ASIAN DEVELOPMENT BANK **PPA: BHU 27260**

PROJECT PERFORMANCE AUDIT REPORT

ON THE

RURAL ELECTRIFICATION PROJECT
(Loan 1375-BHU[SF])

IN

BHUTAN

December 2003

CURRENCY EQUIVALENTS

Currency Unit – ngultrum (Nu)

		At Appraisal (July 1995)	At Project Completion (April 2000)	At Operations Evaluation (August 2003)
Nu1.00	=	$0.03226	$0.02292	$0.0219
$1.00	=	Nu31.00	Nu43.63	Nu45.74

ABBREVIATIONS

AAC	–	all aluminum conductor
ABC	–	aerial bundled conductor
ACSR	–	aluminum conductor steel reinforced
ADB	–	Asian Development Bank
BEA	–	Bhutan Electricity Authority
BPC	–	Bhutan Power Corporation
CHPC	–	Chhukha Hydropower Company
CHPS	–	Chhukha Hydropower Station
DOP	–	Division of Power
EIRR	–	economic internal rate of return
FIRR	–	financial internal rate of return
ICB	–	international competitive bidding
NFE	–	nonformal education
O&M	–	operation and maintenance
OEM	–	Operations Evaluation Mission
PCR	–	project completion report
PPAR	–	project performance audit report
PPTA	–	project preparatory technical assistance
RE	–	rural electrification
RRP	–	report and recommendation of the President
SDR	–	special drawing rights
SF6	–	sulfur hexafluoride
TA	–	technical assistance

WEIGHTS AND MEASURES

cct-km	(circuit-kilometer)		
V	(volt)	–	unit of electrical voltage
kV	(kilovolt)	–	1,000 V
kVA	(kilovolt-ampere)	–	1,000 VA
kWh	(kilowatt-hour)	–	1,000 Wh
mm^2	(square millimeter)		
MVA	(megavolt-ampere)		

NOTES

(i) The fiscal year (FY) of the Government and its agencies ends on 30 June. FY before a calendar year denotes the year in which the fiscal year ends.

(ii) In this report, "$" refers to US dollars.

Operations Evaluation Department, PE-635

CONTENTS

BASIC DATA
Loan 1375-BHU(SF): Rural Electrification Project

Project Preparation/Institution Building

TA No.	TA Name	Type	Person-Months	Amount ($)	Approval Date
2043	Power System Development	PPTA	6	245,000[1]	29 Dec 1993
2400	Institutional and Financial Development of Department of Power	ADTA	12	400,000[2]	19 Sep 1995

Key Project Data ($ million)	As per ADB Loan Documents	Actual
Total Project Cost	9.5	8.21
Foreign Exchange Cost	7.3	6.64
ADB Loan Amount/Utilization	7.5	6.64
ADB Loan Amount/Cancellation		0.05

Key Dates	Expected	Actual
Fact-Finding		5–16 Mar 1995
Appraisal		21–31 May 1995
Loan Negotiations	Aug 1995	28 Jul–4 Aug 1995
Board Approval	Sep 1995	19 Sep 1995
Loan Agreement		17 Nov 1995
Loan Effectiveness	Feb 1996	8 Feb 1996
First Disbursement		2 May 1996
Project Completion	30 Jun 1998	Dec 1999
Loan Closing		6 Apr 2000
Months (effectiveness to completion)	29	46

Economic and Financial Rates of Return (%)	Appraisal	PCR	PPAR
Economic Internal Rate of Return	11.9	11.7	12.5
Financial Internal Rate of Return	1.1	< 0	< 0

Borrower Kingdom of Bhutan

Executing Agency Division of Power

Mission Data	No. of Missions	Person-Days
Fact-Finding	1	36
Appraisal	1	55
Project Administration		
Inception	1	3
Review	4	30
Project Completion	1	36
Operations Evaluation[3]	1	44

ADB = Asian Development Bank, ADTA = advisory technical assistance, PCR = project completion report, PPAR = project performance audit report, PPTA = project preparatory technical assistance, technical assistance.

[1] Financed by the Japan Special Fund.

[2] Financed by ADB.

[3] The Operations Evaluation Mission comprised H. Hettige (Senior Evaluation Specialist/Mission Leader), B. Palacios (Evaluation Officer/Mission Member), W.M. Lewis (Power Engineer/Staff Consultant), and K. Yonten (Social Development Specialist).

EXECUTIVE SUMMARY

The Seventh 5-Year Plan (1992–1997) gave high priority to conserving natural resources and reducing the existing rate of forest depletion. It envisaged that this goal could be achieved through a gradual substitution of electricity for other types of fuel particularly in rural areas. The Asian Development Bank's (ADB's) strategy for the energy sector in Bhutan, which focused on the expansion of the power transmission and distribution systems for balanced regional development, coincided well with this goal. In 1995 at the time of project appraisal, 80% of the population did not have access to electricity; firewood accounted for about 77% of energy consumption. It was envisaged that electricity would also provide part of the basic infrastructure to support Bhutan's transformation from a subsistence economy to a market economy. Although providing rural electricity from the grid to remote villages would be expensive, it was still considered least cost and environmentally appropriate as compared to other sources of power such as solar energy and mini-hydropower units.

