Cost-Effective Potential for Improved Energy Efficiency of Key Electrical Products in India

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ABSTRACT

The economy of the world's second most populous country continues to grow rapidly, bringing prosperity to a growing middle class while further straining an energy infrastructure already stretched beyond capacity. At the same time, efficiency policy initiatives have gained a foothold in India, and promise to grow in number over the coming years. For these reasons, a survey of opportunities for efficiency in India is timely. This paper considers the maximum cost-effective potential of efficiency improvement for key energy-consuming products in the Indian context. The products considered are: household refrigerators, window air conditioners, motors and distribution transformers. These products are chosen not only because they consume a significant amount of energy, but because each possesses well-understood design options for efficiency improvement. They include end uses in the residential, commercial, agricultural and industrial sectors, and together they account for about 22% of electricity consumption in India. The analysis estimates the minimum life cycle cost option for each product class, according to use patterns and prevailing customer marginal rates in each sector. This option represents an efficiency improvement ranging between 10% and 60%, depending on product class. If this level of efficiency were achieved by 2010, we estimate that total electricity consumption in India could be reduced by 2.5% by 2020. Using a detailed shipments forecast and stock accounting model, we estimate national energy savings and economic impacts for products of these classes sold between 2010 and 2020. We find a potential for savings of over 150 million tons of oil equivalent and over 500 million tons of carbon dioxide emissions avoided. Net present financial savings of this efficiency improvement totals 5.5 billion dollars.

Introduction

India is a major energy consumer. Its energy consumption growth is rapid and continual. Efficiency policies have a particularly important role to play since so much new equipment is entering the stock. Cost-effective efficiency measures will save consumers money, but they also address other important issues as well. India is currently unable to generate enough electricity to meet demand. To do so, it will have to expend capital to increase generation capacity and reduce system losses. Improved efficiency has the additional benefits of increasing the number of customers served by existing generation and reducing the investment necessary to meet demand, thus allowing for a re-allocation of capital to other projects and/or other sectors of the economy.

This study focuses on four major electrical products in India. Thus, the estimated benefits represent only a part of the total that might be realized through a comprehensive program of

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efficiency improvement applied to a larger set of energy-using products. Our focus is to provide the most specific and technically accurate analysis available. For this reason, we do not consider likely opportunities where solid technical data is not yet available.

The study combines a bottom-up engineering-economic analysis of specific technologies with a projection of the market evolution for each product. For each product, we first study key characteristics (including efficiency level) for specific product classes. The characteristics of the most common current product establish the baseline, for which we gather data on purchase price and energy-use characteristics. Efficiency improvements and their costs are estimated relative to this baseline. We then estimate the energy savings and additional purchase cost associated with specific technologies that enhance efficiency.

Taking typical product utilization and equipment lifetime into account, we calculate the Life-Cycle Cost (LCC) of owning and operating a product at alternative efficiency levels for a typical user. The LCC accounts for the electricity costs paid by the consumer or, in the case of transformers, the costs of electricity generation. We calculate LCC values using discount rates appropriate for each type of user. The typical user is a household in the case of refrigerators, a household or commercial enterprise for room air conditioners, an industrial firm or agricultural operation in the case of motors, and an electric utility in the case of transformers. We based the discount rates on Indian conditions. For each product, we identify the efficiency level with the lowest LCC, which represents the most economically justifiable design for the consumer. Of course, policy makers will consider other important factors besides consumer LCC in reaching their decisions about target efficiency levels, including impacts on manufacturers.

Our estimate of national impacts considers the outcome if all products installed in the 2010-2020 period embody the identified cost-effective efficiency level. The benefits of this High Efficiency scenario are measured against a Base Case in which the efficiency of each product remains at current levels. The approach for estimating the sales of each product for each year in the 2010-2020 period involves use of historical shipments data (for estimating replacement sales), sales forecasts and consideration of the key drivers for growth of each product. The impacts for each year consider the accumulated stock of products sold in the 2010-20 period. We count impacts through 2030. National impacts include financial benefits to consumers, reduction in primary energy consumption, and carbon emissions mitigation.

