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# Business Case for Energy Efficiency in Support of Climate Change Mitigation, Economic and Societal Benefits in India

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**Disclaimer**

*EXECUTIVE SUMMARY*

There is a strong, profit-based business case for investing in more energy-efficient products and designs. Energy efficiency, however, often is viewed as something that businesses and individuals "should" do as good citizens. The reality is that using energy inefficiently is like walking past money on the ground - money that could be put to far better use than paying electricity bills. Investing in energy efficiency therefore creates economic value. As the study title suggests, the high efficiency or *Business Case* scenario is constructed around a model of cost-effective efficiency improvement. Our analysis demonstrates that a significant reduction in energy consumption and emissions is achievable at *net negative cost*, that is, as a profitable investment for consumers.

Energy savings:

- 60 billion kWh per year in 2020
- 140 billion kWh per year in 2030
- A total of 1,250 billion kWh cumulatively through 2030

Cumulative greenhouse gas emissions mitigation:

- 1350 million metric tons of $CO_2$ through 2030

Financial impacts to consumers through 2030:

- Equipment investment of 38 billion USD
- Energy bill savings of 96 billion USD
- Net savings of 58 billion USD

The study finds that by 2030, cost-effective efficiency improvements could save 60 billion TWh, which represents about 20% of total buildings electricity consumption in that year, according to the International Energy Agency's World Energy Outlook[1]. **This corresponds to 7.1% of electricity consumption in India.**

The approach of the study is to assess the impact of short-term actions on long-term impacts. "Short-term" market transformation is assumed to occur by 2015, while "long-term" energy demand reduction impacts are assessed in 2030. The 15-year time frame is significant for many products, in the sense that delay of implementation would result in putting in place energy-wasting technologies, potentially resulting in expensive investment either in additional energy supplies or in early replacement to achieve future energy or emissions reduction targets. Energy savings, greenhouse gas emissions mitigation and financial impacts for each appliance group studied are summarized in Table ES-1.

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[1] World Energy Outlook 2010 Appendix A "Current Policies Scenario"

**Table ES-1 – Energy Savings and Pollutant Mitigation by Appliance Group**

| Appliance Group | Final Energy Savings | | Emissions Mitigation | | Cumulative Financial Impacts | | |
|---|---|---|---|---|---|---|---|
| | In 2030 | Through 2030 | In 2030 | Through 2030 | Cost | Savings | Net |
| | TWh | | mt $CO_2$ | mt $CO_2$ | $ Billions | | |
| Air Conditioners | 46 | 315 | 49 | 339 | 11.0 | 22.5 | 11.5 |
| Standby | 25 | 249 | 26 | 269 | 6.9 | 17.7 | 10.9 |
| Incandescent Lamps | 4 | 207 | 4 | 226 | 2.2 | 14.8 | 12.6 |
| Refrigerators | 24 | 172 | 25 | 185 | 4.9 | 12.2 | 7.4 |
| Industrial Motors | 12 | 95 | 13 | 103 | 4.9 | 9.3 | 4.4 |
| Distribution Transformers | 13 | 95 | 13 | 103 | 3.5 | 9.3 | 5.8 |
| Commercial Lighting | 8 | 59 | 8 | 63 | 0.7 | 5.4 | 4.6 |
| Fluorescent Lamps | 5 | 38 | 5 | 41 | 2.3 | 2.7 | 0.4 |
| Commercial Cooling | 3 | 22 | 3 | 24 | 1.6 | 2.0 | 0.4 |
| **Total** | **139** | **1251** | **147** | **1351** | **38** | **96** | **58** |

The analysis shows that cost-effective efficiency improvement could yield very significant financial benefits to Indian. consumers. Table ES-1 shows that cost-effective efficiency improvements require an investment of 38 billion dollars over the next 20 years, but these investments will return over twice as much over the same period, for a net savings of 58 billion dollars, or of order of one thousand dollars per capita.  Since the study includes only appliance groups for which cost-effectiveness can be clearly demonstrated, the benefits determined represent only a subset of the economy-wide potential.  In addition, the technologies analyzed represent a snapshot of what is currently on the market.  Technological innovations are certain to occur over the coming decades, and these will likely present new opportunities for efficiency improvement, and exert downward pressure on costs.

# 1. Introduction

Some recent examples of studies that have identified potential energy savings from energy efficiency improvements include:

- *Energy Saving Potential in Indian Households from Improved Appliance Efficiency*. (Prayas Energy Group 2010)
- A World Bank Study – *Strategies for Low Carbon Growth in India: Industry and Non-Residential Sectors,* prepared by LBNL. (Sathaye, S. de la Rue du Can et al. 2010).
- "Potential benefits from improved energy efficiency of key electrical products: The case of India." Lawrence Berkeley National Laboratory , Energy Policy 2008 (precursor to this report). (McNeil, Iyer et al. 2008)
- A recent study by LBNL assessing efficiency improvement potential in the residential sector *Coping with Residential Electricity Demand in India's Future - How Much Can Efficiency Acheive?* – Lawrence Berkeley National Laboratory 2007. (Letschert and McNeil 2007)

This study seeks to provide policymakers and other stakeholders with actionable information towards a road map for reducing energy consumption in the most cost-effective way. A major difference between the current study and some others is that we focus on individual equipment types that might be the subject of policies - such as labels, energy performance standards, and incentives - to affect market transformation in the short term, and on high-efficiency technology options that are available today.

The approach of the study is to assess the impact of short-term actions on long-term impacts. "Short term" market transformation is assumed to occur by 2015, while "long-term" energy demand reduction impacts are assessed in 2030. In the intervening years, most but not all of the equipment studied will turn over completely The 15-year time frame is significant for many products however, indicating that delay of implementation postpones impacts such as net economic savings and mitigation of emissions of carbon dioxide. Such delays would result in putting in place energy-wasting technologies, postponing improvement until the end of their service life, or potentially resulting in expensive investment either in additional energy supplies or in early replacement to achieve future energy or emissions reduction targets.

## 1.1. Policies and Programs to Encourage Efficiency

Over the last 10 years, India has been increasingly paying attention to developing an efficient climate change policy. This chapter first describes the framework policies that have been implemented in India to promote energy efficiency actions, notably, the Energy conservation Act of 2001 and the National Mission on Enhanced Energy Efficiency (NMEEE) in India. Following, a description of government actions that concerns the building sector is given. This encompasses appliance and equipment standards and labeling and building codes. Finally, actions that are pursued either by private investors or utilities to increase the penetration of more efficient appliances are explained.

*Energy conservation Act 2001*

The Energy Conservation (EC) Act, signed in 2001, provides the legal and institutional framework for the government of India to promote energy efficiency across all sectors of the economy. A coordinating body called the Bureau of Energy Efficiency (BEE) was created to implement the EC Act. Furthermore, the Energy Conservation Act was recently amended (2010) to empower BEE to accredit energy auditors and to hire its own staff, and to empower the Central Government to issue energy savings certificate.  The need to improve energy efficiency was further emphasized in the National Action Plan on Climate Change (NAPCC), adopted in 2008.

*National Mission for Enhanced Energy Efficiency (NMEEE)*

Recognizing the importance of addressing issues related to climate change, as well as considering economic and social developmental as priorities, India outlined domestic actions towards climate change mitigation in its National Action Plan  for Climate Change in 2008. The National Action Plan contain 8 National Mission that  represent multi-pronged, long term and integrate strategies for achieving key goals in the context of climate change. These Missions are:

- National Solar Mission,
- National Mission on Enhanced Energy Efficiency,
- National Mission on Sustainable Habitat,
- National Water Mission,
- National Mission for Sustaining the Himalayan Eco-system,
- National Mission for a Green India,
- National Mission for Sustainable Agriculture and
- National Mission on Strategic Knowledge for Climate Change.

Each National Missions is institutionalized by a respective Ministry. The National Mission for Enhanced Energy Efficiency (NMEEE) operates under BEE. The Prime Minister's Council on Climate Change approved draft principles of the NMEEE on August 2009 and the Union Cabinet approved its implementation framework on 24th June 2010 with dedicated funds in tune with Rs. 235.35 crores (53 million US$) [2].
The NMEEE contains four initiatives:

The most advanced is Perform Achieve and Trade Scheme (PAT). PAT intends to create a market where large industries can value and exchange energy savings achieved.
The second initiative is Market Transformation for Energy Efficiency (MTEE), which includes accelerating the shift to energy efficient appliances. This initiative includes a list of recommended actions: designing a national CDM roadmap, developing CDM DSM programs (such as the Bachat Lamp Yojana described in the next sections), expending the scope of

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[2] India Ministry of New and Renewable Energy (India MNRE), "Union Cabinet approves National Mission for Enhanced Energy Efficiency Mission " Press Release, 24-June, 2010 20:40 IST, http://pib.nic.in/newsite/erelease.aspx?relid=62791

standards and labeling, organizing public procurement, developing technology programs, reinforcing Energy Conservation Building Codes (ECBC), promoting ESCOs, and encouraging capacity building and information[3]. MTEE also includes an initiative called SEEP (Super Efficient Equipment Program) which envisages developing equipment 50% more efficient than five star appliances. Ceiling fans have been chosen as the first product for this program, with a power consumption of 20-30 watts instead of 50 watts from the five star rating fans. It is planned that an incentive would be payable for every SEEP fan sold by the manufacturers. This could then be further extended to other products like Television in collaboration with other countries.

NMEEE's third initiative is the Energy Efficiency Financing Platform (EEFP). EEFP main goal is to facilitate energy efficiency project financing by engaging bank and investor to fund ESCOs.

