ECONOMIC ANALYSIS

A. Introduction

1. The Project will finance high-priority areas under Energy Efficiency Services Limited (EESL's) Energy Service Company (ESCO) business. (i) "smart" meters and other intelligent energy management elements (collectively termed "smart grid" investments; (ii) e-mobility with electric vehicles; (iii) loss reduction through solarizing agricultural feeders in eligible states; (iv) efficiency of street lighting; (v) energy efficiency of agricultural and municipality pumps; (vi) energy efficiency in buildings; and (vii) pilot testing of new energy efficient technology (through revolving fund scale up). Only the first three subprojects, which will be funded by ADB, were examined for this economic analysis (based on project information and analysis provided by EESL). Analysis was taken on a per megawatt (MW) basis for subproject (iii) and for the entire subproject for (i) and (ii), in accordance with ADB's guidelines for appraisal of projects [1,2] (although ADB's guidelines for economic analysis of sector loans were also taken into account).[3]

B. Demand Analysis

2. With the exception of the electric vehicles program, EESL's business models for supporting the uptake of energy efficient devices have been structured so that stakeholders are financially incentivized (or not disincentivized) to participate, thereby stimulating demand. The smart metering program allows electricity distributors to implement a solution to the perennial problem of commercial losses. The distributed solar PV program addresses multiple network-related and commercial issues for electricity distributors but does not require any upfront investment from them. On the other hand, the electric vehicle program is designed to generate supply scale-up to allow the government to achieve its ambitious fleet electrification targets; according to EESL, India's automobile industry contributes 7.1% gross domestic product and is fourth largest in the world in terms of volume, but by 2030 the government plans to have entirely electrified the country's vehicle fleet.

3. Demand for the electricity saved through greater end-use efficiency (smart metering and, to a lesser extent, distributed solar PV) is obvious. India's Central Electricity Authority (CEA) has indicated that the national electrical energy deficit was 8.6 TWh (0.8% of demand) and the peak capacity deficit was 3.3 GW (2.0% of demand) for the year ending 31 March 2018. India remains largely dependent on fossil fuel imports to meet its energy demand and electricity generation is still dominated by coal-fired thermal plant. In this context and in the interim, electrification of the country's vehicle fleet will increase the demand for imported coal (for electricity generation) and reduce the demand for imported liquid fuels (for transportation). The efficiency of electric vehicles relative to conventional vehicles and the efficiency of thermal electricity generating plant is therefore critical to ensure a net reduction in energy consumption.

C. Economic Analysis Approach and Key Assumptions

4. **Electric Vehicles.** To assess the economic viability of EESL's electric vehicle program, a "without project' scenario was adopted in which 10,000 conventional vehicles were manufactured from existing manufacturing facilities to meet demand, in comparison with the

[1] ADB (2017). *Guidelines for the 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

10,000 electric vehicles proposed to be manufactured in the "with-project" scenario.[4] It is recognized that this analytical framework is atypical in that the "without-project" scenario also involves capital investment, however adopting a framework in which no new vehicles are manufactured in the "without project" scenario does not reflect reality and imposes an unfair cost disadvantage on the "with-project". Electric vehicles typically contribute economically by reducing the use of imported fuel and by reducing emissions. It is understood that the expectation is for a combination of daytime and night-time charging for the vehicles purchased by EESL; most are expected to be chauffeur-driven and parked at public offices during the day and at night, facilitating continuous charging (as charging stations are available). For this reason, an average grid emission value of 0.754 was adopted for analysis of the electric vehicle initiative. In both "with project" and "without project" scenarios it was assumed that vehicles are driven approximately 100 km per day on average, as indicated by EESL. Fuel consumption for conventional vehicles of 15 km per liter was assumed by EESL in its project report, with specific tailpipe emissions of 2,680 grams of carbon dioxide (gCO2) per liter for diesel variants and 2,310 gCO2 per liter for gasoline variants. Emissions during manufacture were considered as equivalent for electric and conventional vehicles and were therefore ignored for the purposes of this analysis. A 10-year economic life was assumed for electric and conventional vehicles.

