DETAILED ECONOMIC ANALYSIS

A. Project Rationale

1. Madhya Pradesh is experiencing rapid escalation in demand as well as supply in recent years. Energy sales are projected to grow from under 30 terra watt hour (TWh or billion units) per annum in FY 2012 to close to 50 TWh in FY 2015, and further rise to nearly 78 TWh by FY2022. The compounded annual growth rate (CAGR) of energy sales has already been around 8.35% over 2004-2012, but it is projected to increase to 11.01% over the next five years. Generation capacity has also improved significantly in the recent past and is expected to continue to consolidate going forward with 14,554 megawatt (MW) of new capacity planned by FY2020. The state power system is projected to have a 20% peak period surplus according to the Load Generation Balance Report for 2013-14.[1] This is a remarkable amelioration in supply capability considering that 5 to 6 years ago Madhya Pradesh faced 13%14% energy deficit. In order to efficiently facilitate the generation and demand to match, a major augmentation and expansion of the transmission and distribution (T&D) infrastructure is critical.

2. The proposed investment covers a major expansion of the T&D network including *inter alia* 1,800 km of high voltage lines (primarily, 132 kV but also includes 220/400 kV expansion) and 3,125 circuit km of distribution lines. These new lines will add approximately 5% to the existing high voltage (132 kV and above) lines and 5.2% to existing 33 kV line network. The proposed investments will cover transmission investments by MP Power Transmission Company Limited (MP Transco) of Rs17.47 billion mainly at 132 kV level, but also includes 220 kV and 400 kV network. In addition, a total of Rs7.53 billion of capital works have been proposed across the distribution network of the state at 33 kV, 11 kV and low tension (LT) levels, which are owned and operated by three distribution companies.[2] Given the sharp increase in load being experienced currently and the continuing trend of high demand growth, it is important that these extensions are put in place in a timely manner to deliver a stronger and resilient network that can cope with the growing demand. An efficient expansion of the network will not only ensure power cuts are avoided due to network constraints, but also reduce technical losses in the system, that in turn will release additional energy. Apart from the economic benefits of avoided technical losses and power cuts, the power utilities would receive financial benefits in terms of increased sales and hence.

3. The proposed investment under the aegis of Madhya Pradesh Transmission and Distribution System Improvement fits well with the policy framework developed by the Government of Madhya Pradesh (GOMP) and the Central Government to provide greater access to electricity and to reduce technical and commercial losses in the T&D system. The proposed investment is part of a broader ongoing reform initiative of the GOMP with support from development partners and the Asian Development Bank (ADB), to enhance the financial health of the T&D companies in the state. There have already been significant improvements in energy efficiency including a significant reduction in aggregate technical and commercial (ATC) losses from 39.52% in FY2008 down to 27.11% in FY2012. The proposed investments will aid in further lowering losses that would form an integral part of the Madhya Pradesh Electricity Regulatory Commission's (MPERC) aspiration to lower ATC to 17% by FY2014.[3] In addition, these investments will also ensure that the high voltage system can operate without facing

[1] Central Electricity Authority (CEA), *Load Generation Balance Report 2013-14*, May, 2013, New Delhi.
[2] Madhya Pradesh Madhya Kshetra Vidyut Vitaran Company (DISCOM-C); Madhya Pradesh Poorva Kshetra Vidyut Vitaran Company (DISCOM-E); and Madhya Pradesh Paschim Kshetra Vidyut Vitaran Company (DISCOM-W).
[3] MP Electricity Regulatory Commission, *Retail Tariff Order for 2013-14*. May 2013. Bhopal.

major transmission constraints. This effectively would ensure an optimal dispatch of the generation to avoid expensive peaking gas (or, oil) based generation, in the short term, and may also defer/avoid part of the peaking capacity, or captive diesel-based generation on customer premises, that would otherwise be needed in major load centers.

4. The sector context primarily stems from the need for a concomitant expansion of the T&D network so that additional generation including that from the independent power producers (IPP) can efficiently cater to the growing load being faced by the three distribution companies (DISCOMs). The proposed projects are intended to deliver power more reliably and at a lower cost through a reduction of technical losses, both in the T&D networks. As the state moves from being perennially short of peak and energy, to a projected 20.4% surplus position in FY2013, the proposed investments resonate well with the objective of strengthening a critical infrastructure to boost economic growth.

