Estimating Technical Energy Saving Potential from Improved Appliance Efficiency in Indian Households

Alexander Boegle, MEP Management GmbH
Daljit Singh and Girish Sant, Prayas Energy Group

ABSTRACT

Energy efficiency is attracting greater attention in India, and because of the urgency to reduce energy use rapidly and with limited resources, energy efficiency (EE) efforts need to be targeted to achieve the largest reduction. The first step in such targeting is an assessment of the potential savings from various EE measures.

We assess the technical saving potential assuming all new purchases of appliances in Indian households for a five year period (2009-13) are of the most efficient models available in the Indian market. We use a diverse set of data sources – national sample surveys for appliance ownership, manufacturers associations data for production and growth projections, and sample energy consumption studies.

Our calculations show that replacing incandescent bulbs with CFLs and tube-lights with EE models and shifting to the most energy efficient models for all other appliances for all future sales can result in annual savings of about 57 TWh in 2013 which is a reduction of about 30% from a BAU scenario. Retrofitting of lights accounts for about half the saving while ceiling fans, TVs, refrigerators, and reduction in stand-by power account for another 40% of the savings in households. Selecting a longer time period for the study and including new developments in EE could increase the estimate significantly.

Not all this technical potential is achievable. Further work is needed to determine the cost-effective (economic) potential and achievable potential from the estimate of technical potential.

Introduction

Energy efficiency is attracting greater attention in India, and because there is an urgency to reduce energy use rapidly and resources are limited, it is important to ask how best to target energy efficiency (EE) efforts to achieve the largest reduction. The first step in such targeting of efforts is an assessment of the potential savings from various EE measures.

In the last ten years or so, several researchers have looked at the consumption and saving potential in Indian households. Earlier work (IEI CMIE, 2000; Murthy, Sumithra & Reddy, 2001) focused on identifying components of household electricity consumption but not on savings estimates. Later work included discussion of saving estimates but for the whole residential sector and not by appliance (TERI, 2006). More recently, a study (Letschert & McNeil, 2007) has estimated potential savings by appliance but its projections of consumption and savings were much higher than what actually occurred, probably in part because the data used was quite old.

Seeing these differences and that most of the earlier work is based on fairly old data, we felt that it was useful to update the estimate of saving potential based on more recent data.

In this paper, we assess the technical saving potential assuming all new purchases of appliances in households were of the most efficient models available in India currently. The starting year for our analysis is 2008 and we estimate the technical saving potential over the five year period 2008-2013. In order to estimate the technical potential we require three quantitites for each appliance: (1) stock of the appliance in 2008; (2) estimate of sales 2008-2013; and (3) the energy consumption for the most efficient model and for the business-as-usual (BAU) case.

In the following sections, we describe how we used a diverse set of data sources to estimate the stock, sales, and energy consumption per appliance through the use of national sample surveys for appliance ownership, manufacturers associations data for production and growth projections, and sample energy consumption studies.

Our focus in this paper is not to get precise estimates of energy saving potential but rather to get an understanding, with a reasonable degree of accuracy, of the size of technical savings potential available from various appliances.

Method for Estimating Saving Potential

In calculating the potential for the five year period 2008-13, we focus only on future sales of appliances, and calculate the potential as the difference in energy consumption between a BAU case and a 100% EE case.[1] The BAU case assumes that for the following 5 years the purchasing pattern would remain mainly on lowest first-cost basis, that is only the cheapest model will be bought. In contrast, the 100% EE scenario assumes a shift of all sales to the most efficient appliance. We first determine how many new appliances are going to be sold every year over the next five years, and then determine the difference in consumption between the average appliance bought under BAU and an EE case. For lighting, our calculation of potential is based on a one-time retrofit of the following items: (1) All incandescent bulbs replaced by CFLs; (2) All T12s replaced by T8s; and (3) All magnetic ballasts replaced by electronic ballasts. It is assumed that from then on both BAU and EE will use the same appliance so no additional annual savings will occur.