Consumer Impacts Analysis

To estimate the per-unit impacts of more efficient products on consumers, we used payback period, life-cycle cost (LCC) analysis, cost of conserved energy, and return on investment. The payback period is the time required for savings in operating costs to equal the extra initial cost of a more efficient product. The LCC is given by the following formula:

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

where P is the equipment retail price, OC is the annual operating cost (electricity bill), and DR is the consumer discount rate. The sum ranges over the lifetime of the appliance. The denominator in the sum accounts for the fact that future operating cost savings are valued less by the consumer ("discounted") than immediate first costs. We interpret the design option with the lowest LCC to be the most cost efficient, and therefore an appropriate target for government efficiency programs, pending evaluation of other impacts.

Another indicator of cost-effectiveness is the Cost of Conserved Energy (CCE). Cost of conserved energy is the annualized increase in equipment costs divided by the value of annual energy saved through efficiency. These costs can be compared to the marginal price of electricity in order to assess the benefit to the consumer. Finally, we also present the return on investment (ROI), which is the discount rate at which operating cost savings from the efficiency 'investment' equal the incremental first cost.

The consumer impacts analysis uses marginal energy prices to calculate the reduction in consumer energy costs associated with higher efficiency. Marginal energy prices are the prices paid for the last unit of energy used in a given billing period. To estimate the current residential and commercial marginal electricity price, we obtained and analyzed the prevalent tariff structures. Most Indian residential and commercial consumers purchase electricity from State Electricity Boards (SEBs), so we based our estimates on their published tariffs.[2] We arrived at a national average rate of 5.9 cents per kWh by weighting each state's rate by its urban population (those households likely to have refrigerators). Average marginal commercial rates were obtained using the same methodology, and by assuming a nominal monthly consumption of 500 kWh for commercial enterprises. We arrived at a national average rate of 10.7 cents per kWh by weighting each state's rate by total commercial electricity consumption. The price of electricity for agricultural consumers is currently 3.2 cents per kWh. This low price is only a fraction of the estimated cost of electricity production (7.7 cents per kWh), and is highly subsidized, partially via higher rates for customers in other sectors. We assume that by 2010 prices will increase to 3.8 cents per kWh in accord with government policy on tariff reform, which requires that tariffs cover at least half of the cost of production.

We use the Availability Based Tariff (ABT) to represent the marginal cost of electricity supply or generation. ABT unbundles the availability charge from the energy charge. The average generation cost of 7.7 cents/kWh is estimated based on historical data from the Planning Commission's Annual Report on State Electricity Boards and Electricity Departments. The other component of ABT is Unscheduled Interchange (UI) charges. The weighted-average UI charge for all regions is 4.9 cents per kWh. Adding this to the average generation charge yields a total marginal cost of electricity of 12.6 cents/kWh.

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. The sector discount rates are 15% for residential consumers and 12% for commercial customers.

Refrigerators

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(IMRB 2004), direct-cool units command 82% percent of the

[2] Based on Household consumption level of 100 kWh/month as provided by (Murthy 2001)

market, with 18% held by frost-free. While sales of refrigerators are currently growing at about 6% per year, one source indicates, however, that frost-free sector growing at 20% per year.[3], indicating a strong market trend towards this product class (Euromonitor 2004).

The parameters necessary to assess the cost effectiveness of improved refrigerator efficiency are taken from an engineering analysis (Bhatia 1999), 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 reported by Indian refrigerator manufacturers. In order to more accurately estimate energy savings of current Indian refrigerators, we adopt the methodology of a recent report (Harrington 2004), which estimated a compressor activation rate of 38%, with which, in combination with the wattage ratings provided for current models (IMRB 2004), we determine that the baseline refrigerator uses an average of 0.98 kWh per day, or 359 kWh per year.[4] 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.

In order to estimate incremental prices, 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).[5] 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.

For all of the design option combinations shown in Table 1, 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.

