *Capacity (A) x Capacity Factor (B) x Annual Hours (C) = Annual Electricity Generation (D)*
Step 2 *Annual Electricity Generation (D) x Competing Heat Rate (E) = Annual Output (F)*
Step 3 *Annual Output (F) x Emissions Coefficient (G) = Annual Emissions Displaced (H)*

Technology	**Wind**	**Geothermal**	**Biomass**	**Hydropower**	**PV**	**Solar Thermal**
(A) Capacity (kW)	11,558,205	2,232,495	6,594,096	78,312,583	280,355	388,893
(B) Capacity Factor (%)	36.0%	90.0%	80.0%	44.2%	22.5%	24.4%
(C) Annual Hours	8,760	8,760	8,760	8,760	8,760	8,760
(D) Annual Electricity Generation (kWh)	36,449,954,187	17,600,991,128	46,211,427,727	303,176,455,525	552,579,314	831,235,472
(E) Competing Heat Rate (Btu/kWh)	10,107	10,107	10,107	10,107	10,107	10,107
(F) Annual Output (Trillion Btu)	368	178	467	3,064	6	8
(G) Carbon Coefficient (MMTCB/Trillion Btu)	0.01783	0.01783	0.01783	0.01783	0.01783	0.01783
(H) Annual Carbon Displaced (MMTC)	6.569	3.172	8.328	54.635	0.100	0.128

Sources:
Capacity: Projected values for the year 2006 from EIA, *Annual Energy Outlook 2006,* DOE/EIA-0383 (2006) (Washington, D.C., February 2006), Table A16, 2005.
Capacity factors: Hydropower calculated from EIA, *Annual Energy Outlook 2005,* DOE/EIA-0383 (2005) (Washington, D.C., February 2005), Table A16.
All others based on DOE, *Renewable Energy Technology Characterizations*, EPRI TR-109496, 1997, and program data.

Heat Rate: EIA, *Annual Energy Review 2004*, DOE/EIA-0384(2004) (Washington, D.C., August 2005), Table A6.

Carbon Coefficient: DOE, GPRA2003 Data Call, Appendix B, page B-16, 2003.

Notes:
For illustrative purposes only, displacement of fossil generation depends on power system generation portfolio and dispatch order.
Capacity values exclude combined-heat-and-power (CHP) data, but include end-use sector (industrial and commercial) non-CHP data.
Competing heat rate from Fossil-Fueled Steam-Electric Plants heat rate.

Table 12.2 – Number of Home Electricity Needs Met Calculation

Conversion Formula: *Step 1* *Capacity (A) x Capacity Factor (B) x Annual Hours (C) = Annual Electricity Generation (D)*
Step 2 *Annual Electricity Generation (D) / Average Consumption (E) = Number of Households (F)*

Technology	**Wind**	**Geothermal**	**Biomass**	**Hydropower**	**PV**	**Solar Thermal**
(A) Capacity (kW)	11,558,205	2,232,495	6,594,096	78,312,583	280,355	388,893
(B) Capacity Factor (%)	36.0%	90.0%	80.0%	44.2%	22.5%	24.4%
(C) Annual Hours	8,760	8,760	8,760	8,760	8,760	8,760
(D) Annual Electricity Generation (kWh)	36,449,954,187	17,600,991,128	46,211,427,727	303,176,455,525	552,579,314	831,235,472
(E) Average Annual Household Electricity Consumption (kWh)	11,586	11,586	11,586	11,586	11,586	11,586
(F) Number of Households	3,148,804	1,520,497	3,992,068	26,190,515	47,736	71,808

Sources: Capacity: Projected values for the year 2006 from EIA, *Annual Energy Outlook 2006,* DOE/EIA-0383 (2006) (Washington, D.C., February 2006), Table A16, 2006.

Capacity factors: Hydropower calculated from EIA, *Annual Energy Outlook 2005*, DOE/EIA-0383 (2005) (Washington, D.C., February 2005), Table A16. All others based on DOE, *Renewable Energy Technology Characterizations*, EPRI TR-109496, 1997, and program data.
Household electricity consumption: Calculated from EIA, *Annual Energy Outlook 2006*, DOE/EIA-0383 (2006) (Washington, D.C., February), Tables A4 and A8, 2006.

