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Impact of Large Scale Energy Efficiency Programs On Consumer Tariffs and Utility Finances in India

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Acronyms and Abbreviations

AC	Air Conditioner
BRPL	BSES Rajdhani Power Limited
BYPL	BSES Yamuna Power Limited
CAGR	Compounded Annual Growth Rate
CCE	Cost of Conserved Energy
CCGT	Combined Cycle Gas Turbine
CCP	Cost of Conserved Peak
CFL	Compact Fluorescent Lamp
DERC	Delhi Electricity Regulatory Commission
DG	Demand Growth
DSM	Demand Side Management
DTL	Delhi Transco Limited
DVB	Delhi Vidyut Board
EE	Energy Efficiency
FY	(Indian) Financial Year
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MERC	Maharashtra Electricity Regulatory Commission
MU	Million Units (kWh)
NCT	National Capital Territory
NDMC	New Delhi Municipal Council
NDPL	North Delhi Power Limited
NG	Natural Gas
NHPC	National Hydro Power Corporation
NPCIL	Nuclear Power Corporation of India Limited
NR	Natural Retirement (of conventional appliances)
NTPC	National Thermal Power Corporation
PR	Premature Retirement (of conventional appliances)
R-LNG	Regassified Liquefied Natural Gas
RNRL	Reliance Natural Resources Limited
SJVNL	Satluj Jal Vidyut Nigam Limited
T&D	Transmission and Distribution
THDC	Tehri Hydro Development Corporation
WH	Water Heater

Executive Summary

The objective of this paper is to analyze the effect on utility finances and consumer tariffs of implementing utility-funded cost-effective energy efficiency (EE) programs in India. We use the state of Delhi as a case study. A number of studies have demonstrated that end-use EE improvements in the Indian electricity sector has large potential for reducing power shortages, which would enhance the country's energy security and could play a crucial role in India's climate change mitigation plan. However, consumers face several barriers to adopting EE measures, including high initial cost, split incentives, and lack of information. In India, high initial cost is the most important barrier given the low income levels of the vast majority of electricity consumers and the country's relatively underdeveloped credit markets. This barrier can be effectively addressed through utility-funded EE programs.

Large scale utility-funded EE programs may have substantial impacts on consumer tariffs and utility finances[1]. Consumer tariffs may increase although participating consumers benefit from reduction in their electricity consumption and thus total electricity bills. A utility typically faces the following financial disincentives to implementing EE programs:

(a) *Loss of revenue*: EE programs reduce a utility's sales, which reduce its total revenue and might lead to under-recovery of fixed costs. In the Indian context, however, this effect is substantially diminished because of two reasons. First, most distribution utilities face power shortages; they can sell the saved energy to consumers facing power cuts. Secondly, electricity regulators follow annual true-up mechanism that decouples recovery of the utility's fixed costs from actual sales. Since the true-ups are only ex-post, there is a lag of at least one financial year between the loss of revenue due to reduced sales and its recovery. For large scale EE programs, such lag in recovery might have an adverse impact on utility cashflow.

(b) *Reduction in long-run returns*: Reduction in demand due to EE programs might obviate the need for future capital investments thereby affecting utility's long-run returns.

Offering the utility a financial incentive to make up for loss of revenue and/or profitability can address utility disincentives to expanding the EE programs. Current regulatory practices in India allow utilities to recover the EE program costs from consumers while the annual true-up process ensures recovery of lost revenue albeit with a lag of one year. However, they do not address the utility disincentives of negative cashlow and forgone returns. Two incentive mechanisms namely Capitalization (treating EE expenditure the same as infrastructure investments) and Shared Benefit (sharing of a part of resource benefits with the utility) can be effectively used in India to address those. It is important to note that, most distribution utilities are publicly owned and financial incentives may not be as effective as would be the case for private utilities.

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[1] We define large scale EE programs as those changing utility's incremental sales significantly after their implantation.

Since Indian electric utilities have a limited experience in implementing EE programs, we construct hypothetical EE programs for residential and commercial sectors in Delhi for the financial years 2012 through 2015. The programs include deployment of efficient appliances for typical residential and commercial end uses like lighting, space cooling, refrigeration and water heating. Only cost-effective programs (benefits outweighing the costs) are considered in the analysis. We assume that 50% of the total economic potential (i.e. 2,400 GWh) would be realized by 2015. This implies mitigation of 28% of the incremental demand or about 7% of total sales by 2015.

The impacts on utility finances and consumer tariffs are examined by developing scenarios that account for the variations in the following factors.

(a) <u>Utility incentive mechanism</u>
The regulator might continue with the current regulatory set-up that offers no incentive, or the regulator could employ one of the incentive mechanisms viz. capitalization or shared benefit. Under the capitalization mechanism, EE expenditure by the utility is treated as a capital investment and the utility incentive is equivalent to 16% return on equity. Under the shared benefit mechanism, utility is offered a 9% share of the net resource benefits generated by energy savings due to EE programs.

(b) <u>Total program expenditure by utility</u>
Given the benefits described earlier, utilities might consider funding EE programs fully, partially (50%), or not at all. In case of partial or no utility funding, we assume that participating consumers bear the incremental costs.

(c) <u>Treatment of conserved electricity</u>
Once EE programs are successfully implemented, utilities could avoid expensive peak power purchases or sell the electricity conserved through the EE program back to the grid at a higher rate if the utility does not face shortages. For utilities with power shortages, the conserved electricity could be used to reduce the shortages.

(d) <u>Level of power shortage in the state</u>
Although currently there is no power shortage in Delhi, we construct two scenarios where Delhi faces a peak demand shortage (5% by sales) or an intermediate load shortage (10% by sales) to analyze whether EE programs can fully or partially mitigate the shortage. This analysis is intended to make our results relevant for other states in India, most of which face severe shortages.

Impact on Utility Finances

The reduction in sales that results from EE programs affects both the utility's cash flow and long-run returns. When the avoided cost of power purchase is lower than the loss of revenue and the cost of EE programs, utility cash flow would be negative until the next true-up cycle (see table ES.1a). The cash flow is significantly improved if utility is able to sell the conserved electricity into the market. The market price is assumed to be Rs 8/kWh for peak power.

Table ES.1a: Net Effect on Utility Cash Flow and Long Run Returns (Rs million/yr)

(a)

Year	No Shortage		Shortage	
	Avoided Marginal Power Purchase	Grid sale of power	Partial Mitigation	Full Mitigation
2012	-781	439	-1,674	-1,645
2013	-441	748	-2,190	-898
2014	-563	474	-2,823	-10
2015	-533	548	-3,430	915

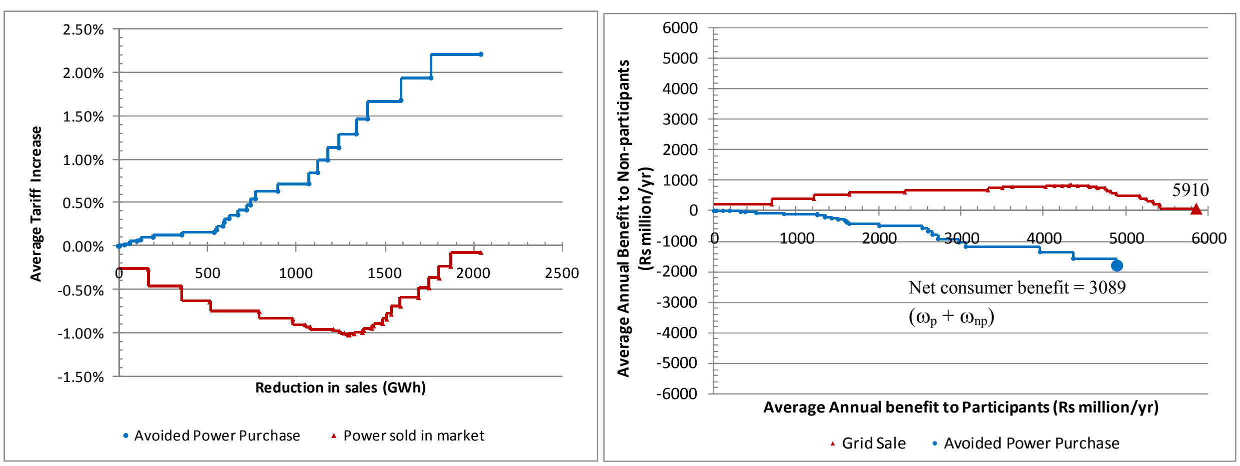
(b)

Foregone returns by the utility	Utility Incentive	
	Capitali-zation	Shared Benefit
24	203	251
49	373	402
74	543	533
100	721	678

If the utility faces power shortages, the electricity conserved through EE programs will likely be used to serve demand that is normally unmet during shortages. This would mean that expensive marginal power purchases to meet peak demand would continue. The net cash flow is very sensitive to the marginal tariff that the utility receives from serving unmet demand. If the marginal tariff is low, the utility cash flow worsens (see table ES.1a). Table ES.1b shows that the utility incentives offered under the incentive mechanisms are significantly larger than the forgone returns by the utility. So, these incentives mechanisms would be effective in overcoming the utility disincentive.

Impact on Consumer Tariffs

Given the scale of EE programs we considered and Delhi's current power purchase profile, consumer tariffs would increase by 2.2% when the power conserved through EE programs is used to avoid expensive marginal peak power purchases. However, if utilities can sell the conserved power on the market at a price higher than the marginal power purchase cost, net resource benefits increase substantially, and consumer tariffs decrease marginally (see figure ES.1a). In case of shortages, the consumer tariff hike would be a little higher, but the primary benefit of EE programs is achieved through reduction in the load shedding.



(a) (b)

Figure ES.1b: Impact of EE programs on Consumer Tariffs and net consumer benefits

In either case, participant consumers benefit significantly from their reduced electricity consumption. The participant benefit is in excess of Rs 5,000 million/yr in both cases. An increase in average tariff implies that non-participants lose on average, but their losses are small compared to the benefits for participants (see figure ES.1b).

Conclusions and Recommendations

Large-scale EE programs would modestly increase tariffs but reduce consumers' electricity bills significantly. However, the primary benefit of EE programs is a significant reduction in power shortages, which might make these programs politically acceptable even if tariffs increase. To increase political support, utilities could pursue programs that would result in minimal tariff increases. This can be achieved in four ways: (a) focus only on low-cost programs (such as replacing electric water heaters with gas water heaters); (b) sell power conserved through the EE program to the market at a price higher than the cost of peak power purchase; (c) focus on programs where a partial utility subsidy of incremental capital cost might work and (d) increase the number of participant consumers by offering a basket of EE programs to fit all consumer subcategories and tariff tiers.

Large scale EE programs can result in consistently negative cash flows and significantly erode the utility's overall profitability. In case the utility is facing shortages, the cash flow is very sensitive to the marginal tariff of the unmet demand. This will have an important bearing on the choice of EE programs in Indian states where low-paying rural and agricultural consumers form the majority of the unmet demand. These findings clearly call for a flexible, sustainable solution to the cash-flow management issue. One option is to include a mechanism like FAC in the utility incentive mechanism. Another sustainable solution might be to have the net program cost and revenue loss built into utility's revenue requirement and thus into consumer tariffs up front. However, the latter approach requires institutionalization of EE as a resource. The utility incentive mechanisms would be able to address the utility disincentive of forgone long-run return but have a minor impact on consumer benefits.

Fundamentally, providing incentives for EE programs to make them comparable to supply-side investments is a way of moving the electricity sector toward a model focused on providing energy services rather than providing electricity.

1 Introduction

A key challenge faced by the rapidly growing Indian economy is meeting its energy needs in a reliable, sustainable, and affordable manner. To sustain the current 8% economic growth rate through 2031-32 and provide basic energy access to all citizens, India needs to increase its primary energy supply by at least three to four times and its electricity generation capacity by at least five to six times over 2004 levels (Planning Commission, 2006). However, the gap between electricity supply and demand has been steadily growing in India. Power shortages have increased from 7% to 10% of energy demand during the past five years.[2] A number of studies have demonstrated that end-use energy-efficiency (EE) improvements or demand-side management (DSM) in the Indian electricity sector has large potential for reducing power shortages, and can play a crucial role in India's climate mitigation plan (Banerjee, 2005; Phadke, Sathaye, & Padmanabhan, 2005; Prayas, 2005; J. Sathaye, L. Price, S. de la Rue du Can, & D. Fridley, 2005).

However, consumers face several barriers to adopting EE measures, including high initial cost, split incentives, and lack of information (Reddy, 1991; J. Sathaye, Bouille, & et al, 2001). In India, high initial cost is the most important barrier given the low income levels of the vast majority of electricity consumers and the country's relatively underdeveloped credit markets. Providing financial incentives, either in the form of subsidies or financing, for consumers to purchase energy-efficient appliances has been an important way to address this barrier in other countries. In several countries including the U.S., revenues from the electricity sector have been used to fund EE programs.