The estimated project cost was $9.5 million, of which 77% was to be in foreign exchange. In September 1995, ADB approved a loan of $7.5 million equivalent from the Asian Development Fund under standard terms for the Rural Electrification Project (the Project), mainly to finance the foreign exchange cost of the Project. The Project was expected to supply electricity to about 3,100 new customers and provide tools, plant, vehicles, and regional maintenance centers to assist in operation and maintenance of the distribution facilities. All construction work was to be carried out by the executing agency, Division of Power, using its staff supplemented by local labor as required.

Overall design of the Project was appropriate. Careful thought was given to both environmental and social aspects and policy dialogue appropriate for that time was incorporated. The recommendation of the feasibility study that the least-cost alternative for rural electrification (RE) was connecting to the grid—although likely correct—could have been substantiated better with supporting data. Less than adequate consideration of Bhutan's mountainous terrain in some aspects of technical design caused several problems and delays during implementation.

To expedite implementation, the executing agency hired the consultants who did the feasibility study and ADB approved advance recruitment prior to loan approval. Nevertheless, there were some shortcomings in the consultants' performance. While they were experienced in the sector, they failed to take into account the lack of roads and the heavy weight of equipment that made their installation difficult on top of a mountainous terrain. Insufficient recognition of aspects of Bhutan's environment led to significant frustration and dissatisfaction by the executing agency and also resulted in implementation delays and subsequent service interruptions.

Other factors that contributed to an 18-month delay in project completion included delayed procurement, malfunctioning of some transformers, incompatibility of some supplies ordered by the consultants, unavailability of sufficient community labor, and transportation problems caused by heavy rain. The actual project cost was 14% below appraisal estimate, mainly due to partial utilization of contingency funds. The Project began operating in December 1999.

Despite the difficulties encountered, it appears that the Project's objectives were substantially met. After the Project, RE ratio in the country went up from 20% in 1995 to 24% in 1999. The outputs produced under the Project were generally in line with those envisaged at approval except for small changes due to the slightly lower number of households connected by project completion. However, at the time of the Operations Evaluation Mission, the number of households connected had slightly exceeded the 3,100 household target set at approval. The

completed system of 10,000 kilovolt-amperes capacity at 33 kilovolts and the additional capacity of the 11-kilovolt feeders can supply its initial customers, as well as serve as the platform for future expansion of RE services.

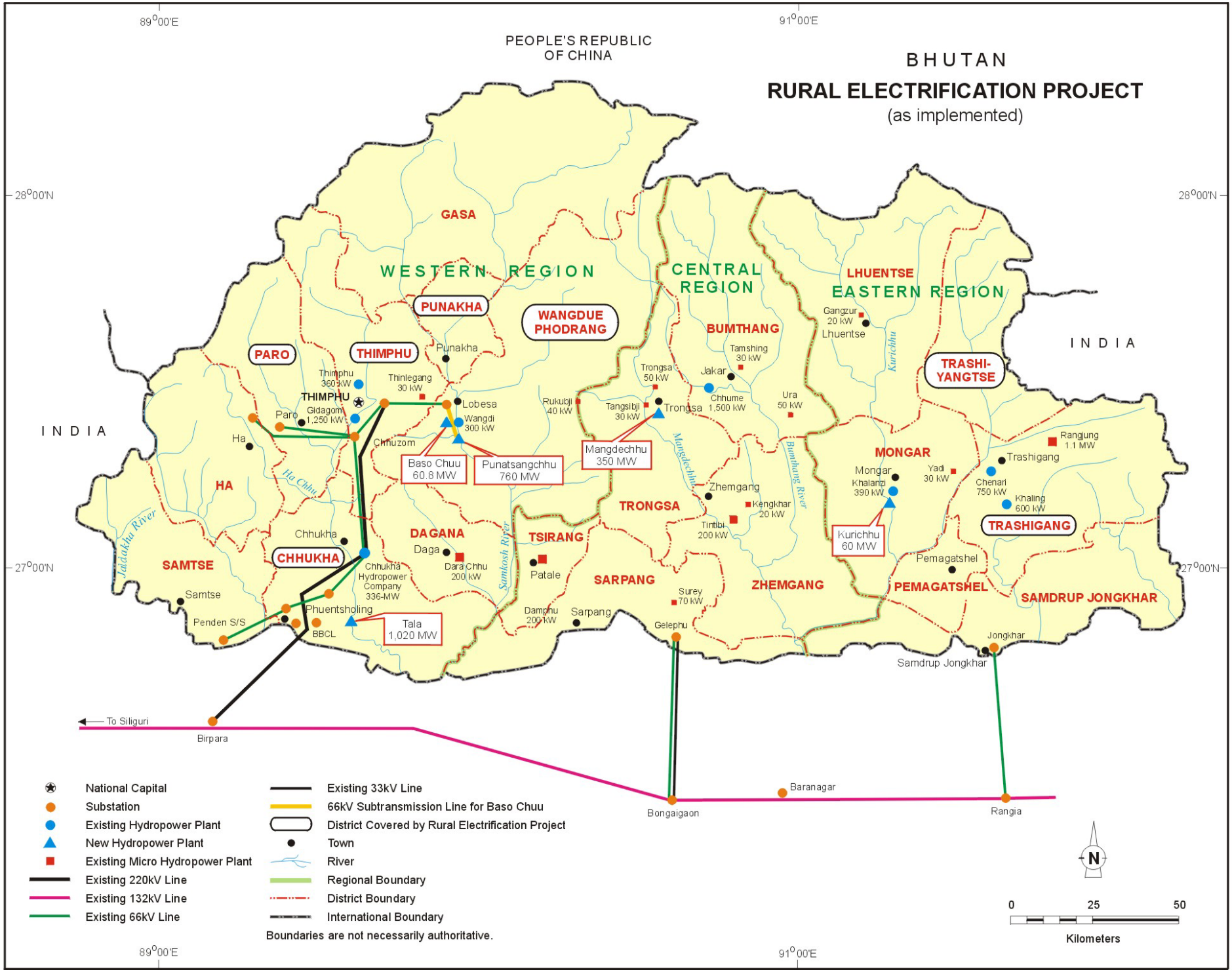
The Project has substantial positive environmental and social impacts. Firewood consumption is reduced by about 75% in the project areas, thereby arresting the forest cover depletion. Internal air pollution is substantially eliminated with the use of electrical appliances in a majority of households that purchase electricity. Consumption and usage of kerosene has dropped by about 90%. Reduction in the use of firewood and kerosene has meant not only cost savings, but also reflect less time spent in collecting or buying these items. Focus group interviews revealed that the quality of life had improved for all members of the household. It has also led to an improvement in sanitation and prevented smoke-related negative health impacts. Socioeconomic circumstances of rural households, the output of school children, and safety in rural areas have also improved. The recalculated economic internal rate of return for the Project is 12.5%.

