2050 Projected Alternative Energy Supply and Demand Study

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Summary

The purpose of this study is to provide a first-pass approximation of world energy needs in 2050, and the ability of alternative energy to meet those needs. We make this approximation according to a specified methodology: We calculate the primary energy consumption per capita of the United States for 2008, and then use that per-capita consumption to project the world energy requirement for 2050. Then, we take that world energy requirement for 2050, and estimate how much of that could be met by alternative energy sources, were the entire world to produce alternative ("renewable") energy at the same per-square-kilometer level as the United States in 2008.

For energy data, we use the figures published by the Energy Information Administration (EIA) of the U.S. Department of Energy, while for population we use the 2008 estimate and 2050 projections from the U.S. Census.

Based upon our calculations, to meet our projected energy requirements for 2050 by solar power alone would require covering roughly half the area of the United States with solar panels. Using all realistic modes of alternative energy—solar/photovoltaic, hydroelectric, geothermal, tidal, wind, and biomass—alternative energy would provide the energy to meet just 3.7% of our projected requirement in 2050.

The Data

The Energy Information Administration of the U.S. Department of Energy publishes an Annual Energy Review which provides figures for total energy consumption in the United States, by a variety of categories. The latest available report contains data for 2008, which shows that the total primary energy consumption in the U.S. was 99.3 quadrillion BTUs for the year, of which 83 quadrillion BTUs came from fossil fuels, 8.5 quadrillion BTUs from nuclear power, and 7.3 quadrillion BTUs came from renewable energy, mainly biomass and hydroelectric power.

Table 1 shows the breakdown of consumption by energy source, and also shows the Joule equivalents.

Table 1. Primary Energy Consumption by Source, 2008
Quadrillion Btu

Energy Source	Quadrillion BTUs	BTUs	Joules /1
Fossil fuels			
Coal	22.421	2.2421E+16	2.3640E+19
Coal coke	0.041	4.1000E+13	4.3228E+16
Natural gas	23.838	2.3838E+16	2.5134E+19
Petroleum	37.137	3.7137E+16	3.9155E+19
Total	83.436	8.3436E+16	8.7971E+19
Nuclear electric power	8.455	8.4550E+15	8.9145E+18
Renewable Energy			
Hydroelectric power	2.452	2.4520E+15	2.5853E+18
Geothermal	0.358	3.5800E+14	3.7746E+17
Solar/PV	0.091	9.1000E+13	9.5946E+16
Wind	0.514	5.1400E+14	5.4194E+17
Biomass /2	3.884	3.8840E+15	4.0951E+18
Total	7.3	7.3000E+15	7.6968E+18
Electricity net imports	0.112	1.1200E+14	1.1809E+17
Total	**99.304**	**9.9304E+16**	**1.0470E+20**

Notes:
1/ Converted at 1054.35 Joules per BTU
2/ Biomass includes wood, waste, and biofuels
Source: Annual Energy Review Table 1.3, Energy Information Administration, U.S. Dept. of Energy

The U.S. Bureau of the Census estimates that the population of the U.S. was 304 million as of July, 2008, and projects that the world population will be 9.3 billion in 2050.

Table 2. Population Estimates

Estimated Population	
U.S. Population, 2008	304,060,000
World Population, 2050	9,309,051,539

Source: U.S. Census

Dividing U.S. energy consumption by population yields an energy consumption per capita of 344 gigajoules (3.4434 E+11 Joules) for 2008.

We then take that U.S. per capita consumption figure as a baseline standard for human energy consumption, and multiply it by the projected world population for 2050. This

yields a projected baseline world energy requirement of 3.2 zettajoules (3.2055 E+21 Joules) for 2050.

Table 3. Energy Consumption Projection

	Quadrillion BTUs	BTUs	Joules /1
U.S. Primary energy consumption	99.304	9.9304E+16	1.0470E+20
U.S primary energy consumption divided by U.S. population, yields:			
U.S. Primary energy consumption per capita	**0.00000033**	**3.2659E+08**	**3.4434E+11**
Multiplied by projected world population in 2050, yields:			
Projected world energy requirement 2050	**3,040**	**3.0403E+18**	**3.2055E+21**

Notes:
1/ Converted at 1054.35 Joules per BTU

Now we turn our attention to renewable energy consumption. Table 4 shows renewable energy consumption in the U.S. in 2008.

