ECONOMIC ANALYSIS

A. Introduction and Economic Rationale

1. Energy Efficiency Services Limited (EESL) was created by the Ministry of Power within the Government of India as the energy efficiency implementation arm of the Ministry of Power and the Bureau of Energy Efficiency. It is positioned to lead the market-related action of the National Mission for Enhanced Energy Efficiency. The project will finance high-priority areas under EESL's energy service company business: (i) more efficient light-emitting diode (LED) municipal street lighting equipped with remote operating technology, (ii) more efficient household appliances, and (iii) more energy-efficient agricultural water pumps. A sector loan financing modality will be adopted.

2. Unlike typical sector loans in which the government's overarching sector development plan is being supported, sector modality has been selected due to the nature of the subprojects to be financed from the loan. Therefore, economic evaluation of the proposed loan was carried out with a focus on physical investments (using data from sample subprojects provided by EESL) in accordance with the guidelines for appraisal of projects of the Asian Development Bank (ADB)[1],[2] (although ADB's guidelines for economic analysis of sector loans were also taken into account).[3] Four sample subprojects were examined: (i) replacement of conventional incandescent domestic light bulbs with efficient LED bulbs in New Delhi, (ii) replacement of inefficient domestic ceiling fans with efficient modern fans in Andra Pradesh, (iii) replacement of inefficient agricultural water pumps with efficient models in Rajasthan, and (iv) replacement of conventional streetlights with efficient LED bulbs and modern control and switching systems in Rajasthan. EESL will benefit financially through the benefit-sharing agreements with end-users that will allow EESL to recover its costs and earn a sustainable return on its investments.

3. The difference between the "with project" and "without project" situation is the lower electricity consumption in the "with project" case arising from the installation of high efficiency appliances. The main assumption in the following analysis is the electricity savings achieved by each of the appliances. This data was provided by EESL based on actual field measurements that were checked against guaranteed performance standards offered by equipment manufacturers. The period of daily use for energy efficiency equipment was also provided by EESL and was subjected to a reasonableness test (and where the guaranteed saving was lower than the savings indicated through field measurements, the more conservative guaranteed figure was adopted for analysis).

B. Demand Analysis

4. There are two dimensions of demand for the project: demand for energy-efficient appliances (agricultural water pumps, streetlights, and domestic lights; and ceiling fans) and demand for the electricity that will be saved as a consequence of the use of these devices. Demand for efficient appliances has typically been suppressed in India due to the higher upfront costs of these devices relative to less efficient devices. This is particularly true for agricultural pumps and streetlights, where consumers (farmers and urban local bodies [ULBs]) are either charged for electricity use on a fixed basis or are heavily direct- and cross-subsidized, and therefore do not see a cost-reflective price signal to encourage the more efficient end-use of electricity. EESL's business models for supporting the uptake of energy-efficient devices have been structured so that all stakeholders are financially incentivized to participate, thereby

[1] ADB. 1997. *Guidelines for Economic Analysis of Projects*. Manila.
[2] ADB. 2013. *Cost-Benefit Analysis for Development: A Practical Guide*. Manila.
[3] ADB. 2005. *Assessing Aid for A Sector Development Plan: Economic Analysis Of A Sector Loan*. Manila.

stimulating demand. For example, the upfront cost of LED bulbs provided to domestic consumers will be no more than the cost of the luminescence-equivalent conventional bulb, and repayments for the balance of the cost of the bulbs will be less than the cost of electricity that would have been consumed through the use of conventional bulbs. Electricity distribution companies, who will be responsible for collecting payments from these consumers for the bulbs on behalf of EESL, benefit from higher revenue (the electricity that would otherwise be sold to cross-subsidized consumers can instead be sold to higher value customers) or lower electricity purchases.

5. Demand for the electricity saved through greater end-use efficiency is evident. India's Central Electricity Authority has indicated that the national electrical energy deficit was 23.5 terawatt hours (2.1% of demand) and the peak capacity deficit was 4.9 gigawatts (3.2% of demand) for the year ending 31 March 2016. These are conservative estimates of deficits; many states still suffer from prolonged scheduled supply interruptions at certain times of the year, and this has the effect of significantly suppressing demand. Even if the gap between demand and supply was eliminated, the economic cost of a unit of electricity saved through improved end-use efficiency is so much lower than the short-run cost of electricity generation from a thermal plant, and demand for saved electricity exists. This is discussed further in paras. 6 and 7.