Under technical assistance (TA) 2400-BHU attached to the loan, assistance was provided for the development of financial systems and its computerization and for a national tariff study. However, it was too early to introduce a government department to a financial system suitable for a corporate entity; as such, these applications were not fully utilized. The tariff study developed a tariff policy for cost recovery based on peoples' ability to pay. Although the proposed tariff increases were not fully implemented, it formed the basis for the current tariff structure. In addition to the institutional impact of the TA, the Project itself had a substantial impact on sector technical staff through learning by doing. Many of the lessons learned by them have already been indirectly incorporated in the third RE project design.

Although the financial internal rate of return for the Project is negative, it is likely to be sustainable. The Bhutan Power Corporation (BPC) has the technical and financial capability to undertake appropriate maintenance activities. The Government does not financially support BPC, but it earns substantial income from transmission activities. Ability to continue to subsidize RE depends on the cross-subsidy available from medium- and high-voltage consumers. Since low-voltage rural consumers are a small proportion, this appears to be feasible. However, it is essential to manage the cross-subsidy to rural consumers to discourage inefficient energy consumption. The Bhutan Electricity Authority has the mandate to determine the tariff structure and oversee the sustainability of BPC.

The Project is relevant, highly efficacious, and achieved significant institutional development and other impacts. During implementation, it was less efficient in the use of time and resources. Its sustainability is likely. Therefore, its overall assessment is rated as successful.

The lessons identified show (i) the need for BPC personnel to be actively involved in designing future projects to provide their experience related to the specific terrain in Bhutan, (ii) the importance of adapting procurement packaging and shipping information to improve supplier participation and to avoid undue delays, (iii) the necessity for load flow analysis and a master plan prior to expanding RE, and (iv) the need for close supervision of consultants working in a particular sector of a country for the first time. Follow-up actions are needed to (i) train key BPC personnel in specific technical aspects, (ii) ensure that programmable auto-reclosers are functional and BPC personnel are trained to calibrate and maintain them, (iii) ensure that BPC financial statements are completed, and (iv) verify that tariff structure is revised when the capacity building phase of the Bhutan Electric Authority is completed.


BHUTAN
RURAL ELECTRIFICATION PROJECT
(as implemented)
PEOPLE'S REPUBLIC OF CHINA
INDIA
INDIA
89°00'E
91°00'E
28°00'N
27°00'N
WESTERN REGION
CENTRAL REGION
EASTERN REGION
GASA
PUNAKHA
WANGDUE PHODRANG
BUMTHANG
LHUENTSE
TRASHI-YANGTSE
PARO
THIMPHU
HA
CHHUKHA
DAGANA
TSIRANG
SARPANG
TRONGSA
ZHEMGANG
MONGAR
TRASHIGANG
PEMAGATSHEL
SAMDRUP JONGKHAR
SAMTSE
Punakha
Thimphu 360 kW
Thinlegang 30 kW
THIMPHU
Gidagom 1,250 kW
Paro
Ha
Chhuzom
Lobesa
Wangdi 300 kW
Baso Chuu 60.8 MW
Punatsangchhu 760 MW
Rukubji 40 kW
Tangsibji 30 kW
Trongsa 50 kW
Trongsa
Mangdechhu 350 MW
Jakar
Chhume 1,500 kW
Tamshing 30 kW
Ura 50 kW
Gangzur 20 kW
Lhuentse
Kurichhu
Rangjung 1.1 MW
Trashigang
Yadi 30 kW
Chenari 750 kW
Khaling 600 kW
Mongar
Khalanzi 390 kW
Kurichhu 60 MW
Zhemgang
Kengkhar 20 kW
Tintibi 200 kW
Chhukha
Daga
Dara Chhu 200 kW
Chhukha Hydropower Company 336-MW
Patale
Damphu 200 kW
Sarpang
Surey 70 kW
Gelephu
Pemagatshel
Jongkhar
Samdrup Jongkhar
Samtse
Penden S/S
Phuentsholing
BBCL
Tala 1,020 MW
To Siliguri
Birpara
Bongaigaon
Baranagar
Rangia
Jaldakha River
Ha Chhu
Samkosh River
Mangdechhu
Bumthang River
Kurichhu
National Capital
Substation
Existing Hydropower Plant
New Hydropower Plant
Existing Micro Hydropower Plant
Existing 220kV Line
Existing 132kV Line
Existing 66kV Line
Existing 33kV Line
66kV Subtransmission Line for Baso Chuu
District Covered by Rural Electrification Project
Town
River
Regional Boundary
District Boundary
International Boundary
Boundaries are not necessarily authoritative.
N
0
25
50
Kilometers