5. The preliminary economic analysis presented in this summary report is conducted in accordance with the *ADB's Guidelines for Economic Analysis of Projects.*[4] Project investments yield savings in terms of avoided cost of outages and energy losses in high voltage lines, T&D system (primarily 33 kV, but also some 11 kV and low tension lines). T&D projects in conjunction with new generation will help to reduce power shortage and provide greater access to electricity in Madhya Pradesh.

6. The key benefits of the project considered in the economic evaluation were (i) savings in technical losses, (ii) economic benefit owing to increased consumption, and (iii) savings owing to reduced expected energy not served (EENS) valued at the cost of unserved energy. To enable a conservative assessment, other economic benefits such as voltage improvement, social benefits of improved access to electricity, etc are not included. The reduction in EENS and technical losses constitute the major benefits that can be attributed to these projects. In addition, some of the generation-linked transmission projects would also help to evacuate power from new and efficient power plants and therefore contribute to reduction in fuel costs. Increasing power supply in a system where consumers have perennially faced major power cuts would have a greater economic benefit from increased consumption that goes beyond the technical loss and EENS reduction benefits. Finally, T&D projects in some cases may also substitute for the need of peaking generation, by allowing existing remote generation capacity to be utilized better. These projects may therefore defer generation capacity in the short to medium term, although the strong growth in demand suggests that the opportunity to defer new generation may be limited. On the balance, the economic rationale for a T&D project would hinge on the materiality of the EENS, loss reduction benefits and increase in consumer surplus benefits, albeit fuel cost reduction and capacity deferral benefits may also strengthen the case for specific projects. The economic evaluation focuses on (i) establishing the economic costs and benefits of the activities proposed project, and (ii) calculating economic internal rate of return and its sensitivity to changes in key input parameters.

B. Demand Analysis

7. Demand for power in Madhya Pradesh historically grew at a relatively low rate of 5% per annum, and had in fact had very slow growth between 1996 and 2004.[5] However, the total increase in power requirement in recent years has been strong with energy sales growing

[4] ADB. 1997 *Guidelines for Economic Analysis of Projects.* Manila.
[5] Seventeenth Electric Power Survey, Section 2.44.13.

between FY2010 and FY2012 as much as 29% over the three year period. The projected energy growth rate for the next five years until the end of FY2017 is estimated at 11% per annum, before it tapers off to 8.26% per annum for the subsequent five year period until FY2022.The growth in rural areas in the next five years (i.e., FY2013-FY2017) projected at 13.76% per annum, is one of the key contributing factors to energy demand growth. In particular, the consumption for the domestic sector in rural areas is projected to more than double over the next decade. As the annual per capita electricity consumption in Madhya Pradesh is 618 kWh per person per annum is well below the national average of 879 kWh per person per annum, there is significant latent demand in the system. Apart from significant number of un-electrified villages, the state has historically faced significant shortages in grid-connected areas including as high as 22% energy shortage as recently as January 2013.[6] One alternative for the project is diesel based power generation by households and businesses. As the cost of back-up diesel based generation has a very high operating costs, at least three times that of grid supply even before we consider relevant capital costs, there is virtually no risk of demand for grid connected power falling in the foreseeable future.

8. Although there is some additional energy released through reduced technical losses due to a more efficient power transfer at a higher voltage, the additional energy is likely to be a very small fraction of increased requirements in future. For instance, the annual energy supply requirement for the state is projected to grow by 48,793 giga watt hour (GWh or million units) per annum between FY2013 and FY2022. In comparison, the reduction in technical losses is projected by MP Transco is just over 400 GWh per annum, i.e., less than 1%. Grid-connected and off-grid distributed generation resources. Solar power may potentially cater to part of the demand, which has been a factor in some countries, including Germany and Australia, with high renewable uptake in recent years.[7] However, the strong growth in demand in Madhya Pradesh and the relatively low current stock of distributed generation in solar roof-top PV in Madhya Pradesh,[8] suggests, this is not an imminent deterrent to demand to be met via the proposed T&D projects.