5. **Distributed Solar PV.** For the distributed solar subproject, analysis was undertaken for a single 1MW installation on the basis of information provided by EESL. In the "without-project" scenario, solar PV plant would not be installed in the 33/11kV substation and instead all electricity would continue to be supplied from upstream thermal sources. In this scenario, seasonality and intermittency of solar power would cause different types of power plant and fuel combinations to be displaced at different times of the day, and savings would vary from month to month in practice. However, for simplicity and based on the likely plant dispatch during a typical day, it was assumed that base-load coal-fired generation would be displaced. An additional 1.5% of avoided thermal generation was assumed to account for the fact that the project is close to load centers and thereby avoids transmission (220kV, 132kV and 33kV) losses, calculated based on average distances, expected loads and typical conductor types used in transmission and sub-transmission in India.

6. **Smart Metering.** For the smart metering subproject, a "without project" scenario was adopted in which existing electro-mechanical and simple electronic meters continue to be used, with meter reading and billing continuing to be done manually. Smart metering provides a direct means through which electricity distributors can address the pervasive issue of non-technical losses (i.e. billing and collection inefficiencies). Collection inefficiencies are addressed automatically for smart meters implemented as prepayment meters (and the conversion requires only a simple software adjustment) because no bills are sent and consumers pay in advance for their consumption. For post-paid customers, consumer bills are generated and transmitted automatically without the need for manual intervention. Billing inefficiencies are addressed in a number of ways. Firstly, electromechanical meters tend to "slow down" over time, producing readings that understate the quantity of electricity consumed. Sometimes the meters will become stuck and no consumption will be recorded at all. Electronic smart meters are inherently more accurate and stable, and when they fail (or are tampered with) an electronic report can automatically be generated and sent instantaneously. Secondly, electricity theft can be identified more-or-less instantaneously based on the difference between the instantaneous demand on a distribution transformer and the sum of the instantaneous consumer demand downstream of the distribution transformer. Of course, the meters themselves cannot eliminate this theft; action is still required by the distribution companies and the opportunity for collusion still exists.

[4] 10,000 vehicles reflects the supply least supply contract executed by EESL, rather than being an assumption for this analysis.

7. Improvement in billing and collection efficiency was estimated from a successful 40,000 smart meter pilot program in Puducherry.[5] There, billing efficiency increased from 86% to 95% and collection efficiency improved from 91% to 96% (that is, an overall reduction in total commercial losses from 22% to 9%). The same level of reduction was assumed in the "with-project" scenario for the post-paid meters to be implemented by EESL, however collection efficiency was assumed to increase to 100% for the prepaid meters (representing an assumed 80% of the total meters to be installed, based on indications from EESL). Of the total reduction in losses, a weighted average of 68% was assumed to be converted to sales, with no net economic benefit. The balance (32%) was assumed to no longer be consumed, resulting in an economic resource cost saving; this was valued at the marginal (fuel) cost of coal-fired generation (INR 3,56 per kWh).[6] The removal of the need to visit consumers' premises to read electricity meters will result in a saving in fuel costs for meter readers' vehicles. This saving has been estimated at 110 kiloliters of fuel per year for a five million meter roll-out. This was valued at the border price equivalent value (BPEV) for imported liquid fuels using the methodology discussed below.