Finally, the Framework for Energy Efficient Economic Development (FEEED) has a goal to develop two funds that will be used to guarantee ESCO repayment - the Partial Risk Guarantee Fund (PRGF) and Venture Capital Fund for Energy Efficiency (VCFEE).

## 1.2. Regulatory Actions

*Standards and Labeling Programs*

Standards and labeling (S&L) programs have been identified as one of the key activities for energy efficiency improvement.  In 2006, BEE launched the National Energy Labeling Programme .The program was initially launched on a voluntary basis for two appliances, frost-free refrigerators and tubular fluorescent lamps. In 2010, the labeling became mandatory for these two appliances in addition to air conditioners and distribution transformers while being voluntary for direct cooling refrigerators, induction motors, pump sets, ceiling fans, LPG stoves, storage water heaters (electric geysers), color televisions and washing machines. The label is a comparative label based on 5-star rating system with the annual or daily energy consumption given to allow comparison between models. More recently BEE began actions to include laptops and printers in its star labeling program. Standards for minimum energy consumption have recently (2010) been adopted for 3 products: room air conditioners, domestic refrigerator - frost free & direct cool refrigerator and distribution transformers[4].

*Building Codes*

In 2007, BEE issued the Energy Conservation Building Code (ECBC) which provides minimum energy performance standards for design and construction of commercial buildings with a connected load of 500 kW and above. ECBC takes into account the five major climatic regions of India and is currently a voluntary program. However, a number of states have recently announced that they will adopt it as a mandatory requirement.

In order to accelerate the energy efficiency activities in the commercial buildings, BEE also

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[3] India Ministry of Power (India MoP), 2010. "National Mission on Enhanced Energy Efficiency", http://www.india.gov.in/allimpfrms/alldocs/15659.pdf

[4] CLASP "Summary of S&L Information for India",http://www.clasponline.org/clasp.online.worldwide.php?countryinfo=93

developed a Star Rating Program for office buildings. The energy performance of a building is measured in terms of annual electricity usage per unit of built up area (in kWh/m2/year). Office buildings are rated on a 1-5 star scale taking into account building type, climate and percentage of building area that is air-conditioned, with a 5-star rating being the most energy-efficient (Kumar, Kapoor et al. 2010).

## 1.3.    Voluntary Programs

*Bachat Lamp Yojana*

In February 2009, BEE launched the Bachat Lamp Yojana (BLY) program. The program aims at providing CFLs to grid-connected residential households in exchange of an incandescent lamp and for the price of an incandescent bulb (i.e. Rs 15). The scheme works on a voluntary basis and is a public-private partnership between the Government of India, private sector CFL suppliers and State level Electricity Distribution Companies (DISCOMs) which leverages the Clean Development Mechanism (CDM) of the Kyoto Protocol to recover the cost differential between the market price of the CFLs and the price at which they are sold to households.

Instead of registering separate CDM projects, a programmatic project has been registered by BEE in 2010 to UNFCCC on behalf of the country.  BEE acts as a program coordinator by developing CDM methodology, monitoring  and facilitating verification of certified emission reductions. CFL suppliers secure financing of initial investment for the cost differential and provide quality CFL. DISCOMs then distribute a maximum of two CFL per household in exchange of incandescent bulbs and insure installation[5].

As of Feb 2011, the program has been successful in the state of Kerala where 13 million CFLs have already been distributed, leading to a reduction of 230 MW in peak power consumption. Similar projects are also under implementation in other States including Punjab and Karnataka (Mathur 2011).

*Utility Financial Incentives*

Electricity efficiency programs in India are driven by the need to solve the problem of electricity shortage. Power shortages represent on average 9% of electricity demand and 14% of peak load (G. Pandian 2008). An additional 100 GW capacity is needed by 2012. In this context, energy efficiency options are among the least-cost options to mitigate the gap between demand and supply.

Utility programs in India are voluntary. There is no national prerequisite or state regulation requiring a utility to implement energy efficiency programs. Power sector reform in India started in the early 90's, and the sector is still experiencing reforms. The restructuring started with the introduction of private investment in the supply side. Electricity management is organized at the

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[5] Bureau of Energy Efficiency (BEE), date not specified. "BACHAT LAMP YOJANA CDM based CFL scheme", Ministry of Power, Govt. of India. http://emt-india.com/BEE-BLY/BhachatLampYojna.pdf

state level. Most of the states have constituted a State Electricity Regulatory Commission and in 2007, about 14 had unbundled their state electricity company (The Energy Research Institute (TERI) 2008),(Singh 2006)  Along with this current trend in reform are additional debates to further broaden and deepen the process to institutionalize DSM in energy planning.

Several utilities have implemented some pilot DSM programs.  Ahmadabad Electric Company (AEC) has been a pioneer in this domain. It is the largest private electric utility in India by serving 820,000 customers (Weisbrod, Tribble et al. 1998) Today the utility has several DSM programs among which is included the leasing of energy efficiency equipment to consumers with the help of an ESCO (Prayas Energy Group 2010). Consumers pay for the capital cost over a long period through the achieved savings.

The Maharashtra state electricity distribution company recently implemented a DSM pilot program to replace incandescent bulbs with compact fluorescent lamps. Consumers repay the initial cost through the savings achieved by the use of the CFL over a nine month period in utility bills (Singh, Sant et al. 2007).

Based on an analysis of the economic potential for DSM programs, regulators in the state of Maharashtra announced plans to pursue DSM programs (Phadke, Sathaye et al. 2005). The Maharashtra Electricity Regulatory Commission (MERC) issued an order in April 2008 for utility companies to pursue DSM programs. Current proposals focus on commercial building retrofits, switching from inefficient T-12 to T-5 fluorescent lamps, new commercial buildings, municipal water pumping, etc. Similar programs are being developed in other states in the country such as Delhi.

## 2.  Energy Demand Scenarios

As the study title suggests, the high efficiency or *Business Case* scenario is constructed around a model of cost-effective efficiency improvement.  The point of the study is to demonstrate that a significant reduction in energy consumption and emissions is achievable at a net negative cost, that is, as a profitable investment for society.  There are a variety of ways of assessing costs and benefits to society. We chose to focus on the end user's perspective:  costs in terms of additional retail equipment prices (capital investments); savings from reduced energy bills (operating costs).  Only direct energy savings are included, without valuing non-energy benefits that may also accrue (comfort, productivity, health). Finally, the cost-benefit analysis is made without the elevated effective energy prices that could be implied by carbon taxes, carbon trading schemes or other policies.  Savings relative to the base case as calculated in this way is often referred to as "economic savings potential".

A national-level high-efficiency scenario is constructed by assuming that market transformation to high-efficiency technologies will occur by 2015, which is judged to constitute the "short term" by the study, because it considers that five years is sufficient time to achieve market transformation through aggressive policies and stakeholder actions. The study does not model

specific actions, which could include mandatory standards, voluntary labeling programs, voluntary agreements by manufacturers, utility demand-side-management programs and others[6].

The target efficiency level chosen is that which *maximizes efficiency while providing a net benefit to consumers*. This is to be contrasted with scenarios which maximize consumer payoff but not necessarily efficiency improvement, or those that include the best available technology ("max tech") without consideration of cost-effectiveness. Consumer cost-benefit analysis is evaluated in terms of cost of conserved energy. Cost of conserved energy (CCE) is the amortized incremental cost of equipment divided by annual energy savings. In other words, it's the additional annual capital investment needed to purchase high-efficiency equipment instead of baseline equipment, divided by the energy savings provided by the investment. This quantity, which has units of USD per unit energy, can be compared to prevailing energy prices to assess consumer cost-effectiveness. Technologies with a CCE less than forecast energy prices in 2015 are deemed cost-effective.

A few comments about whether this definition is optimistic or pessimistic are warranted. On one hand, high efficiency technologies are compared to the current baseline technology, even though there may already be a market for higher efficiency equipment, and the average efficiency of the market is constantly improving. This tends to underestimate the baseline forecast and overestimate savings. On the other hand, it likely underestimates the efficiency that will be achievable in a cost-effective way, first of all because technology costs are generally decreasing (according to technological learning rates) and the emergence of new technologies that may not be available for analysis. Therefore, there are two compensating effects not taken into account in the analysis. The results should therefore be taken as representative of the scale of potential improvement, not as a reliable prediction. The methodology is chosen to maximize concreteness and defensibility by relying on technologies that can be justified by actual cost data.

## 2.1. Literature Review

Some recent examples of studies that have identified potential energy savings from energy efficiency improvements include:

*China*

- China's appliance standards are estimated to have saved 1.08 EJ during 2006-2008, with refrigerators, air conditioners and televisions contributing the bulk of the savings. (Price, Levine et al. 2011)

- (Fridley 2008) estimates potential savings of 1.2 TWh in 2012 and 16 TWh by 2020 for energy labels on refrigerators in China.

- (Cheung and Kamg 2008) describe the growth of China's energy efficiency industry, projecting spending of USD 300 billion over five years.

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[6] For simplicity the high efficiency scenario assumes 100% of the market will reach the target level in 2015, a structure that closely resembles minimum efficiency performance standards. In the later years of the forecast, the scenario is not highly sensitive to the details of the market transformation.

- (Aden, Qin et al. 2010) uses lifecycle assessment to show that for buildings in the Beijing area, 80% of energy use and related emissions is due to operations, and about 20% due to materials.

- (Zhou 2010) provides an overview of China's policies on energy efficiency.

*India*

- (Delio, Lall et al. 2009) estimates potential savings from energy efficiency across all sectors in India to be 183 TWh in five years.
- (de la Rue du Can 2009) provides both retrospective and prospective views of energy use in the residential and transport sectors of India.