03-4456 RM

I. BACKGROUND

A. Rationale

1. The Asian Development Bank's (ADB's) Rural Electrification Project (the Project)[1] in Bhutan was in accordance with the rural electrification (RE) program under the Government's Seventh 5-Year Plan (the Plan) covering the period 1992–1997. The Plan recognized the need to conserve natural resources and reduce the existing rate of forest depletion and envisaged a gradual substitution of electricity for other types of fuel in rural areas. A majority of people living in rural areas depended on pinesap, wood, and imported kerosene for cooking, heating, and lighting. In 1995 at the time of project appraisal, 80% of the population did not have access to electricity; firewood accounted for about 77% of energy consumption. The lack of electric power was also a major bottleneck in achieving the country's development goals. The Plan also expected that electricity would provide part of the basic infrastructure to support Bhutan's transformation from a subsistence economy to a market economy.

2. ADB's strategy for the energy sector at that time supported the Government's objectives including the development of hydropower resources for export and the expansion of the power transmission and distribution systems for balanced regional development. The Project intended to increase economic benefits to rural areas through electrification and to reduce the negative environmental impact of forest depletion and indoor air pollution through substitution of electricity for other fuels. It was also expected to contribute to poverty reduction because most of the new consumers would be from low-income rural households.

B. Formulation

3. Several power system expansion projects were included under the Plan. However, the Division of Power (DOP)[2]—responsible for supply power—did not have the institutional and financial capabilities to carry out the grid extensions planned. Therefore, the Royal Government of the Kingdom of Bhutan (the Government) requested technical assistance (TA) from ADB to prepare a project proposal for RE. Following a TA fact-finding mission in August 1993, a project preparatory TA grant was approved in December 1993.[3] The objectives of the TA were to (i) formulate a power system development project suitable for ADB financing, (ii) prepare the detailed design, and (iii) prepare contract packaging and tender documents for the Project. The final feasibility report was submitted in January 1995.

4. During the Country Programming Mission in February 1995, the Government requested ADB to focus mainly on financing infrastructure sectors, particularly for roads and power. On the basis of the feasibility study completed in January 1995, the Government requested assistance from ADB to finance the Project covering seven districts in the country.[4] ADB emphasized that its participation in the power sector would require an agreed program of sector reforms particularly gradual power tariff increases and capacity building in DOP that aimed to increase its autonomy. A fact-finding mission for the Project was fielded in March 1995. Thereafter, the President approved advance action for recruitment of consultants to minimize implementation delays. Project appraisal was carried out in May 1995. A time-bound plan for tariff increases had been drawn up by this time, and the management requested the Appraisal Mission to discuss

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[1] Loan 1375-BHU(SF): *Rural Electrification Project*, for $7.5 million, approved on 19 September 1995.

[2] DOP was part of the Ministry of Trade and Industry and was responsible for the distribution of electricity at the district and village level. In July 2002, DOP's utility services were unbundled into three institutions with the assistance from TA 3307-BHU: *Corporatization of Division of Power*, for $600,000, approved on 25 November 1999 (para. 29).

[3] TA 2043-BHU: *Power System Development*, for $245,000, approved on 29 December 1993.

[4] The seven districts were Chhukha, Paro, Punakha, Thimphu, Trashigang, Trashiyangtse, and Wangdue Phodrang.

with the Government the possibility of accelerating the introduction of the tariff increases.[5] During appraisal, the Government agreed to carry out tariff revisions after undertaking a tariff study. However, prior to the tariff study, a financial accounting system had to be upgraded. The tariff study would immediately follow the improvements to the financial accounting system. Therefore, a two-phased TA was proposed with the first phase accompanying the loan geared to improve the financial accounting systems of DOP.

5. The staff review committee meeting was held in July 1995. At this meeting, the discussion focused on the poverty reduction aspects of the Project and staff indicated that it clearly addressed poverty. Therefore, the committee agreed that despite the lack of data to meet the technical requirement for the classification guidelines for poverty reduction, the Project's secondary objective should be noted as poverty reduction. The Board discussed the Project's very low financial internal rate of return (FIRR) of 1.1%, which stemmed from the low tariffs and high cost of supplying electricity to rural areas. Although the local electricity tariff was less than the overall supply cost to DOP, it was sufficient to cover average operating costs. Based on this and the developmental and pioneering aspects of the Project, it was considered acceptable. This was the first loan by a multilateral lender to the power sector in Bhutan and Board unanimously supported it. On 19 September 1995, the Board approved Loan 1375-BHU(SF) for $7.5 million equivalent and an associated TA.[6]

C. Purpose and Outputs

6. The project goal was to help promote economic development. This was to be achieved by extending Bhutan's transmission system to seven districts in the western and eastern regions. Only accessible villages experiencing rapid development were selected for electrification in these districts. The primary objective of the Project was to provide indigenously generated hydropower[7] to the domestic market in Bhutan to promote economic development, reduce domestic need for firewood, and reduce expenditure on imported kerosene. The report and recommendation of the President (RRP) did not discuss explicitly the obvious non-income benefits that would be generated through the provision of electricity. However, the Project proposed provision of electricity to even the poorest households which could not afford to pay for electricity by providing free electricity kits, thereby diversifying their income earning potential.[8] Accordingly, the secondary objective of the Project was considered to be poverty reduction.

