Progress towards Managing Residential Electricity Demand: Impacts of Standards and Labeling for Refrigerators and Air Conditioners in India.

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Abstract

The development of Energy Efficiency Standards and Labeling (EES&L) began in earnest in India in 2001 with the Energy Conservation Act and the establishment of the Indian Bureau of Energy Efficiency (BEE). The first main residential appliance to be targeted was refrigerators, soon to be followed by room air conditioners. Both of these appliances are of critical importance to India's residential electricity demand. About 15% of Indian households own a refrigerator, and sales total about 4 million per year, but are growing. At the same time, the Indian refrigerator market has seen a strong trend towards larger and more consumptive frost-free units. Room air conditioners in India have traditionally been sold to commercial sector customers, but an increasing number are going to the residential sector. Room air conditioner sales growth in India peaked in the last few years at 20% per year.

In this paper, we perform an engineering-based analysis using data specific to Indian appliances. We evaluate costs and benefits to residential and commercial sector consumers from increased equipment costs and utility bill savings. The analysis finds that, while the BEE scheme presents net benefits to consumers, there remain opportunities for efficiency improvement that would optimize consumer benefits, according to Life Cycle Cost analysis.

Due to the large and growing market for refrigerators and air conditioners in India, we forecast large impacts from the standards and labeling program as scheduled. By 2030, this program, if fully implemented would reduce Indian residential electricity consumption by 55 TWh. Overall savings through 2030 totals 385 TWh. Finally, while efficiency levels have been set for several years for refrigerators, labels and MEPS for these products remain voluntary. We therefore consider the negative impact of this delay of implementation to energy and financial savings achievable by 2030.

Introduction

The Indian Bureau of Energy Efficiency (BEE) finalized its first set of efficiency standards and labels for frost-free refrigerators in 2006. These regulations were soon followed after with the publication of levels for direct-cool refrigerators and air conditioners. Both the refrigerator and air conditioner program introduce Minimum Efficiency Performance Standards (MEPS) and comparative labels simultaneously, with levels for one to five stars. Also, both define several successive program phases of increasing stringency. This paper performs an analysis of the likely impacts of both schemes, and consists of three components:

- Cost effectiveness to consumers of efficiency technologies relative to current baseline.
- Impacts on the current market from efficiency regulations.
- National energy impacts.

The analysis relies on detailed and up-to-date technical data made available by BEE and industry representatives. Technical parameters were used in conjunction with knowledge about air conditioner use patterns in the residential and commercial sectors, and prevailing marginal electricity prices, in order to give an estimate of per-unit financial impacts. The overall impact of the program is evaluated by combining unit savings with market forecasts in order to yield national impacts.

The analysis begins with the rating plans drafted by BEE, along with an evaluation of the market baseline according to test data submitted by manufacturers. MEPS, label rating levels, and baseline efficiencies are then presented. Baseline efficiencies are used to estimate the fraction of models likely

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to remain on the market at each phase of the program, and the impact on market-weighted efficiency levels. A Life-Cycle Cost (LCC) calculation is used to evaluate the impacts of the program at the unit level, thus providing some insight into the appropriateness of the levels chosen, and additional opportunities for further ratcheting. In addition to LCC, we also calculate payback periods, cost of conserved energy (CCE), and return on investment (ROI).

Finally, we calculate national impacts. This is an extension of unit level estimates in the two previous sections. Extrapolation to the national level depends on a forecast of equipment purchases (shipments. The scenario corresponding to the BEE plan is combined with shipments through a stock accounting model in order to forecast refrigerator and air conditioner energy consumption in each scenario, and associated electricity.

BEE Draft Standards

BEE's published document announcing the first set of efficiency standards for appliances and other energy-consuming equipment described the philosophy of review and update in the following way:

> *"Instead of setting a very tough standard and rating plan at the onset of the program, a phased approach is being adopted, wherein the rating plan will be upgraded every two years till an internationally benchmarked energy efficiency level is achieved." (Source: BEE)*

The original BEE plan called for implementation of refrigerator standards in 2006, with subsequent updates in 2008, 2010 and 2012. Air conditioner ratings were announced in 2007, with updates scheduled for 2008 and 2010. Each successive update will ratchet the entire scheme up one star rating (two-star units become one-star, three-stars become two, etc.) However, the labeling program was made mandatory only in 2008, thus presumably delaying the updates. The original ratings are shown in Table 1.