*United States*

- The National Research Council report, *America's Energy Future,* in 2009 estimated potential cost-effective energy savings in the U.S. of about 20% in 2020 and about 30% in 2030, with the greatest potential in the buildings sector (National Research Council, *Limiting the Magnitude of Future Climate Change*, 2010).
- The American Physical Society report, *Energy Future: Think Efficiency* (2008) estimated 572 TWh of electricity savings in the residential sector in 2030, and about 30% savings for the building sector as a whole, all below the retail price of electricity energy.
- The U.S. Department of Energy's Appliance Standards Programs has conducted extensive studies for regulated product types (http://www1.eere.energy.gov/buildings/appliance_standards/), identifying economically justified and technologically feasible energy efficiency improvements.
- The Energy Information Administration annually publishes additional efficiency scenarios, e.g., high technology cases, in conjunction with the *Annual Energy Outlook* (http://www.eia.doe.gov/oiaf/aeo/).

## 2.2. Construction of the Energy Demand Scenarios

Any study that aims to project energy efficiency improvements from specific technologies must make the link between unit-level improvements and national impacts. The current study achieves this using LBNL's Bottom-Up Energy Analysis System (BUENAS). As the name suggests, BUENAS is a bottom-up technology-oriented model, rather than a top-down macroeconomic model[7]. BUENAS combines unit-level efficiency scenarios with a forecast of stock size and turnover to calculate national energy savings impacts through 2030. Unit level energy demand by baseline and "target" technologies are collected in a database that the model takes as inputs, and which define the base case and high efficiency scenarios. Growth of the stock (number of units operating) by 2030 is a function of economic and population growth.

BUENAS uses minimum efficiency performance standards (MEPS) as a default policy, that is, it models a discrete change in the efficiency of equipment after a specific year. For the current

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[7] BUENAS is described completely in McNeil, M.A., V.E. Letschert and S.A.De la Rue du Can (2008). *Global Potential of Energy Efficiency Standards and Labeling Programs*. LBNL 760E.

study, we chose an implementation year of 2015, assuming that several years lead time are necessary between identification of efficiency targets, and making them mandatory.

Originally constructed as a global model, BUENAS covers a wide range of energy-consuming products, including most appliance groups generally covered by Energy Efficiency Standards and Labeling (EES&L) programs around the world. The global model covered the following appliance groups:

- *Residential Sector:* Lighting, Refrigerators, Air Conditioners, Fans, Washing Machines, Standby Power, Televisions, Electric Ovens, Space Heating and Water Heating.
- *Commercial Building Sector:* Lighting, Air Conditioning, Refrigeration, Ventilation, Office Products, Space Heating and Water Heating.
- *Industrial Sector:* Electric Motors.

For the purposes of the *India Business Case for Energy Efficiency*, many of the end uses needed for the analysis were present in BUENAS. However, some modifications were made. First, the *Business Case* model is dependent on an evaluation of cost-effectiveness. Therefore, appliance groups for which data were insufficient to permit this calculation were not included. On the other hand, some equipment types for which data were available were not included in the original model, such as distribution transformer. In that case, this end use was added. While residential fans are a very important end use in India, cost data for this appliance were not available at the time of the analysis, so they are omitted. Finally, televisions are not covered here. While efficiency improvements are certainly possible in television displays, this is a dynamic and rapidly evolving technology. Recent market trends include a massive shift to flat panel technology, with dramatic increases in screen size, along with market-driven efficiency improvements. Because of the dynamism in television technology, efficiency baselines and technology trends cannot be adequately forecast in order to provide definitive cost-effective improvement potential.

The BUENAS model uses the Long Range Energy Alternatives Planning (LEAP) platform[8] to forecast energy consumption by end use from 2005 (base year) to 2030. The strategy of the model is to first forecast end use *activity*, which is driven by increased ownership of household appliances and growth in the industrial sector. The total stock of appliances can be modeled either according to an econometric diffusion model or according to unit sales forecasts, if available. Electricity consumption or *intensity* of the appliance stock is then calculated according to estimates of the baseline intensity of the prevailing technology in the local market. Finally, the total final energy consumption of the stock is calculated by modeling the flow of products into the stock and the marginal intensity of purchased units, either as additions or as replacements of old units. The high efficiency or "policy" scenario is created by the assumption of increased unit efficiency relative to the baseline starting in a certain year. For example, if the average baseline unit energy consumption (UEC) of new refrigerators is 450 kWh/year, but a MEPS taking effect in 2012 requires a maximum UEC of 350 kWh/year, the stock energy in the policy scenario will gradually become lower than that of the base case scenario due to increasing

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[8] More information about the LEAP platform may be found at http://www.energycommunity.org

penetration of high-efficiency units under the standard. By 2030, the entire stock will generally be impacted by the standard[9]. Figure 1 shows the analytical structure of BUENAS.

**Figure 1 - Structure of BUENAS**
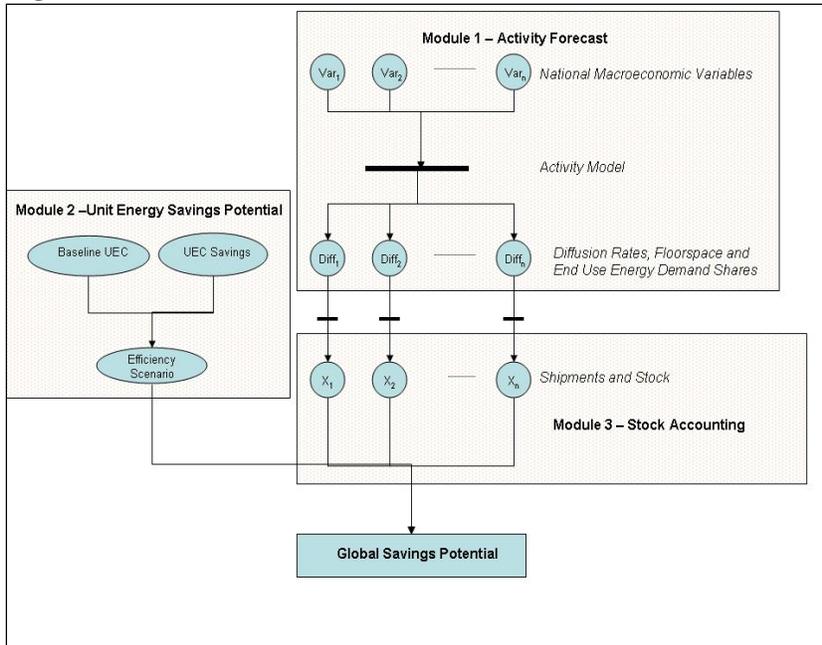


The main outputs of BUENAS are base case energy consumption forecasts to 2030 by end use and energy, energy saving impacts of the modeled policy, and carbon dioxide emissions mitigation impacts. For this study, financial impacts were added to the model in a spreadsheet calculation.

For the residential sector, *activity* as modeled in Module 1 of the model is given by the stock of equipment, that is, the number of appliances installed and operating in Chinese households in a given year.

Once the number of residential products in each appliance group in each year is established, this number is multiplied by the *annual unit energy consumption* (UEC) to yield energy demand for the appliance group. *UEC* is the subject of Module 2 of BUENAS, and determines the efficiency scenario modeled. Determination of the baseline and efficiency scenario UEC is discussed in Section 3 below.

Finally, Module 3 tracks the introduction of each year's cohort of appliances into the stock, taking account of growth in the market, equipment retirements, and replacements. Retirement and survival functions are derived from average lifetimes and assumed to have a distribution around the mean value. This shape of the retirement function is assumed to be that of a normal distribution centered around the mean lifetime by default, but takes the form of a more

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[9] This depends somewhat on the lifetime of the product. For refrigerators we may assume a 15 -year lifetime, but some refrigerators may last 20 years, so the turnover of the stock may not be complete by 2030.

complicated function (Weibull distribution) if such a distribution is available. The survival function is given by:

$$Survival(age) = 1 - \int Retirement(age)$$

Using the retirement distribution, the model calculates the weighted average efficiency of the stock in each year. In the case of the high efficiency scenario, only a small fraction of the stock operates at high efficiency in the years immediately following the policy start date, but this fraction grows over time. The percentage of stock operating in 2030 that was installed after the policy start date is dependent on the assumed average lifetime of the product class.

Compared to the residential sector, energy demand in the commercial building sector is driven by a much wider variety of equipment types and follows distinct usage patterns depending on the type of building. For this reason, BUENAS models commercial buildings in an aggregate fashion, rather than at the level of individual appliances. In Module 2, the commercial sector model uses aggregate energy intensity numbers for major appliance categories, such as lighting, space heating and air conditioning and refrigeration. In order to model energy demand and savings from efficiency improvement, we estimate the fraction of energy covered by individual technologies for which data are available. Energy and demand are thereby calculated from base year values of energy intensity according to a scaling factor.

## 3. Efficiency Improvement Potential – Cost-Benefit Analysis

Cost-effectiveness is defined in terms of cost of conserved energy, that is, how much the end user must pay in terms of annualized incremental equipment investment for each unit of energy saved by higher efficiency equipment. The formula for cost of conserved energy is

$$CCE = \frac{I \times q}{S} \qquad \textbf{Eq. 1}$$

In this equation, $I$ is the total additional investment needed to purchase high efficiency equipment rather than the baseline technology, and $S$ is the resulting annual energy savings. The capital recovery factor $q$ is given in turn by:

$$q = \frac{d}{(1-(1+d)^{-L})} \qquad \textbf{Eq. 2}$$

In this equation, $d$ is the end user discount rate and $L$ is the average lifetime of the equipment, in years. Defined in this way, $I$ times $q$ is an annual payment for an amortized capital investment. Cost of conserved energy is a convenient metric for comparison of cost-effectiveness of measures[10].