Table 1. Consumer Financial Indicators for Direct-Cool Refrigerators

Design	Energy			Retail Price		Annual Electricity Bill	Payback Period	Life-Cycle Cost		CCE	ROI
	Unit Savi	UEC		Δ	Total	Total		Total	Change		
	kWh/day	kWh/day	kWh/yr	$	$	$US	Years	$US		$US/kWh	p.a.
Baseline		**0.98**	359		**$184**	$21.31	0.00	$308	$0.00	$0.000	0%
Gasket Heat Leak Reduction 25%	0.05	0.94	341	$2	$186	$20.24	2.24	$305	-$3.84	$0.023	44%
Higher EER(4.13) compressor	0.23	0.76	276	$7	$191	$16.39	1.46	$287	-$21.54	$0.015	68%
Increase insulation thickness in door and wall by 50%	0.45	0.54	196	$19	$203	$11.64	1.96	$271	**-$37.58**	$0.020	51%
Increase Evaporator area by 33%	0.46	0.52	190	$23	$207	$11.29	2.33	$273	-$35.20	$0.024	43%
Increase condenser area by 50%	0.49	0.49	179	$32	$216	$10.61	2.99	$278	-$30.52	$0.030	33%

Assumed lifetime: 15 years[6]

[3] STAT-USA Industry Sector Analysis – Refrigeration and Air Conditioning Equipment - India

[4] Although refrigerators may not be operational during every hour of the day due to power outages, we assume that any compressor run time lost is compensated for by the increased cooling necessary when power is restored.

[5] 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.

[6] Estimate by Tata Energy Research Institute, Delhi – http://www.teri.res.in/teriin/news/terivsn/issue3/newsbrk.htm. Last Accessed Jan 10, 2005.

For the design options analyzed, CCE ranges from 1.5 to 3.0 cents per kWh, well below the relevant electricity price. Return on investment to the consumer ranges between 33% and 68%, consistent with payback periods of a year or two. Based on the LCC analysis, we chose design option 3 as the policy target in calculating national impacts. 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. Return on investment to the consumer ranges between 48% to 99%, consistent with payback periods of one to two years.

Air Conditioners

Indian businesses and residences use both window-mounted and split air conditioning units, but window units enjoy 83% of production (IMRB 2004). The market share of split units shows some indication of gaining ground on window units, however. Central air conditioning is still relatively rare in India. Detailed engineering data for air conditioners particular to the Indian market are not available as they were for refrigerators. Air conditioner designs tend to be similar among countries, however, so that design option parameters from the U.S. market may be used as a proxy.

Baseline capacity, retail price and efficiency are estimated from a combination of production data, and model data from www.compareindia.com. Market shares of each cooling capacity category are taken from manufacturer production estimates. The market-weighted average capacity is 1.5 tons, or 18,000 Btu/hr, well within the range of the units covered in the product class analyzed for U.S. DOE minimum efficiency standards. The market-weighted average price of the online models is $497, and the average efficiency level (EER) is 9.1. Changes in EER and equipment cost estimated for various room AC efficiency levels in the U.S. DOE's analysis (USDOE 1997). The annual energy consumption in India is estimated using assumptions about utilization by residential and commercial users.[7]

Incremental costs to manufacturers to implement each design option are assumed to be the same in percentage terms in India as in the United States, and we expect these costs be passed on proportionally to the consumer.

Split-system air conditioners are not considered separately for the engineering analysis. Savings and costs for these units are assumed to follow the same pattern as window air conditioners. Considering the small market share of these units, this creates only a small inaccuracy in evaluation of national impacts.

Traditionally, most air conditioner sales in India have been to commercial customers, but rapid economic growth and the rise of a burgeoning middle class is a large driver of new sales. We therefore assume that in 2010, half of sales will be to residential consumers. Therefore, the relevant marginal energy price for air conditioners is taken to be the simple average of the residential marginal rate (estimated at 5.9 cents/kWh) and the commercial marginal rate (estimated at 10.6 cents/kWh)

As shown in Table 2, design option 3, which achieves 10.2 EER, has the lowest LCC. In calculating LCC for air conditioners, we use a discount rate of 13.5%, which is the average of the

[7] We assume that commercial users (mostly office buildings) use AC 8 hours a day, 20 days a month, and that residential users use AC 4 hours a day, 30 days a month over a 6 month cooling season.

residential discount rate of 15%, and the commercial discount rate of 12%. We estimate a discounted net savings of about $35 over the life of the appliance for this unit. For this design option, the CCE is 3.9 cents per kWh, well below the relevant electricity price. Return on investment to the consumer for this level is 36%, consistent with a payback period of 2.8 years. Based on the LCC analysis, we chose the 10.2 EER design option as the policy target in calculating national impacts.