Notes:
For illustrative purposes only.
Capacity values exclude combined-heat-and-power (CHP) data, but include end-use sector (industrial and commercial) non-CHP data.

Table 12.3 – Coal-Displacement Calculation

Conversion Formula:	*Step 1*	*Capacity (A) x Capacity Factor (B) x Annual Hours (C) = Annual Electricity Generation (D)*
	Step 2	*Annual Electricity Generation (D) x Conversion Efficiency (E) = Total Output (F)*
	Step 3	*Total Output (F) / Fuel Heat Rate (G) = Quantity Fuel (H)*

Technology	**Wind**	**Geothermal**	**Biomass**	**Hydropower**	**PV**	**Solar Thermal**
(A) Capacity (kW)	11,558,205	2,232,495	6,594,096	78,312,583	280,355	388,893
(B) Capacity Factor (%)	36.0%	90.0%	80.0%	44.2%	22.5%	24.4%
(C) Annual Hours	8,760	8,760	8,760	8,760	8,760	8,760
(D) Annual Electricity Generation (kWh)	36,449,954,187	17,600,991,128	46,211,427,727	303,176,455,525	552,579,314	831,235,472
(E) Competing Heat Rate (Btu/kWh)	10,107	10,107	10,107	10,107	10,107	10,107
(F) Total Output (Million Btu)	368,399,686	177,893,217	467,058,900	3,064,204,435	5,584,919	8,401,296
(G) Coal Heat Rate (Btu per short ton)	20,411,000	20,411,000	20,411,000	20,411,000	20,411,000	20,411,000
(H) Coal (short tons)	18,049,076	8,715,556	22,882,705	150,125,150	273,623	411,606

Sources: Capacity: EIA, *Annual Energy Outlook 2006,* DOE/EIA-0383 (2006) (Washington, D.C., February 2006), Table A16, 2006.

Capacity factors: Hydropower calculated from EIA, *Annual Energy Outlook 2005*, DOE/EIA-0383 (2005) (Washington, D.C., February 2005), Table A16. All others based on DOE, *Renewable Energy Technology Characterizations*, EPRI TR-109496, 1997 and Program data.

Conversion Efficiency: EIA, Annual Energy Review 2004, DOE/EIA-0384(2003) (Washington, D.C., August 2005), Table A6.

Heat Rate: Annual Energy Outlook 2006, DOE/EIA-0383 (2006) (Washington, D.C., February 2006), Table H1.

Notes:
For illustrative purposes only, displacement of fossil generation depends on power system generation portfolio and dispatch order.
Capacity values exclude combined-heat-and-power (CHP) data, but include end-use sector (industrial and commercial) non-CHP data.

Table 12.4 – National SO_2 and Heat Input Data

	1980	1985	1990	1995	2000	2004
SO_2 (lbs)	34,523,334,000	32,184,330,000	31,466,566,000	23,671,357,600	22,404,150,534	20,518,221,256
SO_2 Heat Factor (lb/MMBtu)	1.935	1.748	1.599	1.081	0.875	0.778
NO_x (lbs)	-	-	-	11,682,226,600	12,024,262,800	10,209,031,650
NO_x Heat Factor (lb/MMBtu)	-	-	-	0.534	0.470	0.387
Heat (MMBtu)	17,838,745,941	18,414,433,865	19,684,094,492	21,889,662,875	25,606,076,726	26,358,516,161

Source: EPA, Clean Air Markets Web site - Data and Maps, Emissions section, http://cfpub.epa.gov/gdm/ accessed February 2006.

Table 12.5 – SO_2, NOx, CO_2 Emission Factors for Coal-Fired and Noncoal-Fired Title IV Affected Units

	1996	1997	1998	1999	2000	2001	2002	2003	2004
SO_2 (lbs/mmBtu)									
Coal	1.241	1.245	1.222	1.166	1.036	1.008	0.976	0.968	0.941
Noncoal	0.246	0.256	0.318	0.267	0.200	0.220	0.126		
Total	1.096	1.093	1.058	0.999	0.875	0.843	0.794		
NO_x (lbs/mmBtu)									
Coal	0.568	0.559	0.532	0.487	0.444	0.425	0.408	0.375	0.340
Noncoal	0.221	0.234	0.251	0.244	0.210	0.176	0.128		
Total	0.518	0.509	0.481	0.442	0.399	0.373	0.348		
CO_2 (lbs/mmBtu)									
Coal	206.377	205.537	205.677	205.586	205.646	205.627	205.672	201.741	201.513
Noncoal	132.731	130.804	131.685	132.001	133.110	130.159	126.858		
Total	195.682	194.056	192.256	191.956	191.672	189.809	188.813		