Table 1 – Star Ratings for Refrigerators and Air Conditioners

Star Rating	Direct Cool Refrigerators		Frost-Free Refrigerators		Air Conditioners (Window and Split)	
	Consumption (kWh/yr) = *k* * *AV* + *c*				EER	
	k	*c*	*k*	*c*		
Unit	kWh/yr/ℓ	kWh/yr	kWh/yr/ℓ	kWh/yr	W/W	Btu/hr/W
*	0.645	541	0.8716	759	2.3	7.8
**	0.516	432	0.6973	607	2.5	8.5
***	0.413	346	0.5578	486	2.7	9.2
****	0.33	277	0.4463	389	2.9	9.9
*****	0.264	221	0.357	311	3.1	10.6

Refrigerator consumption levels are given by the following formula:

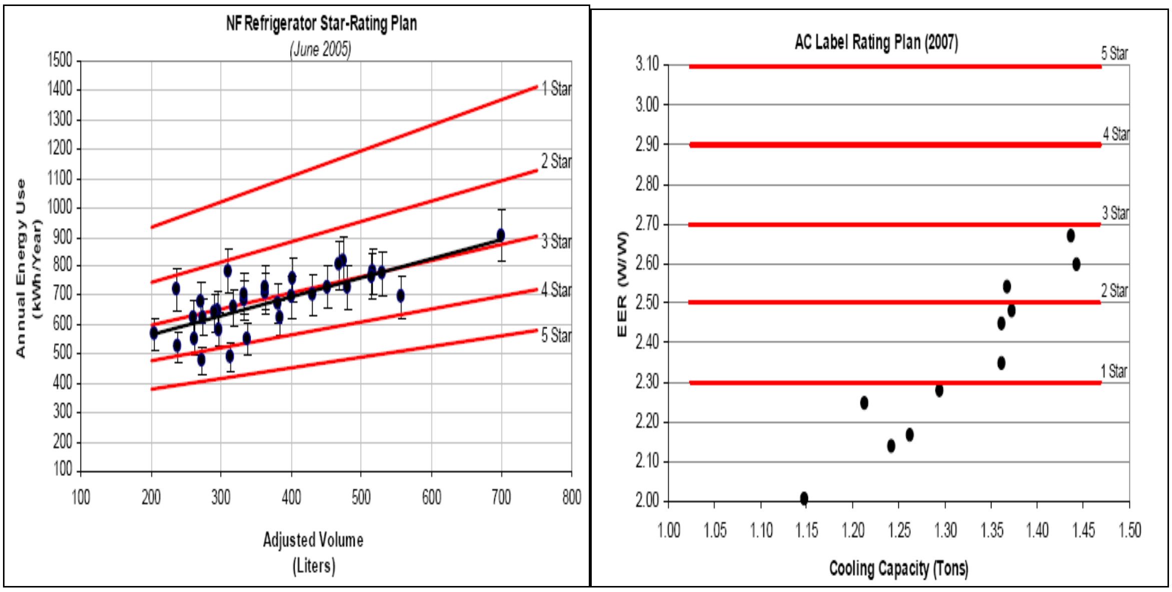
$$\text{Consumption (kWh/yr)} = k * AV + c$$

In this equation, *AV* is the adjusted volume, which is the storage volume of the fresh food compartment plus the storage volume of the freezer compartment multiplied by a constant, which is set at 1.31 for direct cool models, and 1.42 for frost free models. The consumption equation consists of a constant term *c*, and an additional term k, which is multiplied by volume in order to allow for higher consumption for larger units. Air conditioner efficiency is defined in terms of Energy Efficiency Rating (EER), which quantifies cooling energy output divided by electricity energy input. The lowest allowable rating is the one star level. Models not meeting the minimum Energy Efficiency Rating (EER) for this level will be prohibited for sale on the market. Thus, the one star level amounts to a minimum efficiency performance standard (MEPS).

Current Market and Impact of Standards

As part of the regulation development process, a sample of no-frost refrigerators was tested according to the mandated Bureau of Indian Standards (BIS) procedure. No data were available for direct cool refrigerators. However, a sample of models with market share and wattage characteristics were available from an earlier phase of the standards-setting process [1]. Energy consumption was inferred from wattage according to the method used in a report drafted in support of BEE's standards development [2][1]. The results of the market study for frost-free refrigerators and air conditioners is shown in Figure 1.

Figure 1 – Frost Free Refrigerator and Air Conditioner Test Data and Rating Plan



Source: BEE

The results of the test data shows that all of the frost-free refrigerators pass the minimum one-star level, and most fall into the two or three-star category. By contrast, only 6 of the 11 air conditioner models tested will be permitted for sale. Of these, 3 will be rated one star, and three will be rated with two stars. After two updates, where the current three-star level will become the minimum, most of the current frost-free refrigerator models and all of the air conditioners will be prohibited for sale. Therefore, with moderate ratcheting, and assuming that the models tested are representative of the market as a whole, the MEPS and ratings plan are quite stringent. On the other hand, the estimate of energy consumption for direct cool refrigerators in combination with their adjusted volume indicates that ratings for this product class are less stringent, with 51% of models meeting the four-star requirement, and no models rated less than three stars.