Table 2. Consumer Financial Indicators for Room Air Conditioners

Design	EER	UEC	Equip. Price	Elec. Bill	Payback Period	LCC Total	CCE	ROI
		kWh/y	$	$	Years	$	$/kWh	p.a.
Baseline	9.0	1191	497	$99	-	$1,078	$0.000	0%
0 + Incr Compressor EER to 10.8	9.7	1105	514	$92	2.4	$1,053	$0.034	41%
1 + Condenser Grooved Tubes	10.0	1074	520	$89	2.5	$1,044	$0.035	40%
2 + Add Subcooler	10.2	1056	527	$88	2.8	**$1,043**	$0.039	36%
3 + Increase Evap/Cond Coil Area	10.7	998	674	$83	11.1	$1,161	$0.157	4%
4 + Incr Compressor EER to 11.3	11.1	966	723	$80	12.2	$1,195	$0.172	3%
5 + Incr Compressor EER to 11.4	11.2	958	746	$79	13.0	$1,214	$0.183	2%
6 + BPM Fan Motor	11.5	932	865	$77	17.2	$1,320	$0.242	-2%
7 +Variable Speed Compressor	12.8	839	1089	$70	20.3	$1,498	$0.286	-4%

Assumed lifetime: 12.5 years

Motors

In general, motors are relatively efficient products when they are run at design loads (80-90%). The reduction of annual energy consumption from efficiency measures is generally of the order of a few percent, or equivalently, a reduction of losses on the order of 10-40%. Such an efficiency improvement can be highly cost-effective due to the extensive operating hours in many agricultural or industrial applications. Operating hours are highly variable, however, producing a large degree of variability in energy savings. We consider two sectors for motor efficiency improvement: agricultural (irrigation pump) applications, and industrial (manufacturing) applications. Incremental manufacturing costs for motors are generally a closely-held trade secret, and are thus difficult to obtain. Therefore we rely on retail price estimates provided by a recent study performed in a cooperative effort between International Institute for Energy Conservation and the International Copper Promotion Council India (IIEC 1999).

The prototype agricultural motor is a 3.8 kW (5 HP) unit typically used as part of an irrigation pump set. The efficiency improvement offered by a high efficiency motor of this capacity is 2%. The improvement in efficiency from 83% to 85% leads to an increase of 15% in retail price, or an additional $27. We assume that pumps are run 1700 hours per year at 75% of their rated capacity (Banerjee and Parikh 1993).

We consider the example of industrial motors of 11kW (15 HP) and 15 kW (20 HP) capacity as representative of the class of motors between 11 HP and 50 HP, which represents roughly 10% of unit sales of low-tension squirrel cage (LTSC) motors (IIEC 1999) in India.

While smaller motors dominate the market, these are less-likely to be used in high-intensity industrial applications, and actual use patterns are more difficult to estimate. Efficiency improvement for a 11 kW (15 HP) motor is 2.2% (20% reduction in losses), while for a 15 kW (20 HP) motor it is 4.5% (39% reduction in losses). Correspondingly, the percentage increase in price is higher for the larger motors (21% for 15 kW vs. 15% in the 11 kW case). Assuming that a typical industrial application has motors running 250 days per year for 2 eight-hour shifts per day, we arrive at an estimate of 4000 hours. We expect this is a typical load, but realize that there is a large amount of variability in operating hours.

As shown in Table 3, our analysis shows that efficiency measures for larger motors and motors used in industrial applications are highly cost-effective, especially for the larger motor. The CCEs are 2.5 cents per kWh for the 11 kW motor and 1.1 cents per kWh for the 15 kW motor. Both CCEs are much below the industrial electricity price. The high-efficiency motor used in agricultural applications has an estimated CCE of 5.1 cents per kWh, which is above the current price but below the cost of production of 7.7 cents per kWh. Thus, the consumer cost-effectiveness for this application depends on reform of agricultural electricity prices.