In India, there is growing interest in utility-financed EE programs. Electricity regulators in the states of Delhi and Maharashtra have already allocated electricity sector revenues for pilot scale EE programs. The Bureau of Energy Efficiency and the Forum of Regulators have also launched the Regulatory Multi-State DSM Program (RMSDP) which creates a common platform for utilities in different states to initiate EE programs. However, utility-funded programs have substantial impacts on consumer tariffs and utility finances. Consumer tariffs generally increase when EE programs are implemented although participating consumers also benefit from reduction in their electricity consumption. EE programs reduce a utility's sales, which leads to under-recovery of fixed costs that depend on volumetric sales. Secondly, reduction in demand might obviate the need for future capital investments thereby affecting utility's long-run returns.

Because of these financial disincentives, utilities might shy away from expanding EE efforts. Thus, there is interest in developing ratemaking that addresses utility disincentives to pursue

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[2] Source: http://www.powermin.nic.in/indian_electricity_scenario/policy_initiatives.htm last accessed January 15, 2010.

large-scale EE programs. Regulatory initiatives regarding utility EE programs also affect consumer interests. Therefore, the key issue for state regulators and policymakers is how to maximize the cost-effective EE savings attained while achieving an equitable sharing of benefits, costs, and risks among the various stakeholders (Cappers et al., 2009).

The objective of this paper is to analyze the effect on utility finances and consumer tariffs of implementing utility-funded large-scale EE programs in India. We use the state of Delhi as a case study. Because no large-scale EE programs have as yet been implemented in India using electricity sector revenues, our analysis considers hypothetical lighting and appliance EE programs in Delhi for the financial years 2012 through 2015. We examine impacts by developing scenarios for: (a) treatment of conserved electricity, (b) choice of utility incentive mechanism, (c) utility share of total program expenditures, and (d) extent of power shortages in the state. Because the institutional structure of the power sector in Delhi (for example, vertically unbundled utilities, independent regulator, and consumer rates) is similar to that of other Indian states, our analysis provides useful insights for EE program design and implementation in other Indian states.

The remainder of this paper is organized as follows:

Section 2 presents an overview of the Indian power sector and electric utility regulation. Section 3 explains the theory underlying our analysis. Section 4 develops our analytical setup and methodology and presents our preliminary estimate of the cost-effective EE program potential in Delhi. Section 5 analyzes the impacts of hypothetical EE programs in Delhi on utility finances and consumer tariffs. Section 6 summarizes the analysis and presents our conclusions. Appendix A describes the methods used to calculate potential costs and benefits of EE programs and appendix B explains detailed methodology for estimating the impacts on utilities and consumers.

2 Electricity Sector in India

With installed capacity of more than 150 gigawatts (GW), India has one of the largest electricity transmission and distribution systems in the world. More than half of installed generation capacity is owned by state government companies, and a third is owned by central (federal) government corporations. The remainder is owned by the private sector. By contrast, more than 87% of the distribution sector (by sales) is owned by state-government utilities, and the rest is owned by private and municipal utilities (CEA, 2008). Several states (14 out of 28) have unbundled the vertically integrated state-owned utilities into separate companies for generation, transmission, and distribution, and 21 states have constituted independent electricity regulatory commissions (MoP, 2009).

2.1 Tariff (Consumer Rate)-Setting Mechanism

The current approach to electricity tariffs in India is based on cost of service plus a fixed rate of return on utility investments. Recently, many state regulatory commissions have adopted multiyear tariff (MYT) regimes in which the regulator approves costs and sales for three to five years in future. Consumer tariffs for a financial year are normally determined annually based on a review of utility performance in the last year. Deviations in a utility's uncontrollable costs are trued up retrospectively in every annual review and passed on to consumers i.e., these costs are added to the utility's aggregate revenue requirement (ARR)[3] of the following year, and tariffs are adjusted accordingly. Difference in consumer sales from the approved trajectory is treated as an uncontrollable factor and utility revenue would be trued up in every annual review. Thus, the recovery of utility's (uncontrollable) costs is decoupled from sales albeit with a lag time of one financial year. This implies that Indian utilities do not face a disincentive of lower profitability if their sales are reduced.

2.2 Subsidies and Cross Subsidies

Consumer tariffs are characterized by government subsidies and cross subsidies among consumer classes (see Table 1). However, under the current power sector reforms, there is a strong push for tariff rationalization and reduction of the cross-subsidy.

Table 1: Estimated Tariff and Average Cost of Supply in Different Indian States (Rs/kWh)[4]

Consumer category / State	Residential (1kW, 100kWh/month)	Commercial (10kW, 1,500kWh/month)	Heavy Industry (10MW[a])	Agriculture (5 HP[b])	Average cost of Supply
Andhra Pradesh	2.39	6.25	4.19	0.24	2.67
Maharashtra	2.76	5.94	5.20	0.90	3.64
Karnataka	2.92	6.51	5.01	0.45	3.92*
Gujarat	3.48	5.95	5.35	0.55	3.12**

[a] MW stands for MegaWatts
[b] HP stands for horsepower
* Refers to Bangalore Electricity Supply Company
** Refers only to UGVCL – The northern Gujarat electricity distribution company
Source: (CEA, 2009) and annual performance reviews for financial year 2008

An Indian utility loses money on average for electricity supplied to agricultural and residential consumers and earns significant revenues above its cost of supply on electricity supplied to commercial and industrial consumers. Utilities would be reluctant to undertake commercial and industrial EE programs because the loss of revenue would be more than the avoided cost of supply. Because the annual regulatory review takes place ex-post, the utility would be losing

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[3] As the name suggests, the aggregate revenue requirement (ARR) is the total amount of revenue that utilities are entitled to collect from consumers every year. ARR consists of total annual fixed and variable costs and a regulated return based on utilities' investments.

[4] Rs refer to the Indian currency Rupees. 1 USD = 47 Rupees (approx).

money over the course of one financial year while waiting for the losses to be trued up. By contrast, the utility would benefit on average from EE programs in residential and agricultural sectors.

2.3 Marginal Power Purchase and Power Shortage

A significant quantity of the marginal power that utilities purchase comes from expensive short-term transactions that are undertaken primarily to meet peak demand. For example, in the financial year 2009, utilities in Delhi purchased nearly 6% of the total energy input on a short-term basis with an average cost of Rs 5.0/kWh while the rest 94% was purchased at an average cost of Rs 2.6/kWh. Thus, if EE programs can reduce peak demand, utilities could avoid these expensive power purchases, which would be a substantial benefit. However, because most distribution utilities in India face acute power shortages, especially during peak demand periods, utilities might use the electricity conserved through an EE program to reduce the extent of shortages and serve unmet demand rather than reducing their expensive peak power purchases.

3 Theoretical Overview

In this section, we present a theoretical overview of our analysis, based on existing literature addressing utility disincentives to implementing EE programs as well as tariff impacts of EE programs considering the nature of the Indian electricity sector and its regulation.

3.1 Impact on Utility Finances

Utility-funded programs entail up-front and administrative costs in addition to loss of revenue from reduction in sales. These costs and revenue losses affect utility profits in two ways: potential under-recovery of a utility's fixed costs in the short run, and reduction in long-run investments and returns.

A significant part of a utility's costs are fixed, but revenue is largely based on volumetric sales (kWh per month).[5] Therefore, if consumer sales decrease as a result of an EE program, there is a risk of under-recovering fixed costs, which would reduce the utility's net earnings. The company's market value might be affected if these receivables become large relative to its size; this might be of concern especially for private utilities (Cappers et al., 2009). However, if EE programs shave peak demand, the utility could reduce its expensive marginal power purchases. When the avoided power purchase cost is more than the EE program expenditures plus lost revenue, the utility benefits; otherwise, it risks under-recovery of costs. In the Indian context, however, this effect is substantially diminished by the annual true-up mechanism. But, because

[5] It should be noted that in India, the rate design is partially straight fixed variable (SFV) i.e., electricity consumers do pay a fixed charge. However, the SFV's contribution to total revenue does not meet the total fixed costs of the utility.

the true-ups are only ex-post, the utility would still risk under-recovery for at least one financial year. For utilities who face frequent power shortages, the electricity conserved through an EE program could be used to reduce shortages and serve unmet demand; in this case, expensive peak power purchases would continue, which would make the utility cash flow worse. Therefore, the utility would, in the short run, face a disincentive to implementing EE programs.

The second financial impact of EE programs relates to the utility's overall profit. A utility's profits are based on its capital investments. Supply-side investments generate substantial annual returns (14% of equity in the case of generation assets and 16% of equity for distribution assets) and are added to the utility's rate base. Large-scale EE programs would reduce the total demand and could defer additional investment in generation, transmission, and distribution infrastructure, so the utility would have to forgo associated returns. This would create a strong disincentive in the long run to implementing aggressive EE programs.

A range of regulatory mechanisms has been suggested in the literature to address utility disincentives. The common theme in all of these mechanisms is offering the utility a financial incentive to make up for loss of revenue and/or profitability. In general, utility incentive mechanisms achieve the following specific objectives:

- Ensure the recovery of direct costs of the EE program (program cost recovery),
- Mitigate the potential risk of diminished opportunity to earn profits (lost margin recovery), and
- Equate EE expenditures with supply-side investments by offering financial incentives.

(Cappers et al., 2009; Jensen, 2007; Kushler, York, & Witte, 2006)

Current regulatory practices in the Indian states of Delhi and Maharashtra allow utilities to treat EE program costs as expense items and recover them from consumer tariffs.[6] Moreover, the annual true-up process ensures recovery of lost margin, albeit with a lag of one year. However, they do not address the utility disincentive of forgone returns. In the subsections below, we present two utility incentive mechanisms that are relevant in India for equating the EE expenditures with infrastructure investments. Capitalization of EE Expenditures

A mechanism that capitalizes EE program expenditures treats them equivalent to capital investments in distribution assets. Under this mechanism, EE investments are added to the

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[6] Regulators in the states of Delhi and Maharashtra have already directed utilities to allocate budgets, generate, undertake load research, and implement appropriate EE programs on a sustained basis. Regulators have allowed the utilities to recover EE program costs from consumers (Rao, Sant, & Rajan, 2009). The Delhi Electricity Regulatory Commission has approved Rs 350 million toward energy conservation for all three utilities in the state for financial year 2010 (DERC, 2009a, 2009b, 2009c).

utility's rate base, and the utility earns a return on them (16% on equity) until amortization. The utility might also be offered a bonus return for superior performance. This mechanism was used in several U.S. states including Washington, Montana, Wisconsin, and Connecticut during late 1980s and early 1990s (Jensen, 2007). This approach would be effective for incentivizing the unbundled distribution utilities to lower their peak power purchase costs; distribution utilities would prefer additions to the rate base over spending on short-term power purchases. However, because this incentive directly depends on the utility's EE program expenditures, it essentially encourages utilities for undertaking capital-intensive programs, which might lead to inefficient investments and gold plating. Stringent regulatory prudence would be necessary in approving EE programs if this mechanism were used.

3.1.1 Shared Net Resource Benefits

The shared net resource benefit mechanism allows utilities to retain a share of the resource benefits that result from full implementation of an EE program. Because the incentive is linked with resource benefits, this mechanism encourages utilities to undertake programs with large resource benefits and also acts as a performance incentive for successful implementation of these programs. Several U.S. states, including California, Arizona, Connecticut, and Massachusetts, offer utilities a financial reward or penalty for meeting certain targets (Kushler et al., 2006)[7]. If a third party (like an energy services company) implements EE programs, this mechanism is especially suitable because it shares the implementation risk and part of the resource benefits with the third party. However, this mechanism entails a fairly complex determination of avoided costs, net resource benefits, and minimum performance levels, and it necessitates stringent evaluation, monitoring, and verification of the EE program.

It is important to note that in India, most distribution utilities are publically owned, and profit maximization might not be the key driver of a public utility's decisions. So, financial incentives are more likely to be effective for private utilities.

3.2 Impact on Consumer Tariffs

For utility-funded EE programs, regulators would pass on to consumers both the increase in costs resulting from program expenditures and benefits related to avoiding marginal power purchases. At the same time, utility sales would also decrease, ceteris paribus. The average consumer tariff is utility's ARR divided by total sales. Therefore, the impact of EE programs on average tariff depends on the percentage reduction in energy sales from the program relative to the percentage reduction in total ARR. If the avoided cost of power purchases resulting from the EE programs is

[7] California's shared benefit mechanism penalizes utilities if performance drops below 65% of the goals set by the regulator for the three-year EE program cycle; pays 9% of net benefits for achievement between 85% and 100% of goals, and 12% of net benefits for achieving 100% or more, with a statewide cap of $450 million on both earnings and penalties (Cappers et al., 2009).

not significant, the percentage reduction in the ARR would be lower than the reduction in total sales, so the average tariff would increase. If the avoided cost of power purchase was significant, the reverse would hold true. In any case, consumers who participate in EE programs would benefit from the reduction in their consumption. Because the energy consumption of non-participant consumers would remain the same, ceteris paribus, their electricity bills would increase if the average tariff increased, which raises concerns that an unfair burden might be placed on them. Although this concern needs to be addressed, it is worth noting that expensive peak power purchases are also recovered from all consumers. Because tariffs are not differentiated by time of day except for industry, customers who consume less power on peak pay the same share of expensive power purchase as customers consuming more power on peak. Given that the cost of electricity saved is typically lower than the cost of expensive peak power purchases, implementation of EE programs could potentially reduce cross subsidization among consumers. For utilities with frequent power shortages, if EE programs reduce these outages, service quality is improved for all customers, including non-participants.