D. Economic Costs

8. All project costs were expressed using the domestic price numeraire. Financial costs were categorized into traded goods, non-traded goods, foreign skilled labor, local skilled and unskilled labor, and were adjusted with appropriate conversion factors. A shadow rate exchange factor (SERF) of 1.03 was used, based on the rate adopted in the RRP for the previous loan to EESL, and an estimated shadow wage rate factor (SWRF) of 0.75 was used for unskilled labor. Transfer payments and price contingencies were excluded from the analysis. Operations and maintenance expenses for the distributed solar PV subprojects were based on the Central Electricity Regulatory Commission's benchmark of Rs0.7 million per MW of installed capacity per annum, escalating at 4% per annum in nominal terms. For the smart metering subproject, the financial operations and maintenance cost per meter was assessed by EESL as Rs 256 per annum initially, increasing by Rs75 per annum after year 5 to account for extension of the manufacturer's warranty on the meters. Of this, for this economic analysis the "project management fee" was assumed to be 50% cost-reflective and 50% an allocation of existing fixed costs, with the latter being ignored for the purposes of economic analysis. The warranty was assumed to reflect actual meter maintenance costs and was therefore included (spread over the entire life of meters). A downward adjustment of 20% was made to the resulting operation and maintenance cost to account for the avoided cost of maintaining existing meters. For the electric vehicle subproject, operations and maintenance expenses are expected to be common with conventional vehicles and have therefore been ignored for the purposes of this analysis (other than incremental battery-related expenses captured in manufacturers' warranties)

9. The distributed solar PV and the smart metering subprojects displace coal-fired electricity generation, whereas the electric vehicles subproject relies on coal-fired electricity generation for vehicle charging. Coal use was quantified assuming a plant heat rate of 3,300 kilocalories (kCal) per kWh and a coal calorific value of 4,000 kCal per kilogram (reflecting the relatively low calorific value of Indian coal). Coal was valued at its BPEV - forecast cost, insurance, and freight (CIF)

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[5] Ramakrishna Kappagantu, S. Arul Daniel *, N.S. Suresh. *Techno-economic analysis of Smart Grid pilot project- Puducherry.* Tamil Nadu. 2016.

[6] There is no analytical evidence available from pilot studies regarding conversion rate to sales. Therefore, the rate of conversion of commercial losses to sales was deduced on the basis of an assumption of sharing of loss reduction by all consumers and a typical price elasticity of demand of around -0.2. In practice, the loss reduction would not be shared across all customers – customers that are stealing electricity would see an infinite increase in price, suggesting that a much higher reduction in consumption for those consumers.

prices plus estimated local transport and handling charges. The basis of fuel prices used was the actual reported CIF prices of coal in 2018 and the forecast CIF fuel costs for India were estimated following the World Bank commodity prices.[7] Liquid fuels for conventional vehicles (for comparison to electric vehicles) were valued priced on the same basis. The coal BPEV was then converted to the domestic numeraire by multiplying by the SERF. The coal and oil price forecasts are crucial to this analysis and therefore sensitivity to the assumed price paths was examined.

10. **Avoided Emissions.** Emissions of carbon dioxide (CO_2) from coal-fired plant (a saving for the distributed solar PV and the smart metering subprojects and a cost for the electric vehicles subproject) were estimated using the overall grid emission factor for India of 878 tonnes per GWh for the distributed solar PV subproject and 754 tonnes per GWh for other subprojects .[8] Emissions from liquid fuels in the "without project" scenario for the electric vehicles subproject were estimated as discussed above. The overall reductions in emissions peaks at 748,000 tonnes of CO_2.

E. Least Cost Analysis

11. The three main subprojects were assessed to ensure that they are least cost. In the case of the electric vehicles program, their lifecycle cost (expressed as rupees per kilometer travelled) was compared to that of conventional vehicles (with diesel-powered, internal combustion engines). As noted above, all other maintenance costs and vehicle disposal costs were assumed to be common between electric and conventional vehicles. Values for fuel efficiency were provided by EESL and were checked against public domain information. For distributed solar PV, least cost was assessed against the fuel cost of existing, base-load coal-fired generation since this is the generation that would otherwise provide daytime electricity for rural loads. Least cost was confirmed for these two subprojects by comparing levelized costs against their alternatives. The provision of electronic smart meters, with the consequential requirement to invest in related communications and IT infrastructure, is clearly not the least cost means to record consumers' electricity consumption and to produce customer invoices - standard electronic meters are cheaper and do not require sophisticated IT infrastructure. A more appropriate least cost comparison for smart meters is against other commercial loss reducing solutions, and the cost per kilowatt-hour of avoided loss of approximately Rs1.0 is low. However, no other sustainable and practical solutions to the problem of commercial loss reduction have been identified for the Indian context, making a least cost comparison problematic.