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[10] Other metrics such as life cycle cost and payback period establish cost effectiveness, but are not easily compared across disparate technologies and end uses.

## 3.1. Equipment Data

Since we know of no systematic database of efficiency and cost of energy-using equipment in India, the evaluation of cost-effectiveness of Indian efficiency technologies for this study relied on a variety of sources. Identification of efficiency for refrigerators and air conditioners was facilitated by the mandatory Energy Label program and studies related to it (Tathagat and Anand 2011). In the case of lighting and other commercial equipment, we drew on data collected for a previous study performed at LBNL for the World Bank (Sathaye, S. de la Rue du Can et al. 2010). Likewise, the distribution transformer analysis utilizes data from an earlier study (McNeil, Iyer et al. 2008). Finally, we find industrial motor efficiency improvement to be cost effective base on pricing data from the United States. Assumptions of baseline energy consumption, high efficiency levels and price data sources are shown in Table 1.

*Incandescent Lamps*

Replacement of incandescent lamps with compact fluorescent lamps (CFLs) or other technology such as LEDs is generally at the top of the list of attractive efficiency measures because of the large fractional savings (up to 75%) and the high degree of cost-effectiveness. Bans on incandescent lamps are also among the most popular efficiency policies globally.

Indeed, due to Bachat Lamp Yojana and other government programs, we expect increased penetration and eventual phase out of incandescent lamps in favor of CFLs in the base case scenario. In this case, the high-efficiency scenario is characterized by an acceleration of existing policies leading to a complete phase out of incandescent after 2015. In order to model energy savings, we assume that the typical incandescent lamp in India is 60W and is operated for 4 hours per day on average in the residential sector and 8 hours per day in the commercial sector, for an annual energy consumption of 87.6 kWh and 175 kWh respectively. An equivalent CFLs is assumed to use only 15W, or 21.9 kWh and 43.8 kWh per year respectively. We assume that a CFL lasts for 5 years, compared to only 1 year for incandescent lamp.

*Fluorescent Lamps*

Fluorescent tube lights account for approximately 43% of the lighting fixtures in residences (Prayas Energy Group 2010) and roughly 70% of lighting in the commercial sector (Sathaye, S. de la Rue du Can et al. 2010) in India. The baseline fluorescent ballast is taken to be a 40 watt T12 lamp coupled with a magnetic ballast, and is estimated at 46W total. For a high-efficiency option, we consider a high performance T8 with an electronic ballast, estimated at 41W. We assume fluorescent lamps operate for 4 hours per day in the residential sector and 8 hours per day in the commercial sector. With these estimates and assumptions, baseline fluorescent lamp-ballast combinations consume 67.2 and 134.3 kWh per year in the residential and commercial sectors respectively, while high-efficiency combinations consume 59.8 and 119.5 kWh respectively. The lifetimes of fluorescent ballasts are assumed to be 15 years

*Refrigerators*

Estimates for refrigerator improvement potential are based on the current BEE labeling scheme. Current market shares indicate that the bottom of the market is roughly at the 4-star level for direct cool refrigerators and at 3 stars for frost-free refrigerator-freezers (Tathagat and Anand 2011). For high-efficiency, we consider a target of 5-stars[11]. As determined by the labeling definitions, we estimate baseline energy consumption to be 337 kWh for direct cool refrigerators and 675 for frost-free. The 5 star target corresponds to 269 and 432 kWh respectively. In modeling national energy savings from refrigerators, we include a shift from direct cool refrigerators to frost-free units, from 15% frost free in 2005 to 75% in 2030. We assume that a refrigerator lasts 15 years (McNeil, Iyer et al. 2008).

*Room Air Conditioners*

Room air conditioners are also covered by the 5-star BEE labeling scheme. The Indian room air conditioner market includes both window and split type units, with a somewhat larger share for split units. Roughly speaking, the room air conditioner market was found to be at the 2-star level for window units and 3 stars for split units, with about 16% of the overall market still at the 1-star level. Market weighted efficiency for both types of units is 2.61[12]. Air conditioner annual energy consumption is calculated assuming a 6 month cooling season and 8 hours per day use (McNeil and Iyer 2009). The typical unit is assumed to be a 1.5 ton unit operating at 75% capacity, which yields 2160 kWh per year for residential consumers.

As in the case of refrigerators, the analysis is limited to considering the 5-star case due to data considerations. This corresponds to an EER of 3.1 W/W. Scaling the baseline efficiency by energy efficiency yields a target energy consumption of 1812 kWh per year. Room air conditioners also account for roughly 30% of mechanical cooling in commercial buildings. These are considered in the commercial air conditioning section below. The average lifetime of Room Air Conditioners is assumed to be 15 years (Letschert and McNeil 2007).

*Standby Power*

Standby power consumption is a feature of a wide range of products, including major appliances, consumer electronics and home entertainment equipment. This mode of power consumption is increasingly shown to be a major source of energy demand, and has become a prominent candidate for efficiency improvement (IEA, 2001). Reduction of standby power is typically very inexpensive to achieve through redesign of electronic components. Standby power savings potential is modeled after the *Preparatory Study* for recent regulations in the European Union (EC 2007). According to that study, the average product consuming standby used 17.2 kWh in this mode at the time of the study. This consumption was reduced by the EU's Tier 1 standard to 7.1 kWh in 2010 and is set for another reduction, to 3.6 kWh in 2013. In the Indian Business

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[11] This target is likely to be conservative, especially since the current labeling program should be ratcheted to this level in the next few years.

[12] Star rating market shares are Star 1 – 165, Star 2 – 39%, Star 3 – 31%, Star 4 – 3% and Star 5 – 11% according to *BEE-Verified Savings Report for 2009-2010* available at www.beeindia.in

Case scenario, we assume that the EU Tier2 level will be reached by 2015. We assume that the average product using standby power lasts 8 years.

*Commercial Lighting*

Commercial lighting in India is provided primarily by linear fluorescent lamps, incandescent lamps and CFLs. Data provided for a recent LBNL study (Sathaye, S. de la Rue du Can et al. 2010)indicates a 72% / 27% / 7% split between these three main lighting types. Data for high-intensity discharge lamps and other lighting types were not available, so these are not considered. Commercial lighting baseline and target efficiencies are assumed to be the same as for the residential sector. These entail a switch from T12 to T8 and magnetic to electronic ballasts for fluorescent tubes and switching the remaining incandescent lamps for CFLs.. The commercial sector case assumes 8 hours per day lighting usage, however, instead of 4.

*Commercial Air Conditioning*

Air conditioning is provided by a variety of technologies in Indian commercial buildings, including central air conditioners, heat pumps and chillers, in addition to room air conditioners, which are still the most common form of air conditioning. The evaluation of commercial air conditioning potential relies on data collected for a recent LBNL study (Sathaye, S. de la Rue du Can et al. 2010), which estimates incremental equipment costs and energy savings from high-efficiency equipment. Overall improvement potential and net costs are calculated using weighted averages over technology and building types.

*Industrial Motors*

The Indian motor efficiency labeling system is modeled after the original European scheme that defines the highest efficiency motors as IE3, less efficient motors above a standard baseline as IE1 and IE2. Currently, much of the Indian motors market remains below the IE1 level, and there is a small fraction of motors at the IE2 level[13]. However, we expect the market to reach roughly the IE1 level, either through market/voluntary forces or mandatory regulations (Garg 2009). We consider IE1 as a target efficiency level, and assume a constant ratio of IE2 to IE1.

Annual energy consumption for motors is based on estimates from the Preparatory study for recent Ecodesign standards in the E.U. (de Ameida, Ferreira et al. 2008). This study takes into account the variation in motor usage with application and size. We consider three categories of motors: 0.75-7.5 kW, 7.5-75 kW and over 75 kWh. The market average of these categories used in the EU study is 1.1 kW, 11 kW and 110 kW respectively. Average UEC are found to be 1485 kWh, 149800 kWh and 396000 kWh. These estimates show a higher intensity for larger motors in terms of load and hours of use. The distribution of motor capacities in is assumed to be in a 100:10:1 ratio for the three categories. The lifetime for all motors is assumed to be 10 years.

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[13] Motor market shares assumed to be IE1 – 67%, IE2 – 6% and the remaining motors below standards (Source: ICPCI).

*Distribution Transformers*

We analyze distribution transformers according to the star rating defined by the Bureau of Energy Efficiency (BEE). Within this scheme, cost-effective efficiency improvement for distribution transformers was considered in a previous study (McNeil, Iyer et al. 2008). Standards proposed at the time of that study are currently still in effect[14]. While a requirement of Level 1 is nominally in effect, there is a very large amount of 'leakage' in the program and in fact only a small fraction of transformers in India are labeled[15]. Therefore, we consider the lowest BEE rating (Star 1) as the baseline, and consider the cost effectiveness of a market shift to the highest rating (Star 5). Distribution transformer lifetime is assumed to be 22 years.

Average lifetime, baseline and target unit energy consumption are summarized in Table 1. Sources for these data are summarized in the Appendix.