9. Added consumption of electricity either from the part that would have otherwise dissipated from the network as heating losses without the proposed investment, or due to avoided power cuts, are the key component of the economic benefit analysis that is discussed in the following section. New transmission lines will facilitate evacuation of power from generation sites which will reach the final customers through new and refurbished sub-stations via the distribution lines. Apart from meeting the current supressed demand from existing customers, a significant part of the additional supply will cater to new customers.

10. The distribution networks are in dire need for reinforcement, expansion and refurbishment to meet growing demand. None of the DISCOMs have been able to achieve positive net revenue to date and therefore public sector intervention is essential to enable the DISCOMs to implement the project activities. The lack of a strong enabling business environment, presence of subsidized power for agricultural usage, suggest that it is unlikely that the private sector will have a substantial interest in investment in T&D in Madhya Pradesh.[9] It is therefore fair to conclude that the proposed investments are unlikely to crowd out private investments.

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[6] CEA, *ibid*, Annexure IV(a).

[7] For instance, T. Edis, *Solar bites into energy demand*, Clime Spectator, Australia, August 2013.

[8] Ministry of Renewable Energy, *Annual Report 2012-13*, New Delhi. (Table 4.5, data as of 31st December, 2012).

[9] As an aside, it is worth noting that private investment in transmission globally has also been largely unsuccessful. An excellent investigation into the wider economic issues has been conducted by: Paul Joskow & Jean Tirole "Merchant Transmission Investment," *Journal of Industrial Economics*, 53(2), pages 233-264, 2005.

C. Project Alternatives and Least Cost Analysis

11. In theory, there are several technical alternatives to the proposed T&D projects including: (i) alternative higher/lower voltage projects; (ii) alternative timing of the proposed projects; (iii) generation closer to the load center to the extent these are feasible and substitute for transmission projects, including renewable based generation; and (iv) demand side management alternatives.
One has to be careful in assessing the least-cost nature of the proposed projects because these form part of a much larger reform initiative that are preceded by other projects, and would also be augmented with others in future. Many of the MP Transco projects, for instance, are grid reinforcement and extension that reflect on going transmission investment activities that have been continuing over past several years. Some of these projects also reflect grid expansion to accommodate other generation-evacuation projects that are in the offing. It is therefore important to note that the least-cost criterion needs to be applied in a more holistic sense, rather than narrowly focusing on each component.

12. The T&D projects selected are in line with the least-cost philosophy to reliably and economically evacuate generation to meet growing demand from existing customers as well as new customers. The National Transmission Plan prepared by the Central Electricity Authority which is also developed on a least-cost basis is kept in view in developing some of the elements. The MP Transco amply demonstrates that with the proposed projects in, the peak period transmission losses will come down from 414 MW to 384 MW (at 220 kV level), or an estimated 152 GWh per annum, consistent with what is expected of a least-cost plan. The distribution network expansion and augmentation projects in a similar vein recognize that the existing rabbit/raccoon conductors for the 33 kV system is inadequate for the growing load in the system, that will lead to higher losses, or worse require power cuts to avoid overloading. The analyses by all three DISCOMs show that they have taken the longer term load growth in due consideration and have reported a total technical loss reductions of 737 GWh per annum across three DISCOMs. The total loss reduction across the MP Transco and three DISCOMs is 1,140 GWh per annum which represents 2.43% of total annual energy supplied in FY 2013. Given that the energy sales growth rate is predicted to be about 11% over the next five years, it appears that the projects are timely. Nonetheless, in the economic analysis presented in the next section, there are sensitivity analyses considered around delaying the projects by one year to see how it impacts on the project economics.

13. As already noted, local generation alternatives (as opposed to grid supply), including renewable solar, wind, and biomass opportunities, are limited and prohibitively expensive to form a worthy competitor to the proposed T&D expansion. Roof top solar PV is among the most popular options but at an estimated Rs10 per delivered kWh (for < 5 kW roof-top PV), it is still substantially more expensive, compared to grid supply, although it has already become cheaper than diesel, and is widely believed to reach grid parity closer to the end of this decade.[10] Apart from cost, the generation as well as demand side resources can only constitute a small fraction of demand. While these resources, especially demand side response, can usefully augment T&D counterparts in some cases, e.g., remote areas, or during peak periods, they do not at present a suitable alternative to the proposed investments.