7. The Project was expected to supply electricity to about 3,100 new customers and provide tools, plant, vehicles, and regional maintenance centers to assist in operation and maintenance (O&M) of the distribution facilities. Although providing RE from the grid to remote villages was expensive (estimated to average about $3,065 per household),[9] it was still

[5] A tariff increase was put into effect in April 1995 (para. 20).

[6] TA 2400-BHU: *Institutional and Financial Development of Department of Power*, for $400,000, approved on 19 September 1995.

[7] The power was provided to the grid from Chhukha Hydropower Station (CHPS), which generates 336 megawatts, amounting to 90% of the country's total generation. CHPS, which began operating in 1986, exports 90% of its power to India. It was built with the assistance of the Government of India on a grant (60%) and a loan (40%) basis. In return, India receives Chhukha's excess electricity for 99 years at a preferential tariff that is effectively a royalty on power generated.

[8] It was expected that by providing one or two light bulbs and plug points in the poorer homes at a low monthly fee, it would enhance their income earning potential as weaving, carpentry, and other activities could continue at night.

[9] Due to the mountainous terrain and highly scattered and low population density, RE is very costly in Bhutan. According to the Bhutan Power Corporation (BPC) officials, the cost of line extension per household (estimated at $9.5 million/3,100) was higher for the first RE project due to the initial installation efforts. The cost of extending the line under the second and third RE projects would be lower, but it may go up in follow-up projects that have to install additional lines to houses further away from the roads.

considered least cost and environmentally appropriate as compared to other sources of power such as solar energy and mini-hydropower units (para. 14). The distribution was to be achieved by extending the 33 kilovolt (kV) and 11 kV distribution systems from the nearest power source to transformers located in the designated villages in the seven districts. The Project was also expected to establish the associated low-voltage networks and consumer service connections within the villages. To achieve the objectives, the Project was to install the following components:

(i) 40 circuit kilometers (cct-km) of feeder and 33 cct-km of spur 33 kV lines;
(ii) 33 kV pole-mounted load break switches and auto-reclosers;
(iii) 66/33 kV network interconnections and service connections for 3,100 customers;
(iv) 25 cct-km of feeder and 5 cct-km of spur 11 kV overhead lines;
(v) 11 kV load break switches and 206 km of low-voltage bundled conductors;
(vi) 8,090 kilovolt-ampere (kVA) of 33/0.4 kV and 1,170 kVA of 11 kV/0.4 pole-mounted distribution transformers; and
(vii) supply of vehicles, office equipment, and a warehouse.

8. Consulting services were provided as inputs to assist DOP with the implementation of the Project, including procurement, and the design and commissioning of the 66/33 kV interconnections. An advisory TA was approved together with the Project to restructure DOP and improve its financial viability by (i) the development and installation of an accounting and management information system, and (ii) a review of the electricity tariff structure. DOP was the executing agency for both the Project and the TA and also worked as the implementing agency for the Project. The TA included about 12 person-months of consulting services.

D. Cost, Financing, and Executing Arrangements

9. The total project cost at appraisal was estimated at $9.5 million, of which $7.3 million (77%) was to be in foreign exchange. ADB was to finance $7.5 million equivalent (SDR4.8 million) and the balance was to be financed by the Government. The Asian Development Fund loan was provided under standard terms that provided for an amortization period of 40 years including a grace period of 10 years with a service charge of 1% per year. All construction, installation, and erection work was to be carried out using DOP's staff supplemented by local labor as required. The provision of necessary funds for tools and other materials were built into the Project to enable DOP to carry out O&M. A project implementation unit, headed by a senior engineer, was established within the O&M wing of DOP to ensure timely implementation (Appendix 1).

E. Completion and Self-Evaluation

10. ADB's project completion report (PCR) prepared by ADB, rated the Project as successful and was circulated to the Board in January 2002. The Operations Evaluation Mission (OEM) considers that the PCR satisfactorily discussed the implementation, operational, and initial performance of the Project. All project components were reported as "implemented substantially as conceived." The Project's recalculated FIRR at the PCR stage was negative and the recalculated economic internal rate of return (EIRR) was 11.7%. These were reasonably consistent with the appraisal estimates of FIRR (1.1%) and EIRR (11.9%), respectively. The PCR noted that the loan covenants covering organization, an action plan for the restructuring of DOP, tariff review and tariff adjustments, and reporting were satisfactorily complied with. It concluded that the work undertaken by the consultants was satisfactory, but the introduction of computerized accounting system had not operated properly for lack of DOP staff resources. A summary account of TA 2400-BHU was appended, which detailed the progress on items of

consultant's terms of reference. However, the outcome and the benefits of the TA were weakly portrayed. Among the lessons learned, the PCR indicated (i) the usefulness of 25 kVA single-phase transformers for rural areas, (ii) the need for capacity building for DOP personnel, and (iii) the importance of appropriate formulation of contract packages for smooth implementation of the Project.