Cost Effectiveness

It is important to evaluate the cost effectiveness of efficiency measures for both labeling and standards programs, particularly if these are mandatory, as they are in India. In the case of a labeling program, energy efficiency becomes a marketing tool as an attractive selling point to consumers. The attractiveness of buying energy efficient equipment may be offset somewhat, however, by higher retail prices on these models. In the case of MEPS, cost-benefit analysis is even more critical, since in this case the regulation imposes real costs on the consumer, and generally implementing agencies are reluctant to impose onerous costs. On the other hand, MEPS can generally be engineered such that

[1] By comparing wattage values to available test data, the report concluded that on average, baseline direct-cool refrigerator compressors cycle 38% of the time.

they provide a net benefit to consumers, and a cost-benefit analysis allows for design of regulations that maximize financial benefits, or maximize energy savings to the nation. In this section, we evaluate the cost-effectiveness of a variety of efficiency design options from the consumer viewpoint, and compare them to the MEPS levels set by BEE. In addition, the cost-benefit analysis gives some indication of gains likely to be made by the labeling component, and the construction of alternative efficiency scenarios. The methodologies we use to characterize cost-effectiveness are:

- *Life Cycle Cost* – LCC calculates the net incremental cost over the life of the appliance, including increased equipment (first) cost, and lifetime operation cost savings, which are discounted according to the year from purchase they are accrued.
- *Payback Period* – The number of years after which cumulative operating cost savings exceed incremental equipment cost.
- *Cost of Conserved Energy* – The incremental first cost paid divided by discounted energy savings over the life of the appliance. Cost effectiveness is evaluated by comparing the CCE with prevailing electricity prices.

In order to estimate cost effectiveness, the relationship between equipment prices and efficiency must be known. The most reliable way to generate a *price-efficiency curve* is by considering specific design options known to increase efficiency by certain amount, and their associated costs. The cost of efficiency can be estimated in terms of material costs to manufacturers, which can then be scaled by the appropriate markups in order to estimate retail prices.

Unit Energy Consumption and Retail Price

There are two main product classes for residential refrigerators in India: single-door direct cool (manual defrost) and two-door frost-free. Traditionally, direct cool units have dominated the market, but frost-free units are gaining ground. According to a recent survey of Indian refrigerator manufacturers [1], direct-cool units claim 82% percent of the market, with 18% held by frost-free. While sales of refrigerators are currently growing at about 6% per year, one source indicates, that frost-free sector is growing at 20% per year, indicating a strong market trend towards this product class [3]. The parameters necessary to assess the cost effectiveness of improved refrigerator efficiency are taken from an engineering analysis [4], which evaluated the characteristics of a baseline refrigerator model and utilized a simulation software package in order to determine efficiency benefits. This analysis used cost estimates for a 165 liter one-door refrigerator reported by Indian refrigerator manufacturers. This unit is fairly representative of the direct-cool market in India, as most (66%) direct-cool models sold are in the 165-175 liter range [1]. According to the methodology of [2], we determined that the baseline refrigerator uses an average of 0.98 kWh per day, or 359 kWh per year. Frost-free models are more than twice as energy intensive. According to a sample of models tested by manufacturers, the average consumption of a frost-free model is roughly 2.4 kWh/day, or 876 kWh per year. We proceed by applying the cost efficiency results to direct cool models, and then extrapolating these results to the no-frost class, although we realize that it neglects efficiency options related to the defrosting function.

In order to estimate incremental prices of higher-efficiency models, we scale the percentage manufacturer incremental costs according to an estimate of baseline retail price, taken from a survey of a comparison-shopping website in India (www.compareindia.com)[2]. The average of a sample of 17 models between 165 and 175 liters is $184 at current exchange rates (45.45 Rs/$). For frost-free models, the baseline is around 220 liters, with about half of sales for units within the 220 to 250 liter range. A sample of 18 models from the same retail source yields an average price of $311 for frost-free units between 220-235 liters.

Engineering data for window air conditioners was provided to BEE, and shared with LBNL researchers as part of the development of a techno-economic analysis, which was presented to the

[2] Price data are from a sampling of retail outlets, and therefore we judge them to be competitive and potentially more representative of actual prices paid than manufacturers' suggested retail prices.

Air Conditioner Technical Committee in May of 2006. Data were provided only for window units. We assume that incremental retail prices and the cost-efficiency relationship given for window units also hold for split systems. This assumption is a rough approximation which may not reflect the actual cost-efficiency relationship for split units. As noted earlier in section 2.1, although window units currently account for about 60% of the Indian room AC market[3], the market is quickly transitioning to split units. As a result, costs for window units, which may be reflective of split unit costs today, may no longer be representative of split unit costs in the future as manufacturers put more of their attention on the design and production of split units. Thus, although the efficiency options being considered for window units are similar to what would be applied to split units, their cost implications for split units could significantly change due to manufacturing efficiencies gained by increasing split unit product volumes.

Air conditioner data specify the typical configuration of units currently on the market, that is, the baseline design (Design Option 0). The baseline efficiency is estimated to be around 2.3 EER. As discussed in the previous section, about half of the units tested perform better than this level, and half are below. Each successive design option added to the baseline configuration has the effect of raising the efficiency. In addition, inclusion of these features increases manufacturer costs for materials, labor, and retooling.