[10] Cost of solar calculated using capital costs in, Mercados, *Rooftop Solar Development in India*, Jan 2013, available on MNRE website:http://mnre.gov.in/file-manager/UserFiles/presentations-challenges_and_issues_in_solar_RPO_compliance_19122012/Session-7_Rooftop%20Solar%20Development%20in%20India_V1.pdf

D. Cost Benefit Analysis

14. The cost-benefit analysis framework used for the analysis of MP Transco, DISCOM-C, DISCOM-E and DISCOM-W projects compares discounted cost of the proposed projects with discounted benefits over a 27-year life. Economic assessment is centered around: (i) economic internal rate of return (EIRR); and (ii) net present value of (net) economic benefit.

15. Project **net economic benefits** primarily comprise value of total additional energy served due to project interventions that includes incremental sales due to capacity expansion and removal of bottlenecks in T&D system. Benefit of these incremental sales is estimated as the relevant area under the demand curve.[11] This is equal to:

(i) revenue of the incremental sales,
(ii) resource cost savings due to loan reduction, valued at cost of generation,
(iii) plus consumer surplus,
(iv) less the cost of additional generation associated with incremental sales.

16. Consumer surplus is evaluated using the following formula:

$$Consumer\ surplus = 0.5[P_1\ (\Delta Q)^2] / [e_d\ Q_1] = 0.5\ [\Delta Q.\ \Delta P]$$

Where, the prevailing electricity price is P_1, and electricity consumption without the project is Q_1. With the project, the electricity consumption increases to Q_2 with ΔQ being the additional consumption from reduced losses. Finally, e_d is the absolute value of the price elasticity of demand.

17. In addition, we have also prepared estimates of reduction in EENS that reflects the improvement in transmission system reliability to lower the number of power outages. We have developed a measure of expected unserved energy by looking at:

(i) demand forecast for peak and energy,
(ii) typical load duration curve (LDC) or the peak demand share and load factor of demand, and
(iii) transmission and distribution system availability including any enhancement to the system availability due to incumbent projects;
(iv) derive an estimate of *average* MWhs that will be unserved at peak without the proposed projects.

18. However, we have not explicitly included EENS benefits in monetary terms in our base case estimates of benefits to be on the conservative side. That said, if EENS benefits are significant, it would indicate potential strong upside opportunities that the proposed investments may deliver, over and above the net economic benefits discussed above. It should be noted that EENS benefits are routinely included as part of international best practice including the Regulatory Investment Test (RIT) employed in Australia, parts of the USA, Canada and New Zealand.[12]

19. **Key assumptions for net economic benefit estimation**: All costs and benefits in the analysis are expressed at 2013 prices. A discount rate of 12% was used in the net present

[11] This methodology is recommended by ADB's new economic analysis guide –Cost Benefit Analysis for Development: A Practical Guide, 2013, ADB, Manila

[12] For instance, Australian Energy Regulator, *Regulatory Investment Test for Transmission and Distribution*, 2009, Melbourne, Australia.

value calculations. A period of 27 years was used for economic assessment of T&D projects for the base case. Capital costs considered in the economic evaluation include project material and construction costs, physical contingencies, but excluded taxes, price contingencies, and financial charges during construction. Non-tradable commodities were valued through shadow prices using a standard conversion factor of 0.93,[13] and the following specific conversion factors were used to convert other project costs: 1.0 for equipment, 1.5 for steel, 0.76 for cement, 0.82 for timber, 2.0 for skilled labor, and 0.67 for unskilled labor. These conversion factors were taken from previous ADB project preparatory documents or from other published data. Project costs were phased-in over a 3-year period for the DISCOMs as 20% in FY2014, 50% in FY2015, and 30% in FY2016. The MP Transco project costs are phased over a four year period. Project maintenance costs each year were estimated to be 3% of the economic costs of the project disbursed by the end of the previous year.

