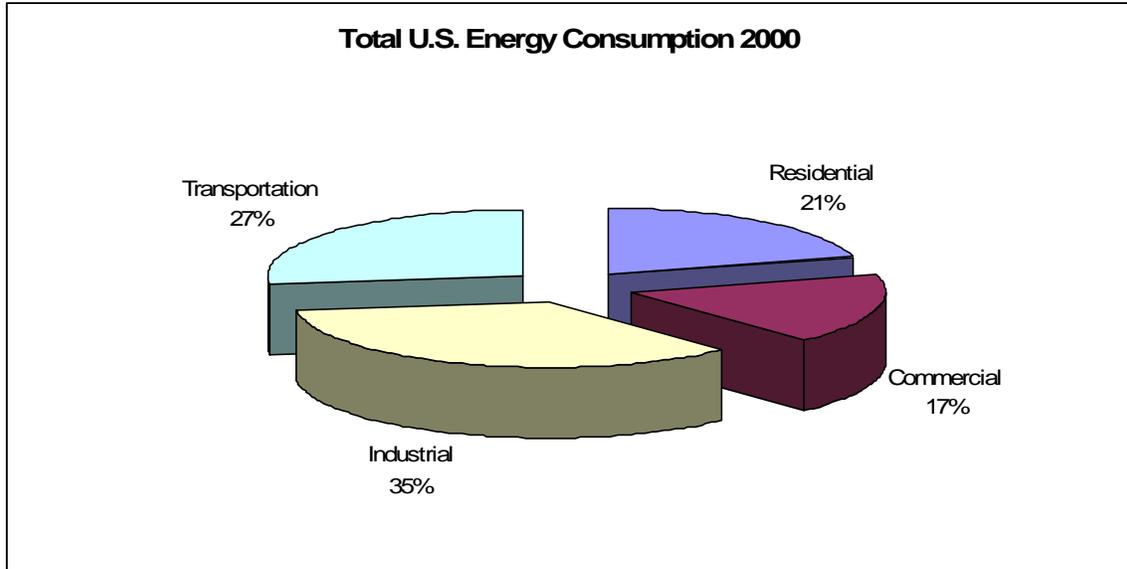


All Together Now: Total Savings

Total U.S. energy usage in 2000 was around 98.942 quads divided as follows²⁵⁸:



Using the same information, we derive the following table with percentage consumption from each sector, along with the percent savings from the appropriate preceding chapters, along with the premium we can pay for renewables.

	Percent Total Consumption	Savings	Consumption Remaining	Multiple of current fossil fuel price savings from efficiency measures would let us pay for renewables.
Residential	20.73%	68.75%	6.48%	1.87x
Commercial	17.38%	70.00%	5.21%	2.83x
Industrial	35.05%	75.00%	8.76%	2.10x
Transportation	26.84%	77.07%	6.15%	5.00x
Total	100.00%	73.39%	26.61%	2.79x

So we can save ~73% of energy used on a per capita basis. After those savings, we can pay ~2.8 times what we currently spend for fossil fuels, and break even on total national energy bill.

But this is not the end of potential for efficiency gains. We also lose energy converting fuels into electricity, and then transmitting that electricity along power lines; around 38% of total primary energy consumption is used to generate electrical power²⁵⁸.

Around 30% of electricity today comes from non-combustion sources²⁵⁹; that is from sources other than burning something. Nothing is burned to create hydroelectricity; it taps the energy of falling water. Geothermal energy uses the heat of the earth to boil water for steam. Wind, solar, wave, and tidal energy provide small amounts of non-combustion electricity. (So does nuclear power. But nuclear energy has its own problems.)

Burning fuel produces the rest - around 70%. This requires a bit less than three units of fuel to produce one unit of electricity. In the year 2000, according to the International Energy Agency, the U.S. produced about 36.7 BTUs of electricity for each 100 BTUs burned to generate it²³⁹. (This included line losses of around 10%²⁶⁰, as well as thermal conversion losses.)