C. Least Cost Analysis

6. To assess if the proposed subprojects represent the least cost means to meet demand for electricity, the concept of a "negative watt" or "negawatt" is useful: this is a theoretical unit representing the amount of power saved from an energy efficiency intervention. In general, if the economic cost of a "negawatt-hour" of electricity from an energy efficiency investment is lower than the economic cost of a unit of electricity generation, then the energy efficiency investment is the least cost means to meet demand. Table 1 shows the negawatt and negawatt-hour values for each of the sample subprojects, with economic costs of each subproject calculated as outlined in para. 13 and energy savings (relative to conventional alternatives) estimated by EESL. To provide a basis for comparison, the life-cycle (levelized) cost of base-load coal-fired generation (including capital, fuel, and operating costs) is also presented.[4] As shown in Table 1, the first three sample subprojects (replacement of domestic bulbs, domestic ceiling fans, and agricultural water pumps) represent much lower levelized costs that coal-fired generation, indicating that the energy efficiency investments are the lowest cost means to reduce the gap between electricity demand and supply and to reduce the overall cost of generation. In other words, these three subprojects are significantly cheaper than the equivalent generating plant contributing the same quantity of electricity to the system.

Table 1: Levelized Costs of Energy Saved for Sample Subprojects

	Levelized Costs	
Sample Subproject	**Energy[a] (Rs/kWh)**	**Capacity[b] (Rs/kW)**
1. Domestic LED bulbs	1.1	10,123
2. Efficient domestic ceiling fans	2.6	46,881
3. Efficient agricultural pumps	0.6	12,552
4. Efficient streetlights	6.5	217,115
AIC of coal-fired generation (for comparison)	3.2	60,000

AIC = average incremental cost, kW = kilowatt, kWh = kilowatt-hour, LED = light-emitting diode.
[a] The cost per unit of energy saved = a "negawatt-hour."
[b] The cost per unit of capacity saved = a "negawatt."
Source: Asian Development Bank estimates.

[4] The levelized cost of base-load generation is only provided for comparative purposes. The short-run marginal cost of coal generation was used to value off-peak electricity savings.

7. The efficient street lighting subproject presents a less obvious least cost solution when evaluated within this framework; it is evidently not the least cost means to bridge the electricity demand–supply gap. However, given that public lighting is mandated in urban areas across India, an alternative and valid least cost evaluation framework for street lighting is a comparison of the levelized costs of the competing streetlight technologies (LED, compact florescent, and sodium vapor). This analysis shows that LED streetlight bulbs have a life cycle cost 50% lower than the equivalent compact florescent bulb and 59% lower than the equivalent sodium vapor bulb. This demonstrates that LED bulbs are the least cost means to provide street lighting, and on this basis the efficient street lighting subproject meets the least cost criteria.

D. Economic Benefits

8. **Quantification of benefits.** Estimates of the quantity electricity savings achieved by each device were provided by EESL based on field measurements. Benefits were assumed to accrue progressively as capital investments are made over 2017–2021. A "with project" and "without project" framework was adopted. From an economic perspective, benefits accrue through resource cost savings arising from a reduction in electricity used for water pumping, street lighting, and domestic appliances. A conservative assumption was adopted that the government will be able to deliver on its stated intention to provide 24-hour, 7-day per week electricity to all consumers by 2019, and on this basis all project output was assumed to be non-incremental. Table 2 summarizes the annual benefits of the sample subprojects (scaled to reflect the size of each subproject to be supported by the proposed loan). Because the subprojects under consideration are to replace inefficient appliances with efficient alternatives, an additional benefit accrues to the two lighting sample subprojects because of the shorter lives of conventional bulbs compared to their efficient LED equivalents (that is, higher levels of ongoing replacement capital expenditure would be required in the "without project" scenarios than in the "with project" scenarios for the two lighting subprojects). However, this benefit has only been quantified and valued for the street lighting subproject.[5]

Table 2: Annual Economic Benefits for Sample Subprojects[a]
(GWh)

Sample Subproject	Electricity saved during peak demand periods	Electricity saved during off-peak demand periods
1. Domestic LED bulbs	236	550
2. Efficient domestic ceiling fans	0	54
3. Efficient agricultural pumps	0	1,339
4. Efficient streetlights	72	108
Total Benefit	**307**	**2,051**

GWh = gigawatt-hours, LED = light-emitting diode.
[a] All project output is assumed to be non-incremental.
Source: Asian Development Bank estimates.

9. **Valuation of benefits.** All outputs are valued on the basis of resource cost savings. The estimated short-run marginal cost of typical coal-fired generators was adopted as a minimum estimate of the unit value of resource cost savings during off-peak periods (calculated at Rs2.8 per kilowatt-hour (kWh) expressed in economic terms, based on typical coal plant parameters in India and using the World Bank's coal price forecast).[6] The estimated short-run marginal cost of typical new closed-cycle gas turbines was adopted as a minimum estimate of the unit value of

[5] Replacement capital expenditure was modeled as the difference of two annuities—one annuity reflecting the replacement of LED bulbs at the end of their lives (around 16 years) in the "with project" case and one annuity reflecting the replacement of conventional equivalents (with lives ranging from 1 year to 3 years at typical usage rates) in the "without project" case.