**Table 1 – Lifetime and Energy Parameters for Indian End Uses**

| Equipment | Lifetime | Baseline UEC | Target UEC |
|---|---|---|---|
| Electric Equipment | years | kWh | |
| Incandescent Lamps (Residential) | 5* | 88 | 22 |
| Incandescent Lamps (Commercial) | 5* | 175 | 44 |
| Fluorescent Lamps (Residential) | 15 | 67 | 60 |
| Fluorescent Lamps (Commercial) | 15 | 134 | 120 |
| Refrigerators (Direct Cool) | 15 | 277 | 221 |
| Refrigerators (Frost Free) | 15 | 486 | 311 |
| Air Conditioners (Residential) | 15 | 2160 | 1812 |
| Standby Power | 8 | 17 | 4 |
| Commercial Cooling | 15 | - | 1012** |
| Motors | | | |
| 10HP (90%) | 10 | 1485 | 1395 |
| 50 HP (9%) | 10 | 19800 | 19365 |
| 100 HP (.9%) | 10 | 396000 | 392234 |
| Distribution Transformers | | | |
| 25 kVA (6%) | 22 | 1036 | 441 |
| 60 kVA (25%) | 22 | 1834 | 797 |
| 100 kVA (44%) | 22 | 2619 | 1068 |
| 160 kVA (3%) | 22 | 3757 | 1653 |
| 200 kVA (14%) | 22 | 4989 | 1880 |

\* Lifetime of CFL replacement

\*\* Only energy savings available

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[14] http://220.156.189.26:8080/beeLabel/Schedules/Schedule4-DistributionTransformer.pdf

[15] Source: ICPCI

## 3.2. Cost of Conserved Energy Calculation

Prices used for the calculation of cost of conserved energy are given in Table 2. Sources for these are provided in the Appendix. These parameters are used in the calculation of cost of conserved energy according to Equation 1 by comparing each design option to the baseline, according to:

$$I = Price_{DesignOption} - Price_{Baseline}$$

and

$$S = UEC_{Baseline} - UEC_{DesignOption}$$

The parameters used in calculation of $q$ in Equation 2 are as follows:

*Product Lifetime* (*L*) – Average number of years that a product is used before failure and retirement. Lifetimes vary by product class and are estimated from manufacturer reports, or from survey data.

*Discount Rates* – In order to evaluate cost-effectiveness to consumers, the analysis takes into account the real cost of financing for Indian consumers. We assumed a *real discount rate* of 10% for all consumers. This rate is intended to represent actual interest rates on the financing of equipment, and does not include consumers' high sensitivity to first costs, such as an *implicit discount rate*. This discount rate is high compared to rates used in appliance efficiency studies in the United States which use rates of about 5% for residential and 6% for commercial consumers (McNeil, Bojda et al. 2011).

*Energy Prices* – Current consumer electricity and natural gas prices in India generally do not fully reflect the cost of production and include cross-subsidization between tariff groups. However, in recent years, Indian electricity tariffs have been increasing as subsidies are lowered. We estimate electricity prices based on state-wise/utility wise average rates of electricity for domestic and industrial consumers[16]. In order to make an estimate of the national level, state-level tariffs are weighted by state populations[17]. Using this method, average residential rates from 2009-2010 were found to be 3.49 INR/kWh, or $0.0714 USD/kWh. Industrial rates were 4.47 INR/kWh or $0.0915/kWh. Commercial rates were not available – industrial rates were uses as a proxy for those. We assume that electricity rates remain constant at these levels, an assumption that is likely conservative.

Using these parameters, we calculate cost of conserved energy for each design option for each product class. The results of this calculation, shown in Table 2, are the basis of construction of the efficiency scenario.

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[16] Available at http://indiabudget.nic.in/es2009-10/chapt2010/tab133.pdf
[17] India Census, available at
http://www.thehindu.com/multimedia/archive/00517/India_Census_2011___517160a.pdf

As stated above, the target efficiency level chosen is that which *maximizes efficiency while providing a net benefit to consumers*. Following this definition, we identify the target UEC for each product class as the lowest UEC for which cost of conserved energy is below the utility price.

To illustrate the construction of the efficiency scenario, we consider the example of frost-free refrigerators. Table 2 shows *UEC*, *Price* for baseline (3 Star) and high-efficiency (5 Star) refrigerators. According to a retrospective study of program impacts in 2010 (Tathagat and Anand 2011), a 5 Star frost-free refrigerator costs 2000 INR or $41 USD more than a similar 3 Star unit. Annual Unit Energy Consumption (UEC) savings of this substitution is 175 kWh per year. With a discount rate of 10% and a lifetime of 15 years, equation 2 gives a *q* value of 0.131. Cost of conserved energy is therefore given by

$$\frac{\$41 \times 0.131}{243 \ kWh} = 0.022 \ \$/kWh$$

Calculation parameters and results for cost-of conserved energy for all products studied are shown in Table 2. References and assumptions for energy, efficiency and price parameters for appliances are presented in the Appendix.

**Table 2 – Cost of Conserved Energy Calculation**

| Equipment | Lifetime | q | Baseline UEC | Target UEC | Baseline Price | Target Price | Target CCE |
|---|---|---|---|---|---|---|---|
| Electric Equipment | years | | kWh | | $ | $ | $/kWh |
| Incandescent Lamps (Residential) | 5* | 0.264 | 87.6 | 21.9 | 0.29 | 4.11 | 0.011 |
| Incandescent Lamps (Commercial) | 5* | 0.264 | 175 | 43.8 | 0.29 | 4.11 | 0.005 |
| Fluorescent Lamps (Residential) | 15 | 0.131 | 67 | 59.8 | - | 3.46** | 0.062 |
| Fluorescent Lamps (Commercial) | 15 | 0.131 | 134 | 119.5 | - | 3.46** | 0.031 |
| Refrigerators (Direct Cool) | 15 | 0.131 | 337 | 269 | - | 20** | 0.040 |
| Refrigerators (Frost Free) | 15 | 0.131 | 675 | 432 | - | 41** | 0.022 |
| Air Conditioners (Residential) | 15 | 0.131 | 2160 | 1817 | - | 77** | 0.035 |
| Standby Power | 8 | 0.187 | 17.2 | 3.6 | - | 2** | 0.028 |
| Commercial Cooling | 15 | 0.131 | - | 1012** | - | 178** | 0.072 |
| Motors | | | | | | | |
| 10HP (90%) | 10 | 0.163 | 1485 | 1395 | 100 | 125 | 0.046 |
| 50 HP (9%) | 10 | 0.163 | 19800 | 19365 | 403 | 575 | 0.065 |
| 100 HP (.9%) | 10 | 0.163 | 396000 | 392234 | 2858 | 3991 | 0.049 |
| Distribution Transformers | | | | | | | |
| 25 kVA (6%) | 22 | 0.114 | 1036 | 441 | 1036 | 441 | 0.065 |
| 60 kVA (25%) | 22 | 0.114 | 1834 | 797 | 1834 | 797 | 0.051 |
| 100 kVA (44%) | 22 | 0.114 | 2619 | 1068 | 2619 | 1068 | 0.037 |
| 160 kVA (3%) | 22 | 0.114 | 3757 | 1653 | 3757 | 1653 | 0.016 |
| 200 kVA (14%) | 22 | 0.114 | 4989 | 1880 | 4989 | 1880 | 0.030 |

* Lifetime of CFL replacement
** Only incremental price or energy savings available

The cost of conserved energy for all appliance groups is compared to utility prices in Figure 2. It is notable that in general, the results are not highly sensitive to assumptions about future electricity price, since the efficiency targets studied all fall well below current electricity prices. This result is indicative of two major factors. First, the efficiency technology baseline of India is relatively low. This generally means that there is more 'low hanging fruit' still available to be captured in the Indian context. Second, however, we considered only those technologies for which prices were available and could be evaluated in the Indian market[18].

**Figure 2 – Cost of Conserved Energy and Energy Prices**
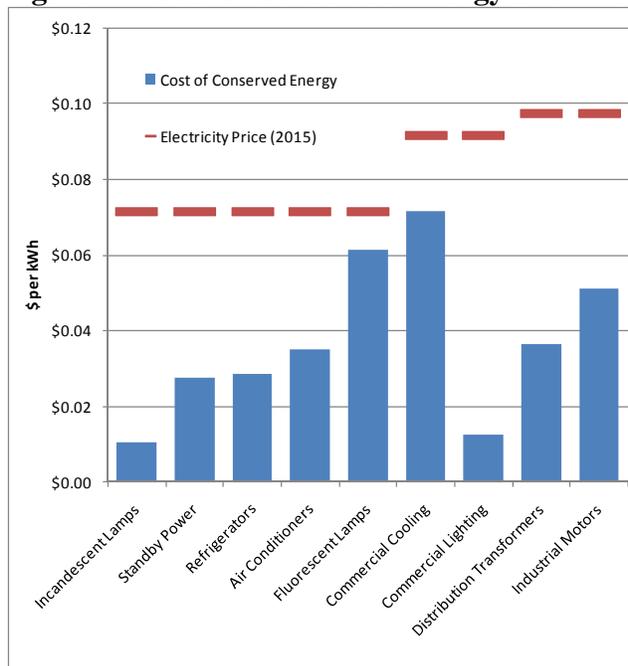


The main inputs to the construction of the two scenarios, the *Base Case* and the *Business Case* scenario are the baseline *UEC* and the UEC established by CCE in Figure 2. We call this the *Business Case UEC*.

## 4. National Level Energy Savings Opportunities

Because of the modular structure of the BUENAS model (see Figure 1), once the inputs are established it is a relatively straightforward process to construct the two energy demand scenarios and compare them to calculate savings potential. The full details of the calculation of energy demand are provided in (McNeil, Letschert et al. 2008) and are omitted here.