Source: EPA, *Acid Rain Program Compliance Report 2001*, Emission Scorecard, updated April 2004, Table 1, http://www.epa.gov/airmarkets/emissions/score01/index.html, and EPA, Clean Air Markets Web site - Data and Maps, Emissions section, http://cfpub.epa.gov/gdm/ accessed March 2006.

Table 12.6a – Sulfur Dioxide Uncontrolled Emission Factors, Electricity Generators

		Boiler Type/Firing Configuration					
Fuel	**Emissions Units[1]**	**Cyclone**	**Fluidized Bed**	**Opposed Firing**	**Spreader Stoker**	**Tangential**	**All Other**
Agricultural Byproducts	Lbs per ton	0.08	0.01	0.08	0.08	0.08	0.08
Blast Furnace Gas	Lbs per MMCF	3.5	0.35	3.5	3.5	3.5	3.5
Bituminous Coal*	Lbs per ton	38	3.1	38	38	38	38
Black Liquor	Lbs per ton ***	7	0.7	7	7	7	7
Distillate Fuel Oil*	Lbs per MG	142	14.2	142	142	142	142
Jet Fuel*	Lbs per MG	142	14.2	142	142	142	142
Kerosene*	Lbs per MG	142	14.2	142	142	142	142
Landfill Gas	Lbs per MMCF	3.5	0.35	3.5	3.5	3.5	3.5
Lignite Coal*	Lbs per ton	30	1	30	30	30	30
Municipal Solid Waste	Lbs per ton	1.7	0.17	1.7	1.7	1.7	1.7
Natural Gas	Lbs per MMCF	0.6	0.06	0.6	0.6	0.6	0.6
Other Biomass Gas	Lbs per MMCF	3.5	0.35	3.5	3.5	3.5	3.5
Other Biomass Liquids	Lbs per MG	1.42	1.42	1.42	1.42	1.42	1.42
Other Biomass Solids	Lbs per ton	0.08	0.01	0.08	0.08	0.08	0.08
Other Gases	Lbs per MMCF	3.5	0.35	3.5	3.5	3.5	3.5
Other	Lbs per MMCF	0.6	0.06	0.6	0.6	0.6	0.6
Petroleum Coke*	Lbs per ton	39	3.9	39	39	39	39
Propane Gas	Lbs per MMCF	0.6	0.06	0.6	0.6	0.6	0.6
Residual Fuel Oil*	Lbs per MG	157	15.7	157	157	157	157
Synthetic Coal*	Lbs per ton	38	3.1	38	38	38	38
Sludge Waste	Lbs per ton	2.8	0.28	2.8	2.8	2.8	2.8
Subbituminous Coal*	Lbs per ton ***	35	3.1	35	38	35	35
Tire Derived Fuel*	Lbs per ton	38	3.8	38	38	38	38
Waste Coal*	Lbs per ton	38	3.1	38	38	38	38
Wood Waste Liquids	Lbs per MG	1.42	1.42	1.42	1.42	1.42	1.42
Wood Waste Solids	Lbs per ton	0.08	0.01	0.08	0.08	0.08	0.08
Waste Oil*	Lbs per MG	147	14.7	147	147	147	147

Source: EIA, *Electric Power Annual 2004,* DOE/EIA-0348(2004) November 2005, Table A1.

Notes:
[1] Lbs = pounds, MMCF = million cubic feet, MG = thousand gallons.
* For these fuels, emissions are estimated by multiplying the emissions factor by the physical volume of fuel and the sulfur percentage of the fuel (other fuels do not require the sulfur percentage in the calculation). Note that EIA data do not provide a sulfur content for TDF. The value used (1.56 percent) is from http://www.epa.gov/appcdwww/aptb/EPA-600-R-01-109A.pdf, Table A-11.
** Source is EPA emission factors reported in http://www.epa.gov/ttn/chief/ap42/ and http://www.epa.gov/ttn/chief/software/fire/index.html.
*** Although SLW and BLQ consist substantially of liquids, these fuels are measured and reported to EIA in tons.