20. **Assumptions for EENS estimation**: Base EENS estimates are calculated assuming a 99.44% availability of the system for the bulk transmission system which reflects current system conditions. EENS reduction has been calculated by assessing the improvement in system availability using historic system availability information from MP Transco. A regression model has been developed using historic system availability that shows system availability since 2005 is growing at a reasonably steady rate of 0.1119 points every year since the grid enhancement program has been commissioned. It has been assumed that the system availability will continue to improve as per the historic trend to a maximum level to 99.80%. It is also assumed that absent the proposed investment grid reliability will stagnate at the current level, i.e., remain at 99.44%. EENS reduction is valued conservatively at $500 per MWh (or INR 25 per kWh) which is around half of the value used in most developing nations including Thailand and Sri Lanka. It is significantly lower than estimates for developed nations and in this respect may be viewed as a conservative estimate.[14] On balance though, the chosen $500 per MWh, is deemed to be a better reflection of the lower opportunity costs in rural areas where majority of the EENS reduction is likely to occur. It may be mentioned that Rs25 per kWh was assessed as the value of unserved energy for rural Karnataka region in a survey conducted by TERI and this has also been used in a recent ADB study (ADB RDTA 7529).[15]

21. Project costs and benefits have been estimated in constant 2013 prices The project construction period was considered to be from FY 2014-2016 (except for MP Transco which has a four year construction period, and the benefits would occur till FY 2038. Project costs were phased over three (or four in the case of MP Transco) as per the cost schedule provided by the project proponents. Project maintenance costs each year were typically estimated to be 3% of the capital costs of the project.

22. Savings in technical losses for all four entities have been estimated by the proponents using load flow studies for a single year FY 2015. Greater loss reduction would typically be achieved for subsequent years as the system load increases until such time that the capacity limits on the new investments are achieved. In order to arrive at a conservative estimate, it has

[13] ADB 2011, Cross Sectoral Implications of Biofuel Production and Use in India. A Report submitted to Government of India

[14] The Energy Research Institute, Cost of Unserved Energy, prepared for the World Bank, TERI Report, 2010.
The following survey has a comprehensive summary of value of unserved energy across different countries: D. Chattopadhyay and S. Schnittger (2008),Investigation of Value of Unserved Energy, prepared for the Electricity Commission of New Zealand, http://www.ea.govt.nz/.../our.../investigation-of-the-value-of-unserved-energy/
A 2012 study by the Australian Energy Market Operator has more recent estimates for Australia of up to AUD 54,000 per MWh: http://www.aemo.com.au/Electricity/Policies-and-Procedures/Planning/National-Value-of-Customer-Reliability-VCR
The Sri Lankan estimate is based on Ceylon Electricity Board power system planning studies conducted as part of the ADB project on SAARC Regional Power Exchange (RDTA 7529).

[15] ADB RDTA 7529: *Regional Power Exchange Study*, Final Report, December 2012.

been assumed that loss reductions remain constant over the years as part of the base case. Therefore, only the value of incremental sales and a conservative static estimate of technical losses were used as benefits in the economic analysis. However, the project also provides other benefits such as technical loss reduction growing over the years as system load increases and EENS reduction. Potential for technical loss reduction included in the analysis is conservative. However absent the proposed investment, if the existing system is used to transmit increasing quantities of power losses can increase significantly. Greater loss reduction would typically be achieved for subsequent years as the system load increases.

23. Sophisticated dynamic and probabilistic modeling is required to quantify increasing losses over time and EENS benefits, respectively. Therefore the benefits of increasing technical loss reduction or EENS benefits were not included in the analysis. To enable a conservative assessment, other economic benefits such as ability of T&D investments to defer new peaking generation capacity, voltage improvement, social benefits, etc., are also not included. The benefit-cost analysis for the base case shows that the project is economically viable with an estimated Economic Internal Rate of Return (EIRR) of 21.02%. Economic cost and benefit flows are in Table 1.