Traditionally, commercial firms have been the dominant purchasers of air conditioners in India, but this situation is changing. In 2002-2003, RAMA estimates that half of the air conditioners sold in India were purchased for use in homes, and this fraction rose gradually to 58% by 2006. Because of the significant difference in use patterns and electricity rates between commercial and residential users, we evaluate cost effectiveness separately for each user type. Unit Energy Consumption (UEC) is calculated by estimating the number of hours per day and per month that the business or household operates each air conditioner. Investigations by RAMA indicate the following use patterns:

<u>Commercial Use</u> - *9 months/yr × 25 days/month × 8 hours/day = 1800 hours/yr.*

<u>Residential Use</u> - *6 months/yr × 30 days/month × 8 hours/day = 1440 hours/yr*

The hours of use can be combined with the power consumption of a typical air conditioner in order to arrive at energy consumption. The capacity rating of air conditioners is based on being operated at full power. We assume that the consumer operates the air conditioner at 75% of full capacity on average, and apply a scaling factor of 0.75. A 1.5T unit typically operates at 2kW full power[4]. Therefore, UEC is given by

$$2\text{kW} \times 0.75 \times \text{Hours},$$

which yields 2700 kWh per year for commercial users, and 2160 kWh per year for residential users.

Marginal Electricity Prices and Discount Rates

Residential electricity rates are much lower than commercial rates in India. Residential electricity rates are subsidized to a large degree (but to a much lesser degree than agricultural rates), and consumers pay low rates on average. Rates collected by most State Electricity Boards in India, however, have a residential tariff schedule that charges significantly higher rates for usage above a certain baseline. The impact of higher electricity efficiency will be to reduce consumption in the highest block. Therefore, the relevant consumer electricity savings is calculated according to this *marginal* price. Marginal prices were calculated by LBNL for a previous study using SEB tariff rates that covered most of India, and found to be \$0.059/kWh for residential customers and about \$0.083/kWh for commercial customers [5].

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[3] Source: Indian Refrigerator and Air Conditioner Manufacturers Association (RAMA)

[4] A 2000W unit with baseline EER of 2.29 has a cooling capacity of 4580 W/h, which is typical of the tested sample of 1.5 T units.

Consumers value immediate savings more than future savings. The time value of money is typically accounted for by discounting future savings using a discount rate. There is limited data on which to base consumer discount rates in India. The rate currently used by utilities for their investment in demand-side efficiency programs is 10%. We assume that rates used for other sectors will be somewhat higher, with residential consumers discounting deferred savings by the largest factor. We therefore assume a discount rate of 15% for residential consumers and a slightly lower rate of 12% for commercial consumers.

Life Cycle Cost, Payback Period and Cost of Conserved Energy

Given estimates of retail price, UEC, marginal electricity prices and discount rates, calculation of cost-benefit estimators is straightforward. The first of these is a Life Cycle Cost (LCC) calculation. LCC is given by

$$LCC = P + \sum_{n=1}^{L} \frac{OC}{(1+DR)^n}$$

In this equation, *P* is the appliance retail purchase price, *OC* is the annual operating cost (refrigerator or air conditioning utility bill), and *DR* is the discount rate. The sum runs over the life of the appliance, which we assume to be 15 years for both products. Simple payback period, in years is given by the incremental cost ΔP between two options, divided by the annual operating costs savings ΔOC.

Finally, the cost of conserved energy (*CCE*) is also a useful indicator of the value of the investment into efficiency. Cost of conserved energy is given by

$$CCE = \frac{P}{\sum_{n=1}^{L} \frac{\Delta E}{(1+DR)^n}}$$

In this formula, retail price *P* appears in the numerator, where the denominator is energy savings ΔE over the life of the appliance, discounted in each year after purchase. *CCE* can be compared to electricity prices in order to judge cost-effectiveness.

Table 2 Cost-Effectiveness of Direct Cool Refrigerators

Design	**UEC**		**Equipment Price**	**Elec. Bill**	**Payback Period**	**LCC**	**ΔLCC**	**CCE**
	kWh/day	kWh/yr	$US	$US	Years	$US		$US/kWh
0	0.98	359	$184	$21.31	0.00	$308	$0.00	$0.000
1	0.94	341	$186	$20.24	2.24	$305	-$3.84	$0.023
2	0.76	276	$191	$16.39	1.46	$287	-$21.54	$0.015
3	0.54	196	$203	$11.64	1.96	$271	-$37.58	$0.020
4	0.52	190	$207	$11.29	2.33	$273	-$35.20	$0.024
5	0.49	179	$216	$10.61	2.99	$278	-$30.52	$0.030

For all of the design option combinations shown in Table 2, payback to the consumer relative to the baseline is less than three years, and all of them lower the LCC. Design option 3 has the lowest LCC. We estimate a discounted net savings of about $38 over the life of the appliance for this option. For the design options analyzed, CCE ranges from 1.5 to 3.0 cents per kWh, well below the relevant electricity price. Using the parameters in Table 1, a five-star 165 liter refrigerator with no freezer should consume less than 264 kWh/per year. Therefore, the analysis concludes that efficiency options are cost-effective well beyond the levels set by the labeling scheme.

