Tables to Convert Energy or CO2 (saved or used) to Familiar Equivalents - Cars, Homes, or Power Plants (US Average Data for 1999).

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Energy savings are normally measured in megawatt hours of electricity (MWh) or in million Btu[1], or avoided millions of tons of C (MtC) or of CO2 (MtCO2). But most of us have little "feel" for these strange units, so for the news media we tend to convert to avoided cars, homes, or power plants.

Tables 1-3 will show us how to do this, but first we must define a typical car, home, and power plant - things we can visualize. We define

- a Typical Car with an average fuel economy of 24 mpg, driven 12,000 miles/year for a gasoline use of 500 gallons/year. This suggests a passenger car, not a van or SUV or light truck.
- a Typical Home with an average annual electric use of 12,000 kWh (corresponding to primary energy use back at the power plant, of 125 million Btu) plus 75 million Btu of fuel for heat (typically natural gas), adding to 200 million Btu. Note, for the discussion below, that electricity accounts for about 2/3 of this 200 million Btu.
- a Typical Power Plant with a 500 MW generation capacity, running slightly under 5000 hours per year[2], and thus selling annually 2.5 billion kWh, also called 2.5 TWh (Tera = 10^{12}). Although a typical 20-year-old power has a generating capacity ~ 1000 MW or 1 GW (Giga = 10^{9}), we chose a smaller power plant because newly constructed power plants tend to have a capacity ~ 500MW.

These typical uses are shown in Col. A of the three tables below.

Table 1 converts cars, homes, and plants to "primary" energy (also called "source" energy). Thus the primary energy for electricity includes the energy burned back at the power plant, not just the 30% delivered to the home.

Of the three tables, Table 1 is probably all you need (but below we explain why Tables 2 and 3 give slightly different conversions). Both cost to the customer and air pollution (NOx and CO2 from combustion, SOx from coal) are roughly proportional to primary energy, although, per million Btu, gasoline is 50% more expensive than average electricity or natural gas[3].

How to Use Table 1 (Primary Energy)

Suppose you learn that low-E windows are saving one "quad"/year. (1 quad = 10^{15} Btu, called 1 quadrillion Btu), which is about 1% of the total US energy use. We can use Col. C of Table 1 to divide one million cars

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1.MBtu notation will be completely avoided. Although M normally stands for mega or million it is often interpreted as Roman M or a thousand in conjunction with an English unit such as Btu.
2.A more accurate number is 4850 hours/year (3300 billion kWh/680 GW from table 7.1 in *Monthly Energy Review*, February 2001 and table 35 in *1999 Electric Power Annual, Volume 2,* October 2000 respectively).
3. At $1.50/gallon, gasoline costs $12 per million Btu. Residential electricity at 8.4 cents/kWh, costs $8, and natural gas at 70 cents/therm costs $7.

(62.5 trillion Btu) into 1000 trillion Btu to find that the equivalent number of cars is about 16 million. Similarly we can calculate 5 million equivalent homes or 38 power plants avoided.

How to Use Table 2 (Electricity)

But suppose you learn instead that the 2001 refrigerator standard will save 30 billion kWh = 30 TWh annually. Table 2 reminds us that a typical plant sells 2.5 billion kWh, so the standard has avoided 12 plants. And it reminds us that 1 million homes use 12 TWh, so we have freed up electricity to supply 2.5 million homes.

But we noted above that for every 100 Btu of electric energy, homes use another 50 Btu of fuel, so we have not saved enough energy and pollution to offset 2.5 million homes, but only about 1.7 million[1].

How to Use Table 3 (CO2)

Finally, suppose that manufacturers want to get CO2 credit for the same refrigerator standards, so they use Table 3 to convert the 12 power plants avoided into 18 MtCO2/year. As before, we can divide 18 Mt of CO2 by the 1 million homes row (4.4 MtCO2) to find about 4 million equivalent homes.

Often the CO2 savings will be stated in Mt of carbon, rather than CO2, and we must know that 1 ton of carbon is equivalent to 44/12 = 3.67 tons of CO2.

Col. D of Tables 1 and 3 show that the two tables differ slightly in their equivalence of cars and homes. Table 1 shows that 1 million homes use as much energy as 3.2 million cars, but Table 3 shows that the same 1 million homes produce only as much CO2 as 2.5 million cars. This is because, per Btu, gasoline produces 4/3 as much CO2 as electricity or natural gas.

Which Table to Use?

The conversion by energy (Table 1), electricity (Table 2) and carbon or CO2 (Table 3) differ by up to 50%, and the choice depends on your "model".

Those of us most interested in saving money, primary energy, and air pollution will prefer Table 1; but electric trade-off calls for Table 2 (which has no cars), and CO2 traders will chose Table 3. To avoid confusion, we have presented all 3 tables. The *Metric Prefix and US Multipliers* table shown below is the basis of all notations used in Tables 1-3.

Metric Prefix and US Multiplier

Unit Multiple	Metric Prefix	Symbol	US Multiplier for Btu
10^3	kilo	k	thousand
10^6	mega	M	million
10^9	giga	G	billion
10^{12}	tera	T	trillion
10^{15}	peta	P	quadrillion

1.We can check this 1.7 million homes offset by converting 30 TWh to trillion btu (using the grid's heat rate of 10,500 Btu/kWh), and then using Table 1.