11. The OEM considers that the PCR recounts the design aspects of the Project without commenting on its appropriateness. The PCR content was sufficient to present an overall assessment of the Project, but its objectivity suffered somewhat by the conclusion that the consultant's performance was satisfactory overall. The executing agency's PCR strongly disagreed about the consultant's performance (para. 30). ADB's PCR implied that the lack of experience of the implementing agency, combined with the weak assistance from the consultants, delayed the completion of the Project. It also correctly identified aspects of procurement problems, the design of new equipment, and geographical difficulties as contributing factors for these delays, but did not assign responsibility. It did not explain that the problems originated with the consultants ordering inappropriate connectors, approving some weakly performing transformer, and recommending sophisticated auto-reclosers. In one instance, however, ADB's PCR correctly identified that the consultants' performance in commissioning of the aerial bundled conductor (ABC) was not satisfactory but did not elaborate. It also did not take into account economic and health benefits in the economic analysis (para. 43).

F. Operations Evaluation

12. This project performance audit report (PPAR) is based on a review of the project documents, discussions with ADB staff, and persons met by the OEM in the field. The OEM visited Bhutan in August–September 2003, inspected the power distribution facilities, including selected project sites, and met with relevant government officers and project implementation officers. During the site visits, the OEM had discussions with district managers and engineers maintaining the project facilities and carried out a reconnaissance-level physical inspection of some facilities constructed under the Project. It held focus group interviews in four electrified villages in four districts.[10] About 160 beneficiaries participated in the focus group discussions at the four locations. The OEM also visited the 17-year old Chhukha Hydropower Company,[11] which currently provides most of the electricity to the country. The PPAR assesses the relevance, efficacy, efficiency, sustainability, and institutional development and other impacts of the Project to identify lessons and follow-up actions. The evaluation also focuses on other aspects, including rural systems design, subsidies, and social impacts. The views of concerned ADB departments and offices, and those of the Government and Bhutan Power Corporation (BPC) have been considered in finalizing the PPAR.

II. PLANNING AND IMPLEMENTATION PERFORMANCE

A. Formulation and Design

13. Overall, the project design was appropriate in that it was to provide electric power access to the rural areas of Bhutan by extending the existing grid. It had several positive features that led to its envisaged impact. However, with the benefit of hindsight, some

[10] The villages were Changkha, Gangkha, Isuna, Lhaku, respectively, in Wangdue Phodrang, Chhukha, Paro, and Punakha districts.

[11] Chhukha Hydropower Company is well managed. It sells power to the domestic market at Nu0.38 per kilowatt-hour (kWh) and exports excess supply to India via BPC at a charge of Nu1.5/kWh. BPC charges a wheeling charge of Nu0.125/kWh.

weaknesses in the design that contributed to implementation delays and service breakdown are also apparent. The positive features, as well as the weaknesses, are discussed below. Appendix 2 elaborates further on the technical design aspects.

1. Least-Cost Justification

14. The RRP indicated that the Project represented a least-cost option for supplying electricity to the seven districts. However, the feasibility study did not convincingly present the various alternative options available for RE and appeared to have taken the policy of extending the high voltage distribution from the nearest power source as a given. The sole alternative cited was diesel generation. There was no discussion of solar, wind, or additional mini-hydro schemes. Such a discussion would have been valuable to justify the high connection cost of households to the grid (para. 7). Solar or photovoltaic generation, circa 1994, had a relatively high initial cost. In order to provide a reasonable amount of power and (fairly) constant supply, solar panels had to be combined with significant battery storage. Wind generation is site specific and does not offer high reliability in most applications. These were significant considerations justifying the extension of the existing grid for the Project that were not analyzed adequately in the feasibility study.

15. Without supporting data, the RRP argued that the option of diesel was not viable in some locations due to transportation problems. It also indicated that the use of kerosene would require foreign exchange and would also not be an environmentally friendly option. Integration of rural areas to a high voltage grid was also seen as part of a long-term plan for balanced regional growth. Although the feasibility study did not specifically elaborate the justification for connection to the grid given the Government's environmental objectives and the long-term growth objectives, as well as the social development aspects (para. 50), the connection to the national grid may have been justified, except in the cases of very isolated households/temples on high mountains.

16. The feasibility study did, however, compare the use of distribution voltages of 11, 22, and 33 kV[12] from the grid. Evaluation was made by a comparison of the assumed advantages and liabilities of each voltage without a detailed cost analysis. Although the feasibility study recommended that the 11 kV not be continued and would be phased out by a 33 kV system in the future, it was decided during implementation to extend the existing 11 kV system in some areas and to provide a 33 kV system in others. The flexibility in the design to use the best site-specific option based on the existing demand was a good feature. Two new 66–33 kV substations were provided as a source of 33 kV.[13]

2. Environmental Aspects

17. Through its main objectives, the Project intended to create positive environmental impacts by reducing forest depletion and indoor air pollution. During implementation, the Project attempted to minimize land acquisition and negative impacts on the environment. Adequate compensation was to be paid for any land acquisition or trees felled for right-of-way purposes. Land acquisition by the Project was minimal.[14] Distribution transformers were pole mounted, minimizing their footprints and the right-of-ways were completed at no cost. Poles were to be erected along the road to the extent possible. Where paddy or other productive land was

[12] Eleven and 33 kV systems existed with the 33 kV serving as subtransmission. Twenty-two (or 20) kV was proposed as an eventual replacement for the existing 11 kV circuits.
[13] A 66–33 kV 5 megavolt-ampere bay was added to the Lobeysa substation and a new substation (of 66–33 kV, 5 megavolt-amperes) was constructed at Watsa (Chhukha).
[14] An area of about 33,000 square feet was purchased in fee for the 66–33 kV Watsa (Chhukha) substation.

traversed, no restrictions on agriculture were made. The use of insulated bundled conductor for low-voltage (230/400 volts [V]) circuit minimized its required clearance and also resulted in reduced right-of-way.

