ECO-III-1029

Energy Conservation and Commercialization (ECO-III)

Demystifying Energy Use: From Home to a Power Plant in a Car

Tables to Convert Energy, CO_2 (saved or used) to Familiar Equivalents (India Average Data)

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June, 2010

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Demystifying Energy Use: From Home to a Power Plant in a Car

Tables to Convert Energy, CO_2 (saved or used) to Familiar Equivalents
(India Average Data)[1]

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Background

Energy consumption and savings are normally measured in several different units, but can easily be converted to kilowatt hours (KWh), the unit of electricity. The energy savings can be directly converted into avoided millions of tons of Carbon (MtC) or of carbon dioxide ($MtCO_2$). But most of us have little "feel" for these strange units, so the news media tends to convert energy savings to avoided cars, homes, or power plants.

Tables 1 & 2 will show us how to do this, but first we must define a typical car, home, and power plant for India – things we can visualize. We define:

- A Typical Car with an average fuel economy of 13 km/liter of petrol (LBNL 2009), driven 8,000 km/year (LBNL 2009), with petrol use of 615 liters/year. This suggests a passenger car, not a van or SUV or light truck.
- A Typical Urban Home with an average annual electric use of 1720[2] kWh. This suggests a typical middle-class urban home.
- A Typical (Coal-Fired) Thermal Power Plant with a 600[3] MW (CEA 2009) generation capacity, running for 7060 hours per year[4], and thus generating 4.24 billion kWh annually, (or 4.24 billion units)[5] of electricity. However, considering the thermal efficiency of a typical coal-fired steam power plant[6] to be 32.69%[7], the typical thermal power plant consumes 12.97 billion kWh of primary energy in the form of coal combustion to generate 4.24 billion kWh of electrical energy at the power station. Additionally, transmission, distribution and unaccounted electricity losses were 27.20% (CEA 2009) during the year 2007-08, which means that the actual electricity sold to consumers would only be

[1] **The preparation of the equivalent matrix is an attempt by the ECO-III team to convert energy units into real-world examples that lay persons can understand and relate to. The other objective of the paper is to highlight the difference between source (coal, gas, oil, etc.) and site (electricity) energy and the role it can play in devising sensible energy policies. The paper has been adapted from Equivalent Matrix paper (Rosenfeld and Kumar, 2002) developed for the US. As can be seen, there are many assumptions and estimates that have been used to derive the equivalence concepts with the hope that the feedback that ECO-III team will get will help us improve and refine this document even further.**

[2] Based on LBNL analysis that electricity consumption per urban household will increase from 908 units in 2000 to 2972 units in 2020 – considering a linear rate of growth, this comes to approximately 1720 kWh during 2007-08.

[3] Median value of the 97 coal and lignite fired power plants in the country as on March 31st 2008 (CEA 2009)

[4] Plant load factor of thermal power stations in the country was 80.6% during 2007-08 (CEA 2009). Owing to fluctuations in power demand or operation and maintenance requirements, a typical Indian power plant runs for approximately 7,060 hours/year .

[5] 1 electricity unit = 1 kWh

[6] Steam power plants are Thermal Power Plants which use Coal as the source of primary energy

[7] All India thermal efficiency for coal and lignite based plants during the year 2007-08 (CEA 2009)

72.80% of the 4.24 billion kWh generated at the power plant, that is, 3.09 billion kWh – or, 100 units of electricity saved on site avoid the need to generate 137 units at the source. Effectively, this gives a primary energy factor of 4.20 for coal-fired thermal power plants – that is, 4.20 units of primary energy are consumed to provide 1 unit of electricity where it is used. Conversely, 1 unit of electricity saved on site, avoids the consumption of 4.20 units of primary energy at a typical coal-fired power plant.

These typical uses are shown in Column A of the two tables below.

Table 1 converts energy used in cars, homes, and plants to electrical energy. It compares the annual energy consumption of a typical car, a typical home with the electricity generated by a typical thermal power plant.