F. Economic Internal Rate of Return

12. The economic evaluation was carried out for the 25-year period from 2020 to 2044. 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. The aggregate EIRR calculation is shown in Table 1. The subproject EIRRs are 9.5% (electric vehicles), 15.7% (distributed solar PV), and 21.5% (smart meters). Based on the expected weighting of these three subprojects in the overall investment program, the estimated aggregate EIRR is 15.5%.

G. Sensitivity Analysis

13. Analyses were carried out to examine the sensitivity of the EIRR to changes in assumed values of the key variables: a 20% increase in capital costs, a sustained 20% reduction in the

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[7] World Bank (2018). *Commodity Markets Outlook*. April 2018 update.

[8] ADB. 2017. *Guidelines for Estimating Greenhouse Gas Emissions of Asian Development Bank Projects - Additional Guidance for Clean Energy Projects.* Manila.

value of avoided emissions, a 50% increase in operating and maintenance costs and a one-year delay in implementation (that is, one-year delay in benefits beginning to accrue). A combined downside scenario was also modelled. Table 1 shows that the sample subprojects are expected to provide reasonably robust economic performance. In the case of electric vehicles, shorter than expected battery life represents a risk to the subproject's economic performance. To test this sensitivity, the assumed vehicle life was reduced from 10 years to 8 years. For simplicity, the assumed economic life of conventional vehicles was also reduced to 8 years. With this reduction in life, the EIRR reduces to 6%. A more realistic assumption of the life of conventional vehicles remaining at 10 years would further reduce the EIRR to well below 0%. This risk cannot be mitigated in practice, although the manufacturing and operational experience gained through this intervention will provide valuable feedback so that, over time, battery lives can be better understood and consequently extended.

H. Conclusions

14. The economic assessment shows that the economic performance of the overall project is robust, despite some residual risks concerning the economic life of electric vehicle batteries and the sustainability of commercial loss reduction arising from the use of smart meters. The EIRRs of all subprojects also exceed the assumed hurdle rate under most of the single sensitivities tested. In this context and from economic standpoint, the proposed loan is considered economically viable.

Table 1: Aggregate Economic Internal Rate of Return Calculation [1]

(Rs million)

Year	Benefits		Costs		Net Economic Benefits
	Non-Incremental Output	Avoided Emissions	Capital	Operating	
2020	0	0	15,906	0	(15,906)
2021	1,810	962	7,036	633	(4,898)
2022	2,811	1,423	3,239	894	100
2023	3,947	2,041	140	1,155	4,693
2024	3,934	2,068	140	1,153	4,710
2025	3,922	2,096	0	1,152	4,866
2026	3,923	2,125	0	1,150	4,898
…	…	…	…	…	…
2044	724	731	0	78	1,378
				EIRR:	**15.5%**
				ENPV:	**9,538**

( ) = negative, EIRR = economic internal rate of return, ENPV = economic net present value
1/ For brevity, only selected years are shown.
Source: Asian Development Bank staff estimates.

Table 2: Subproject EIRR Sensitivities

Subproject	Base Case	Capital Cost	Emissions value	O&M	Delay	Combined
		+20%	-20%	+50%	1 year	
1. Distributed solar PV	15.7	12.7	14.1	13.3	15.0	9.5
2. Electric vehicles	9.5	5.6	9.3	7.8	9.5	4.5
3. Smart meters	16.6	12.9	14.3	13.1	12.2	6.6
Aggregate	15.5	12.1	13.7	12.6	12.6	13.1

( ) = negative, EIRR = economic internal rate of return, ENPV = economic net present value

Source: Asian Development Bank staff estimates.