Table 12.6b – Nitrogen Oxide Uncontrolled Emissions Factors, Electricity Generators

		Boiler Type/Firing Configuration[1]					
Fuel	**Emissions Units[2]**	**Cyclone**	**Fluidized Bed**	**Opposed Firing**	**Spreader Stoker**	**Tangential**	**All Other**
Agricultural Byproducts	Lbs per ton	1.20	1.20	1.20	1.20	1.20	1.20
Blast Furnace Gas	Lbs per MMCF	15.40	15.40	15.40	15.40	15.40	15.40
Bituminous Coal	Lbs per ton	33.00	5.00	22.00	11.00	15.0 [14.0]	22.0 [31.0]
Black Liquor	Lbs per ton ***	1.50	1.50	1.50	1.50	1.50	1.50
Distillate Fuel Oil	Lbs per MG	24.00	24.00	24.00	24.00	24.00	24.00
Jet Fuel	Lbs per MG	24.00	24.00	24.00	24.00	24.00	24.00
Kerosene	Lbs per MG	24.00	24.00	24.00	24.00	24.00	24.00
Landfill Gas	Lbs per MMCF	72.40	72.40	72.40	72.40	72.40	72.40
Lignite Coal	Lbs per ton	15.00	3.60	13.00	5.80	7.10	7.1 [13.0]
Municipal Solid Waste	Lbs per ton	5.90	5.90	5.90	5.90	5.90	5.90
Natural Gas	Lbs per MMCF	280.00	280.00	280.00	280.00	170.00	280.00
Other Biomass Gas	Lbs per MMCF	72.40	72.40	72.40	72.40	72.40	72.40
Other Biomass Liquids	Lbs per MG	1.66	1.66	1.66	1.66	1.66	1.66
Other Biomass Solids	Lbs per ton	1.20	1.20	1.20	1.20	1.20	1.20
Other Gases	Lbs per MMCF	14.90	14.90	14.90	14.90	14.90	14.90
Other	Lbs per MMCF	1.50	1.50	1.50	1.50	1.50	1.50
Petroleum Coke	Lbs per ton	21.00	21.00	21.00	21.00	21.00	21.00
Propane Gas	Lbs per MMCF	19.00	19.00	19.00	19.00	19.00	19.00
Residual Fuel Oil	Lbs per MG	47.00	47.00	47.00	47.00	32.00	47.00
Synthetic Coal	Lbs per ton	33.00	5.00	22.00	11.00	15.00	22.00
Sludge Waste	Lbs per ton	5.00	5.00	5.00	5.00	5.00	5.00
Subbituminous Coal	Lbs per ton ***	17.00	5.00	12.00	8.80	8.40	12.0 [24.0]

Tire Derived Fuel	Lbs per ton	33.00	5.00	22.00	11.00	15.00	22.00
Waste Coal	Lbs per ton	21.70	21.70	21.70	21.70	21.70	21.70
Wood Waste Liquids	Lbs per MG	1.66	1.66	1.66	1.66	1.66	1.66
Wood Waste Solids	Lbs per ton	1.50	1.50	1.50	1.50	1.50	1.50
Waste Oil	Lbs per MG	19.00	19.00	19.00	19.00	19.00	19.00

Source: EIA, *Electric Power Annual 2004*, DOE/EIA-0348(2004) November 2005, Table A1.

Notes:

[1] All Dry-Bottom Boilers, Except Wet-Bottom as indicated by values in brackets

[2] Lbs = pounds, MMCF = million cubic feet, MG = thousand gallons.

** Source is EPA emission factors reported in http://www.epa.gov/ttn/chief/ap42/ and http://www.epa.gov/ttn/chief/software/fire/index.html.

*** Although Sludge Waste and Black Liquor consist substantially of liquids, these fuels are measured and reported to EIA in tons.