4 Methodology[8]

We describe below our methodology for estimating the impact of EE programs on utility cash flow, returns, and consumer tariffs, which is based on the theoretical framework developed above. We begin by stating the scenarios for the analysis.

4.1 Scenarios for Analysis

The impacts on utility finances and consumer tariffs are examined by developing scenarios that account for variations in the following key factors:

(a) Utility incentive mechanism
The regulator might continue with the current regulatory set-up that offers no incentive, or the regulator could employ one of the utility incentive mechanisms identified above, i.e., capitalization or shared benefit.

(b) Total program expenditure by utility
Given the benefits described earlier, utilities might consider funding EE programs fully, partially, or not at all. In case of partial or no utility funding, we assume that participating consumers bear the incremental costs.

(c) Treatment of conserved electricity
Once EE programs are successfully implemented, utilities could avoid expensive peak power purchases or sell the electricity conserved through the EE program back to the grid at a

[8] For detailed explanation of the methodology and associated equations, please refer to appendix B.

higher rate if the utility does not face shortages. For utilities with power shortages, the conserved electricity could be used to reduce the shortages.

(d) Level of power shortage in the state

Although there is currently no power shortage in Delhi, we create two scenarios where Delhi faces a peak demand shortage (5% by sales) or an intermediate load shortage (10% by sales) to analyze whether EE programs can fully or partially mitigate the shortage. This analysis is intended to make our results relevant for other states in India, most of which face severe shortages.

4.2 Impact on utility cash flow

The net impact on utility cash flow over a year (*U*) is the net under-recovery (or over-recovery) of its ARR. This is calculated as:

$$U = R + I - k - l + u \qquad \ldots\ldots (1)$$

where *R* represents the gross resource benefits from EE programs i.e., either reduction in power purchase expenses or additional revenue from selling saved electricity to grid, *I* is the incentive given to the utilities, *k* is the annualized utility expenditure on EE programs, *l* is the revenue lost because of reduced consumption by customers participating in the program, and *u* is the increase in revenue obtained by selling the saved electricity to customers facing shortages (this applies only if the utility experiences shortages).

Estimating R

In case utilities do not face power shortage, *R* can either be the avoided cost of marginal power purchase or the additional revenue that utility might earn if it sells the conserved power into the grid. Power purchase costs are projected by applying the previous five-year compounded annual growth rate (CAGR) to the actual data for 2009-2010 while the grid sale price for conserved power is taken as Rs 8/kWh based on the market clearing prices on the Indian energy exchange during the peak demand periods in 2009-10. The transmission and distribution (T&D) losses are taken as 15% over the course of analysis.

Utilities that face regular power shortages can use the electricity conserved through EE programs to serve unmet demand and minimize power outages. When the amount of conserved electricity is less than the extent of shortages, utilities' expensive peak power purchases are not reduced. If EE programs fully make up shortages and leave the utility with an energy surplus, the utility could use the surplus to avoid expensive peak power purchases or sell the surplus on the market.

Estimating I

Under the current regulatory practice, utilities are not awarded any explicit incentive for implementing EE programs. When the EE expenditures are capitalized, utility incentive depends on utility's equity share of the total EE investments. We assume that the regulatory practice of allowing 30% equity in infrastructure investment and 16% return on equity will be applied to the EE investments as well. In case of the shared benefit mechanism, we hypothesize that utilities successfully implement EE programs and 9% of the net resource benefits are shared with the utility.[9]

Estimating l

Utilities stand to lose marginal tariffs from consumers due to reduction in sales. Note that consumers within a category (for example residential and commercial) are divided in to several tiers based on their monthly electricity consumption (for example 0-200 kWh, 201-400 kWh); the higher the consumption, the higher the "marginal tariffs" for that tier. Generally, the marginal tariffs for high-consumption tiers are significantly higher than the average tariff especially for residential consumers. l is calculated by multiplying the projected reduction in consumption for each tier (as described in appendix A and B) and the marginal tariff for that tier.

Estimating u

Utilities that face shortages earn additional revenue by using saved energy to serve demand that would normally be unmet. Such additional sales would be limited

Thus, utility cash flow becomes negative when the gross benefits plus incentive are less than the total annual program cost plus the loss in revenue. It would be especially pronounced for commercial programs where the revenue loss is high because the marginal tariffs are almost comparable to marginal power purchase costs. When the utility sells the electricity conserved through an EE program to the grid, R increases significantly, and utility's cash flow improves. Partial utility funding of EE programs would lower the utility's net cost, and might improve cash flow. When savings from EE programs are not able to fully mitigate shortages, net cash flow depends on the difference between the marginal tariffs of conserved electricity and unmet demand. In any case, net under or over recovery, U would be passed on to consumers in the following true-up cycle.

4.3 Impact on Utility Returns

For estimating the impact of EE programs on utility returns, we first project the BAU peak demand, over the analysis period, by applying the last five-year CAGR to the 2010 value. Assuming that the infrastructure investment directly depends on the peak demand, we project the additional distribution infrastructure investment over the analysis period using the ratio of total capital investment and peak demand from 2002 onward. Reduction in peak demand due to EE programs obviates the need for new infrastructure investment resulting into loss of utility returns. Therefore, the total incentive offered to the utility should be at least equal to the lost return.

[9] This value is same as what the California Public Utilities Commission allows as an incentive payment under its shared benefit scheme when utilities achieve 65-100% of the target.

4.4 Impact on Annual Revenue Requirement and Total Sales

Utilities' ARR and electricity sales in a year under BAU conditions are identified as A and E, respectively. Once EE Programs are implemented, these values change to A' and E'.

$$E' = E - S \quad \text{...(2)}$$

$$A' = A - R + k + I \quad \text{...(3)}$$

Where, S represents the total reduction in sales in GWh and k is the annual EE program cost to the utility.

Note that gross resource benefits, R are significantly higher than the annual EE program cost and utility incentive. Therefore, EE programs reduce the total utility ARR; i.e., $A'' < A$.

For utilities facing shortages, EE programs might improve the service quality due to reduction in power cuts and thus, their impact should be analyzed with reference to the same service quality. To this end, we construct hypothetical alternatives in which the utility improves service quality in the absence of the EE programs but to the same level as would be achieved through EE programs. We construct three such "alternative service improvement" scenarios. In the first, the utility has already bought all available power in the market, so no service improvement is possible, ceteris paribus. In the second, the utility could purchase additional power at the short-run marginal cost; this is equivalent to expensive power purchases from the real-time market (Unscheduled Interchange [UI][10]) or the day-ahead spot market (operated by Power Exchange Indian Ltd. or Indian Energy Exchange). In the third, the utility purchases additional power at the long-run marginal cost, equivalent to long-term bilateral contracts. Therefore, each of these scenarios would have different ARR and sales than the BAU case.

4.5 Consumer Tariffs and Net Benefits

The average consumer tariff is nothing but the net ARR divided by total sales. Note that we have frozen the BAU case consumer tariff at 2011 levels. Sales are projected using historical growth rates, and the ARR is estimated as a product of average tariffs and total sales. After the EE programs have been implemented, the average consumer tariff would change because of the changes in both the ARR and sales. When the net reduction in ARR as a percentage of the original ARR is lower than the reduction in sales as a percentage of original sales, average consumer tariffs would increase. Likewise, if the percentage reduction in ARR is more than the reduction in sales, average tariffs would reduce, resulting in benefits for non-participants as well. Thus, if a utility is able to sell the power conserved through the EE program to the grid at a price

[10] UI is the real-time power market in India where the price is linked to grid frequency, which is allowed to vary within a certain range. Lower frequency(indicating greater demand) is matched to a higher price, and vice versa.

higher than its marginal power purchase cost, the impact on consumer tariffs would be significantly lower. Note that the participating consumers always benefit. This is because even if the average tariff increases, their consumption reduces significantly. On the other hand, non-participants' consumption does not decrease, ceteris paribus, and thus, when EE programs result in a tariff hike, non-participants lose, but they benefit in case of tariff reduction.

Detailed methodology for estimating the impact on utility cashflow, returns and consumer tariffs is explained in Appendix B of this report.

4.6 Potential Costs and Benefits of EE Programs in the state of Delhi[11]

In this section, we present our estimate of the total potential for cost-effective EE programs in Delhi over four years: 2012 through 2015. Detailed assumptions, methodology, and calculations can be found in the Appendix A to this paper.

4.6.1 Electricity Demand

Three private distribution utilities – North Delhi Power Limited (NDPL), BSES Yamuna Power Limited (BYPL), and BSES Rajdhani Power Limited (BRPL) – currently supply power to Delhi. Table 2 shows actual electricity sales in Delhi for financial year 2010 and our projections over the analysis period (2012-2015) assuming BAU conditions.

Table 2: Current and Projected Sales in Delhi (excluding sales by New Delhi Municipal Council [NDMC])

Total Sales (GWh*)	Total Delhi - BAU (BRPL, BYPL, NDPL)				
	FY 2010	FY 2012	FY 2013	FY 2014	FY 2015
Residential	8,827	10,244	11,035	11,888	12,806
Commercial	4,993	6,454	7,338	8,342	9,484
Industrial	2,953	3,563	3,914	4,299	4,723
Other	1,420	1,793	1,995	2,206	2,422
Total	18,193	22,054	24,282	26,734	29,435

*Gigawatt hours

Sources: (BRPL, 2010; BYPL, 2010; NDPL, 2010); Authors' estimates

[11] Note that the numbers presented here are approximate primarily because of the lack of load research data. We have estimated these numbers by making several simplifications and assumptions. Details of our methodology and calculations can be found in Appendix A to this paper.

4.6.2 Power Purchase Cost

The cost of power purchases is the largest component (more than 70%) of utilities' annual budgets. Power purchased from central generating stations and intra-state generation plants is significantly cheaper than interstate short-term purchases, as shown in Table 3.

Table 3: Average Cost of Power Purchase in Delhi (excluding NDMC) (2009)

Source	Total Delhi (BRPL, BYPL, NDPL) (2009)	
	Power Purchase GWh	Average Cost Rs/kWh
Central Generating Stations	18,128	2.54
State Generating Stations	4,266	2.79
Interstate + Bilateral purchase	1,938	3.81
UI	128	9.14
Total	21,612	2.40

Source: (BRPL, 2010; BYPL, 2010; NDPL, 2010)

It is clear that the UI is the most expensive form of power, which is primarily used to meet the peak demand. Demand peaks are also met by interstate and bilateral purchases, which more or less act as intermediate load sources while Central Generating Stations and most Delhi State generating stations act as sources of low-cost baseload power.

4.6.3 Large-Scale EE Programs in Delhi

Nearly 75% of Delhi's current electricity consumption and 76% of projected growth in consumption over the analysis period is from the residential and commercial sectors. Therefore, we restrict our analysis to these two sectors only. We specifically focused on installation of energy-efficient products for typical end uses such as lighting (replacement of T-12 fluorescent lamps with more efficient T-5 lamps), water heating (replacing electric water heaters with natural gas or solar heaters), space cooling (replacing less-efficient fans and air conditioners with more efficient models) and refrigeration (replacing less-efficient refrigerators with more efficient direct cool or frost-free models, in the residential sector only). These end uses were chosen because they are responsible for a large part of the residential and commercial electricity consumption (Boegle, Singh, & Sant, 2010; McNeil, Iyer, Meyers, Letschert, & McMahon, 2005). Moreover, energy-efficient products for these end-uses are readily available in the market, which would make implementation of large-scale programs easier[12].

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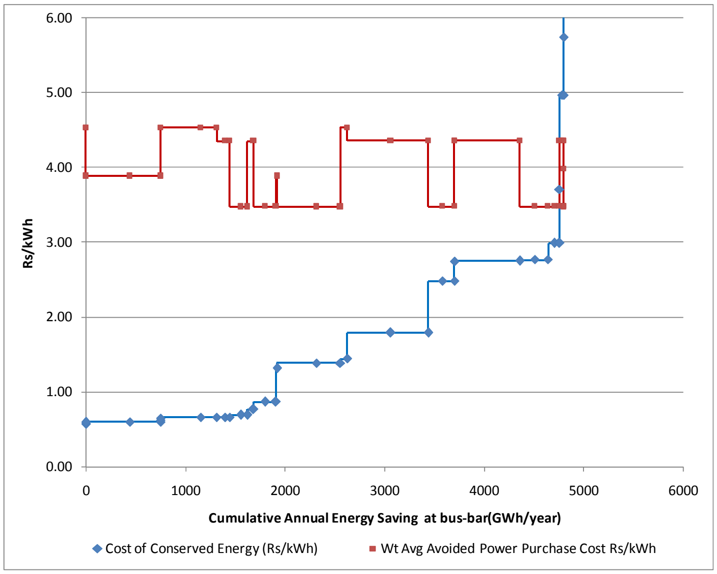
[12] Compact fluorescent lamps (CFLs) are not included because preliminary load surveys indicate that there is already a high penetration of CFLs, and the central government has embarked on a national CFL program. Our detailed methodology for estimating economic potential is described in Appendix A.