Table 3 Cost-Effectiveness of Frost-Free Refrigerators

Design	UEC		Equipment Price	Elec. Bill	Payback Period	LCC	ΔLCC	CCE
	kWh/day	kWh/yr	$US	$US	Years	$US		
0	2.40	876	$311	$51.94	0.00	$615	$0.00	0
1	2.28	832	$315	$49.35	1.56	$603	-$11.15	0.01578
2	1.85	674	$323	$39.97	1.01	$557	-$57.89	0.01027
3	1.31	479	$343	$28.38	1.36	$509	-$105.78	0.01378
4	1.27	464	$350	$27.53	1.62	$511	-$103.29	0.01639
5	1.20	436	$365	$25.88	2.07	$516	-$98.35	0.02104

For frost-free units, we assume that incremental equipment costs and energy savings will scale with the direct-cool analysis. The estimated discounted savings for design option 3 is about $106 over the life of the appliance. For the design options analyzed, CCE ranges from 1.0 to 2.1 cents per kWh. From the testing sample, the average frost-free refrigerator is found to have an adjusted volume of 319 liters. For such an appliance, Design 5 corresponds to a four-star refrigerator in the BEE scheme

Cost effectiveness parameters are shown for various air conditioner design options for residential customers in Table 4, and for commercial customers in Table 8. Life Cycle Cost is about twice as high for commercial customers because of the higher electricity rates, higher hours of operation, and a lower discount rate. The lifetime costs for these consumers is over $2,000. First cost only accounts for a sixth of LCC for these users, while it’s about a third of residential user LCC.

Table 4 Cost-Effectiveness of Energy Efficiency – Residential Customers

Design	EER	UEC	Equip. Price	Elec. Bill	Payback Period	Life-Cycle Cost Total	Life-Cycle Cost Change	CCE
	W/W	kWh/yr	$US	$US	Years	$US		$US/kWh
0	2.3	2160	$377	$128	-	$1,150	-	-
1	2.4	2038	$400	$121	3.2	$1,130	-$20	$0.033
2	2.6	1872	$414	$111	2.1	$1,084	-$66	$0.022
3	2.7	1831	$428	$109	2.5	$1,083	-$67	$0.027
4	2.8	1755	$451	$104	3.0	$1,079	-$71	$0.031
5	2.9	1685	$553	$100	6.1	$1,156	$7	$0.064
6	3.3	1504	$743	$89	9.1	$1,281	$132	$0.096

Table 5 Cost-Effectiveness of Energy Efficiency – Commercial Customers

Design	EER	UEC	Equip. Price	Elec. Bill	Payback Period	Life-Cycle Cost Total	Life-Cycle Cost Change	CCE
	W/W	kWh/yr	$US	$US	Years	$US		$US/kWh
0	2.3	2700	$377	$288	-	$2,399	-	-
1	2.4	2547	$400	$271	1.4	$2,308	-$91	$0.023
2	2.6	2340	$414	$249	0.9	$2,167	-$232	$0.015
3	2.7	2289	$428	$244	1.1	$2,142	-$257	$0.018
4	2.8	2194	$451	$234	1.3	$2,094	-$305	$0.021
5	2.9	2106	$553	$224	2.7	$2,131	-$268	$0.044
6	3.3	1880	$743	$200	4.1	$2,151	-$248	$0.066

Design option 4 gives the minimum LCC for both consumer categories, and therefore is the most cost-effective option according to this metric. Using a 2.8 EER product instead of a 2.3 EER model saves commercial consumers about $300 and residential consumers $70. It is important to note that in the commercial user case, LCC of design options 5 and 6 (2.9 and 3.3 EER) are also cost-effective and thus provide savings over the life of the appliance. This is not true, however, in the residential case, where the high price of these models would cause LCC to exceed that of the base case, although at the 2.9 EER level the difference is somewhat marginal. This means that all of the star ratings are cost-effective to consumers, except for the five-star category for the case of residential consumers. It is important to note, however, that currently there are no such units on the market, and over time manufacturers may learn how to produce these products at a lower price. More importantly, electricity tariff reform is a constant and pressing issue in India where residential (and agricultural) consumer tariffs do not currently cover the price of production. It is likely, therefore, that five-star air conditioners will become cost-effective to households in the near future.

The calculation of simple payback yields similar results to the LCC analysis. Payback is almost always less than 3 years for commercial consumers. For residential consumers, payback is between 2.1 and 3.2 years for the first four design options. For the most efficient two options, it is 6 years and 9 years. The discount rate for residential consumers used in the LCC analysis means that this is too long to wait for a return on investment for these users. For commercial consumers, CCE is always less than the marginal electricity price, and it is less for residential consumers for all but the two highest efficiency options.