We recognize that both BAU and EE scenarios are hypothetical scenarios. In general, one would not expect people to buy only the cheapest model in the BAU. However, in the case of India, since many of the future purchases will be made by those households that are now poor or not electrified, they will be highly price sensitive, and therefore the assumption of the cheapest model in the BAU case is appropriate. We also recognize that energy efficiency of appliances for both BAU and the EE case is likely to improve over time. However, given that we are estimating technical potential over a relatively short period of five years, the assumption of no autonomous change in energy efficiency is unlikely to introduce significant error in the result.

Stock of Appliances

Stock estimates are in most cases based on National Sample Survey Organization (NSSO) surveys. However, because the most recent NSSO survey for the relevant data was done in 2004, we could not obtain stock data for 2008 directly from the NSSO surveys. Instead, we

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[1] We use the term 100% EE case to indicate that we assume that all appliances bought in the future will be of the most energy efficient models. We recognize that this is hypothetical because in reality there would be a transition period as consumers moved to more efficient models.

first extracted the stock for 2004 and then used appliance sales data / estimates for the years 2005-2008 to arrive at the stock of appliances for 2008. Because NSSO survey results do not give the stock of appliances directly but instead give saturation levels for the different appliances, we calculated stock of appliances as the product of the saturation level, the number of households, and the number of units of each appliance used per household. While the number of units used per household is close to one for most appliances, it is about 1.8 per household for fans. NSSO surveys do not cover lighting. For lighting, we used data on sales from Electric Lamp and Component Manufacturers' Association of India (ELCOMA) to estimate the stock and future sales.

In order to get sales data for extending the stock data from 2004 to 2008, we used data mostly from the Consumer Electronics and Appliances Manufacturers′ Association (CEAMA) and TV Veopar Journal. We also used stock data from NSSO surveys in 1999, 2002 and 2004 to cross-check sales estimates based on changes in stock. While using sales data to calculate additions to stock, we made appropriate corrections to account for the fact that a part of annual sales is used simply to replace "old" stock and therefore does not contribute to increase the stock of appliances. Table 1 gives the stock of each appliance in 2008 based on our calculations.

Consumption Data

In order to estimate the consumption we reviewed studies of Lawrence Berkeley National Laboratory (LBNL), The Energy and Resources Institute (TERI), International Energy Initiative (IEI) & Centre for Monitoring Indian Economy Pvt. Ltd (CMIE) and an analysis of the Karnataka Survey from 1994/1995 by Murthy, Sumithra & Reddy.

For many of the appliances, there is a large variation in size and type of appliance used in Indian households. All the studies that we reviewed, calculated an average consumption for the appliances. Table 1 gives the stock, consumption per year and total consumption in TWh of the most commonly used appliances in Indian household in 2008. The total consumption in all households of almost 152 TWh in Table 1 is reasonably close to the total of 148 TWh estimated by the Central Electricity Authority (CEA) for 2008, giving us some confidence in the validity of the assumptions we have made in our calculations.

Components of Current Electricity Consumption in Households

In Table 1 we see that a major part of the consumption comes from: fans, lighting (incandescent bulbs and tube lights), refrigerators, ACs, air coolers, electric water heater, televisions (active mode) and stand-by power (incl. Set-Top-Boxes, DVD Players, TVs, and Computers). Together, these nine end-uses or appliances account for almost all the total consumption. Therefore, our study focuses on these nine appliances. Savings from replacement of incandescent bulbs by CFLs form a significant portion of the total savings, and they are included. However, we exclude savings from replacing one type of CFL by another because we expect that there would not be a significant difference in the efficiency of CFLs. We also exclude washing machines, VCRs/VCPs and music systems (incl. radios) because their contribution to total consumption is negligible.