Table 4. Renewable Energy Production and Consumption by Primary Source, 2008

	Trillion BTU	BTUs	Joules /1
Production			
Biomass			
Biofuels	1,429	1.4290E+15	1.5067E+18
Biomass Total	3,900	3.9000E+15	4.1120E+18
Total Production	**7,316**	**7.3160E+15**	**7.7136E+18**
Consumption			
Hydroelectric Power	2,452	2.4520E+15	2.5853E+18
Geothermal	358	3.5800E+14	3.7746E+17
Solar/PV	91	9.1000E+13	9.5946E+16
Wind	514	5.1400E+14	5.4194E+17
Biomass			
Wood	2,041	2.0410E+15	2.1519E+18
Waste	431	4.3100E+14	4.5442E+17
Biofuels /2	1,413	1.4130E+15	1.4898E+18
Biomass Total	3,884	3.8840E+15	4.0951E+18
Total Consumption	**7,300**	**7.3000E+15**	**7.6968E+18**

Notes:
1/ Converted at 1054.35 Joules per BTU
2/ Biofuels include fuel ethanol and biodiesel
Source: Annual Energy Review Table 10.1, Energy Information Administration, U.S. Dept. of Energy

To generate enough electricity from solar power to meet our projected world energy requirements on 2050, would require large swaths of the planet to be covered with solar

panels. Solar power, using your figure of 450 Watts per square meter per hour, six hours a day, would yield 2,700 Watt-hours per day, which at 365 days per year would be 985,000 Watt-hours. Thus is would take 904,127 square kilometers of solar-panel surface-area—some 1.3 times the area of Texas—to produce the desired amount of energy.

However, only about 20% of that potential power, at best, can be turned into electricity. On that basis, each solar panel would produce 540 Watts per day of usable energy, or 197,100 Watt-hours per year. At that rate, it would take 4.5 million square kilometers of solar-panel surface-area to meet our projected 2050 requirements. That is an area equivalent to 47% of the total area of the United States, and 6.5 times the area of Texas.

Some have suggested that the usable power of a solar panel is closer to 12%, a rate at which it would require an area equivalent to 78% of the land area of United States.

Note that these calculations include only the surface-area of the solar panels themselves, and not any associated areas such as access areas between arrays of panels, so the actual area required would be greater.

Table 5. Solar power generation calculations

Assuming solar-panel output of 450 Watts per square meter, six hours a day, 365 days per year:

	Nominal total	At 20% efficiency
Output per day, in Watt-hours	2,700	540
Annual output, in Watt-hours	985,500	197,100
Annual output, in kiloWatt-hours	986	197

If one square meter of solar panel can produce that output per year, how many square meters of
solar-panels would be required to meet our projected 2050 energy requirement with solar power alone?

Projected 2050 energy requirement:	
in BTUs	3.0403E+18
in kWh	8.9102E+14
conversion factor kWh per BTU:	0.00029307108333

	Nominal total	At 20% efficiency
Square meters of solar-panel area required	9.0413E+11	4.5206E+12
same, in square kilometers	904,127	4,520,633
(1 million quare meters per square kilometer)		

Land use comparisons	Square kilometers	Pct. of requirement (20% efficiency)
United States	9,629,091	47%
Lower 48 states	8,080,465	56%

Texas	695,622	650%
World (land area only)	148,940,000	3%
USA, as pct. of world land area	*6.47%*	
World land area, multiple of USA	*15.47*	

As a rough first-pass approximation of world renewable potential for renewable energy production in 2050, we take the U.S. total consumption for 2008 and extrapolate it to the land area of the world as a whole (the United States is 6.5% of the world, in terms of land area). Assuming the world as a whole in 2050 produced renewable energy at the same per square kilometer rate as the U.S. did in 2008, the amount of energy produced would be just 3.71% of the requirement (Table 6)

Table 6. Projected World Renewable Energy Capacity, 2050

	Trillion BTU	**BTUs**	**Joules /1**
Projected world energy requirement 2050	3,040,275	3.0403E+18	3.2055E+21
U.S. renewable consumption 2008	7,300	7.3000E+15	7.6968E+18
Extrapolated to entire world			
using USA as % of world	112,914	1.1291E+17	1.1905E+20
using world as multiple of USA	112,914	1.1291E+17	1.1905E+20
Renewable as % of 2050 world requirements	3.71%	3.71%	3.71%