Table 12.6c – Uncontrolled Carbon Dioxide Emissions Factors, Electricity Generators

Fuel	Factor (lbs of CO2 per MMBtu)*
Blast Furnace Gas	116.97
Bituminous Coal	205.45
Distillate Fuel Oil	161.27
Geothermal	0.34
Jet Fuel	159.41
Kerosene	159.41
Landfill Gas	115.12
Lignite Coal	215.53
Municipal Solid Waste	14.63
Natural Gas	116.97
Other Biomass Gas	115.11
Other Gases	141.54
Petroleum Coke	225.13
Propane Gas	139.04
Residual Fuel Oil	173.72
Synthetic Coal	205.45
Subbituminous Coal	212.58
Waste Coal	205.16
Waste Oil	163.61

Source: EIA, *Electric Power Annual 2004*, DOE/EIA-0348(2004), November 2005, Table A1.
* CO_2 factors do not vary by boiler type or firing configuration.

Table 12.7 – Global Warming Potentials (GWP)

(100-year time horizon)

Gas	GWP
	SAR
Carbon dioxide (CO2)	1
Methane (CH_4)[1]	21
Nitrous oxide (N_2O)	310
HFC-23	11,700
HFC-32	650
HFC-125	2,800
HFC-134a	1,300
HFC-143a	3,800
HFC-152a	140
HFC-227ea	2,900
HFC-236fa	6,300
HFC-4310mee	1,300
CF_4	6,500
C_2F_6	9,200
C_4F_{10}	7,000
C_6F_{14}	7,400
SF_6	23,900

Source: EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2003*, EPA 430-R-05-003 (Final Version: April 2005), Table ES-1.

Notes:

The GWP of a greenhouse gas is the ratio of global warming, or radiative forcing – both direct and indirect – from one unit mass of a greenhouse gas to that of one unit mass of carbon dioxide over a period of time.

GWP from Intergovernmental Panel and Climate Change (IPCC) Second Assessment Report (SAR) and Third Assessment Report (TAR). Although the GWPs have been updated by the IPCC, estimates of emissions presented in this report use the GWPs from the Second Assessment Report. The UNFCCC reporting guidelines for national inventories were updated in 2002, but continue to require the use of GWPs from the SAR so that current estimates of aggregated greenhouse gas emissions for 1990 through 2001 are consistent with estimates developed prior to the publication of the TAR. Therefore, to comply with international reporting standards under the UNFCCC, official emission estimates are reported by the United States using SAR GWP values.

[1] The methane GWP includes direct effects and those indirect effects, due to the production of tropospheric ozone and stratospheric water vapor. The indirect effect due to the production of CO_2 is not included.

Table 12.8 – Approximate Heat Content of Selected Fuels for Electric-Power Generation

Fossil Fuels [1]	
Residual Oil (million Btu per barrel)	6.287
Distillate Oil (million Btu per barrel)	5.799
Natural Gas (Btu per million cubic ft)	1,027
Coal (million Btu per Short Ton)	20.411

Biomass Materials [2]	
Switchgrass Btu per pound	7,341
Bagasse, Btu per pound	6,065
Rice Hulls, Btu per pound	6,575
Poultry Litter, Btu per pound	6,187
Solid wood waste, Btu per pound	6,000-8,000

Sources:

1. EIA, *Annual Energy Outlook 2006*, DOE/EIA-0383 (2006) (Washington, D.C., February 2006), Table G1.

2. Animal Waste Screening Study, Electrotek Concepts Inc., Arlington, VA. June 2001.

Table 12.9 – Approximate Heat Rates for Electricity

(Btu per Kilowatthour)

	1980	1990	2000	2001	2002	2003	2004
Fossil-Fueled Steam-Electric Plants[1, 2]	10,388	10,402	10,201	10,146	10,119	10,107	10,107
Nuclear Steam-Electric Plants[3]	10,908	10,582	10,429	10,448	10,439	10,439	10,439
Geothermal Energy Plants[4]	21,639	21,096	21,017	21,017	21,017	21,017	21,017

Source: EIA, *Annual Energy Review 2004*, DOE/EIA-0384 (2004) (Washington, D.C., August 2005), Table A6

Notes:

[1] Through 2000, used as the thermal conversion factor for wood and waste electricity net generation at electric utilities. For all years, used as the thermal conversion factor for hydro, solar, and wind electricity net generation.
[2] Through 2000, heat rates are for fossil-fueled steam-electric plants at electric utilities. Beginning in 2001, heat rates are for all fossil-fueled plants at electric utilities and independent power producers.
[3] Used as the thermal-conversion factor for nuclear electricity net generation.
[4] Used as the thermal-conversion factor for geothermal electricity net generation.