Table 1 : Annual Costs and Benefits in Rs Million: Base Case

Year	Project Investment	Project maintenance costs	Total project cost	Value of total energy loss saved	Incremental Sales	Less Cost of Generation	Additional Consumer Surplus	Total economic benefit	Net Economic Benefit of the Project
1	3,211	0	3,211	0	0	0	0	0	3,211
2	10,647	0	10,647	0	0	0	0	0	10,647
3	7,565	0	7,565	0	0	0	0	0	7,565
4	3,577	226	3,803	0	0	0	0	0	3,803
5	0	750	750	1,519	1,839	1,329	2,560	4,589	3,839
6	0	750	750	2,278	2,759	1,993	3,839	6,884	6,134
7	0	750	750	3,038	3,679	2,657	5,119	9,178	8,428
8	0	750	750	3,038	3,679	2,657	5,119	9,178	8,428
9	0	750	750	3,038	3,679	2,657	5,119	9,178	8,428
10	0	750	750	3,038	3,679	2,657	5,119	9,178	8,428
11	0	750	750	3,038	3,679	2,657	5,119	9,178	8,428
12	0	750	750	3,038	3,679	2,657	5,119	9,178	8,428
13	0	750	750	3,038	3,679	2,657	5,119	9,178	8,428
14	0	750	750	3,038	3,679	2,657	5,119	9,178	8,428
15	0	750	750	3,038	3,679	2,657	5,119	9,178	8,428
16	0	750	750	3,038	3,679	2,657	5,119	9,178	8,428
17	0	750	750	3,038	3,679	2,657	5,119	9,178	8,428
18	0	750	750	3,038	3,679	2,657	5,119	9,178	8,428
19	0	750	750	3,038	3,679	2,657	5,119	9,178	8,428
20	0	750	750	3,038	3,679	2,657	5,119	9,178	8,428
21	0	750	750	3,038	3,679	2,657	5,119	9,178	8,428
22	0	750	750	3,038	3,679	2,657	5,119	9,178	8,428
23	0	750	750	3,038	3,679	2,657	5,119	9,178	8,428
24	0	750	750	3,038	3,679	2,657	5,119	9,178	8,428

Year	Project Investment	Project maintenance costs	Total project cost	Value of total energy loss saved	Incremental Sales	Less Cost of Generation	Additional Consumer Surplus	Total economic benefit	Net Economic Benefit of the Project
25	0	750	750	3,038	3,679	2,657	5,119	9,178	8,428
26	0	750	750	3,038	3,679	2,657	5,119	9,178	8,428
27	0	750	750	3,038	3,679	2,657	5,119	9,178	8,428
								NPV	**18,420**
								EIRR	**21.02%**

E. Sensitivity and Risk Analysis

24. As part of the sensitivity and risk analysis, the primary objective is to check exposure of the proposed investments to *downside* risk as reflected in an increase in cost, or a decrease in benefit parameters. In particular, it is checked if there is a risk of the project EIRR falling below the notional hurdle rate of 12%. Table 2 shows the results of the sensitivity analyses that confirm that the project economics is adequately robust and will not go below the hurdle rate due to variation in project capital as well as operating costs by 10%. Any underachievement in loss reductions or new connection by 10%, or a one-year delay in project would still render the project economically viable. However the delay reduces EIRR substantially and measures should be incorporated in the project design to minimize project delays.

Table 2: Results of Sensitivity Analyses

	Sensitivity	NPV of Net Benefit (Rs million)	EIRR
1	Project capital cost Increase by 10%	16,518	19.58%
2	Capital cost as well as O&M cost increase by 10%	16,136	19.41%
3	Total energy savings reduced by 10%	14,294	19.25%
4	One year delay in project completion	13,615	18.18%

EIRR = economic internal rate of return, NPV = net present value, O&M = operation and maintenance.

25. Reduction in EENS is estimated using a progressively higher level of system availability achieved through new investment at a rate of 0.1119 points per year until FY2017-FY2018 when the maximum system availability of 99.80% is expected to reach. This again reflects a conservative assumption because system availability can potentially improve beyond 99.80%. Nevertheless, even at a 99.80% max availability, and Rs25 per kWh of EENS reduction, the annual benefits from FY2017 would increase by Rs1.2 billion which will improve the EIRR from 21.01% to 23.64% – a significant increase. This is a significant upside opportunity that would more than offset any of the potential downside risks considered above.

F. Conclusion

26. The economic analysis of the proposed T&D investments by MP Transco and three DISCOMs concludes that proposed investments are economically viable. The overall portfolio has an EIRR of 21.02% for the base case. Sensitivity analyses that consider downside risks of inter alia 10% variation in costs and benefits demonstrate that the base case is robust in these cases. There are also potentially significant upside opportunities in terms of reduction of EENS that may significantly improve the EIRR.