Table 1 - Stock & Consumption (In kWh/Year & Total) of Each Appliance Type in 2008

Type of appliance	Number Per HH	Saturation (%)	Year for Saturation Data	Stock in million	kWh/year	Total TWh
Fan	1.78	51.55	2004	246	112	27.60
Incandescent bulb	NA	NA	-	302	80	24.22
Refrigerator	1.04	12.73	2004	37	588	21.95
Television (TV)*	1.02	37.87	2004	99	175	17.27
Tube light	NA	NA	-	280	107	30.08
Air conditioner	1.20	1.08	2004	5	1199	6.05
Room heater	1.00**	3.23	2002	9	555	5.00
Electric Water heating	1.00**	2.64	2002	10	438	4.58
Air cooler	1.20	7.54	2004	19	195	3.70
Stand-by-power						3.06
Washing machine	1.01	3.58	2002	15	185	2.77
Radio	1.03	28.51	2004	60	33	1.96
Compact Fluorescent Lamp	NA	NA	-	68	22	1.49
Tape recorder, CD player		14.38	1999	37	34	1.24
Computer*	1.00**	1.34	2002	6	105	0.60
Set-Top Box*	NA	NA	-	11	22	0.24
DVD Players*	NA	NA	-	29	1	0.03
VCR VCP	1.02	1.40	2002	3	2	0.01
Total						151.86

* without Stand-by-power ** Authors' assumption

Figure 1 - Focus Areas and Their Share of Total Consumption in 2008

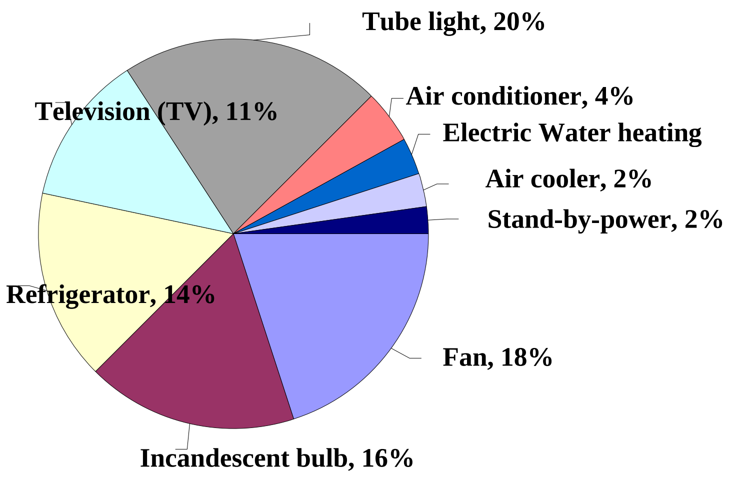

Figure 1 shows graphically the share of the total consumption of the nine appliances we are focusing on. It is interesting that just four appliances / end-uses– lighting (incandescent bulbs and tube lights), fans, refrigerators and TVs– contribute 80% of the household consumption.

Sales Estimates

In order to estimate future sales, an analysis of the past sales was conducted. As discussed earlier we used from CEAMA and TV Veopar Journal to arrive at sales growth rates for the period 2004 to 2008. Based on this data and our judgment we developed estimates for the period 2009 to 2013. For simplicity, we assume that the growth rate remains constant. Since sales are reported for all sectors and not just households, an estimate of the household share is applied. Table 2 shows the result for our focus areas.

Table 2 - Sales in Millions in 2009 and 2013, Growth Rate and Household Share

	Sales in 2008	**Sales in 2013**	Growth rate	% of sales HH sector
Fan	30.00	48.32	10%	85%
Incandescent bulb	734.00	774.12	1%	80%
Refrigerator	5.46	10.99	15%	85%
Television (TV)	16.50	31.08	14%	85%
Tube light	186.00	196.46	1%	66%
Air conditioner	2.63	8.01	25%	60%
Electric Water heating (Geyser)	1.70	3.12	13%	85%
Air cooler	0.90	0.70	-5%	95%
Set-Top Box	5.00	12.44	20%	95%
Computer	7.80	19.41	20%	20%
DVD Players	8.00	11.22	7%	95%

Technical Potential Savings

To simplify our analysis we do not look at individual sizes of appliance, but instead use either an average size or the most common type and size for each appliance. We do not expect that this simplification in the analysis will seriously bias the results of the analysis in either direction, because the impact will be off-setting to some extent. For example, larger savings from bigger appliances will be off-set by smaller savings from smaller appliances. We also exclude technological change that is likely to lower, to some extent, the consumption of the cheapest as well as the most efficient appliance.