3. Social Aspects

18. The project design also included several key social aspects that helped to introduce the provision of electricity in a safe and equitable manner:

(i) In line with the government policy of providing access to electricity to all households, the Project was to provide electricity to all households in an electrified village. An electricity kit was provided to a few very poor households in the village, which met the eligibility criteria. These houses typically had one room and were given two light bulbs at a cost of Nu5 per bulb per month with no consumption charge and a plug point at Nu25 per month.[15] It was expected that this would improve their quality of life and also enable them to do some income generating activities at night.

(ii) In an attempt to build community ownership, the project design also included provision of community labor for erection of poles, digging, and carrying equipment. Mindful of the value of daily labor to a household at subsistence level, community labor was compensated at the prevailing government minimum wage level. However, during implementation, there were problems of getting adequate labor during the peak agriculture season, resulting in delayed construction activities. In subsequent RE projects, the paid community labor was substituted by privately contracted labor from nearby areas.

(iii) The design also included a public awareness campaign concerning associated safety hazards, as the rural consumers were first time electricity users. Through videos and public speeches, the rural communities were informed about the safety precautions for using electricity. In addition, the service providers also ensured that the internal wiring was properly done prior to connecting the power.

4. Technical Aspects

19. The technical design of the Project had the following characteristics mainly based on the feasibility study recommendations:[16]

(i) The system design selection for the rural circuits was similar to that of the existing urban distribution in Bhutan. That is a delta primary with three-phase delta-wye distribution transformers of 11 kV or 33 kV primary and four-wire 230/400 V secondary.[17] Alternatives (i.e., single-phase distribution, combinations of single and three phase circuits, 11 kV extensions from 33 kV circuits) were evidently not considered. The OEM felt that the lack of any consideration of the use of single-phase transformers or single-phase circuits in the project design was a significant shortcoming.

(ii) The design introduced ABC for the low-tension circuits. This was slightly more costly than the typical four-wire bare circuits but was justified on its apparent advantages. The OEM supports the use of ABC, as it allows for easier erection of

[15] However, a majority of houses particularly in the western district did not qualify for these free electricity kits, as they were large. After the formation of BPC in July 2002, all households were required to pay consumption charges.

[16] See Appendix 2 on technical design for more details.

[17] The secondary voltage of the distribution transformers is actually 240/415 V. The commonly used 230/400 V nomenclature represents the normal voltage regulation and will be used herein.

the low-tension circuits and protects the circuits from contact with trees and can be considered a safety enhancement. Besides, the cost disadvantage was shown to be slight.

(iii) Other significant design innovations (for Bhutan) were the use of pole-mounted auto-reclosers and the use of fused load-break switches designed for operation with hotsticks for the isolation of distribution transformers. The poles were designed as two-piece bolted steel to minimize weight. Three standard heights were selected. The OEM endorses this design feature. However, the auto-reclosers recommended in the feasibility study were of hydraulic control type as opposed to the more complex electronic programmable auto-reclosers that were installed during implementation.

(iv) Distribution transformers of 25, 63, and 100 kVA ratings were standardized for the Project. These were to be platform mounted on two-pole structures. These ratings were properly determined bearing in mind that they are exclusively three-phase values and can, therefore, be endorsed.

(v) System load flow studies were not made in any detail for the Project.[18] It may be that these types of studies could not be made due to a lack of system data. Accepting such a lack of data, the effort is acceptable for the timeframe of the Project.

5. Policy Aspects

20. Another positive feature of the design was that it was accompanied by policy dialogue on the following key issues to address key reforms needed in the sector:

(i) In a discussion on tariffs and related cross-subsidies, ADB indicated that while it understood the need for subsidizing low-income households, these subsidies should be targeted and transparent. In response in April 1995 prior to project approval, the tariff was increased from a uniform rate of Nu0.40 per kilowatt-hour (kWh) to Nu0.50/kWh. TA 2400-BHU provided for a tariff study to look into tariffs that were differentiated by voltage and consumption groups. A loan covenant was included that the tariffs would be revised based on the findings of the study as per a mutually agreed time-bound plan.

(ii) A two-phased approach was discussed for the institutional development of DOP to make it a commercially-oriented autonomous public utility. The same TA provided funding for the first phase, which included the development and installation of a commercially-based accrual accounting system within DOP to reflect its costs and revenues. The second phase was expected to be its corporatization.[19]

B. Achievement of Outputs

21. The outputs produced under the Project were generally in line with those envisaged at approval except for small changes due to the slightly lower number of households connected by project completion. Instead of 3,100 households as planned, by project completion, 2,982 houses were connected.[20] The slightly lower number reflects the high cost of connection in mountain areas. Although a total of 103 cct-km feeder and spur lines of 11 kV and 33 kV were proposed, altogether 150 cct-km of lines were constructed to reach these consumers. The

[18] Some sample runs (4) of load flows were presented in the feasibility study, but these did not include the Project in conjunction with the grid but compared voltage regulation and other aspects of individual circuits.
[19] A subsequent TA for corporatization of DOP was provided under TA 3307-BHU (footnote 2).
[20] At the time of the OEM, the number of households attributed to the Project had reached 3,123 households.