National Energy Savings

The cost-benefit analysis described in the previous section is a critical element of policy development and evaluation, because it assesses the appropriateness of efficiency targets in terms of impacts on individual consumers. It can also help identify additional opportunities for improvement. Ultimately, however, the goal of any efficiency program is to reduce growth in energy consumption and associated emissions of greenhouse gases and other pollutants at the national level. National energy impacts are evaluated by combining the market average efficiency improvement scenarios with projections of shipments. It takes into account the rate at which new, higher efficiency products will enter the stock by use of a retirement and replacement model.

Market Efficiency Impacts

Energy savings in the appliance market due to an efficiency program depends on the response of the market as a whole. This behavior is impossible to predict with certainty, but conclusions drawn from the current distribution of products is indicative, if not precise. Some market transformation can be attributed to MEPS only, especially as minimum levels are updated. As Figure 1 indicates, the frost-free refrigerator market will be relatively unaffected by MEPS, until the current three-star level becomes mandatory. For direct cool refrigerators, removal of a significant percentage of models from the market would require that the four-star level become mandatory. The impact of MEPS is likely to be more significant for air conditioners about half the models do not pass the current one-star level, and none can be qualified as three-star or above. In developing the S&L scenario, we assume that the labeling scheme become mandatory in 2009, and levels of both products are ratcheted by one star level every two years, in 2011, 2013 and 2015.

The transformation of the market is likely to be greater than that suggested by MEPS alone, for two reasons. First, manufactures implementing efficiency technologies may find that it is cost-effective and in their interest to go beyond the minimum required by the standards. More important, however, is the impact of the labeling program. As mandatory enforcement comes into effect, all models will be rated with at least one star. The goal of the labeling program, however, is precisely to encourage manufacturers to market a significant number of models at the three or four star level.

In the case of refrigerators, we assume that the effect of the labeling program will be such that the average refrigerator efficiency will be 10% higher than it would be in the MEPS Only case. This corresponds to the situation where every model that remains after standards imposed also moves up a 'half star' in ratings. Equivalently, this level of efficiency would be achieved if half of the remaining models sold were a full star level higher than they would be in the absence of a labeling program.

For air conditioners, we also assume that efficiency levels for some models go beyond the requirement of MEPS. In 2009, we assume that the market will be divided evenly into one-, two- and three-star models, with the two and three star models just meeting the efficiency requirement of 2.5 and 2.7 EER respectively. In 2011, the one star models are eliminated. In this year, and 2012, we assume that the market is composed of 33% 2.5 EER (two-star), 33% 2.7 EER (three-star) and 33% at 2.8 EER (the minimum LCC level). Finally, in 2013 and beyond, the 2.5 EER will be eliminated. We then assume that the market will be divided evenly between models of 2.7 and 2.8 EER.

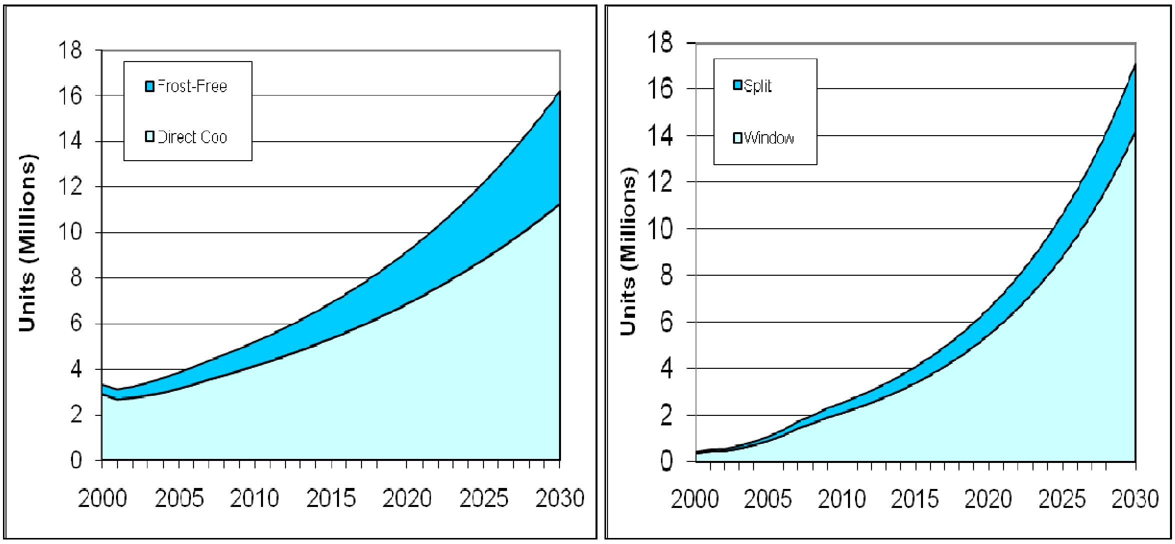
Market Forecast

Currently, about 4 million refrigerators are sold in India each year. Although the market does contain a component due to replacements of old refrigerators, growth is dominated by the entrance of households to the expanding middle class. Total sales of refrigerators in the years 1997-2002 was taken from a recent report [6]. For 2003-2008, we relied on an estimate of sales provided by Euromonitor [3], a marketing research firm. These two sources combined indicate a ten-year average growth rate of 5.9% per year. We assume that this rate of total sales will continue throughout the forecast period. We assume that the market share of frost-free refrigerator will increase from the current rate of 18% to 30% by 2030.