To collect data on the energy performance of the cheapest model, we conducted market research on several Indian comparison-shopping websites (naaptol, compareindia, pricesbolo, open2save) and also visited shops selling appliances. To estimate the technical saving potential a review of both, appliance efficiency studies (McNeil et.al. 2005; Letschert & McNeil 2007) and star labeling information for high efficient models according to the Bureau of Energy Efficiency (BEE) (EMT, 2009a, 2009b) was conducted.

Table 3 shows the average consumption of the cheapest model in comparison to the consumption of the most efficient appliance. For this comparison, we give the consumption in watts for appliances where the number of hours of usage will not change between the BAU and EE case, such as light bulbs, TVs and fans, For refrigerators, ACs, and air coolers where cooling capacity is important and hours of operation could change, we provide the consumption in kWh/year. In all cases, the output of the BAU appliance and EE case appliance measured in lumens, tons of cooling etc remains the same.

Table 3 - Average Consumption of the Cheapest and Most Efficient Model

Appliance	Cheapest model	Energy efficient model	Savings (%)
Incandescent bulb to CFL	55W	15W	73%
Direct Cool Refrigerator	350 kWh/yr	179 kWh/yr	49%
Flat Screen TV	73	51	30%
Fan	70	50	29%
Tube light T12 to T8[2]	49	36	27%
Window AC (1.5 ton)	(8.1 EER avg) 1892 kWh/yr	(12.8 EER) 1406 kWh/yr	26%
Air cooler	181 kWh/yr	140 kWh/yr	23%

Special Cases

We now discuss standby losses and water heating for which the potential for savings is calculated in a different manner from that discussed above.

Stand-by losses. Stand-by loss is defined as the electricity consumption of an appliance when it is actually not in use. There are a variety of stand-by/off modes that still consume electricity. For our analysis we include the stand-by losses of Set-Top-Boxes, DVD Players and TVs. We add the off mode of computers (including screens) because the transformer causes a significant consumption in some models even in the off mode. That means if the main supply is not switched off a desktop computer and its screen will continue to consume power. For each appliance the stand-by consumption is estimated based on a small pilot study carried out by Prayas. Table 4 shows the result.

Assuming that 1W becomes the international standard[3], we have assumed in our calculations that the stand-by loss of all appliances can be reduced to 1 W or less. If the future sales from 2009 -2013 were limited to 1 W stand-by consumption that would result in a

[2] We have not opted for T-5, as we do not think it is possible as well as economical or desirable to change all tube lights by T-5s in next five years.

[3] EU has already set standards for standby loss to be a maximum of 1W by 2010 and 0.5 W by 2013 for all appliances. We have used 1W as the standard in our calculations, but using 0.5W will not change the results significantly.

reduction of the 2013 household consumption of about 4.5 TWh. We further assume that an awareness campaign about switching off appliances could reduce the stand-by consumption of the 2008 stock by 50%[4] (1.5 TWh).

Table 4– Stand-By Consumption

Appliance	Stand-by hours / day	Days / year	Stand-by Watt	Stand-by kWh/year	% of appliances on stand-by
Set-Top-Box	16	365	10	58	85%
TV	16	365	7	41	50%
Computer[5]	22	365	9	72	30%
DVD Player	23.5	365	6	51	25%

Water heating. Water heating offers another significant saving of electricity. So far electric water heaters were the most common way of heating water apart from burning wood. However, gas or solar water heating is much less expensive than electric water heating. Thus a shift to gas or solar water heaters can effectively reduce electricity consumption. If 35% of the 2008 water heater stock was replaced by solar or gas until 2013 this would reduce household consumption of electricity by around 3.22 TWh.