## 4.1. Energy Savings and Emissions Reductions

Site energy savings is the basis for all national impacts calculations. Site energy demand refers to electricity and natural gas consumed in a home or business, and does not include fuel inputs in

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[18] Industrial motors are the exception – we use U.S. prices for these because recent Indian prices were available for this important end use. We consider the use of U.S. prices to be conservative.

generation of electricity, or losses in transmission or distribution. Site energy is the energy affected most immediately by efficiency improvement. It is also the energy consumption that appears on consumer utility bills, and forms the basis for the cost-benefit analysis detailed above.

Site energy consumption is calculated by BUENAS for both the *Base Case* and *Business Case* scenarios. Energy *activity* is the same in both cases[19], so the difference between them is driven by the trend in *marginal intensity*, that is, the UEC of products sold in each year. The UEC for the two scenarios are identical until the policy implementation date of 2015[20]. After that date, the efficiency target in the *Business Case* is the high efficiency level determined by cost-benefit analysis, while it remains at the baseline efficiency level in the *Base Case*. The difference in UEC in the two scenarios applies only to new products – in this way, the policy modeled has the structure of a minimum efficiency performance standard, and does not imply retrofits of existing equipment. By 2016 overall energy demand of stock in the *Business Case* is only slightly lower than the *Base Case*, because only one year's sales are affected by the policy. Moving through the forecast, LEAP tracks the gradual flow of high efficiency products into the stock and the retirement of less efficient ones, so that the average stock UEC gets closer to the target level. Depending on the lifetime of the product, the entire stock may not be converted by 2030, since some low-efficiency products installed before 2015 will survive. Figure 3 shows the evolution of site energy savings by appliance group. From 2015 onward, energy savings grows for all products as high efficiency products begin to penetrate the stock in the *Business Case*.

**Figure 3 – Site Energy Savings by Appliance Group– 2015-2030**



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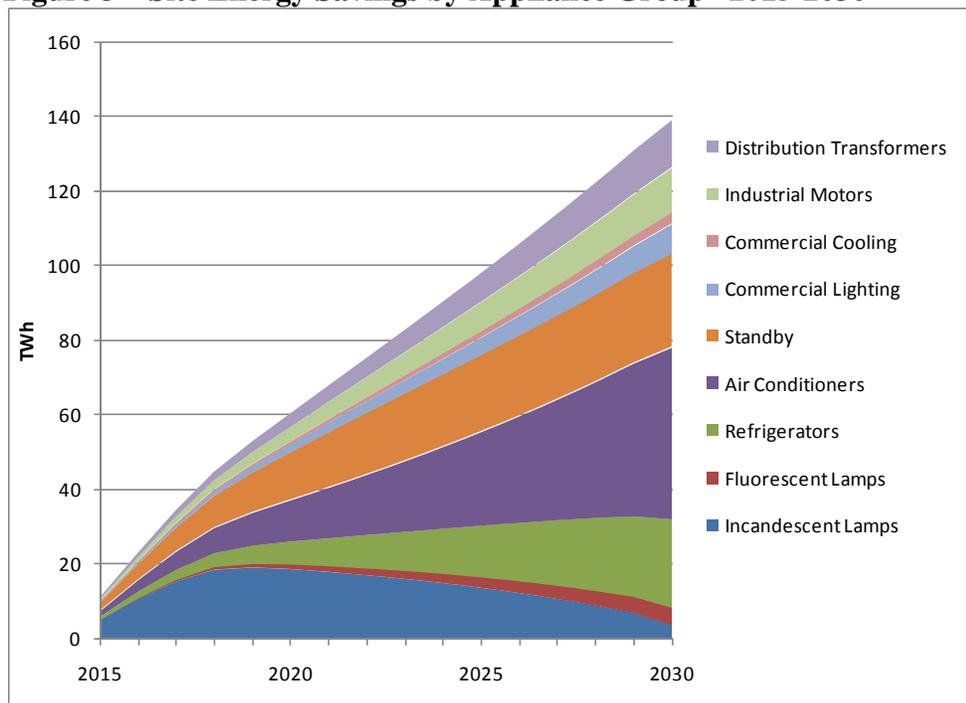
[19] It is possible to model, for example, the reduction of sales or fuel switching resulting from price increases associated with efficiency regulations. This effect is not captured in BUENAS.
[20] The exception is the phase-out of incandescent lamps, which begins in 2012 in the *Business Case*.

Site energy savings results are summarized in Table 3. Savings for all appliance groups totals 139 TWh in the year 2030. Cumulative savings through 2030 total 1,251 TWh.
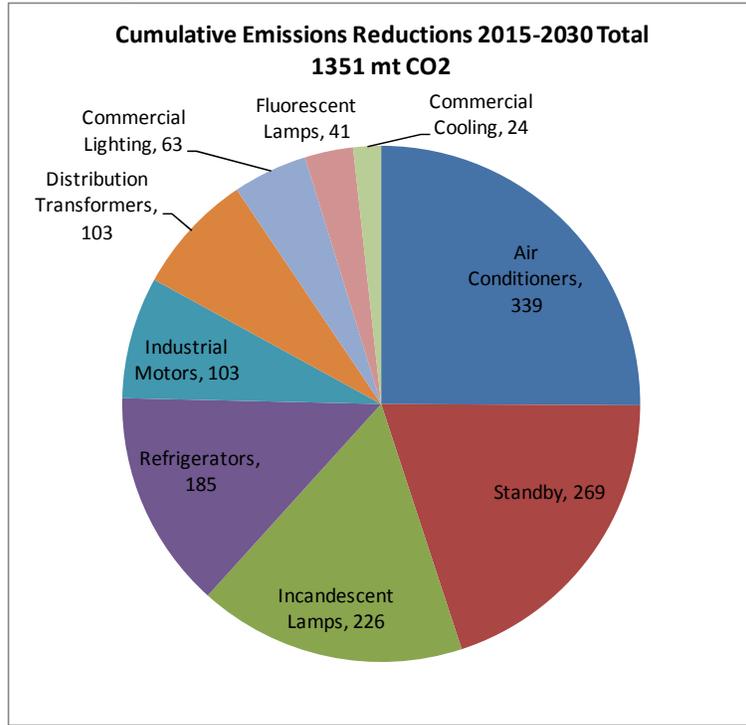
Emissions reductions are calculated directly from energy savings according to a carbon factor. The carbon factor for electricity includes fuel inputs to generation, and accounts for transmission and distributions losses. The carbon factor taken in the base year 2005 is estimated in (Price, S. de la Rue du Can et al. 2006). The forecast of carbon factor is derived using the base year data, and scaling by the growth rate from IEA's World Energy Outlook (WEO) 2006 (International Energy Agency 2006). Using this method, the carbon factor in India is found to be 1.12 kg $CO_2$/kWh in 2015, decreasing to 10.06 kg $CO_2$/kWh in 2030. Carbon factors for natural gas and fuel oil are assumed to remain constant at 0.202 and 0.264 kg/$CO_2$, respectively. Emissions reductions from energy savings determined by multiplying energy savings by carbon factors are shown in Table 3. Total mitigation in the *Business Case* is found to be 146 mt $CO_2$ in 2030 and 1350 mt $CO_2$ over the entire forecast. Figure 4 shows the contribution to cumulative $CO_2$ mitigation from all appliance groups.

**Table 3 – Energy Savings and Pollutant Mitigation by Appliance Group**

| End Use | Final Energy Savings | | | Emissions Mitigation | | |
|---|---|---|---|---|---|---|
| | In 2020 | In 2030 | Through 2030 | In 2020 | In 2030 | Through 2030 |
| | TWh | | | mt CO2 | | mt $CO_2$ |
| Air Conditioners | 11.0 | 46.0 | 315 | 12.1 | 48.6 | 339 |
| Standby | 12.6 | 25.0 | 249 | 13.9 | 26.4 | 269 |
| Incandescent Lamps | 18.5 | 3.6 | 207 | 20.4 | 3.8 | 226 |
| Refrigerators | 6.2 | 23.7 | 172 | 6.8 | 25.1 | 185 |
| Industrial Motors | 3.8 | 12.0 | 95 | 4.2 | 12.7 | 103 |
| Distribution Transformers | 3.7 | 12.6 | 95 | 4.0 | 13.3 | 103 |
| Commercial Lighting | 2.2 | 8.0 | 59 | 2.4 | 8.4 | 63 |
| Fluorescent Lamps | 1.5 | 4.9 | 38 | 1.7 | 5.1 | 41 |
| Commercial Cooling | 0.8 | 3.2 | 22 | 0.8 | 3.3 | 24 |
| **Total** | **60** | **139** | **1251** | **66** | **147** | **1351** |

Several conclusions can be drawn from Table 3 and Figure 4. First, emission reduction potential is well distributed among end uses and sectors. The largest potential exists for residential air conditioning, incandescent lamps and refrigerators and standby power, each of which could provide over 200 mt $CO_2$ over the forecast period. The large savings from room air conditioners is driven by a combination of both the high cooling load in India and the related rapid growth of this end use in Indian homes. Savings from incandescent lamp phase out is high cumulatively, but low in terms of savings in 2030. This is because incandescent are assumed to be phased out by that year even in the Base Case – the Business Case for lamps is an acceleration of that phase out. Finally, significant savings potential is also shown for refrigerators, industrial motors and distribution transformers.

**Figure 4 – Cumulative CO$_2$ Emissions Reductions 2010-2030**



Cumulative Emissions Reductions 2015-2030 Total 1351 mt CO2

(Pie chart segments: Commercial Cooling, 24; Fluorescent Lamps, 41; Commercial Lighting, 63; Distribution Transformers, 103; Industrial Motors, 103; Refrigerators, 185; Incandescent Lamps, 226; Standby, 269; Air Conditioners, 339)

## 4.2. Consumer Financial Impacts

By construction, the *Business Case* implements energy efficiency in a way that is cost-effective to consumers. Because this study insisted on quantifying investments needed to improve efficiency relative to the base case technology, the necessary information to evaluate these investments and financial benefits of energy savings, and therefore net financial impacts to consumers, is available for all appliance groups considered.