Table 3. Consumer Financial Indicators for Motors

	Energy		Equipment Price	Operating Cost	Payback Period	LCC	CCE	ROI
	UEC	Losses						
	kWh/year	kWh/year	$US	$US	Years	$US	$/kWh	Per Annum
AGRICULTURAL - 5 HP								
83% Efficiency	5837	992	$190	$224.82	$0.00	$1,263	-	-
85% Efficiency	5720	875	$219	$220.30	6.32	$1,270	$0.051	8%
INDUSTRIAL - 15 HP								
89% Efficiency	37079	4079	$648	$2,824	$0.00	$21,290	-	-
91% Efficiency	36264	3264	$746	$2,762	1.58	$20,934	$0.025	63%
INDUSTRIAL - 20 HP								
89% Efficiency	50562	5562	$561	$7,584	$0.00	$28,708	-	-
93% Efficiency	48387	3387	$678	$7,258	0.71	$27,616	$0.011	277%

Assumed lifetime: 9 years for agricultural, 15 years for industrial

Distribution Transformers

In general, efficiency improvement of distribution transformers in the Indian context is highly cost-effective. For this reason, and for simplicity, we consider only the transformer models that would receive the highest rating under the current rating scheme proposed by the Bureau of Energy Efficiency (BEE), India. The baseline is set at the current standard (IS-1180). Efficiency levels for 5 star transformers are 98.8%, 99.2%, 99.4%, 99.3% and 99.4%.

There are two major components of energy loss incurred by distribution transformers: *no-load losses*, and *load losses*. The first of these occurs whenever the transformer is active, and is not significantly dependent on the transformer load. These losses are related to the transformer core. The other type of loss takes place in the coil, and is proportional to the square of the power passing through the unit at any given time. Load losses are calculated as the square of root-mean-square (RMS) loading adjusted for load growth. We estimate the current RMS loading of the system according to the current average load of 21% of capacity and the current load factor of 0.47. The load is assumed to increase at a constant rate of 1% per year over the life of each transformer.

Retail prices are estimated according to data provided by manufacturers to BEE. The prices submitted through this process reflected the FORD, or the Free on Railway Destination price. This price is close to what can be considered the manufacturer's selling price as it includes sales tax, excise duty, shipping and packaging charges. As shown in Table 4, installation of high efficiency transformers provides a significant financial benefit to utilities. Even though increased incremental costs are large in percentage terms, the reduction in terms of losses is also large. Since transformers incur losses at all times they are in operation, the cumulative energy savings are substantial. As a result, payback period ranges from 4.5 years for the smallest capacity ratings to around 1 year for the 160 kVa class. Cost of conserved energy ranges from 1 to 5.2 cents per kWh, well below the cost of electricity delivery. For the larger capacity transformers, which are the most common, the installation of high efficieny equipment could save the utility thousands of dollars per unit installed.

Table 4. Consumer (Utility) Financial Indicators for Distribution Transformers

Capacity	BEE Rating	Energy	Equipment Price	Cost of Losses		Payback	LCC	CCE	ROI
		UEC		First Year	Average	Period			
kVA	Star	kWh	$US	$US	$US	Years	$US	$/kWh	Per
25 kVA	1 Star	1036	$670	$131	$161	-	$2,101	-	-
	5 Star	441	$1,007	$56	$68	4.5	$1,615	$0.052	19%
63 kVA	1 Star	1834	$1,218	$231	$284	-	$3,750	-	-
	5 Star	797	$1,678	$101	$124	3.5	$2,779	$0.041	26%
100 kVA	1 Star	2619	$1,446	$331	$406	-	$5,062	-	-
	5 Star	1068	$1,951	$135	$166	2.6	$3,426	$0.030	38%
160 kVA	1 Star	3757	$2,438	$474	$583	-	$7,625	-	-
	5 Star	1653	$2,741	$209	$256	1.1	$5,024	$0.013	89%
200 kVA	1 Star	4989	$2,976	$629	$774	-	$9,863	-	-
	5 Star	1880	$3,789	$237	$291	2.1	$6,384	$0.024	49%

Assumed lifetime: 22 years

National Impacts of the High Efficiency Case

The High Efficiency Case assumes achievement of the full cost-effective potential of efficiency improvement. All sales of products during the 2010-20 period are affected by the policy, and savings are estimated from these products only. Sales that occur after 2020 do not affect national energy savings; however, lifetime savings due to units that remain in the stock after this time are included in the net present value. We calculate energy and cost savings until the last unit shipped in 2020 is retired from the stock. Stock is calculated for each year using a straightforward accounting method that takes each year's sales as input, and retires units according to average equipment lifetime.