[6] World Bank. 2016. *Commodity Markets Outlook*. January 2016 update.

resource cost savings during peak periods (calculated at Rs3.5 per kWh expressed in economic terms, based on typical gas plant parameters in India, and using recent non-adjusted price mechanism gas prices in India as a proxy for the border price equivalent value of natural gas).[7]

E. Economic Costs

10. All project costs were expressed using the domestic price numeraire[8]. Financial costs were categorized into traded goods, non-traded goods, foreign skilled labor, local skilled and unskilled labor, and fuel and transfer payments; and were adjusted with appropriate conversion factors.[9] The estimated shadow rate exchange factor of 1.03 was used to convert traded costs, and an estimated shadow wage rate factor of 0.75 was used for unskilled labor. Transfer payments and price contingencies were excluded from the analysis. None of the subprojects is expected to incur any additional operations and maintenance costs over and above the costs of the existing equipment installed (a reduction in operations and maintenance is probable, but for conservatism this has been ignored). The longer lives of LED bulbs compared to their conventional equivalents mean that, on a “with project versus without project” basis, the periodic replacement of bulbs is a benefit rather than a cost. It is noted that LED bulbs have lower power factor than conventional bulbs, so an additional capital cost allowance was included in the “with project” case for power factor compensation capacitor banks (estimated on the basis of the supply cost of low voltage capacitor banks in the Indian market).

F. Economic Internal Rate of Return

11. The economic evaluation was carried out for the 25-year period from 2017 to 2041. The economic internal rate of return (EIRR) was calculated for each sample subproject separately comparing the economic costs and benefits expected for each year within the evaluation period. Calculation of the aggregate EIRR (31.6%) is presented in Table 3. The subproject EIRRs are 35.2% (domestic LED bulbs), 31.8% (domestic ceiling fans), 43.9% (agricultural pumps), and 14.5% (LED streetlights). With the exception of the street lighting subproject, the very high EIRRs reflect the low per unit costs to reduce electricity consumption (as demonstrated in the levelized costs per “negawatt-hour” and per “negawatt” in Table 1) compared to the cost to generate electricity and its economic value to consumers. The street lighting subproject is marginally viable as the per unit cost to reduce electricity consumption is high relative to the value non-incremental consumption of electricity; however, the resource cost saving arising from the less frequent replacement of bulbs (as compared to the “without project” case) is sufficient to ensure that the subproject meets the 12% hurdle rate.

G. Sensitivity Analysis

12. Analyses were carried out to examine the sensitivity of the EIRR to changes in assumed values of the key variables: a 15% increase in capital costs, a 15% reduction in energy savings, and a combined downside scenario considering increased capital and reduced energy savings. Because equipment will be procured and then immediately deployed, project delay is deemed very unlikely and so EIRR sensitivities to delay were not examined. Table 4 shows that, with the

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[7] This estimated short-run marginal cost reflects the typical clearing price of the spot market for peak power of Rs3 to Rs3.5 per kWh.

[8] Domestic price numeraire refers to expressing all economic prices at equivalent domestic market price level.

[9] EESL ran a competitive tender for bulk supply of domestic LED bulbs, a process that resulted in a unit price of bulbs that is between 50% and 70% lower than current market prices. Some domestic manufacturers and retailers are concerned that this unit price is a distortion of the true cost of supply and would not be sustainable in the absence of EESL’s government-led activity. In this context and for conservatism, the unit economic price of domestic LED bulbs has been taken as 200% of the financial price.

exception of efficient street lighting, sample subprojects are expected to provide robust economic performance.

Table 3: Aggregate Economic Internal Rate of Return Calculation
(Rs million)[a]

	Benefits	Costs	
Year	Non-Incremental Output	Capital	Net Benefits
2017	0	2,883	(2,883)
2018	986	7,407	(6,421)
2019	3,157	8,361	(5,204)
2020	5,525	4,838	688
2021	7,553	326	7,227
2022	7,668	0	7,668
2041	7,668	0	7,668
		EIRR	**31.6%**

( ) = negative, EIRR = economic internal rate of return.
[a] For brevity, only selected years are shown.
Source: Asian Development Bank estimates.

Table 4: Sensitivity Analysis
(% EIRR)

Subproject	Base Case	Capital Cost +15%	Energy Savings -15%	Combined
1. Domestic LED bulbs	35.2	30.5	29.8	25.9
2. Efficient domestic ceiling fans	31.8	27.6	26.9	23.3
3. Efficient agricultural pumps	43.9	38.2	37.3	32.4
4. Efficient streetlights	14.5	12.4	12.1	10.2
Aggregate	**31.6**	**27.5**	**26.8**	**23.3**

EIRR = economic internal rate of return, LED = light-emitting diode.
Source: Asian Development Bank estimates.

H. Conclusions

13. The economic assessment shows that the economic performance of the overall project is robust. The EIRRs of the domestic LED lighting, domestic ceiling fan, and agricultural pump replacement sample subprojects comfortably exceed the assumed hurdle rate under all of the sensitivities tested. The EIRR of the street lighting subproject is marginal under each of the sensitivities examined. It is probable that the street lighting replacement program would provide economic benefits that have not been quantified (for example, the analysis assumes that all street light bulbs being replaced are actually working currently, which is unlikely to be the case). In this context and from an economic standpoint, the proposed loan is considered economically viable and should proceed.