Recalling the definition of cost of conserved energy from Equation 1:

$$CCE = \frac{I \times q}{S}$$

The denominator of this equation $I \times q$ is the annualized equipment investment necessary to yield an annual energy savings $S$. BUENAS calculates the total savings $S_T(y)$ in each year, given by:

$$S_T(y) = S \times Stock'(y)$$

In this equation, *Stock'(y)* is the affected stock, that is, the number of units operating in the stock that were installed after the policy implementation date, and are each providing a savings $S$ relative to the *Base Case*. Likewise, the total annualized investment in each year $I_T(y) \times q$ is given by:

$$I_T(y) \times q = I \times q \times Stock'(y)$$

Substituting Equation 1, and cancelling terms, yields:

$$I_T(y) \times q = S_T(y) \times CCE$$

In other words, total annualized investment can be calculated for each appliance group by multiplying its total energy savings by the cost of conserved energy shown in Table 5.

Financial savings from energy savings is given simply by the utility price in each year multiplied by the total energy savings $S_T(y)$. Net financial impacts are then given by:

$$N(y) = S_T(y) \times (Utility\ Price - CCE)$$

Costs, Savings and Net Impacts calculated in this way are shown in Table 5. In evaluating the financial value of efficiency or other government programs, it is customary to take account of deferred benefits through a discount rate calculation. The resulting *Net Present Value* (NPV) of benefits is given by:

$$NPV = \sum_{y=2010}^{2030} \frac{N(y)}{(1+DR)^{y-2010}}$$

In this equation, *DR* is a "societal" discount rate that parameterizes the preference for immediate returns on public investments. We consider two scenarios in which the societal discount rate is taken to be 3% or 7%. Cumulative equipment costs, energy bill savings, net savings and *NPV* are shown in Table 5.

The analysis shows that cost-effective efficiency improvement could yield very significant financial benefits to Indian consumers. Table 4 shows positive net savings for all appliance groups, which is not surprising, since the target efficiency levels were constructed to be cost-effective. The table shows that cost-effective efficiency improvements require an investment of 38 billion USD over the next 20 years, but these investments will return over more than twice as much over the same period, for a net savings of 58 billion dollars, or of order of fifty dollars per capita. The present value of net savings is 36 billion USD assuming a discount rate of 3%, and 22 billion USD with a 7% discount rate.

Of the appliance groups studied, residential room air conditioners require the largest investment at 11 billion USD, but provide a payoff of 22.5 billion USD. Standby power generates similar savings, but with only half of the investment. Phasing out incandescent lamps is extremely cost effective compared to other appliance groups, with a payoff of over six times as high as the required investment.

**Table 4 – Cumulative Financial Impacts of Efficiency Improvement**

| Appliance Group | Cumulative Financial Impacts | | | | |
| | Cost | Savings | Net Savings | NPV @ 3% DR | NPV @ 7% DR |
|---|---|---|---|---|---|
| | Billions USD | | | | |
| Incandescent Lamps | 2.2 | 14.8 | 12.6 | 8.9 | 5.9 |
| Standby | 6.9 | 17.7 | 10.9 | 8.4 | 4.9 |
| Air Conditioners | 11.0 | 22.5 | 11.5 | 7.3 | 4.1 |
| Refrigerators | 4.9 | 12.2 | 7.4 | 4.7 | 2.7 |
| Distribution Transformers | 3.5 | 9.3 | 5.8 | 2.8 | 1.6 |
| Commercial Lighting | 0.7 | 5.4 | 4.6 | 1.6 | 0.9 |
| Industrial Motors | 4.9 | 9.3 | 4.4 | 1.2 | 0.7 |
| Fluorescent Lamps | 2.3 | 2.7 | 0.4 | 0.2 | 0.1 |
| Commercial Cooling | 1.6 | 2.0 | 0.4 | 1.1 | 0.6 |
| **Total** | **38** | **96** | **58** | **36** | **22** |

Finally, financial impacts, emissions savings and their relationship can be shown using a "conservation supply curve". This unique way of expressing the cost and benefits of carbon mitigation measures has become very widespread in the literature because of the key information it conveys. A conservation supply curve for the *Business Case* is presented in Figure 5. The x-axis shows cumulative carbon mitigation and expresses the relative importance of each appliance group. The total extent of the curve is 1351 mt $CO_2$, as shown in Table 3. The y-axis displays relative affordability according to cost of conserved energy. The blocks corresponding to each measure are ordered with increasing cost of conserved energy, from left to right.

**Figure 5 - Conservation Supply Curve for Indian End Uses 2010-2030**



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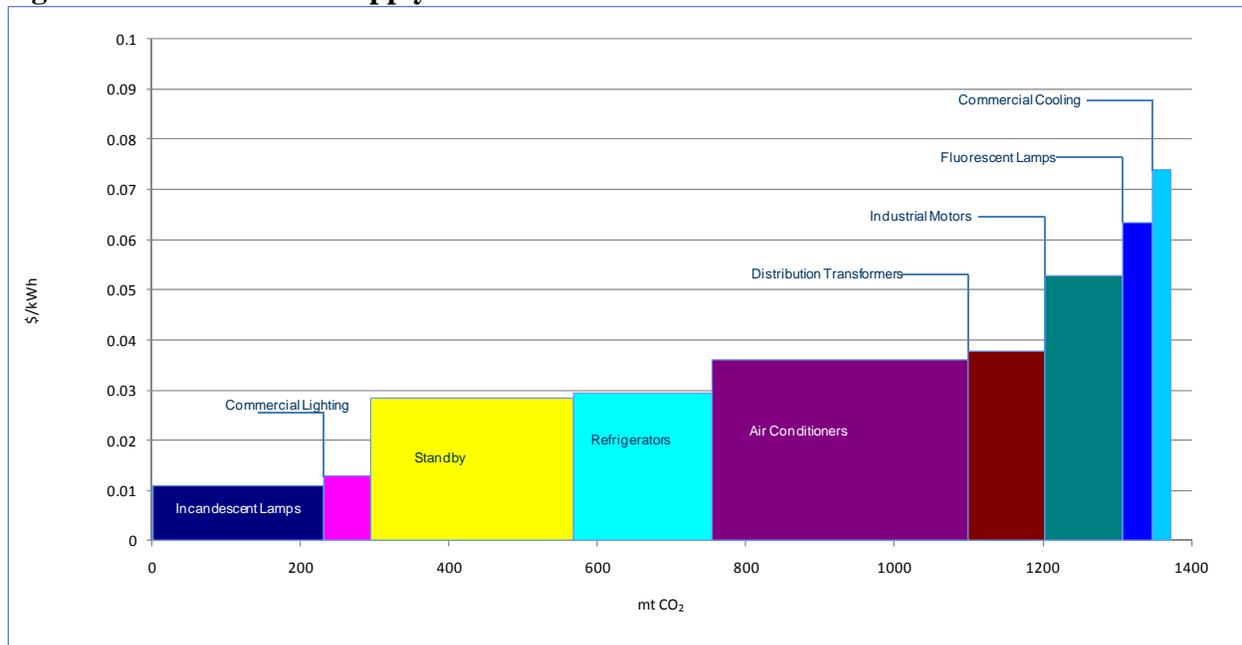
Finally, we note that there are other benefits to the energy savings achieved in the *Business Case* besides the direct energy and financial benefits. The effect of reduction of greenhouse gas emissions and resulting avoided costs are difficult to quantify, but could be very large. One metric to consider the order of magnitude of the value of these types of impacts is the assumption of a carbon price. The assumption of a price of 25 USD per ton of carbon dioxide yields an additional 34 billion USD of savings, while a 100 USD per ton price yields 135 billion additional USD, more than tripling the total.

The negative impacts of emissions of $SO_2$ and NO from power plants are well-known (see, for example, EPA 2010), including acid rain, acidification of watersheds and lakes, and respiratory illness from inhaling particulates. Likewise, the reduction of mercury emissions from coal-burning power plants reduces fish contamination, which is now recognized as a major health risk. We do not try to quantify the health impacts of reduction of these emissions, only point out the obvious – that savings due to efficiency is equivalent to installation of clean electricity generation. In the *Business Case*, this reduction provides a large net financial benefit to consumers, which may not be true with alternatives.

# 5. Conclusions

The *Business Case* analysis found additional potential for cost-effective efficiency improvement in India for seventeen appliance groups in the residential and commercial building sectors and industrial motors. Efficiency improvement for these technologies could deliver twice as much financial benefit to Indian households and business than the investment needed to implement them. In addition to direct financial benefits, impacts on greenhouse gas emissions and are significant. Total net impacts from additional deployment of high efficiency technology include:

Energy savings:

- 60 billion kWh per year in 2020
- 140 billion kWh per year in 2030
- A total of 1,250 billion kWh cumulatively through 2030

Cumulative greenhouse gas emissions mitigation:

- 1350 million metric tons of $CO_2$ through 2030

Financial impacts to consumers through 2030:

- Equipment investment of 38 billion USD
- Energy bill savings of 96 billion USD
- Net savings of 58 billion USD

The "business case" analysis shows that the Indian market already has access to efficiency technologies that could provide Indian consumers with a financial benefit and make a dent in the growth of Indian emissions if widely adopted. Most of the equipment studied has been the subject of at least one efficiency standard, but opportunities for improvement are not exhausted. To some extent, therefore, the savings potential estimated by this study can be captured through expansion and aggressive pursuit of existing Indian government policies. It should also be noted that many of the technologies included in the "business case" scenario were not available ten to twenty years ago, or at least weren't be shown to be cost effective. These technologies have become available and cost-effective through research, new materials and components, improvements in production processes, or changes in design of systems. Likewise, we expect that a similar analysis performed 10 years from now will show improvements not accessible to the current study due either to lack of data or prohibitively high cost of "prototype" technologies.