Table 1: Energy use of a typical car and home, and by a 500 MW power plant

	A	B	C	D
	Typical Annual Use (Rounded)	**Conversion to Btu**	**Annual Energy Use (Btu)***	**Energy used in units of one million cars**
1.Passenger Cars, Vans, SUVs, Light Trucks	US Stock (Private and Commercial): 200 million†			
Typical Car	500 gal‡	1 gal = 125,000	62.5 million	–
One million cars	500 million gal	"	62.5 trillion	1
2.Homes	US Stock: 100 million**			
Typical Home (Electricity + Gas/Oil)	200 million Btu	Not needed	200 million	–
One million homes	200 trillion Btu	–	200 trillion	3.2
3.Power Plants	US Stock: 3300 TWh†† ≡ 1320 Plants (½ GW)			
Typical Power Plant (½ GW × 5000 hours/year)	2.5 TWh	1kWh = 10,500‡‡	26.2 trillion	0.4

*. For metric units (e.g. kWh and the metric prefix has been used but for Btu, US multiplier has been used as shown in the table titled *Metric Prefixes and US Multiplier*

†. US Auto Stock: Table MV1 and MV9 in *Highway Statistics 1998*, *http://www.fhwa.dot.gov/ohim/ohimstat.htm*

‡. Table MF21 (for motor fuel use) and Table MV1 and MV9 (for private and commercial auto stock) in *Highway Statistics 1998*, *http://www.fhwa.dot.gov/ohim/ohimstat.htm.* Table 1.10 for average annual miles in *Monthly Energy Review*, DOE/EIA 0035(2000-04) April 2000

**. US Households, Figure 2.1 in *A look at Residential Energy Consumption*, DOE/EIA 0632(97)

††. Table 7.5 in *Monthly Energy Review*, DOE/EIA 0035(2000-04)

‡‡. Table 2.6 and 7.5 in DOE/EIA 0035(2000-04) April 2000, *Monthly Energy Review*. In 1999, the US Electric **Grid** consumed 34.5 quads of source energy to generate and sell 3300 TWh of electricity. This yields a “heat rate” of 10,500 Btu/kWh.

Table 2: Electricity use by a typical home and generated by a 500 MW power plant

	A	D
	Annual Electricity Use	**Electricity use in units of one million homes**
Typical Home	12,000 kWh	–
One million homes	12 TWh	1
Typical Power Plant (½ GW × 5000 hours/year)	2.5TWh	0.2

Table 3: CO_2 Released by Cars, Homes, Power Plants (Units: metric tons of CO_2)

	A	B	C	D
	Typical Annual Use (Rounded)	**Conversion to CO_2***	**Annual Use (CO_2)**	**CO_2 used in units of one million cars**
1.Passenger Cars, Vans, SUVs, Light Trucks	US Stock (Private and Commercial): 200 million†			
Typical Car	500 gal‡	1 gal = 8.8 kg**	4.4 t	
One million cars	500 million gal	"	4,4 Mt	1
2.Homes	US Stock: 100 million††			
Typical Home (Electricity + Gas/Oil)	200 million Btu	1 million Btu = 55 kg‡‡	11 t	
One million homes	200 trillion Btu	"	11 Mt	2.5
3.Power Plants	US Stock: 3300 TWh*** ≡ 1320 Plants (½ GW)			
Typical Plant (½ GW × 5000 hours/year)	2.5 Twh	1 Twh = 0.6 Mt†††	1.5 Mt	0.34

*. Notes 1. 1 Mt/quadrillion Btu = 1 kg/million Btu.
2. 1 tC corresponds to 3.67 tCO_2.

†. US Auto Stock: Table MV1 and MV9 in *Highway Statistics 1998*, *http://www.fhwa.dot.gov/ohim/ohimstat.htm*

‡. Table MF21 (for motor fuel use) and Table MV1 and MV9 (for private and commercial auto stock) in *Highway Statistics 1998*, *http://www.fhwa.dot.gov/ohim/ohimstat.htm.* Table 1.10 for average annual miles in *Monthly Energy Review*, DOE/EIA 0035(2000-04) April 2000,

**. Table B1 on p 104 in *EIA Emissions of Greenhouse Gases in the US*, DOE/EIA - 0573 (98)

††. US Households, Figure 2.1 in *A look at Residential Energy Consumption*, DOE/EIA 0632(97)

‡‡. Table A19 for Mtc on p 133 and Table A2 for primary quads on p 118 in Annual Energy Outlook, DOE/EIA-0383 (2000)

***. Table 7.5 in *Monthly Energy Review*, DOE/EIA 0035(2000-04)

†††. Table A19 for Mtc on p 133 in Annual Energy Outlook, DOE/EIA-0383 (2000)

Converting Power Plants (or Peak Shaving) to “Homes”

In the above analysis, we have discussed energy (kWh) and not power (kW or MW). However, with the California power shortage, there is current interest in converting power to “homes”.

National newspapers often use “1 kW = 1 home” conversion factor. This is nearly but not quite true. A more realistic conversion is roughly 1.6 kW for an average California home, and roughly 2.4 kW for an average U.S. home. This is based on the following assumptions:

An average California home uses approx. 8,000 kWh whereas an average U.S. home uses 12,000 kWh. However, owing to fluctuations in power demand, a typical power plant only runs for approximately 5,000 hours/year and not 8,760 hours/year.