Table 1: Energy Use of a Typical Car, a Typical Home, and a Typical Power Plant in India

	A	B	C	D
	Annual Energy Consumption	**Conversion to kWh**	**Equivalent Annual Energy**[8]	**Number of Equivalent Typical Homes (in lakhs)**
Home	Total Indian houses (Urban (73) + Rural (159)): 232 million[9]			
Typical Urban Home	1720 kWh	Not needed	1720 kWh	–
One lakh (0.1 million) typical urban homes	172 million kWh	Not needed	172 million kWh	1
Passenger Car	Indian Stock (Private and Commercial): 7.63 million[10]			
Typical Car	615 liters[11]	1 liter = 10 kWh[12]	6150 kWh	–
One lakh typical cars	61.50 million liters	1 liter = 10 kWh	615 million kWh	3.58
Typical Power Plant (600 MW × 7060 hours/year)	Energy Generated per year: 4.24 billion kWh			
Energy Sold / Used at Site	3.09 billion kWh	Not needed	3.09 billion kWh	17.97
Primary Energy Consumed at Source	12.97 billion kWh	Not needed	12.97 billion kWh	75.41

[8] For all units, the International multiplier has been used as shown in the table titled *Metric Prefixes and International Multiplier*

[9] Measured data for the year 2005 as per LBNL 2009

[10] As on 31st March 2006 (MoSRH. 2009)

[11] As discussed above.

[12] As quoted in Lyons and Plisga 2005

How to Use Table 1 (Electrical Energy)

It is estimated that by implementing the Energy Conservation Building Code (ECBC), 1,975 million units of electricity can be saved annually (BEE n.d.). We can use Column C of Table 1 to divide this by the energy used by one lakh typical urban homes to get an equivalent of approximately 11 lakh homes. This means, implementing the ECBC will allow us to power approximately 11 lakh typical urban homes without the need for adding new power generation capacity. Further, using Column C, we can also determine that the savings from ECBC implementation would be equivalent to keeping approximately 41 lakh typical cars off the roads for an entire year, which is the equivalent of saving 2.53 billion liters of petrol.

It is also estimated that about 400 million light points in India today are lit by incandescent lamps; their replacement by compact fluorescent lamps (CFLs) under the Bachat Lamp Yojana scheme, would lead to a reduction of over 10,000 MW in electricity demand (BEE 2008) during the course of the program. As this is an estimate for demand savings, if one were to account for these at the source, this would free up the capacity of approximately 17 typical thermal power plants (600 MW each) in India, as described above. If one were to account for this demand reduction at site, accounting for transmission, distribution and unaccounted electricity losses, using Table 1, this would free up the capacity of approximately 23 typical thermal power plants in the country. This means that the Bachat Lamp Yojana scheme will allow us to power approximately 411 lakh typical urban homes without the need for adding new power generation capacity.

Table 2 below provides the Carbon Dioxide emission by typical home, car and thermal power plant.

Table 2: CO_2 Released by Cars, Homes, and Power Plants (Units: metric tons of CO_2)

	A	B	C	D
	Typical Energy Consumption/ Generation (Rounded)	**Conversion to CO_2**	**Annual CO_2 Emissions**	**Number of Equivalent Typical Homes (in lakhs)**
Homes (Urban) (Energy consumption)	Indian Stock: 73 million			
Typical Home (Urban) (Electricity)	1720 kWh	1 kWh = 1.11 kg[13]	1.91 t	-
One lakh typical homes	172 million kWh	"	0.19 Mt	1
Passenger Cars (Energy Consumption)	Indian Stock (Private & Commercial): 7.63 million			
Typical Car	615 liters	1 liter = 2.358 kg[14]	1.45 t	-
One lakh typical cars	61.5 million liter	"	0.14 Mt	0.76
Power Plants	Energy Generated per year: 4.24 billion kWh			

[13] As mentioned in Zamuda, C and Sharpe 2007
[14] As mentioned in EIA 2009

Typical thermal plant (Energy sold at user end)	3.09 billion kWh	1 kWh = 1.11 kg	3.43 Mt	18.05
Typical thermal plant (Energy generated at source)	4.24 billion kWh	"	4.71 Mt	24.79

How to Use Table 2 (CO_2)

Similarly we can use Table 2 to calculate tons of CO_2 avoided with the implementation of different energy efficiency policies and measures.