As explained in Appendix A, total cost-effective energy savings potential in Delhi's residential and commercial sectors between 2012 and 2015 is about 4,800 gigawatt hours (GWh) at bus bar, which translates to a reduction of 14% in total BAU sales by 2015. This is shown in the EE cost curve for Delhi (residential + commercial) in Figure 1.[13] The curve plots the cost of conserved energy and the marginal power purchase cost against the cumulative annual energy savings for every EE program.



Note: Each point on this curve indicates one EE technology. The difference between avoided power purchase cost and the cost of conserved energy curves essentially indicate the net benefits of EE program.

Figure 1: Cost Curve of Residential and Commercial EE programs in Delhi between 2012 and 2015

Given that no large-scale EE program has yet been implemented in India, we assume that the regulator sets a target of achieving 50% of the total cost-effective potential, i.e., a reduction in sales of 2,040 GWh or 7% by 2015. Note that the target of 50% is applied to each program individually.

5 Results

In this section, we present the results of our analysis of the financial impacts of large-scale EE programs on Delhi utilities and consumers for the period 2012 through 2015. We assume that Delhi utilities would achieve the EE targets irrespective of their cash flow situation and that the regulator performs an annual true-up of cost and revenue deviations. When utilities partially fund

[13] Note that the avoided power purchase cost in Figure 1 varies for every EE program because every end use has a different peak coincidence factor. The difference between the avoided power purchase cost and cost of conserved energy is a resource benefit that results from EE programs.

EE programs, we assume that participating consumers bear the rest of the cost. For utilities that regularly experience power shortages, our analysis does not include the economic benefits of reducing power shortages.[14]

5.1 Impact on Utility Finances

We estimate two impacts on utility finances: impact on cash flow (or net annual under-recovery) and on long-run returns. Key characteristics of the utility, such as the consumer mix and amount of power purchased from each source, are assumed to remain the same throughout the analysis period.

5.1.1 Effect on Utility Cash Flow

Table 6 shows the effect on utility cash flow, under the capitalization and shared benefit incentive mechanisms, of two choices the utility could make for using the power conserved through the EE program: one choice is to use the conserved power to avoid marginal peak power purchases and the other is to sell the conserved power to the grid.

Table 4: Net Effect on Utility Cash Flow (Rs million/yr)

	Avoided Marginal Power Purchase			Grid sale of power		
Year	Current Reg Setup	Capitalization	Shared benefit	Current Reg Setup	Capitalization	Shared benefit
2012	-781	-506	-497	439	714	723
2013	-441	-280	-276	748	909	913
2014	-563	-394	-423	474	643	614
2015	-533	-426	-376	548	655	704

Given the scale of hypothesized EE programs and Delhi's current power purchase profile, the weighted average cost of avoided marginal power purchase reduces significantly (Rs 4.68-5.59/kWh depending on the year in our case). This avoided marginal power purchase cost turns out to be less than the sum of average EE expenditure (1.50-1.98 Rs/kWh) and typical marginal tariff (Rs 4.2-4.3/kWh) leading to a negative cash flow. Note that the amount of under-recovery is significant enough to erode the utility's net profitability. For example, under-recovery in 2012 under the current regulatory setup is more than 10% of the projected net profits for that year. Under-recoveries in the following years are estimated assuming regular annual true-ups; if the lag between annual reviews is more than one year, the impact on profitability is even more pronounced. However, sale of peak power to the grid at a higher price (Rs 8/kWh) than the price of marginal power purchases generates significant resource benefits, and utility cash flow is

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[14] Please refer to (Phadke et al., 2005) and (Jayant Sathaye & Gupta, 2010) for discussions on economic benefits of shortage reduction through efficiency improvement.

positive for all four years. Incentive mechanisms improve the utility's cash flow, but the effect is small. Similarly, if the utility only partially funds the EE programs, cash flow would be only marginally better. This is mainly because utility incentives or total program cost is significantly less than the gross resource benefits of EE programs.

For utilities that face shortages, conserved power is predominantly used to serve currently unmet demand, so the expensive peak power purchases remain intact. This makes net cash flow worse, as shown in Table 7.

Table 5: Net Effect on Utility Cash Flow with Power Shortages (Rs million/yr)

Year	*Average marginal tariff (*Rs. 4/kWh)			*Marginal tariff for low paying consumers (* Rs. 2/kWh)		
	Shortage = 10% (Savings < shortage)	Shortage = 5% (Savings > shortage)		Shortage = 10% (Savings < shortage)	Shortage = 5% (Savings > shortage)	
		Avoid power purchase	Grid Sale of excess power		Avoid power purchase	Grid Sale of excess power
2012	-1,674	-1,645	-1,645	-3131	-3,314	-3,314
2013	-2,190	-898	-365	-4545	-2,736	-2,203
2014	-2,823	-10	1,265	-6018	-2,034	-759
2015	-3,430	915	2,984	-7510	-1,314	756

Note: Power shortages are expressed as a fraction of total BAU sales. Thus, as BAU sales are assumed to increase at historical growth rates, shortages in absolute terms (GWh) also increase over years.

Table 7 makes clear that utilities would face a strong disincentive when conserved power is used to alleviate shortages experienced by low-paying consumers. Meeting these shortages essentially means that expensive peak power purchases are used to serve currently unmet demand from low-paying consumers. Because the difference between the power purchase cost and the revenue from these consumers is large, the utility ends up losing money. When EE programs result in savings that are greater than shortages, the saved electricity can be sold back to the grid at higher prices than the marginal power purchase cost, significantly improving the revenue earned by the utility.

It is clear that utility incentive mechanisms and the current annual true-up mechanism provide little help in managing the negative cash flow. Therefore, a more flexible and sustainable solution to the cash flow management issue is needed. One of the options is to emulate a mechanism like FAC and include it as a part of the utility incentive mechanism. For example, utility sales and revenues would be trued-up on a regular basis like monthly or quarterly subject to a mutually agreed monitoring and Verification (M&V) plan. Another option might be to have the net program cost and revenue loss built into consumer tariffs ex-ante. However, the latter approach requires institutionalization of the EE programs that might take time.

5.1.2 Utility Returns

Table 8 shows the total infrastructure investments and returns deferred by utilities as a result of reduction in peak demand.

Table 6: Deferred Infrastructure Investments and Utility Incentives (Rs Million/yr)

Year	Deferred Infrastructure Investments	Cumulative Forgone returns by the utility*	Utility Incentive	
			Capitalization	Shared Benefit
2012	504	24 (0.3%)	203	251
2013	514	49 (0.6%)	373	402
2014	524	74 (1.0%)	543	533
2015	536	100 (1.3%)	721	678

*Figures in the brackets indicate forgone returns as the percentage of the projected annual returns by the utilities.

The forgone returns are not trivial; therefore, utility incentive mechanisms are critical. The incentive mechanisms can address the utility disincentive since the incentive is greater than the forgone returns. Total incentives under both mechanisms are almost identical and are equivalent to the total returns utilities would earn if they invested the EE program costs in distribution assets. The capitalization incentive is substantially higher than the forgone return because the distribution utility only loses the return on deferred distribution investment and not on deferred transmission and generation investment.

5.2 Impact on Consumer Tariffs

Large-scale EE programs significantly influence consumer tariffs and consumer benefits. Tariffs generally increase with EE programs, but the programs create significant benefits for participating consumers. Figure 2 plots the average increase in consumer tariffs over the analysis period, against total reduction in sales.

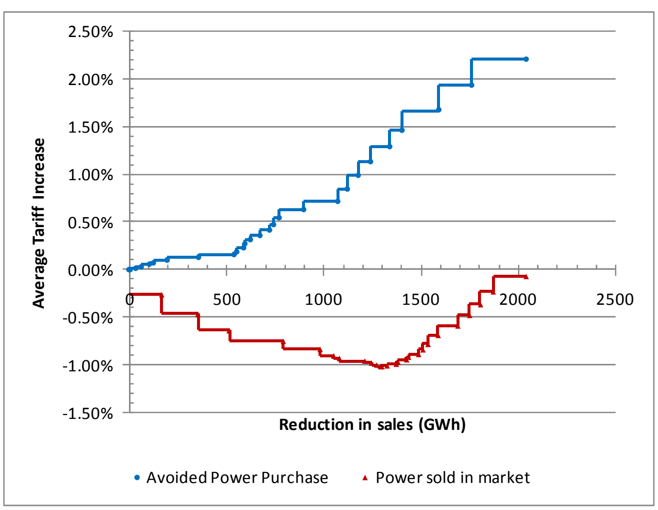
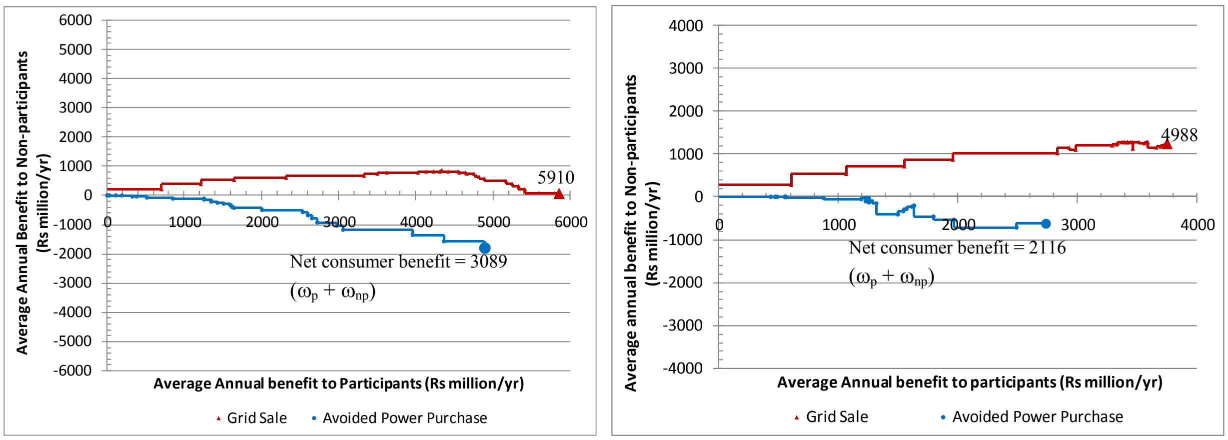


Figure 2: Impact of EE programs on Consumer Tariffs

Given the scale of EE programs we considered and Delhi's current power purchase profile, the marginal power purchase cost for Delhi utilities would reduce over the years with the addition of EE programs. This generates low gross resource benefits, *R,* and results in a 2.2% tariff hike. If the power conserved through EE programs is sold to the market at a higher price (Rs 8/kWh) than the marginal power purchase cost, *R* increases significantly, and average tariffs slightly reduce. In both cases, participant consumers benefit because their total consumption decreases. However, tariff increases cause a loss to non-participants, as shown in Figure 3.



(a) 100 % utility expenditure **b) No utility expenditure**

Figure 3: Impact of EE programs on Participant and Non-participant Benefits

Figure 3 can be thought of as the inverse of Figure 2 on a different x-axis, representing benefits to participants. Thus, if tariffs increase, non-participants lose; if tariffs reduce, non-participants gain. Figure 3(b) is drawn to show the impact of utility funding. If the utility does not fund any program expenditures, participating consumers bear the program cost, so their benefits are reduced by the amount of direct program expenditure, and non-participant benefits increase because program cost is not loaded into consumer tariffs. In all four cases, net consumer benefits (participants minus non-participants) are positive. As noted earlier, the utility incentive, *I*, being small compared to the gross resource benefits, would not have a significant impact on consumer tariffs or benefits. Figure 4 compares the total utility incentive and net consumer benefit.