National Energy Impacts

Total annual energy consumption by consumers in the Base Case and the High Efficiency Case is calculated by multiplying the remaining stock from each cohort by the unit energy consumption. We take into account the likely growth in capacity of frost-free refrigerators by applying a UEC growth rate of 1% for frost-free units over the forecast period. No increase in average capacity over time is assumed for other products. In calculating national energy impacts of a high efficiency policy for air conditioners, we take into account that roughly 5% of the models available on the retail website surveyed (www.compareindia.com) were above the target efficiency level of 10.2 EER. We assume that this percentage corresponds to the sales market share of efficient models, thus lowering the market-weighted base case UEC. Table 5 gives the Base Case and Efficiency Case average UEC values by product in 2010.

Table 5. Average Unit Energy Consumption Values in 2010

Product	Base Case (kWh/year)	Efficiency Case (kWh/year)	Percentage Improvement
Refrigerator - Direct-cool	381	208	45%
Refrigerator - Frost-free	930	508	45%
Room Air Conditioner - Window[9]	1191	1056	11%
Motors - Agricultural – 5 HP	992[10]	875	12%
Motors - Industrial – 15 HP	4079	3264	20%
Motors - Industrial – 20 HP	5562	3387	39%
Distribution transformer - 25 kVA	1036	441	57%
Distribution transformer - 63 kVA	1834	797	57%
Distribution transformer - 100 kVA	2619	1068	59%
Distribution transformer - 160 kVA	3757	1653	56%
Distribution transformer - 200 kVA	4989	1880	62%

Forecast of Product Sales

For each product, we developed a forecast of sales in each year in the 2010-20 period.

Refrigerators. Currently, between 3 and 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 (CLASP 2003). For 2003-2008, we relied on a forecast for sales provided by Euromonitor, 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 25% by 2020.

[9] Consumption patterns and engineering parameters for window air conditioners assumed to hold for split systems for the purposes of this study.

[10] For comparison with other products, energy consumption and percentage improvement for motors is given in terms of losses, thus excluding the useful mechanical output energy produced by the motor.

Air conditioners. Air conditioner sales in India have grown at rates of more than 20% per annum.[11] There is still great potential for growth in the residential sector, as household saturation rates are still around the 1% level. We forecast sales only for the organized sector (currently 80% of the market) as we assume that it would be more difficult to implement efficiency measures in the unorganized sector. Sales in the organized sector totaled 660,000 units in 2002, a dramatic increase from only 264,000 in 1998 (a 17% per annum growth rate). Growth in air conditioners is expected to be even larger during the 2002-2007 period, reaching 25% per annum (Euromonitor 2004). We assume that the growth rates will level to 15% between 2008 and 2010, and remain constant at 10% throughout the period 2010-2020, as saturation effects become significant. We assume that the share of split-system air conditioners remains constant at 17% throughout the forecast period.

Motors. Recent estimates indicate that, as of 2002, over 13 million motorized pump sets were energized throughout India (Planning Commission - GoI 2002). The same report estimates the total potential for pump-sets at just under 20 million. Recent increase in the number of energized pump sets implies new sales of pump sets on the order of 400,000 to 500,000 per year, with a sales growth of about 3.3% in recent years (1995-2001). At this rate, the total potential of 20 million will be approached around 2020. We forecast a smooth approach to market saturation, with energization rates continuing to grow at 1% per year until 2010, but thereafter dropping off proportional to the remaining potential in each year. According to IEEMA production statistics, domestic production of low-tension squirrel cage (LTSC) motors in the organized sector grew from 467,000 in 1992 to 620,000 in 1997, with a high of 715,000 in the intervening years (1994) (IIEC 1999). In addition, there were a large number of imports. Only 10% of the LTSC motors are over than 10 HP (a large fraction of the small motors are accounted for by agricultural pump sets). Between 1998 and 2003, production of 10-50 HP motors is assumed to scale with IEEMA production indices in terms of total motor capacity (IEEMA 2003). After 2003, since motor use is such an integral contributor to industrial production, we assume that motor sales will increase with forecasts of growth in industrial production. These are 5.3% in the period 2004-2010 and 5.7% in the period 2010-2020 (Planning Commission - GoI 2002).