The new and increasing residential customer base for air conditioners has caused dramatic growth in the industry in recent years at rates of more than 20% per annum, according to RAMA. Growth peaked in 2003-2004 at 25%, and has since come down a bit, to 20%. The residential portion of the market grew from 50% to 58% percent over the data period. Sales in 2003-2004 totaled about a million units according to RAMA, and reached 1.5 million by 2005-2006. While we believe the RAMA data to be accurate, a long term forecast based on recent years is difficult. The Indian economy is expected to grow rapidly over the next few decades, but it is hard to be sure whether the current extremely high rates will continue. Therefore, we take the conservative approach and assume that sales will continue to grow, albeit at a more moderate level. Specifically, we assume a 15% growth rate over the next few years, to 2010, after which we forecast that it will stabilize at 10% per annum. The fraction of window shipments is estimated at 60% by RAMA, and is assumed to persist throughout the forecast.

We assume that the fraction of air conditioners which are sold to residential customers will continue to increase throughout the forecast period, at a rate of 2.5% per year, or somewhat lower than the growth rate over the last few years. According to this assumption, the residential market share will reach 64% by 2010, and 82% by 2020.

Figure 2 Refrigerator and Air Conditioner Shipments 2000-2050



National Energy Consumption

When regulations take effect and are stepped up, the average efficiency of products sold increases, but products installed before the new rules become effective are not affected. The number of affected and unaffected stock in each year is tracked by a lifetime accounting model that considers the lifetime of the products and when old inefficient products are replaced with new more efficient ones. Shipments figures allow for an estimate of the total stock of appliances when combined with a retirement function. The retirement function we use is a simplistic one: we assume that the mean life of a refrigerator or air conditioner in India is 15 years, and that units are retired and replaced with an equal probability between the 10th and 20th years after installation[5]. Energy savings is provided by calculating the total energy of the stock in the regulations scenario and comparing it to the *base case*, or 'business-as-usual' scenario. The total energy consumption (*NEC*) of the national stock of products in year *y* is given by:

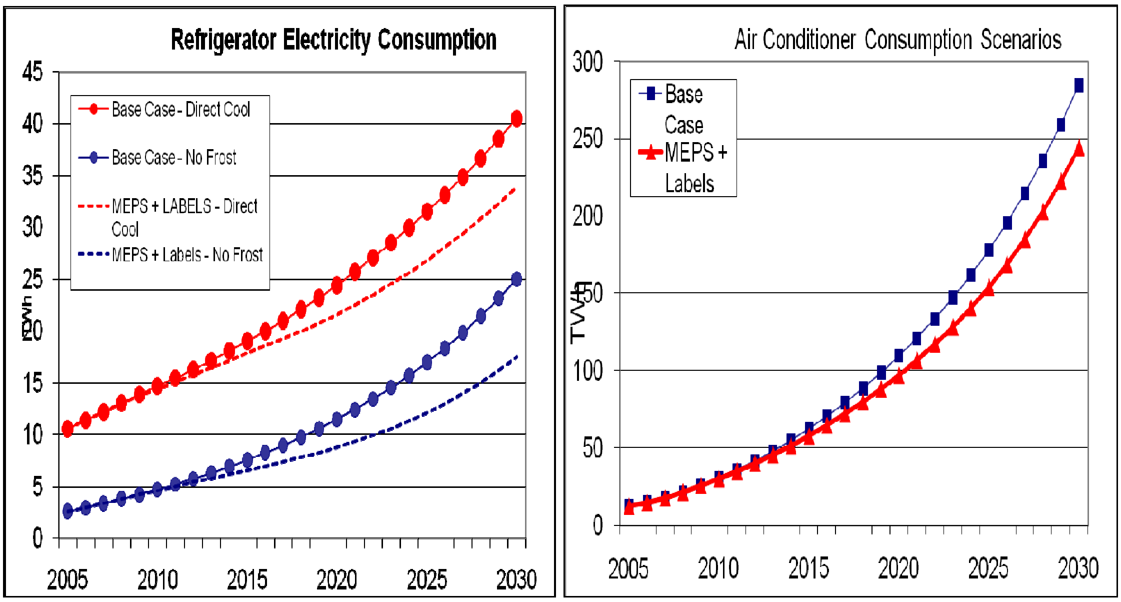
$$NEC(y) = \sum_{age} Stock(y, age) \times UEC(y - age)$$

where the *UEC* of each cohort is determined according to the year of purchase *(y-age)*. For refrigerators, the UEC is estimated from the scenario description above, and UEC is calculated using the UEC for each star category, weighted by the market share of each. For air conditioners *UEC* is given for each scenario according to the following relationship:

$$UEC'(y) = UEC_{Base}\ (y) \times EER(y)_{Base}/EER(y)'$$

The *UEC* in the base case is assumed to remain constant in time for each type of consumer, but decrease overall due to the growth in the fraction of air conditioners used in homes. The results of the NEC for each scenario are shown in Figure 3.