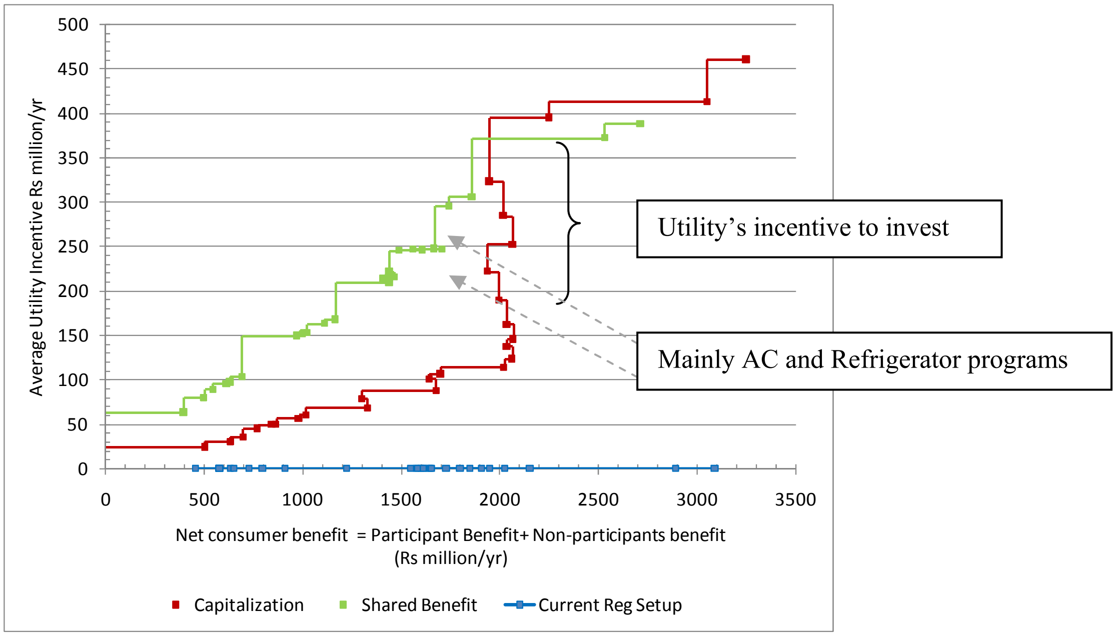
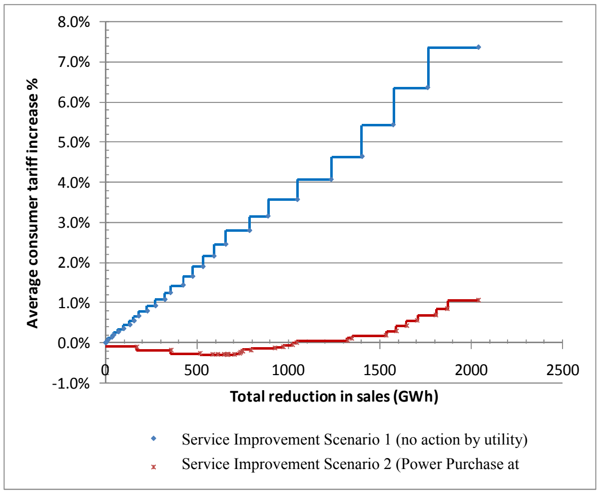


Figure 4: Average Utility Incentive versus Net Consumer Benefit (participants + non-participants)[15]

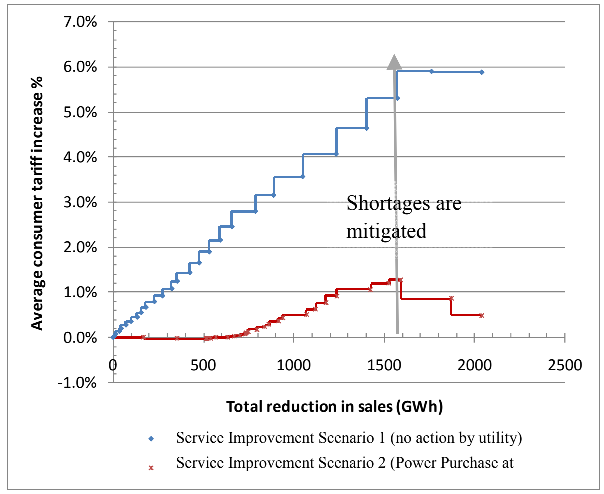
Although the utility incentive under the two mechanisms is very similar, the shapes of the two curves are vastly different. For the capitalization incentive, the utility's incentive rises sharply when it implements capital-intensive EE programs like refrigerator and air conditioner replacements. This incentive would likely lead the utility to focus only on capital-intensive programs. For the shared-benefit incentive, the utility incentive increases almost linearly because it is directly proportional to the total resource benefits.

The tariff impact for utilities that face power shortages depends on the extent of the shortages, θ, and the alternative service improvement scenarios we constructed, as shown in Figure 6.

[15] Note that numbers presented in this chart are average values of the utility incentives and consumer benefits. Therefore, they might not exactly match with the yearly values.



(a) Shortage = 10% of sales
(savings lower than shortage)



(b) Shortage = 5% of sales
(savings more than shortage)

Figure 5: Impact of EE programs on Consumer Tariffs When Utility Faces Shortages

Figure 5(a) plots the average tariff increase when savings from EE programs cannot fully mitigate power shortages. When the utility does not (or cannot) take any action to mitigate shortages (service improvement scenario 1), consumers face a large tariff increase because the resource benefits are zero; conserved power is used to serve the unmet demand. However, service quality improves significantly when shortages are reduced; this is not accounted for in this analysis. When the utility purchases expensive power specifically to mitigate shortages (service improvement scenario 2), conserved power can be used to displace that purchase, so the tariff hike is substantially lower. Figure 5(b) plots the same lines as 5(a) but assumes that savings from EE programs fully mitigate shortages. Once the shortages are mitigated, utilities could sell the surplus energy into market. This is reflected in the slight drop in consumer tariffs after the entire unmet demand is served. The effect of service improvement scenario 3 (when the utility purchases power through bilateral contracts at long-run marginal cost) would be between these two extremes.

5.3 Sensitivity Analysis

The cost and benefit numbers presented here are based on the specific EE programs we considered, Delhi's current power purchase profile and market prices. In this section, we discuss the sensitivity of our results on these key assumptions in order to apply the results to other states.

5.3.1 Marginal Cost of Power Purchase

The marginal power purchase cost of Delhi utilities is significantly lower than that in other states such as Maharashtra the average cost of peak power purchase in 2009 was Rs 7.09/kWh (MSEDCL, 2010). This implies that the resource benefits of EE programs, *R*, would be significantly higher in other states; it would be close to the "grid power sale" scenario of the Delhi case. Thus, the utility cash flow might be positive and consumer tariffs might reduce after the implementation of EE programs.

5.3.2 Choice of EE Programs

As noted earlier, different EE programs have significantly different costs and resource benefits. For example, replacement of T-12s with T-5 tubelights would generate significant peak shaving benefits at a low cost. On the contrary, replacement of conventional refrigerators with efficient ones would be costly to implement but would not avoid expensive power purchase. Thus, the net benefits would change in case utility funds only high-cost, low-benefit programs. This can be seen in Figure 4. Similar framework can be applied if utility chooses programs in other sectors like industry or agriculture. The impact on consumer tariffs and utility finances depend on the net resource benefits of those programs. Industrial consumption does not make a significant contribution to peak demand and therefore, the avoided cost of marginal power purchase would be lower. In case of agricultural programs, the avoided cost of power purchase would be even lower because most of agricultural consumers are supplied power only at off-peak hours. Therefore, both these programs would result in low resource benefits and higher tariff hike. In case of agricultural programs, utility cash flow would improve because the loss in revenue would be low as a result of low tariffs. In fact in several states, most agricultural consumers pay only a fixed charge in which case, the loss in revenue would be zero.

5.3.3 Marginal Tariff for Resale

Most utilities in India face severe power shortages. In many cases, rural and agricultural consumers face long power cuts. Therefore, saved electricity due to EE programs might be used to partially alleviate their shortages. As shown in Table 5, utility cash flow is highly sensitive to marginal tariffs of consumers to whom the saved electricity is sold. When it is sold to low-paying consumers, utility faces a substantially negative cash flow thereby creating a strong disincentive to implementing EE programs. If saved electricity is sold to agricultural consumers paying only fixed charge, the cash flow would be even worse.

Impact on utility finances and consumer tariffs are not very sensitive to the share of total expenditure by the utility and total incentive paid to the utility.

6 Conclusion

In this paper, we analyzed the impacts of large scale EE programs on utility finances consumer tariffs in India, using the state of Delhi as a case study. The analysis was performed by hypothesizing that Delhi utilities undertake residential and commercial EE programs between 2012 and 2015.

Given the scale of EE programs we considered and Delhi’s current power purchase profile, consumer tariffs would modestly increase when the power conserved through EE programs is used to avoid expensive marginal peak power purchases. However, if utilities can sell the conserved power on the market at a price higher than the marginal power purchase cost, net resource benefits increase substantially, and consumer tariffs decrease. In either case, participant consumers benefit significantly from their reduced electricity consumption. An increase in average tariff implies that non-participants lose on average, but their losses are small compared to the benefits for participants.

If utilities faced power shortages, the tariff impact depends on the extent of the shortages and utilities' efforts to decrease the shortages in absence of EE programs. If the utility does not (or cannot) purchase additional power to mitigate shortages, consumers would face a large tariff impact on average when EE programs are implemented. However, the primary benefit of EE programs is reduction in load shedding, which might make them politically acceptable even if tariffs increase. To increase political support, utilities could pursue programs that would result in minimal tariff increases. This can be achieved in four ways: (a) focus only on low-cost programs (such as replacing T-12 fluorescent lamps with more efficient T-5s, or replacing electric water heaters with gas water heaters); (b) sell power conserved through the EE program to the market at a price higher than the cost of peak power purchase; (c) focus on programs where a partial utility subsidy of incremental capital cost might work and (d) increase the number of participant consumers by offering a basket of EE programs to fit all consumer subcategories and tariff tiers.

The reduction in sales that results from EE programs affects both the utility's cash flow and long-run returns. In case of shortages, the impact on cash flow is very sensitive to the marginal tariff that the utility receives from serving unmet demand. If the marginal tariff is low, i.e., the customers normally subject to outages are in a low-paying rate class, the utility cash flow worsens. This can significantly erode the utility's overall profitability.

Our findings clearly call for a flexible, sustainable solution to the cash-flow management issue. One option is to include a mechanism like FAC in the utility incentive mechanism. Another sustainable solution might be to have the net program cost and revenue loss built into utility's revenue requirement and thus into consumer tariffs up front. However, the latter approach requires institutionalization of EE as a resource; utilities would have to propose EE programs annually along with their resource procurement plans. Both options are significantly different from current regulatory practice in India.

EE programs also affect utilities' long-run returns. Regulated utilities have an incentive to make more capital investments because their guaranteed returns are linked to their asset base. However, enhancing efficiency may obviate the need for new investments, thereby lowering net profits. This paper describes two utility incentive mechanisms – capitalization and shared benefit – to overcome this disincentive. Since the incentives are larger than the forgone returns by the utility, we conclude that these incentives mechanisms would be effective at overcoming in the utility disincentive.

Fundamentally, providing incentives for EE programs to make them comparable to supply-side investments is a way of moving the electricity sector toward a model focused on providing energy services rather than providing electricity. Incentivizing EE could also play an important role in India's climate change mitigation plan.

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Appendix A: Potential Costs and Benefits of Residential and Commercial Energy-Efficiency programs in Delhi: Calculation Methods

This appendix describes the methods we used to calculate potential costs and benefits of residential and commercial energy-efficiency programs in Delhi.

Costs and Benefits of Energy-Efficiency Programs

We selected the following specific energy efficiency measures for analysis in this paper:

Residential Sector

(i) Replacement of T12 fluorescent lamps by T5 lamps
(ii) Replacement of electric water heaters by natural gas or solar water heaters
(iii) Replacement of conventional refrigerators by direct cool or frost-free energy-efficient refrigerators available on the market
(iv) Replacement of conventional air conditioners by energy-efficient air conditioners available in the market
(v) Replacement of conventional fans by efficient fans

Commercial Sector

(i) Replacement of T12 fluorescent tubes by T5 tubes
(ii) Replacement of conventional air conditioners by energy-efficient air conditioners available on the market
(iii) Replacement of electric water heaters by solar water heaters
(iv) Replacement of conventional fans by efficient fans

We did not include compact fluorescent light (CFL) programs in our estimation because, according to recent load surveys, CFL penetration in Delhi is high the central government already has a program specifically targeted at household consumers to replace incandescent bulbs with CFLs.

We consider two types of refrigerators: frost free and direct cool. Frost-free refrigerators have a volume of 230 liters; direct-cool refrigerators have a volume of 180 liters. Frost-free refrigerators would consume more energy than direct cool refrigerators and are more costly. Similarly, two types of air conditioners are commonly used in India: window and split. Assuming the same cooling capacity (typically 1 ton), split air conditioners would be more costly than window-type air conditioners. However, there is a great variation in manufacturing and maintenance practices for window-type air conditioners, which also have many local vendors/manufacturers. As a results, it was hard for us to get reliable data on their consumption, so we decided to not consider them in our analysis.