Results for Potential Savings

The results of our calculations for the reduction in consumption in 2013 if all future additions of appliances were of the most energy efficient model available today[6] are shown in Table 5 and Figure 2.

We also estimated the reduction in the requirement for new capacity associated with the shift to efficient appliances and the savings of 57 TWh by 2013. As shown in Table 6, based on the annual usage hours and peak coincidence factor for the various appliances, and accounting for T&D losses of 15% and average availability of 90% for new capacity, the potential reduction in capacity requirement is over 25,000 MW by 2013. This is equivalent to avoiding more than one ultra-mega power plant[7] every year for five years.

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[4] Laquatra et. al. (2009) report that almost 70% of those who participated in EE consumer education programs implemented recommended practices. In that case there were face-to-face interactions and therefore their success rate may be higher than the awareness campaign being carried out by the Bureau of Energy Efficiency in India. On the other hand, higher energy prices in India may lead to greater implementation of EE measures. On a conservative basis, we assume that 50% of the population would switch off appliances.

[5] Although in several cases the soft switch-off of the computer keeps the monitor on, and some people keep their computers on for much longer than required; we have not considered these. Only the transformer losses in CPU and monitor are considered

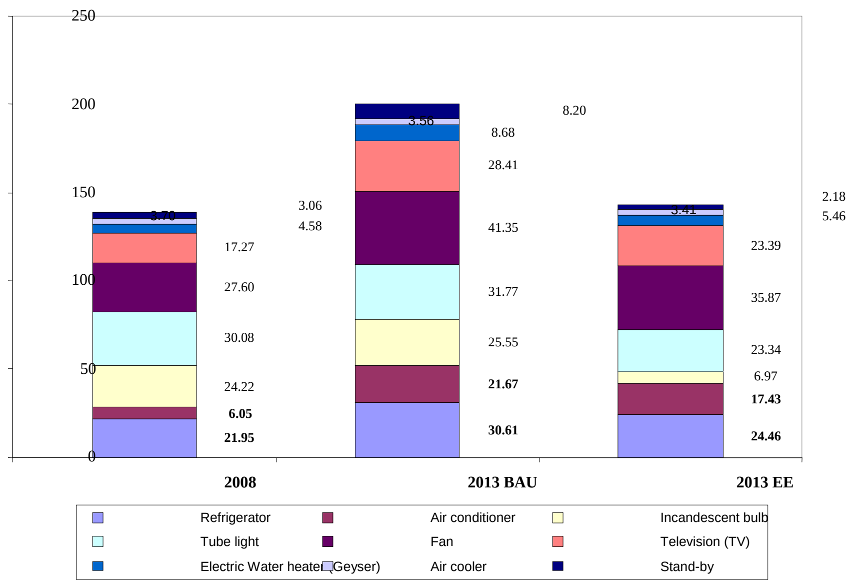
[6]. Note: The figures only displays the savings in consumption in the year 2013 if a complete switch from cheap to EE sales from 2009 onwards is achieved PLUS the special saving potentials are applied. Excluded are savings from replacements of old appliances. Replacements can result in additional savings if the old appliance was less efficient than the cheapest new model.

[7] Ultra-mega power plants are coal-fired generating stations with a capacity of 4000 MW.

Table 5- Potential Savings in TWh in 2013

Appliance	Savings in 2013 TWh
Incandescent bulb	18.58
Tube light	8.43
Refrigerator	6.16
Stand-by-power	6.02
Fan	5.48
Television (TV)	5.04
Air conditioner	4.24
Water heaters	3.22
Air cooler	0.15
Total	**57.32**

Figure 2 – Total Consumption of Key Areas in 2008 and for Both 2013 Scenarios



Further Research

This work shows that a very large amount of energy can be saved over just five years if all new purchases of appliances are of the most efficient models available in the Indian market today. However, more work needs to be done in order to develop a road map for rapidly improving the efficiency of electrical appliances in Indian households. First, the assessment of technical potential needs to be extended to technologies beyond those available in the Indian market today including the world's best available technologies. Second, the period covered in the study needs to be extended to 2020 or 2030 so that long term plans for EE can be developed.