Figure 3 –Air Conditioner Electricity Consumption Scenarios



Several important features can be noticed in Figure 3. First, currently, the consumption of direct cool refrigerators is about three times as high as that of no-frost units since, although these refrigerators use less energy per unit, they dominate the market. As the forecast proceeds, the energy consumption of both products rises fairly rapidly, driven largely by new households entering the refrigerator market. Because the market share of no-frost refrigerators is growing, the energy consumption is growing more rapidly. By 2030, the consumption of surviving direct cool units is larger, but only by about 60%. Overall, in the base case, electricity consumption from Indian refrigerators will increase significantly, with a four-fold increase for direct cool and nearly a tenfold increase for no-frost. Total electricity consumption for refrigerators is estimated at 13.2 TWh currently, but is projected to be 65.5 TWh by 2030.

[5] This is an approximate assumption, since repairs that significantly extend the lifetime of room air conditioners are common in India. The efficiency of extended-life units is expected to degrade. This is likely to affect baseline as well as high efficiency units, however. Therefore, while we acknowledge this point as having an impact on total consumption, we do not consider it has having a significant effect on net savings.

For air conditioner, the most obvious feature is the dramatic growth in consumption that is expected to occur between 2005 and 2030. This growth arises from a simple extrapolation of current sales, and the assumption that sales growth will continue at relatively high rates, although much lower than current rates of 20% per year. By 2020 most of the market will consist of units sold after the implementation of the MEPS and labeling program. Table 9 summarizes electricity consumption and savings results. The results show significant savings in percentage terms for both appliances by 2020, and even more so in 2030. Percentage savings are higher for refrigerators, because refrigerators generally afford more improvement at lower cost (from straightforward insulation measures). In absolute terms, however, by 2030 electricity savings from air conditioners are many times larger than that from refrigerator, due to the high consumption and rapid growth of this appliance. In order to better put these savings in context, we note that the total savings of 18 TWh in 2020 corresponds to 1.4% of total national electricity demand in that year, according to a recent report [7].

Table 6 – Electricity Consumption and Savings Results 2020 and 2030

Annual Savings	**Refrigerators**		**Air Conditioners**		**Total**	
In Year	**2020**	**2030**	**2020**	**2030**	**2020**	**2030**
	TWh		TWh		TWh	
Base Case Demand (TWh)	36	66	110	285	146	351
Policy Case Demand (TWh)	30	51	97	245	128	296
Annual Savings (TWh)	6	14	12	41	18	55
Annual Savings (Percent)	15%	22%	11%	14%	12%	16%
Cumulative Savings from 2009	15	64	58	321	73	385

Conclusions

This paper has considered the impacts of standard and labeling programs for refrigerators and air conditioners recently implemented in India. These appliances are both major consumers of electricity in India, with rapidly growing markets. The growth in air conditioner sales is particularly impressive. We can confidently conclude that the scheme as formulated by BEE is likely to be quite effective, and will save a significant percentage of electricity used by these end uses by 2020 and 2030, when virtually all of the stock will have been installed under the standards regime. Having said this, it is clear that there is room for increased stringency. First of all, the refrigerator standards set seem to have concentrated on frost-free units, and appear to be somewhat lax for direct cool units. Even though frost-free models are increasing in market share, and are much more energy intensive, our analysis finds that direct cool refrigerators will dominate electricity demand, because of their traditional dominance of the market (which may persist for some time due to their low price).

Improvement of efficiency of refrigerators and air conditioners in India is likely to be quite cost effective to Indian consumers. Our analysis finds that adoption of even the highest efficiency levels lower the life-cycle cost relative to the current baseline. This result holds for air conditioners as well, except for the very highest efficiency levels, and only for residential consumers, with the assumption that there is no increase in residential marginal electricity prices, which is unlikely. The cost-effectiveness analysis finds that in general, there is room to even further increase efficiency through the standards and labeling program. Updates in the scheme beyond those already announced by BEE are of course likely, and we hope that the Indian government would consider significantly increasing efficiency levels beyond those identified in the current scheme.

Finally, we note that an analysis such as the one we have conducted here makes a significant assumption about the effectiveness of the program, namely that updates will be issued on time, that compliance with the program will be good, and that a significant enough effort will be placed on publicity and education campaigns (including retailer training) to ensure a strong response to labels by consumers. We have already seen a delay in the program becoming mandatory, effectively resulting in several years in delay of impacts, in which time millions of appliances were sold. We can be optimistic about effective implementation, but not inattentive. Given a relatively robust technical bases for Indian standards, whether or not the predicted savings are achieved will depend on political will, support for BEEs mission at the highest levels of the Indian government, as well as support from the international community of energy experts.

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