Given the efficiencies we are looking at, the total drop in electricity use, we should be able to supply all our electricity entirely from sources that don't involve combustion of fuel - hydroelectricity, wind and geothermal plus solar thermal. So after countervailing factors, (small additional amounts of electricity used in transportation, and additional line losses from sending power longer distances), we should have a net savings of an additional ~9.6% of remaining energy consumption¹. Including that, we can save a total of 83% of energy use per capita, without lifestyle reductions or shrinking our economy.

Remember that, though our target date for a complete switch to renewable sources is 2040, we want to meet the energy needs of 2050 by that date. That is because we don't want to supply most energy from renewables in 2040, and then run short the next year.

¹We calculate this as follows. Current line losses, as mentioned, are about 10%. But if we are going to generate electricity renewably without assuming breakthroughs - without assuming cheap solar cells, inexpensive fuel cells, inexpensive electrolysis, we will have to ship electricity from where inexpensive renewable sources may be found - a lot of it a long distance from where consumed. So that means we will need longer distance transmission lines, and greater losses from transmission - maybe as much as 10% greater (bringing total line losses to 20%).

Current losses are ~63% (current net conversion) of 70% (the percent of our electricity we generate from fossil fuel) of 38% (primary energy used to generate electricity) - equals ~16.76%. Instead we would lose ~20% of ~70% of ~38% - equals a ~5.3% loss. This is about an 11% gross saving.

However the 30% we currently generate from non-combustion sources will also have to be shipped further, doubling our 10% transmission loss there to 20%. So instead of 10% of 30% of 38% (~1%), we will lose 20% of 30% of 38% (~2%), another ~1%.

Lastly, about ~2% of total energy will be additional electricity used for transportation currently powered by fuel. This will be a tremendous savings over IC and jet engines; but we will still have a 20% transmission loss - an additional ~0.4%. Subtracting that 1% and .4% from the 11% gross saving still lets us save ~9.6% of total energy remaining.

These savings are economic, and environmental. A hydroelectric turbine does not convert the power of falling water to electricity with 100% efficiency (though it can come surprisingly close). Neither do wind generators, nor geothermal power stations.

The environmental differences are obvious; a solar thermal power plant emits no greenhouse gases in operation. The economic difference is important too. If you burn natural gas to produce electricity you could have used that same natural gas somewhere else - to heat homes, to drive high temperature industrial processes, to use as a raw feedstock. When we tap the power of the wind to generate electricity or pump water, that is the first stage at which the natural resource has been converted to an economic one. The opportunity costs are of a different order. (They are not zero of course; resources go into building a wind generator. But your operating input is not something that otherwise would have gone to a different economic purpose.)

What do we project energy consumption as in 2050 as? Up to 2010, we are looking at DOE projections that include per person economic growth. From 2010 forward we look only at population growth. (We explain why at the end of this chapter)

Projected energy consumption for 2010 is ~112 quads²⁶¹. The middle (most probable) case U.S. population growth from 2010 to 2050 is projected to be slightly less than 35%²⁶². So without increased efficiency, and (only for the moment) not considering economic growth, that means consumption is expected to be under ~152 quads of primary energy. With a bit less than factor a factor four increase in efficiency, the 73% reduction we talked of, this results in a consumption of ~41 quads in 2050, ~6.8 quads of which will be electricity. Not burning fuel to produce that electricity saves us 9.6% of the total energy consumption – an additional ~3.6 quads.

Sector	Quads
Residential	~9.85
Commercial	~7.93
Industrial	~13.32
Transportation	~9.64
Savings From Increased Efficiency in Electrical Production	(~3.88)
Total	~36.86
Absolute (as oppose to relative savings)	~63%

Note that a bit over one sixth of the total will be electrical.

Why deal only with population growth, and not per capita economic growth that exceeds it? We are looking at savings possible through technology available today. This means we assume no breakthroughs in renewables, no hydrogen path, and no inexpensive solar cells. In general the price per BTU of renewable energy has dropped faster than the economy has grown. (For example, the price of photovoltaic cells dropped from almost \$500 per peak watt in 1965 to around \$5.00 per peak watt in 2001²⁶³.)