Efforts at improving EE should focus on cost-effective measures only. Therefore, cost-effectiveness of the measures considered in the technical potential need to be determined so that it can be decided how much of the technical potential should be included in the economic potential. This would require the calculation of the cost of conserved energy (CCE) for each measure which can then be compared with the marginal cost of supply to see if the measure is cost-effective. For that calculation, some projection of appliance prices will be required particularly for new super-efficient technologies which may not be widely available in the market.

Table 6- Reduction in New Capacity Requirements by 2013

Appliance	Energy Saved in 2013 (TWh/yr)	Usage days/yr	Usage hrs/day	Peak Coincidence Factor	Reduction in Capacity Reqmts (MW)
Refrigerator	6.16	365	24	1.00	919
Air conditioner	4.24	120	6	0.50	3849
Incandescent bulb	18.58	365	4	0.75	12476
Tube light	8.43	365	6	0.75	3773
Fan	5.48	200	8	0.50	2239
Television (TV)	5.02	365	6	0.75	2247
Electric Water heating (Geyser)	3.22	200	1.25	0.00	0
Air cooler	0.15	120	9.3	0.50	89
Stand-by-power					0
Set-Top-Box	1.90	365	16	0.80	339
TV	1.83	365	16	0.80	327
Computer	0.27	365	22	0.25	11
DVD Players	0.50	365	23.5	1.00	76
TOTAL	56				26345

Note: 1. Calculations assume T&D Loss of 15% and average availablity factor of generating capacity to be 90%

2. The total energy savings is less than 57TWh as calculated earlier because not all appliances shown.

Not all the economic potential will be achieveable during the study period because of consumer preferences and barriers such as high first cost of EE equipment and high discount rate used by consumers in their selection of appliances. The level of barriers will also be affected by the mechanism used to deliver EE. Instead of delivering EE improvement through traditional utility DSM programs, for mass-market appliances, India is considering national or multi-state DSM programs where upstream incentives would be given to manufacturers based on the number of highly efficient (or super-efficient) appliances that the manufacturers sell. It is expected that such programs would reduce transaction costs and lower the required incentives compared to customer rebates. Because incentives will be given to manufacturers based on the number of highly efficient appliances that they actually sell, we expect manufacturers will make extra efforts to sell the highly efficient appliances and thus the program is likely to be more of a success than traditional utility programs.

Conclusions

Our calculations show that nine end-uses or appliances contribute almost all the electricity consumption in Indian households. Furthermore, just four appliances / end-uses– lighting (incandescent bulbs and tube lights), ceiling fans, TVs, and refrigerators are responsible for 80% of the electricity consumption in households. In addition, shifting to the most energy efficient appliances available now for all future sales results in annual savings of about 57 TWh in 2013 which is about 30% of the additional annual consumption that would otherwise have happened under a BAU scenario in the year 2013. It should also be noted that our results indicate that if all new sales are of energy efficient appliances, then the consumption in 2013 will be similar to the 2008 consumption even though many more new appliances will have been added. These potential savings in energy would avoid more than 25,000 MW in generating capacity additions, equivalent to one ultra-mega power plant every year for five years.

Our estimate of the savings potential is really the technical potential because we assume that all appliances from now on will be EE models. Clearly such a shift will occur over time and thus the actual savings achieved will be less. However, we only looked at a short time period of 5 years. A longer forecast and new developments in energy efficiency can increase the savings significantly. Further work needs to be done to expand the estimation of the technical potential to a longer study period. Additional research needs to done on determining the economic and achievable potential which can be the basis for developing a long-term roadmap for improving EE of Indian households.

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