A preliminary market survey indicates that Indian Bureau of Energy Efficiency (BEE) star-labeled products have a significant share of the new refrigerator and air conditioner markets. Therefore, we consider a 3-star-labeled refrigerator as the baseline “conventional” appliance and a 5-star-labeled refrigerator as the efficient (direct cool or frost-free) one, for both direct cool and frost-free refrigerators. We understand that consumption of the non-star -rated and/or old conventional appliances currently in use may be significantly higher than the star-rated conventional appliance we have assumed here. Our use of a more efficient baseline conventional model means our projections of the amount of energy saved by installing more efficient models is likely smaller than the actual potential savings. For air conditioners, we assume that 1-star-labeled air conditioners are the conventional models, and 5-star air conditioners are the efficient replacement, with a cooling capacity of 1 ton in both cases.

Tables 4 and 5 show key data on consumption and other parameters of conventional as well as energy-efficient appliances.

Table A4: Data on Energy Efficient Measures in the Residential Sector

Program/technology	Lighting (florescent lamps)		Water Heating			Refrigeration (Direct Cool)		Refrigeration (Frost Free)		Split AC		Fans	
			Electric Geyser	Natural Gas	Solar	Conven-tional	Effi-cient	Conven-tional	Effi-cient	Conven-tional	Effi-cient	Conven-tional	Effi-cient
Power requirement (Watts)	52	25	3,000	-	-	108	76	165	108	1,350	1,100	70	50
Appliance life (hours)	3,000	3,000	10(yrs)	10(yrs)	15(yrs)	10(yrs)	10(yrs)	10(yrs)	10(yrs)	10(yrs)	10(yrs)	10	10
Usage (hours/year)	1,460	1,460	250	250	250	3,329	3,329	3,329	3,329	800	800	1,600	1,600
Retail market price (Rs./Unit)	185	340	2,500	3,100	20,000	8,500	11,200	12,800	16,200	15,000	25,000	800	1,000
Annual electricity use (kWh/year)	76	37	750	-	-	360	253	549	360	1,080	880	112	80
Peak Coincidence Factor	0.9	0.9	0.75	0.75	0.75	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
Coincidence of Use Factor	1	1	0.15	0.15	0.25	0.9	0.9	0.9	0.9	0.75	0.75	0.9	0.9

Table A5: Data on Energy Efficiency Measures in Commercial Sector

Program/ technology	Lighting (fluorescent lamps)		AC (Split)		Water Heating		Fans	
	T-12 lamp	T5 lamp	Conventional	Efficient	Electric Geyser	Solar	Conventional	Efficient
Power requirement (W)	52	25	1,350	1,100	3,000	-	70	50
Appliance life (hours or years)	3,000	3,000	10 (yrs)	10 (yrs)	10 (yrs)	15 (yrs)	10 (yrs)	10 (yrs)
Usage (hours/year)	2,920	2,920	2,400	2,400	900	900	2,000	2,000
Retail market price (Rs./Unit)	185	340	15,000	25,000	2,500	20,000	800	1,000
Annual electricity use (kWh/year)	152	73	3,240	2,640	2,700	-	140	100
Peak Coincidence Factor	0.5	0.5	0.3	0.3	0.8	0.8	0.33	0.33
Coincidence of use factor	1.0	1.0	0.75	0.75	0.25	0.25	0.90	0.90

Estimation of the Cost of Energy Efficiency Programs

Main costs in implementation of energy efficiency measures are (a) incremental capital cost of the efficient appliance and (b) program administrative costs if implemented at the utility level. In case of LPG and natural gas water heaters, fuel cost is also a significant part of the total annual cost. The following formulae give details of how the Cost of Conserved Energy (CCE) and the Cost of Conserved Peak (CCP) are estimated.

$CCE(Rs/kWh) = \frac{\tilde{k} + \tilde{f}}{S}$, where

$\tilde{k}$ is the incremental annualized capital cost of the efficient appliance (Rs/year) which essentially is the difference between the annualized capital costs of the efficient appliance and the conventional appliance,

$\tilde{f}$ is the annual incremental fuel (non-electricity) cost due to installation of the efficient appliance. For example, replacement of electric water heaters by LPG heaters would require additional expenditure for LPG. $\tilde{f}$ would be applicable only in case of LPG and natural gas water heaters. For all other appliances, it would be zero.

S is the total annual energy saving at the bus bar in kWh/year

$\tilde{k} = k_{ee} - k_c$ where,

$k_{ee} = K_{ee} \frac{r}{1-(1+r)^{-T_{ee}}}$ is the annualized capital cost of the efficient appliance and

$k_c = K_c \frac{r}{1-(1+r)^{-T_c}}$ is the annualized capital cost of the conventional appliance

K_{ee} and K_c are the upfront capital costs of efficient and conventional appliance respectively. Note that K_{ee} includes the administrative cost for running the EE program by the utility.

r is the discount rate and,

T_{ee} and T_c are the life in years of efficient and conventional appliance respectively

Annual energy saving S is estimated by the following formula

$S = \frac{\omega . h}{(1-l)}$ where,

ω is the potential load saving by an efficient appliance at the end use (kW),

h is equipment usage hours per year and,

l is the Transmission and Distribution (T&D) loss of the utility expressed as a fraction of total input energy. In this report, we have assumed a T&D loss of 15%.

Cost of Conserved Peak (CCP) is calculated by,

$$CCP(Rs/kWsaved/year) = \frac{\tilde{k} + \tilde{f}}{P}$$ where,

$$P = \omega \frac{\mu.\delta}{(1-l)}$$ is the peak load saving at the bus bar in kW

μ is the peak coincidence factor[16] and,

δ is the coincidence factor[17] of appliances

Because of the large seasonal variation in Delhi's power demand, peak coincidence factor and the coincidence factor would be different for every season. However, in order to keep the analysis simple, we have not considered any seasonal variation in these factors.

Based on the above formula, the following table shows the CCE for residential and commercial EE options that we considered for the analysis.

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[16] Peak coincidence factor is the probability that the appliance use takes place during the system peak demand period.

[17] Coincidence factor is the probability that any two appliances in the system are used simultaneously.

Table A6: Cost of Energy Efficient Appliances in the Residential Sector from Consumers' Perspective

Program/ technology	Lighting	Water Heating		Refrigerators		Space Cooling	
	T-5	Natural Gas	Solar	Direct Cool	Frost Free	Split AC	Fans
Program Administrative Cost (as % of capital cost of efficient appliance)	15%	15%	15%	15%	15%	15%	15%
Discount Rate (real) %	10%	10%	10%	10%	10%	10%	10%
Incremental Annualized Capital Cost, $\tilde{k}$ (Rs/year)	38	98	2,104	374	553	651	33
Fuel Cost (LPG and Natural Gas), $\tilde{f}$ Rs/year	-	660	-	-	-	-	-
Energy Saving at the bus bar, *S* (kWh/year)	58	424	424	125	223	235	38
Cost of Conserved Energy (CCE) Rs/kWh	0.66	1.79	4.97	2.99	2.48	2.77	0.86
Peak power saving at bus bar (W/unit)	25	397	397	11	20	73	7
Cost of Conserved Peak (CCP) (Rs/kW-peak)	1,499	2,931	5,298	33,477	27,783	8,943	4,658

Fuel cost for LPG and natural gas is calculated by estimating the equivalent energy required to increase the temperature of 100 liters of water by 15^{o}C per household per day. Prices for LPG and natural gas exclude the government subsidy in order to calculate the real cost of the program. Price of LPG (without subsidy) is taken Rs 39 per kg (equivalent to $21.3/mmbtu) while that of natural gas is taken as the spot LNG price plus transportation cost which comes to $13.2/mmbtu.

The following table shows the CCE for different commercial appliances. It can be observed that they have a lower CCE than residential appliances as they are used for a much longer period. However, they have a lower peak coincidence factor making their CCP higher than the residential appliances.

Table A7: Cost of Energy Efficient Appliances in Commercial Sector from Consumers' Perspective

Program/ technology	Lighting	Space Cooling		Water Heating
	T-5	AC	Fans	Solar Water Heater
Program Administrative Cost %	15%	15%	15%	15%
Discount Rate (real) %	10%	10%	10%	10%
Incremental Annualized Capital Cost (Rs/year)	56	651	33	2,104
Energy Saving at the bus bar (kWh/year)	93	471	47	3,176
Cost of Conserved Energy (CCE) Rs/kWh	0.60	1.38	0.69	0.66
Peak power saved at bus bar (W/unit)	16	73	7	397
Cost of Conserved Peak (CCP) Rs/kW saved	3,504	8,943	4,658	5,298

It should be noted that CCE would change significantly if an appliance is changed prematurely mainly because the value of the conventional appliance is not fully depreciated by the time it is replaced. This can be illustrated by a simple example. Consider a conventional refrigerator with useful economic life of 10 years. Suppose that it is replaced after 3 years with an efficient refrigerator. Therefore, the salvage value of the old conventional refrigerator is 7/10th of the initial capital cost. Now, as the refrigerator would be replaced by an efficient one, the incremental capital cost is the difference between the initial capital cost of efficient and conventional appliances plus the salvage value on the old (conventional) appliance. However, we could not determine the exact salvage value of different appliances in Delhi due to heterogeneity in appliance vintages and absence of any load research data. Therefore, we err on the conservative side and do not consider any depreciation on the conventional appliance being replaced i.e. salvage value of the conventional appliance is its full capital cost. Thus, the incremental investment, $\tilde{K} = (K_{ee} - K_c) + K_c = K_{ee}$. In short the incremental investment is nothing but the total capital cost of the efficient appliance. Naturally, this would result in conservative estimates of the CCE but they still happen to be competitive with consumer tariffs and marginal costs of power purchase as shown in the following table.

Table A8: CCE for Premature Replacement in Residential Sector

Program/ technology	Lighting	Water Heating		Refrigeration		Space Cooling	
	T-5	Natural Gas	Solar	Direct Cool	Frost Free	Split AC	Fans
Total Investment Rs/unit	340	3100	3100	18500	10800	16200	25000
CCE Rs/kWh (Premature Replacement)	1.44	3.71	2.75	5.74	14.03	11.81	17.29
CCP Rs/peak kW saved (Premature Replacement)	3,289	3,955	2,933	6,126	157,197	132,377	55,892

Table A9: CCE for Premature Replacement in Commercial Sector

Program/ technology	Lighting	Space Cooling		Water Heating
	T12 to T5	AC	Fans	Solar Water Heater
Total Investment (Rs/unit)	340	25,000	1,000	18,500
CCE Rs/kWh (Premature Replacement)	1.32	8.65	4.07	0.77
CCP Rs/peak kW saved (Premature Replacement)	7,687	55,892	23,288	6,126

The data on costs of the energy efficient appliances used in the above tables were collected by in-person and phone interviews with retailers and dealers in Pune and Mumbai in August 2008, in Delhi in January 2009 and from the website www.compareindia.com. Information on efficiencies and appliance ratings was partly sourced from the website of the Bureau of Energy Efficiency (BEE), Government of India (www.beeindia.nic.in). BEE has posted the data on energy consumption of the efficient appliances by all major manufacturers participating in the voluntary labeling program on their website.

Estimation of the Benefits of Energy Efficiency Measures

Energy efficiency measures result in benefits to all stakeholders – consumers, utility companies, government and society at large. A consumer benefits if he/she can save electricity at a lower cost than the electricity tariff. Thus, CCE estimated in the previous sections can be directly compared with the electricity tariff to estimate net benefits to consumers if EE programs are implemented. However, reduction in consumption also means that utility loses on the revenue from the sale of power. In case of commercial consumers, electricity tariffs are higher than the average cost of supply and in some cases marginal rate of peak power purchase as well, making this loss significant. On the other hand, utility benefits because of the reduction in power purchase cost. Such avoided cost of power purchase would be very significant if energy saving avoids purchase of peak power. However, these benefits cannot be retained by the utility because of the truing-up exercise during the annual ratemaking process; they would be passed on to consumers through tariff reduction in the following year. From a societal perspective, reduction in consumption avoids the need for investment in new power plants and also reduces CO_2 emissions significantly. Energy saving and peak demand reduction would also result in elimination of power shortage and more energy being available to commercial/industrial consumers. This increases their economic output in general increasing tax revenue for the government as discussed by (Phadke et al., 2005). The following table shows benefits to consumers and utilities for a single energy efficient appliance. These numbers are then multiplied by the total potential for energy efficient appliances to arrive at total benefits for Delhi.