Per capita economic growth stems from two sources. One, which can be beneficial, is improvement in technology or business processes. Better technology, better workflow, and reductions in waste are all examples of this. Another comes from sweating workers more - lowering wages, making people work longer hours for no extra pay, making people work in more unpleasant or more dangerous working conditions. (For example, real U.S hourly wages for 80% of us peaked in 1972; they have fallen and risen since then, but never again reached the 1972 peak – nor, since 1980, even returned to the 1968 level again²⁶⁴. 100% of benefits from economic productivity increases have gone to capital and the top 20% of wage earners¹. The only reason incomes for the rest of us have risen at all since 1972 is due to longer work hours.) Growth from this second source is not worth the price to the overwhelming majority of us whose hourly wage has been lowered.

¹ The top 20% of households earned more than \$84,000 in 2000.

So if we stick to growth from actual improvement in the way work is done, then we can count on renewable technology to automatically keep up with it. In short we want to demonstrate that the technology we have **now** can maintain the 2010 U.S. per capita GDP through 2050. If we show that, with a transition to essentially zero emission by 2040, then we have shown (by usual economic standards anyway) that normal renewable innovation rates will sustain economic growth over and above population increases.

(To be on the safe side though, you will note that we do have a section near the end of the book where we specifically consider R&D areas that would cover economic growth beyond that in population. It is speculative – but then again so are the innovations that will create such per capita growth. In that context we can consider things like cheap solar cells – because their uncertainty is no greater than the processes which will consume their power.)

End Notes

²⁵⁸United States Department of Energy, Energy Information Administration, "Table 2.1a Energy Consumption by Sector, 1949-2002," *Annual Energy Review*, 2004, United States Department of Energy, Energy Information Administration, 20/Aug/2004 <<http://www.eia.doe.gov/emeu/aer/txt/ptb0201a.html>>. Table 2.1a Energy Consumption by Sector, 1949-2002 (Trillion Btu)

²⁵⁹States Census Bureau, "Section 19 - Energy and Utilities," *Statistical Abstract of the United States 2002*. December 2002. *United States Census Bureau* <<http://www.census.gov/prod/2003pubs/02statab/energy.pdf>>.p572. Energy and Utilities - Table No.892. Electric Power Industry Capability,and Consumption of Fuels:1990 to 2000 [Net generation for calendar years; capability as of December 31]

²⁶⁰Los Alamos National Laboratory, *Los Alamos--Energy Security Overview*. 2003, Los Alamos National Laboratory, 31/Aug/2004 <<http://www.lanl.gov/energy/overview.html>>.

²⁶¹United States Department of Energy, Energy Information Administration, *Annual Energy Outlook 2004 with Projections to 2025*, DOE/EIA-0383(2004). January 2004, Table 2. Energy Consumption by Sector and Source, United States Department of Energy, Energy Information Administration, 21/Aug/2004 <http://www.eia.doe.gov/oiiaf/aeo/excel/aeotab_2.xls>.

Table 2. Energy Consumption by Sector and Source (Quadrillion Btu per Year, Unless Otherwise Noted)

²⁶²U.S. Census Bureau, *Table 1a. Projected Population of the United States, by Race and Hispanic Origin: 2000 to 2050*. 18/March 2004, 16/March/2005 <<http://www.census.gov/ipc/www/usinterimproj/>>.

²⁶³Brian A. Toal, "Renewables:Future Shock,". *Oil & Gas Investor* October 2001, Chemical Week Associates Inc., *National Renewable Energy Laboratory*, 2/Jul/2005 <<http://www.nrel.gov/docs/gen/fy02/31353.pdf>>. p2

²⁶⁴U.S. Bureau of Labor Statistics *Series Reports*. 2/Jul/2005 <<http://data.bls.gov/cgi-bin/srgate>>. Series CEU0500000049 [Employment, Hours, and Earnings from the Current Employment Statistics survey (National)] All Years, Not Seasonally Adjusted, Super Sector - Total Private, Industry -Total Private, Data Type - AVERAGE HOURLY EARNINGS, 1982 DOLLARS

"Production and nonsupervisory workers account for about 80 percent of all employment measured by the CES survey."

Bureau of Labor Statistics, "Planned Changes to the Current Employment Survey," *Employment, Hours, and Earnings from the Current Employment Statistics Survey (National)*, 18/April 2005, 12/06/2005 <<http://www.bls.gov/ces/cesww.htm>>.