Distribution transformers. Distribution transformer sales are primarily driven by increases in the total generation capacity of the power system. Generation increased at an average rate of 6.7% from 1990-2000. According to energy sector researchers in India, high growth rates are expected to continue through the coming decades, with annual growth rates ranging between 5 and 7% (Planning Commission - GoI 2004). Once the total transformer capacity shipments are determined, shipments of each capacity class are calculated according to estimated market shares of each class.

National Financial and Environmental Impacts

The Net Present Value (NPV) represents the net financial savings to consumers yielded by use of the High Efficiency Case products, discounted to the present year (2005). Financial impacts are calculated at the national level using the aforementioned shipments and stock forecasts. The net savings in each year arises from the difference in incremental equipment and

[11] Source: Euromonitor

operating costs in the High Efficiency Case versus the Base Case. Net Present Value of the High Efficiency Case is then defined as the sum over the forecast period of the discounted net national savings in each year. We make the conservative assumption that marginal rates remain constant at the levels given in the Consumer Impacts Analysis section, and use a national discount rate of 10%, the rate currently used by the World Bank for projects in India.

In general, efficiency measures are highly cost effective to the consumer, thus NPV is positive. The exception is agricultural motors for which the cost of conserved energy is higher than the subsidized tariff of 3.8 cents/kWh. In this case, we model the simple scenario that 50% of incremental costs of equipment to this sector will be subsidized by utility rebate programs or other government incentives. In this scenario, both costs and benefits are shared equally between the utility and the end user, making efficiency investment cost-effective for both parties.

Primary energy savings represent the energy use that would be avoided by the High Efficiency Case. We assume that the current situation of electricity shortages is greatly relieved by 2010 (as envisioned by government plans). Thus, reduced electricity consumption from higher efficiency products has an effect on electricity generation. To the extent that electricity shortages continue in the 2010-2020 period, the primary energy savings and avoided emissions would be lower than presented below, since much of the 'saved electricity' would be sold to a customer whose demand would otherwise be unmet.[12] The calculation of primary energy savings considers the heat rate -- the power plant fuel input needed to produce one unit of electricity, and transmission and distribution losses as a fraction of generation. According to data collected by the Indian Ministry of Non-Conventional Energy (GoI 2003), the heat rate of currently operating plants is 9621 Btu/kWh, equal to an input-to-generation factor of 2.82. This factor is weighted over all electricity generation, including hydroelectric and nuclear (which have assumed factors of 0 and 3, respectively). We calculated the average heat rate for each year in the forecast according to current plants in operation, in combination with planned additions to 2020 (GoI 2003). The T&D loss rate is expected to drop from 32% today to 20% by 2020 (TERI 2001). To calculate avoided CO_2 emissions, we note that the current rate of CO_2 emissions is 0.87 ton of CO_2 per generated MWh. This figure is expected to decrease to 0.79 $T(CO_2)$/MWh by 2020 due to installation of more efficient thermal plants (GoI 2003). Cumulative avoided CO_2 emissions in the High Efficiency Case are summed over the lifetime of all products shipped between 2010 and 2020. Table 6 summarizes costs and savings in the High Efficiency Case, including financial impacts, primary energy savings and carbon mitigation.

Table 6. Estimated Cumulative Primary Energy Savings and Avoided CO_2 Emissions in the High Efficiency Case for products shipped between 2010 and 2020

Product	Additional	Electricity	NPV	Primary	Carbon
	$billion	$billion	$billion	MTOE	Mt CO_2
Refrigerator	0.6	1.9	1.3	77	259
Distribution Transformer	0.7	3.2	2.5	45	153
Room Air Conditioner	0.1	1.3	1.2	23	78
Motor	0.2	0.7	0.5	14	47
TOTAL	1.5	7.0	5.5	159	538

[12] If 'saved electricity' is saved during times when demand is below average, there may not be any unmet demand, and thus no opportunity to sell the 'saved electricity'.

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