Table A10: Benefits of Energy Efficiency Measures in Residential Sector

	Program/ Technology	Lighting	Water Heating		Refrigeration		Space Cooling	
		T-5	Natural Gas	Solar	Direct Cool	Frost Free	AC	Fans
Consumer	CCE Rs/kWh	0.66	1.79	4.97	2.99	2.48	2.77	0.86
	Consumer Tariff Rs/kWh	3.43	3.43	3.43	3.43	3.43	3.43	3.43
	Net benefit Rs/appliance/yr	136	589	-555	47	180	132	82
Utility	Loss of Revenue Rs/appliance/yr	169	1,233	1,233	365	650	685	110
	Avoided Cost of Power Purchase[18] Rs/kWh	4.5	4.4	4.4	3.5	3.5	3.5	3.5
	Avoided Cost of Power Purchase Rs/appliance/yr	263	1,845	1,844	436	776	818	131
	Net benefit to utility Rs/appliance/yr	94	612	611	71	126	133	21
Net Social Benefits[19]	Net Social Benefit Rs/ appliance/yr	230	1,201	56	118	306	265	103
	Net reduction in CO_2 emissions kg/appliance/yr	46	339	339	100	179	188	30

[18] Avoided cost of power purchase = Peak coincidence factor*peak power cost + (1-peak coincidence factor)*base load power cost.

[19] Net Social Benefit = Consumer Benefit + Utility Benefit.

Table A11: Benefits of Energy Efficiency Measures in Commercial Sector

	Program / Technology	Lighting	Space Cooling		Water Heating
		T-5	AC	Fans	Solar Water Heater
Consumer	CCE Rs/kWh	0.60	1.38	0.69	0.66
	Consumer Tariff Rs/kWh	6.18	6.18	6.18	6.18
	Net benefit Rs/appliance	440	1918	219	14894
Utility	Loss of Revenue Rs/appliance	487	2471	247	16682
	Avoided Cost of Power Purchase Rs/kWh	3.89	3.48	3.48	4.35
	Avoided Cost of Power Purchase Rs/appliance	360	1636	164	13824
	Net benefit to utility Rs/appliance	-127	-836	-84	-2858
Society	Net Social Benefit Rs/appliance	313	1082	136	12036
	Reduction of CO_2 emissions kg/appliance/yr	74	376	38	2541

It can be seen from the above tables that utility actually loses money for EE programs implemented in the commercial sector. This leaves the utility no incentive to encourage and implement energy efficiency programs in the commercial sector. Main reasons that this might happen are (a) high electricity tariffs paid by commercial consumers which are way higher than the cost of power purchase and, (b) lower peak coincidence factor which is generally responsible for lower power purchase cost. On the other hand, utility benefits in the residential sector are significant and utility would find it profitable to encourage and implement energy efficiency programs for residential consumers. However, as the utility cannot retain such benefits because of the truing up process, it has no incentive to do so.

Energy Efficiency Programs in Delhi

As mentioned before, for the residential sector we analyze benefits from replacement of T12 tubelight with T5, energy efficient refrigerators, water heaters (solar, natural gas, LPG) and efficient air conditioners. For the commercial sector we consider replacement of T12 lamps with T5, use of solar water heater and, efficient air conditioners and fans. This section estimates the total energy saving of the conventional appliance in Delhi in next three years by implementing these programs and total costs and benefits to consumers and utilities.

Estimation of EE Potential

In this section, we estimate the potential energy savings and load reduction from the consumer purchase and installation of energy efficient appliance over the next three years. In order to make this projection, we need to estimate the market penetration and electricity consumption of conventional as well as energy efficient appliances.

Approach for Estimating the EE Potential

We first estimate the present ownership of the conventional appliances for every end-use mentioned above. This is used to project the potential demand for new energy efficient appliances. The demand for energy efficient appliances is characterized by the following three types:

(i) Retirement of Existing Conventional Appliances

New demand for energy efficient appliances is created as the existing conventional appliances would have to be replaced at the end of their life. Assuming that the distribution of existing appliances are at their "equilibrium"[20] level in the year 2011, natural retirement every year would be the inverse of their life in years. Thus, total potential demand for energy efficient appliances due to natural retirement of conventional appliances in the next three years,

$$D_{NR_i} = \frac{4.N_i}{T_{c_i}} - \sum_{j=1}^{4} D_{PR_{i,j}}$$ where,

i indicates a particular conventional appliance considered to be replaced under the EE programs (for example, incandescent bulbs) and *j* indicates the year (for example, j=1 means financial year of 2011).

N_i is the total number of existing conventional appliances for a particular end-use (for example, incandescent bulbs) in 2011 and,

T_c is the life of the conventional appliance in years.

D_{PR} is the number of conventional appliances replaced by an efficient appliance prematurely i.e. before the end of its life span. This is explained in detail subsequently.

It should be noted that appliances with life higher than 4 years such as ACs, Refrigerators etc would never get replaced fully. On the other hand, appliances with life shorter than 4 years (like tube lights etc) would be fully replaced in these 4 years. Once the energy efficient appliances are installed, we assume that they are replaced by a similar appliance or another equivalent program. Thus, demand due to the retirement of energy efficient appliances is not considered. Therefore, for appliances with life less than or equal to three years (such as incandescent bulbs and tube lights),

$$D_{NR_i} = N_i - \sum_{j=1}^{4} D_{PR_{i,j}}$$

[20] What we mean by the "equilibrium" distribution is that there are equal number of appliances of every vintage.

(ii) Growth in Demand
There is demand for new appliances because of addition of new consumers and increase in consumption of the existing consumers. As we are considering a short time frame of 3 years, we assume that the consumption pattern remains the same. Therefore, appliance ownership pattern in a given consumer category (or more specifically sub-category) would not change. Thus, increase in appliance demand would follow the growth rate for overall electricity demand. In absence of the sub category wise demand growth numbers, we have used the growth rate for the consumer category (residential or commercial) for the period of 2012-2015 to project the appliance numbers during this period. Also, new demand due to increase in consumption of existing consumers is neglected in light of the short time horizon. Thus, demand for new efficient appliances due to growth in demand in these three years,

$D_{Gi} = N_i .(1 + \rho)^4 - N_i$ where,

ρ is the compounded annual demand growth rate for the consumer category for the period of 2012-2015 and,

N_i is the total number of existing conventional appliances for a particular end-use in 2011 (for example, incandescent bulbs)

(iii) Premature Retirement of Conventional Appliances
We assume that utility implements a special EE program for replacement of a small fraction of existing conventional appliances that are still operational. It should be noted here that as the appliances are being replaced prematurely, CCE would be significantly higher for this component. Demand for efficient appliances through premature replacement in next three years is,

$D_{PRi} = 4.\theta_i .N_i$ where,

Where, N_i is the total number of existing conventional appliances for a particular end-use in 2011 and θ_i is the fraction of conventional appliances replaced prematurely every year. We assume θ_i to be 15%. Given that premature replacement would be costly, only T-5 and natural gas water heater programs would be cost-effective. Premature replacement of all other programs is not cost effective and thus is not considered. Note that T-12 tubelights need not be replaced prematurely from the second year onwards because of their short life – they would be already replaced by

Thus, total energy/peak power saving potential for Delhi by a particular appliance is estimated by multiplying the total potential demand for efficient appliances and energy/peak power saving per appliance.

$$TotalEnergySavingPotential = \sum_i (D_{NRi} + D_{Gi} + D_{PRi}).\frac{\omega_i.h_i}{(1-l)}$$

Similarly, $TotalPeakReductionPotential = \sum_i (D_{NRi} + D_{Gi} + D_{PRi}).\omega_i.\frac{\mu_i.\delta_i}{(1-l)}$

Approach for Estimating the Number of Appliances

Estimating the number of existing conventional appliances, N_i is the key in projecting the potential demand for energy efficient appliances. The best way to estimate this number would be a thorough consumer survey. However, as there is no data available about such load surveys in the public domain and therefore we had to resort to other indirect methods. One alterative was to use the appliance ownership data reported in the National Sample Survey (NSS). The latest round of the NSS on "Household Consumption of Various Goods and Services in India" took place in 2004-05 (61st round). However, NSS did not report the ownership data for all appliances. For example, it did not contain data on water heaters. Moreover, ownership of bulbs and tubelights was clubbed together. It reports only the number of households possessing a particular good but does not report number of appliances per household, which is quite crucial for estimating the total number of appliances. Though the household appliance ownership is reported for various levels of monthly expenditure, we did not have information about the linkage between monthly expenditure and electricity consumption. Moreover, NSS did not report information on commercial establishments (NSSO, 2005). In light of these issues, we could not use NSS numbers as they are; but they would be extremely helpful in cross-checking the numbers we would estimate. As a part of the Annual Revenue Requirement filing process, Delhi utilities are required to file detailed information about the subcategory wise number of consumers, electricity consumption and revenue. Based on the total consumption and number of consumers in a particular subcategory we first calculated average monthly consumption per consumer in that subcategory. We then chose appropriate number of typical household appliances (conventional) to match the average consumption in that subcategory. Average number of appliances per consumer is then multiplied by the total number of consumers in that subcategory. Summation of number of appliances in all subcategories gives the total number of existing conventional appliances in Delhi. The numbers were fine-tuned after comparison with the NSS data on goods ownership. New demand for energy efficient appliances is then estimated as described above. Subcategory wise number of consumers and average consumption was taken from the actual data for financial year 2009 and 2010 submitted by the utilities to DERC as a part of the annual review requirement process for the financial year 2011.

Projected Energy Savings for Delhi

Potential energy and peak power savings are estimated by multiplying the demand for new energy efficient appliances by the saving potential for every appliance as estimated above. 15% of existing conventional appliances are assumed to be replaced prematurely through a EE program (i.e. θ_i = 15%). Projected CAGR (ρ) for the demand growth in Delhi between 2012 and 2015 is 7.7% for the residential sector and 13.7% for the commercial sector. While estimating the demand for new efficient appliances for water heating (in order to replace electric water heaters), we assumed that 95% of the new appliances would be based on natural gas and rest 5% on solar. Existing number of conventional appliances and potential demand for new appliances in next three years are presented in the following table.

Table A12: Potential Demand for New Energy Efficient Appliances in the Residential Sector

<table>
<tr><th rowspan="2">Conventional Technology</th><th rowspan="2">T-12</th><th rowspan="2" colspan="2">Electric Water Heater</th><th colspan="2">Conventional Refrigerators</th><th rowspan="2">Conventional AC</th><th rowspan="2">Conventional Fans</th></tr>
<tr><th>Direct Cool</th><th>Frost Free</th></tr>
<tr><td>Existing number of conventional appliances (N_i) millions (2011)</td><td>8.14</td><td colspan="2">2.71</td><td>1.22</td><td>1.59</td><td>1.62</td><td>8.04</td></tr>
<tr><td colspan="7">Potential Demand for Energy Efficient Appliances (2012 – through 2015)</td><td></td></tr>
<tr><th rowspan="2">Efficient Technology</th><th rowspan="2">T-5</th><th rowspan="2">Nat. Gas</th><th rowspan="2">Solar</th><th colspan="2">Efficient Refrigerators</th><th rowspan="2">Efficient AC</th><th rowspan="2">Efficient Fans</th></tr>
<tr><th>Direct Cool</th><th>Frost Free</th></tr>
<tr><td>Natural Retirement (million)</td><td>6.92</td><td>1.03</td><td>0.05</td><td>0.49</td><td>0.64</td><td>0.65</td><td>3.21</td></tr>
<tr><td>New demand due to growth (million)</td><td>2.82</td><td>0.89</td><td>0.05</td><td>0.42</td><td>0.55</td><td>0.56</td><td>2.79</td></tr>
<tr><td>Premature Replacement (million)</td><td>1.22 [21]</td><td>1.54</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
</table>

Table A13: Potential Demand for New Energy Efficient Appliances in the Commercial Sector

Conventional Technology	T-12	Electric Water Heater	AC	Fans
Existing number of conventional appliances (N_i) millions (2011)	4.92	0.04	1.26	3.51
Potential Demand for Energy Efficient Appliances (2012 – through 2015)				
Efficient Technology	T-5	Solar Water Heater	Efficient AC	Efficient Fans
Retirement in 4 years (million)	4.78	0.01	0.50	1.40
New demand due to growth (million)	3.30	0.03	0.85	2.35
Premature Replacement in 4 years (million)	0.13 [22]	0.02	0	0

Please note that we understand that these estimates of potential demand may not be very accurate. They can be significantly improved if a detailed load survey is undertaken. However,

[21] Premature replacement in case of T-12 tubelights is limited only to the first year because second year onwards all appliances would already be replaced due to natural retirement.

[22] Premature replacement in case of T-12 tubelights is limited only to the first year because second year onwards all appliances would already be replaced through natural replacement.

on average they match with the consumption figures and are in reasonable agreement with the appliance ownership patterns observed in the NSS. The following table shows the total energy and peak saving potential and costs and benefits calculated per the formulae presented in the previous section.