Because the rigor of the methodology used to evaluate cost-effectiveness requires a significant amount of technical data, we only cover a subset of equipment types for which significant savings potential might be available. In particular, the appliance groups covered are limited to buildings applications. For this sector, however, we believe a large fraction of energy demand is accounted for. For this reason, while the overall savings potential is large, it cannot be interpreted as "comprehensive".

Finally, we believe this study to be among the few to attempt to evaluate the "economic" potential of efficiency improvement in India in a transparent way. In addition to demonstrating significant savings potential, we hope that it demonstrates a clear and consistent methodology for

creation and expansion of alternative energy scenarios in India. Additional scenarios that could be explored include the potential impact of carbon taxes, cap-and-trade, R&D investments and other policy- or market-based drivers.  The ability of the research community to utilize this type of analysis to inform government and private sector decision makers will depend largely on investments made in development of the type of data used here, both more widely and with greater frequency.

**REFERENCES**

Aden, N., Y. Qin, et al. (2010). Lifecycle Assessment of Beijing-Area Building Energy Use and Emissions: Summary Findinga and Policy Applications. Berkeley LBNL.

Cheung, R. and A. Kamg (2008). China's Booming Energy Efficiency Industry, World Resources Institute.

de Ameida, A. T., F. J. T. E. Ferreira, et al. (2008). EUP Lot 11 Motors Preparatory Study, ISR - University of Coimbra.

de la Rue du Can, S. (2009). Residential and Transport Energy Use in India: Past Trends and Future Outlook, LBNL.

Delio, E. A., S. Lall, et al. (2009). Powering Up: The Investment Potential of Energy Service Companies in India, World Resources Institute.

EC (2007). ENER Lot 6 Stand by and Off Mode Losses Final Preparatory Study.

G. Pandian (2008). Progress of Standards and Labeling Programme in India. International Conference on Standby Power. New Delhi.

Garg, S. (2009). Standards and Labeling Program for Motors in India. MEPSA, Sydney, Australia.

International Energy Agency (2006). World Energy Outlook 2006, OECD.

Kumar, S., R. Kapoor, et al. (2010). Developing an Energy Conservation Building Code Implementation Strategy in India. ACEEE Summer Study.

Letschert, V. and M. McNeil (2007). Coping with Residential Electricity Demand in India's Future - How Much Can Efficiency Achieve? ECEEE Summer Study. Côte d'Azur, France.

Mathur, A. (2011). National Mission on Enhanced Energy Efficiency. Energy Synergy Dialogue. World Energy Council.

McNeil, M. A., N. Bojda, et al. (2011). Business Case for Energy Efficiency in Support of Climate Change Mitigation, Economic and Societal Benefits in the United States, LBNL.

McNeil, M. A. and M. Iyer (2009). Progress towards Managing Residential Electricity Demand: Impacts of Standards and Labeling for Refrigerators and Air Conditioners in India. 5th International Conference on Energy Efficiency in Domestic Appliances and Lighting. Berlin.

McNeil, M. A., M. Iyer, et al. (2008). "Potential Benefits from Improved Energy Efficiency of Key Electrical Products: The Case of India." Energy Policy 36(9): 3467-3476.

McNeil, M. A., V. E. Letschert, et al. (2008). Global Potential of Energy Efficiency Standards and Labeling Programs, LBNL/CLASP.

Phadke, A., J. Sathaye, et al. (2005). Economic benefits of reducing Maharashtra's electricity shortage though end-use efficiency improvement, LBNL.

Prayas Energy Group (2010). "Energy Saving Potential In Indian Households From Improved Appliance Efficiency."

Price, L., M. D. Levine, et al. (2011). "Assessment of China's Energy-Saving and Emission-Reduction - Accomplishments and Opportunities During the 11th Five Year Plan." Energy Policy 39(4): 2165-2178.

Price, L., S. de la Rue du Can, et al. (2006). Sectoral Trends in Global Energy Use and Greenhouse Gas Emissions, Lawrence Berkeley Lab.

Sathaye, J., S. de la Rue du Can, et al. (2010). Strageties for Low Carbon Growth In India: Industry and Non-Residential Sectors, LBNL.

Singh, A. (2006). "Power sector reform in India: current issues and prospects." <u>Energy Policy</u> **34**(16): 2480-2490.

Singh, D., G. Sant, et al. (2007). Review of Nashik Pilot CFL Program of Maharashtra State Electricity Distribution Co Ltd. Pune.

Tathagat, T. and M. Anand (2011). Impact Assesment for Refrigerator and Air-conditioner Voluntary Labeling Program in India, Collaborative Labeling and Appliance Standards Program.

The Energy Research Institute (TERI) (2008). TEDDY: TERI's Energy Data Directory and Yearbook 2007. New Delhi, TERI.

Weisbrod, G., M. Tribble, et al. (1998). Learning from India: Defining Profitable DSM and ESCo Programs for a Utility.

Zhou, N. (2010). "Overview of Current Energy Efficiency Policies in China." <u>Energy Policy</u> **38**(11): 6439-6452.

# APPENDIX – Assumptions and Sources for Appliances Cost-Benefit Calculation

| Equipment | Lifetime | Discount Rate | Baseline UEC | Target UEC | Baseline Price | Target Price |
|---|---|---|---|---|---|---|
| Electric Equipment | years | years | kWh | | $ | $ |
| Incandescent Lamps (Residential) | Letschert 2007 | Assumption - Res. 10% | 60 W IL 4hr/day | 15 W CFL 4hr/day | | |
| Incandescent Lamps (Commercial) | Letschert 2007 | Assumption - Com. 10% | 60 W IL 8hr/day | 15 W CFL 8hr/day | Chinese Data | |
| Fluorescent Lamps (Residential) | Assumption | Assumption - Res. 10% | F40T12/ES Mag. 4 hr/day | Hi-perf T8 Elec. 4 hr/day | | |
| Fluorescent Lamps (Commercial) | Assumption | Assumption - Com. 10% | F40T12/ES Mag. 8 hr/day | Hi-perf T8 Elec. 8 hr/day | Sathaye (2010) | |
| Refrigerators (Direct Cool) | McNeil 2008 (1) | Assumption - Res. 10% | 4 Star | 5 Star | | |
| Refrigerators (Frost Free) | McNeil 2008 (1) | Assumption - Res. 10% | 3 Star | 5 Star | CLASP - EDS Impacts | |
| Air Conditioners (Residential) | Letschert 2007 | Assumption - Res. 10% | 2 Star Window, 3 Star Split | 5 Star | CLASP - EDS Impacts | |
| Standby Power | Ecodesign Prep Study | Assumption - Res. 10% | Ecodesign Prep Study | Ecodesign Prep Study | Assumption | |
| Commercial Cooling | Sathaye (2010) | Assumption - Com. 10% | Data from WB Study | Eff. Imp from WB Study | Sathaye (2010) | |
| Motors | | | | | | |
| 10 HP (90%) | Revised downward | | | | | |
| 50 HP (9%) | from 15 in McNeil 2008 | | Ecodesign - EPACT (EFF2) | Ecodesign - NEMA Premium (EFF1) | Garcia 2007 - U.S. 2003 prices for rough equivalent to EFF2 and EFF1 | |
| 100 HP (.9%) | (1) | Assumption - Ind. 10% | | | | |
| Distribution Transformers | | | | | | |
| 25 kVA (6%) | | | | | | |
| 60 kVA (25%) | | | | | | |
| 100 kVA (44%) | | | | | | |
| 160 kVA (3%) | | | | | | |
| 200 kVA (14%) | McNeil 2008 (1) | Assumption - Ind. 10% | McNeil 2008 (1) Star 1 | McNeil 2008 (1) Star 5 | McNeil 2008 (1) Star 1 | McNeil 2008 (1) Star |

1. McNeil, M. A., M. Iyer, S. Meyers, V. E. Letschert and J. E. McMahon (2008). "Potential benefits from improved energy efficiency of key electrical products: The case of India." Energy Policy 36(9): 3467-3476
2. McNeil, M.A., V.E. Letschert and S.A.de la Rue du Can (2008). Global Potential of Energy Efficiency Standards and Labeling Programs. LBNL 760E
3. Letschert, Virginie E. and M.A.McNeil. 2007. "Coping with Residential Electricity Demand in India's Future – How Much Can Efficiency Achieve?" LBNL-63199, July 2007.
4. Garcia (2007)    Garcia, A. G. P., A. S. Szklo, R. Schaeffer and M. A. McNeil (2007). "Energy-Efficiency Standards for Electric Motors in Brazilian Industry". Energy Policy 35(6): 3424-3439. LBNL-62395
5. Sathaye, J., S. de la Rue du Can, et al. (2010). Strategies for Low Carbon Growth In India: Industry and Non-Residential Sectors, LBNL -4557E
6. McNeil, M. A. and M. Iyer (2007). Techno-Economic Analysis of Indian Draft Standard Levels for Room Air Conditioners.
7. Tathagat, T. and M. Anand (2011). Impact Assessment for Refrigerator and Air-conditioner Voluntary Labeling Program in India, Collaborative Labeling and Appliance Standards Program.