Table 12.10 – Heating Degree-Days by Month

	1980	1990	2000	2001	2002	2003	2004	Normal[1]
January	887	728	886	935	778	944	957	917
February	831	655	643	725	670	801	769	732
March	680	535	494	669	624	572	487	593
April	338	321	341	302	282	344	302	345
May	142	184	115	115	185	165	105	159
June	49	29	29	29	23	41	28	39
July	5	6	12	8	3	4	5	9
August	10	10	12	6	8	5	16	15
September	54	56	69	71	38	62	42	77
October	316	246	244	267	299	261	241	282
November	564	457	610	400	561	477	484	539
December	831	789	1,005	696	813	784	788	817
Total	4,707	4,016	4,460	4,223	4,284	4,460	4,224	4,524

Source: EIA, *Annual Energy Review 2004*, DOE/EIA-0384(2004) (Washington, D.C., August 2005), Table 1.7

Notes:

[1] Based on calculations of data from 1971-2000
• This table excludes Alaska and Hawaii. • Degree-days are relative measurements of outdoor air temperature. Heating degree-days are deviations below the mean daily temperature of 65° F. For example, a weather station recording a mean daily temperature of 40° F would report 25 heating degree-days. • Temperature information recorded by weather stations is used to calculate statewide degree-day averages based on resident state population. Beginning in 2002, data are weighted by the estimated 2000 population. The population-weighted state figures are aggregated into Census divisions and the national average. Web Pages: • For data not shown for 1951-1969, see http://www.eia.doe.gov/emeu/aer/overview.html.• For current data, see http://www.eia.doe.gov/emeu/mer/overview.html. Sources: • 1949-2003 and Normals—U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), National Climatic Data Center, Asheville, North Carolina, Historical Climatology Series 5-1. • 2004—Energy Information Administration, Monthly Energy Review, February 2004-January 2005 issues, Table 1.10, which reports data from NOAA, National Weather Service Climate Prediction Center, Camp Springs, Maryland.

Table 12.11 – Cooling Degree-Days by Month

	1980	1990	2000	2001	2002	2003	2004	Normal[1]
January	9	15	10	3	8	5	5	9
February	4	14	10	12	6	7	5	8
March	13	21	25	11	17	24	26	18
April	23	29	28	37	53	30	41	30
May	95	86	131	114	92	110	140	97
June	199	234	221	220	242	187	208	213
July	374	316	284	302	369	336	310	321
August	347	291	302	333	331	345	254	290
September	192	172	156	138	202	156	178	155
October	42	57	50	46	57	65	69	53
November	10	16	8	18	11	21	17	15
December	5	9	4	11	5	4	6	8
Total	1,313	1,260	1,229	1,245	1,393	1,281	1,260	1,215

Source: EIA, *Annual Energy Review 2004*, DOE/EIA-0384(2004) (Washington, D.C., August 2005), Table 1.8

Notes:

[1] Based on calculations of data from 1971-2000
• This table excludes Alaska and Hawaii. • Degree-days are relative measurements of outdoor air temperature. Cooling degree-days are deviations above the mean daily temperature of 65° F. For example, a weather station recording a mean daily temperature of 78° F would report 13 cooling degree-days. • Temperature information recorded by weather stations is used to calculate statewide degree-day averages based on resident state population. Beginning in 2002, data are weighted by the estimated 2000 population. The population-weighted state figures are aggregated into Census divisions and the national average. Web Pages: • For data not shown for 1951-1969, see http://www.eia.doe.gov/emeu/aer/overview.html. • For current data, see http://www.eia.doe.gov/emeu/mer/overview.html. Sources: • 1949-2003 and Normals—U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), National Climatic Data Center, Asheville, North Carolina, Historical Climatology Series 5-2. • 2004—Energy Information Administration, Monthly Energy Review, February 2004-January 2005 issues, Table 1.11, which reports data from NOAA, National Weather Service Climate Prediction Center, Camp Springs, Maryland.