Table A14: Potential Energy Saving between 2012 and 2015 (Residential and Commercial)

Program / Technology	Lighting	Water Heating		Refrigeration		Space Cooling		Total
	T-5	Nat Gas	Solar	Direct Cool	Frost Free	AC (Split)	Fans	
Residential Sector								
Natural Retirement (GWh)	401	436	23	61	142	152	121	1336
Premature Replacement (GWh)	71	654	0	0	0	0	0	725
Demand Growth (GWh)	164	378	20	53	123	132	105	974
Total Energy Saving Potential (GWh)	636	1468	43	114	265	284	226	3035
Commercial Sector								
Natural Retirement (GWh)	444	-	48	-	-	237	66	795
Premature Replacement (GWh)	12	-	62	-	-	0	0	75
Demand Growth (GWh)	206	-	81	-	-	398	111	895
Total Energy Saving Potential (GWh)	762	-	191	-	-	635	177	1764
Total Energy Saving GWh (Residential + Commercial)	1398	1468	234	114	265	919	403	4800

Note: Totals might not match due to rounding off.

Thus, total quickwin EE program potential in Delhi between 2012 and 2015 for residential and commercial sectors is 4,800 GWhs at the bus bar. Net increase in Delhi's electricity consumption in the same period is 7381 GWh, out of which 5,593 GWh (76%) are on account of increase in residential and commercial consumption. Allowing for T&D losses of 15%, cost effective EE programs in residential and commercial sectors can satisfy about 75% of the entire increase in consumption from these sectors.

Appendix B: Detailed Methodology for Estimating the Impact on Utilities and Consumers

Impact on utility cash flow

The net impact on utility cash flow over a year (U) is the net under-recovery (or over-recovery) of its ARR. This is calculated as:

$$U = R + I - k - l + u$$

where R represents the gross resource benefits from EE programs i.e., either reduction in power purchase expenses or additional revenue from selling saved electricity to grid, I is the incentive given to the utilities, k is the annualized utility expenditure on EE programs, l is the revenue lost because of reduced consumption by customers participating in the program, and u is the increase in revenue obtained by selling the saved electricity to customers facing shortages (this applies only if the utility experiences shortages).

Estimating R

To estimate R, we let P be the avoided cost of marginal power purchase in a year that results from EE programs. P is calculated based on total energy savings and power purchase costs during peak and off-peak periods. During peak periods, electricity savings result in avoiding peak power purchases. By contrast, savings during off-peak hours typically result in savings of only the variable cost of generation under long-term contracts. If the utility does not face shortages, P is given as:

$$P = \sum_i \frac{e_i.w.S_i + (1-e_i).b.S_i}{(1-L)}$$

where i represents each EE program, S_i is the total electricity savings in that year from the i^{th} EE program, e is the peak coincidence factor of the electricity saved by the i^{th} programs, w is the weighted average cost of peak power purchase, b is the variable cost of baseload power purchases, and L is the transmission and distribution loss in the grid, which is conservatively assumed to be 15%. Estimation of w and b would entail modeling a merit-order dispatch of the available units, meaning that the utility, during peak as well as off-peak periods, would avoid the most expensive power purchases first and then move on to cutting its cheaper supply sources. Power purchase costs from various generation units are determined by applying the previous five-year compounded annual growth rate (CAGR) to the actual data for 2009-2010.

If utilities decide to sell the conserved power to the grid, the gross resource benefits, G, in a year is calculated as:

$$G = \sum_i \frac{e_i.m.S_i + (1-e_i).b.S_i}{(1-L)}$$

where m is the market price of the peak power, and all other symbols have their usual meaning. We assume m to be 8 rupees (Rs)/kWh[23] and that the utility does not sell the conserved power during off-peak periods but simply avoids baseload power purchases.

Utilities that face regular power shortages can use the electricity conserved through EE programs to serve unmet demand and minimize power outages. When the amount of conserved electricity ($\sum_i S_i$) is less than the extent of shortages, utilities' expensive peak power purchases are not reduced, and $P, G = 0$.

If EE programs fully make up shortages and leave the utility with an energy surplus, the utility could use the surplus to avoid expensive peak power purchases or sell the surplus on the market. Thus:

$$P = \frac{\bar{e}.w.(\sum_i S_i - \theta) + (1-\bar{e}).b.(\sum_i S_i - \theta)}{(1-L)} \quad \text{and,}$$

$$G = \frac{\bar{e}.m.(\sum_i S_i - \theta) + (1-\bar{e}).b.(\sum_i S_i - \theta)}{(1-L)}$$

where θ is the total unmet demand at the consumer end, and $\bar{e}$ is the average peak coincidence factor weighted by the savings achieved by each program. As mentioned earlier, we create two scenarios for θ: 5% (peak demand) and 10% (intermediate load shortage) of business-as-usual (BAU) sales every year.

For gross resource benefits from EE programs, R equals P when utilities avoid marginal peak power purchases, and $R = G$ when utilities sell conserved peak power to the grid.

Estimating I

To estimate the incentive, I, we let K be the total utility investment in EE programs during one year and k be the annual cost of the EE investment, including the administrative costs of management and monitoring and verification. Average administrative expenses (indirect costs) in U.S. demand-side management programs between 1996 and 2007 were 12% of direct program costs (EIA, 2009). Recognizing that Indian utilities lack experience in undertaking large-scale EE programs, we assume that administrative costs would be slightly higher, 15% of direct program expenditures.

Because current regulatory practice does not award any explicit incentive to the utility, $I = 0$,

When the EE expenditures are capitalized, $I = r.q.K$,

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[23] This is based on market clearing prices during peak demand periods of the last year (2009-10) as observed on the Indian Energy Exchange. Given the demand and supply gaps, a similar trend is likely to continue in the near future.

where q is utility's equity share in total EE investments, and r is the return on equity. Continuing the regulatory practice of allowing 30% equity in infrastructure investment and 16% return on equity, $q = 30\%$ and $r = 16\%$.

For the shared benefit mechanism, the incentive depends on the net resource benefits achieved through EE programs. Thus:

$$I = h.(R - k)$$

where, h is the benefit-sharing ratio with the utility. Because we hypothesize that utilities successfully implement EE programs, h is set at 9%.[24]

Estimating l and u

The marginal consumer tariff that utilities could lose from a reduction in sales as a result of EE programs is represented as σ. Note that marginal tariffs[25] for the commercial and residential sectors and consumption categories within those sectors are different; σ is the average of these different values weighted by reduction in sales. Thus, the total loss of utility revenue is represented as:

$$l = \sum_i \sigma . S_i$$

Utilities that face shortages earn additional revenue by using saved energy to serve demand that would normally be unmet. In this case, ρ is the marginal tariff for the unmet demand. The additional revenue is given by:

$u = \sum_i \rho . S_i$, when shortages are partially mitigated, i.e. $\sum_i S_i < \theta$,

and by $u = \sum_i \rho . \theta$ when shortages are fully mitigated, i.e. $\sum_i S_i \geq \theta$.

Additional revenue in the no-shortage case is 0.

Thus, utility cash flow becomes negative when the gross benefits plus incentive are less than the total annual program cost plus the loss in revenue. It would be especially pronounced for commercial programs where the revenue loss is high because the marginal tariffs are almost comparable to marginal power purchase costs. When the utility sells the electricity conserved through an EE program to the grid, R increases significantly, and utility's cash flow improves.

[24] This value is same as what the California Public Utilities Commission allows as an incentive payment under its shared benefit scheme when utilities achieve 65-100% of the target.

[25] Note that consumers *within* a category (for example residential and commercial) are divided in to several tiers based on their monthly electricity consumption (for example 0-200 kWh, 201-400 kWh); the higher the consumption, the higher the "marginal tariffs" for that tier. Generally, the marginal tariffs for high-consumption tiers are significantly higher than the average tariff especially for residential consumers.

Partial utility funding of EE programs would lower the utility's annual cost, *k,* and might improve cash flow. When savings from EE programs are not able to fully mitigate shortages, net cash flow depends on the difference between the marginal tariffs of conserved electricity and unmet demand. In any case, *U* would be passed on to consumers in the following true-up cycle.

Impact on Utility Returns

For estimating the impact of EE programs on utility returns, we first project the BAU peak demand, *D,* over the analysis period, by applying the last five-year CAGR to the 2010 value. Assuming that the infrastructure investment directly depends on the peak demand, we project the additional distribution infrastructure investment as:

$$= \lambda . \Delta D$$

where λ is the proportionality constant determined by using the historical figures for total capital investment and peak demand from 2002 onward. Peak demand reduces to *D'* after implementation of EE programs. Thus, total deferred infrastructure investment due to EE programs is $\lambda . (D - D')$, and the utility's forgone return is:

$$\square = r . q . \lambda . (D - D').$$

Therefore, to prevent an adverse impact on utility returns, the total incentive offered to the utility should be at least equal to i.e. $I \geq \square$.

Impact on Annual Revenue Requirement and Total Sales

Utilities' ARR and electricity sales in a year under BAU conditions are identified as A and E, respectively. Once EE Programs are implemented, these values change to A'' and E''.

$E'' = E - \sum_i S_i$ and,

$$A'' = A - R + k + I$$

Note that gross resource benefits are significantly higher than the annual program cost and utility incentive. Therefore, EE programs reduce the ARR; i.e., $A'' < A$.

For utilities facing shortages, we construct three service improvement scenarios as explained earlier. ARR (A^c) and sales (E^c), would be different from the BAU case to reflect the improvement in quality of service i.e., reduction in power cuts.

If utilities take no action to mitigate shortages, there is no change in the alternative service scenario ARR and sales.

$A^c = A$ and $E^c = E$.

If utilities purchase additional power at a price equivalent to the short-run marginal cost (SRMC) of power, the alternative service improvement scenario ARR and sales both increase from their

BAU values. If the EE programs fully mitigate shortages, then the improvement in service quality is equivalent to the unmet demand, θ.

That is, when $\sum_i S_i \geq \theta$, $E^c = E + \theta$ and,

$$A^c = A + \frac{\bar{e}.SRMC^{peak}.\theta + (1-\bar{e}).SRMC^{base}.\theta}{(1-L)}$$

where $SRMC^{peak}$ and $SRMC^{base}$ indicate the day-ahead market prices during the peak and off-peak demand periods respectively.

If shortages are only partially mitigated, the improvement in the service quality is equivalent to total energy saving or $\sum_i S_i$:

That is, when $\sum_i S_i < \theta$, $E^c = E + \sum_i S_i$ and,

$$A^c = A + \frac{\bar{e}.SRMC^{peak}.\sum_i S_i + (1-\bar{e}).SRMC^{base}.\sum_i S_i}{(1-L)}$$

If utilities purchase additional power at a price equivalent to the long-run marginal cost of power, the alternative service improvement scenario ARR and sales are as follows:

If $\sum_i S_i \geq \theta$, $A^c = A + \frac{LRMC.\theta}{(1-L)}$ and, $E^c = E + \theta$.

If $\sum_i S_i < \theta$, $A^c = A + \frac{LRMC.\sum_i S_i}{(1-L)}$ and, $E^c = E + \sum_i S_i$.

Similar to the no-shortage case, the new ARR and sales after implementation of EE programs are:

$E'' = E^c - \sum_i S_i$ and,

$A'' = A^c - R + k + I$.

Consumer Tariffs and Net Benefits

The average consumer tariff, μ, is nothing but the net ARR divided by total sales. Thus, the BAU case average tariff is: $\mu = \frac{A}{E}$.

Note that we have frozen the BAU case consumer tariff at 2011 levels. Sales, E, are projected using historical growth rates, and A is estimated as a product of average tariffs and total sales.

For utilities facing shortages, $\mu = \frac{A^c}{E^c}$.

The average tariff after EE program implementation is: $\mu' = \frac{A''}{E''}$

The increase in average tariff as a percentage of the original tariff is $\delta = \frac{\mu'}{\mu'} - 1$

$$\delta = (1 + \frac{-R+k+I}{A}) \cdot \frac{E}{E-\sum_i S_i} - 1$$

When the net reduction in ARR as a percentage of the original ARR is lower than the reduction in sales as a percentage of original sales, average consumer tariffs would increase. Likewise, if the percentage reduction in ARR is more than the reduction in sales, average tariffs would reduce, resulting in benefits for non-participants as well. Thus, if a utility is able to sell the power conserved through the EE program to the grid at a price higher than its marginal power purchase cost, the impact on consumer tariffs would be significantly lower.

Participating consumers also face the tariff increase, but, because of the significant reduction in their consumption, they always benefit. Net participant benefits, ω_p, are given by:

$$\omega_p = l - (\mu' - \mu).(\tau.E - \sum_i S_i) - k_{consumer}$$

where τ is participants' annual electricity consumption expressed as a fraction of total sale, and $k_{consumer}$ is the program expenditure borne by participants when the utility partially funds the program. Note that the savings on electricity bills (loss of revenue for the utility) are large enough so that even when $\mu' > \mu$ and $k_{consumer} \equiv 100\%$ of the program expenditure, ω_p is always positive. Non-participants' consumption does not decrease, ceteris paribus, and they do not bear any direct program cost. Therefore, net benefits to non-participants are:

$$\omega_{np} = (\mu' - \mu).(1 - \tau).E$$

Thus, when EE programs result in a tariff hike, non-participants lose, but they benefit in case of tariff reduction.

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