We already know that 1,975 million units of electricity can be saved annually with the implementation of ECBC. This would mean we could save the generation of 2,713 million units of electricity or avoid putting 3.01 Mt of CO_2 into the atmosphere every year. As discussed earlier, this is the equivalent of the CO_2 emitted (at source) by approximately 11 lakh homes annually. Also, using Column C of Table 2, we can see that this is equal to the CO_2 emissions of approximately 22 lakh typical cars every year.

Often the CO_2 savings will be stated in Mt of carbon, rather than CO_2, and we must know that 1 ton of CO_2 is equivalent to 12/44 = 0.27 tons of carbon.

Column D of Tables 1 and 2 shows that the two tables differ slightly in their equivalence of cars and homes. *Table 1 shows that 1 lakh cars use as much energy as 3.58 lakh homes, but Table 2 shows that the same 1 lakh cars produce only as much CO_2 as 76,000 thousand homes. This is because, per kWh, petrol produces less than a quarter of CO_2 as compared to electricity. This concept is important to grasp so that the full benefits of fuel switching options in the context of mitigating climate change can be understood and appropriate energy policies can be developed.*

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

Electricity sold by one power plant is sufficient for approximately 18 lakh homes (Table 1). Dividing this number by 600 MW (capacity of a typical power plant) gives us an average conversion factor of “1 kW = 3 urban homes”. It is important to note here that this is an average number, based on the average urban household electricity use. This is not based on actual demand or peak load from homes, which would be higher, although one would also take into account diversity of use.

Comparisons and Contrasts:

Some pertinent comparisons and contrasts with the US, for some of these metrics, have been noted here.

- An average urban Indian home uses approximately 1720 kWh whereas an average U.S. home uses 12,000 kWh.
- All India average coal-fired power plant efficiency was 32.69% in 2007-08 (CEA 2009), whereas the average efficiency for coal-fired power plants in the US was 33% in 2007 (Koomey 2009).
- Transmission and Distribution (T&D) losses (including unaccounted electricity) in India in 2007-08 were 27.2% (CEA 2009), whereas the T&D losses in the US in 2007 were 6.7% (Koomey 2009). This calls for a pressing need to make reduction in T&D losses an overarching priority in India, especially in view of the persistent power demand and electricity shortage in the country.

- In terms of the newly formulated unit the *Rosenfeld*, which is described as a unit for energy savings, and quantified as 1 Rosenfeld of energy savings being equal to the avoided output of one typical US power plant at the electricity meter, or 3 billion kWh (Koomey 2009) – at current conditions (CEA 2009), in keeping with the data put forth in this paper, an *Indian Rosenfeld* can be taken as equal to the *US Rosenfeld* – as the electricity at the meter by typical coal-fired power plants in India is 3.09 billion kWh.

Which Table to Use?

The conversions for energy (Table 1), and carbon or CO_2 (Table 2) differ in their values, and the choice depends on your "model".

Those of us most interested in saving money, energy, and electric trade-off will prefer Table 1; and CO_2 traders will chose Table 2. To avoid confusion, we have presented both the tables. The Multiplier tables shown below are the basis of all notations used in Tables 1-2.

Indian Multiplier

Unit Multiple	Indian Multiplier
10^3	Thousand
10^5	Lakh
10^7	Crore

Metric Prefixes and International Multiplier

Unit Multiple	Metric Prefix	Symbol	International Multiplier
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

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