Project delivered an estimated 4.6 gigawatt-hours annually[21] to the consumers in 2000. The completed system of 10,000 kVA (10 megavolt-ampere) capacity at 33 kV and the additional capacity of the 11 kV feeders can serve its initial customers, as well as become the platform for future expansion of the RE services. Accordingly, despite the difficulties encountered, it appears that the Project's objectives were substantially met. The number of transformers installed was, however, half of that envisaged perhaps due to the implementation problems that occurred (para. 27).

C. Cost and Scheduling

22. Due to the depreciation[22] of the special drawing rights (SDR) vis-à-vis the US dollar, the dollar equivalent of the ADB loan was reduced to $6.7 million, of which $6.64 million was disbursed and $0.05 was cancelled at loan closing. Actual project cost at completion including interest during construction was $8.2 million or $1.3 million (14%) lower than appraisal estimates (Appendix 3). The cost underrun was due to the partial utilization of contingent funds. From an allocation of $172,669 for civil works, only 24% was disbursed from the ADB loan. According to the executing agency, the Government decided to cover a substantial share of the actual expenditures for this item because of administrative uncertainty on how to book the costs between the ADB loan and the Government.

23. During project implementation, the Government requested reallocation of part of the budget from contingencies to procure additional insulated piercing connectors to overcome the problems encountered in commissioning the ABC. At completion, the amount allocated from the ADB loan for equipment was $6.1 million or $0.9 million (18%) over the revised estimate of $5.2 million. Another item with an allocation in excess of the revised estimate was consulting services.[23] Total disbursements for this category were $366,044 or $93,172 (34%) more than the allocated amount of $272,743. Actual consulting services turned out to be more than the 12 person-months originally anticipated as the implementing consultants required more time due to procurement problems and for detailed design of substations.[24]

24. The project implementation was expected to be 2.5 years; however, due to various implementation difficulties, it was completed in December 1999, an 18-month delay. Implementation delays were caused mainly by (i) delayed tendering, (ii) delays in approval of vendor drawings by the implementation consultant, (iii) difficulties in finalization of bills of quantities due to unfamiliarity with some items, (iv) delays in getting supplies shipped, (v) excessive time required for the delivery of small distribution transformers due to manufacturer problems, (vi) failure to specify and tender for connectors and other assorted hardware associated with the installation of ABC, (vii) lack of community labor for construction during peak demand periods for agricultural labor, and (viii) heavy monsoon rains which made accessibility and transportation of equipment to the villages very difficult. The loan was closed after one extension in April 2000, 16 months behind schedule.

25. Prior to project completion in December 1999, a follow-up RE project (RE-2) was approved in November 1999 with similar goals of economic development and poverty

[21] Assumes an average of 127 kWh monthly usage by the approximately 3,000 consumers.
[22] The exchange rate changed from SDR1.00 = $1.5595 at loan negotiations to SDR1.00 = $1.3468 at loan closing.
[23] However, there was no cost overrun in the total consultant budget for the Project.
[24] Detailed design of substations at Lobeysa and Watsa was required during implementation as a source for 33 kV circuits.

reduction.[25] A third project (RE-3)[26] has been approved in September 2003 during the preparation of this PPAR. Its objectives were to expand delivery of electricity to rural areas and provide opportunities for the rural poor to increase their economic productivity. Due to the timing of the follow-up projects, the RE-2 project included only lessons learned from TAs, but the RE-3 incorporated many of the lessons learned during the implementation of the two previous projects.

D. Procurement and Construction

26. The executing agency informed the OEM that the lack of familiarity with Bhutan on the part of equipment manufacturers was a substantial disadvantage in procurement, leading to a small number of respondents as well as delays in shipping. The bid documents for procurement were prepared under TA 2043-BHU by the international consultants according to ADB's *Guidelines for Procurement*. During implementation, it was evident that these packages had several weaknesses and were not adequately adapted to the unique conditions of Bhutan. For example, the packages for international competitive bidding (ICB) proposed were very large and in some cases consisted of disparate items. These were subsequently separated into smaller sizes of more closely associated items, which were more appropriate to manufacturers familiar with Bhutan. Therefore, the originally proposed nine packages (with four ICBs) were changed to 22 (with two ICBs) packages resulting in implementation delays.

27. The Project required a number of 33–0.4 kV three-phase transformers in sizes ranging from 25 kVA to 100 kVA. From the onset, the selected bidder is required to do factory testing. The smaller transformers (which were manufactured by the bidder for the first time) repeatedly failed the acceptance tests. Since there were only a few bidders and project implementation was delayed, there was little time to change the supplier. The prototype specifications were later changed as per the consultant's advice and the transformers eventually passed the tests and were delivered.[27] However, a high (15–20%) proportion of the smaller capacity transformers failed in the field either upon their initial energizing or soon thereafter. Replacement of these units created delays in the commencement of service in numerous circuits. In addition, the weight of the larger 33 kV units, about 800 kilograms, created extreme problems in installation given the terrain of Bhutan and the limited road access. Erection of these transformers was also a problem. It was known from project inception that many of the villages to be electrified were far from roads and that all installation would be manual. Therefore, considerable efforts to utilize lighter transformers were warranted.

E. Organization and Management

28. Since this was the first ADB loan to the sector, the executing agency found it difficult to match ADB procurement procedures with those of the Government procurement procedures, which were even more stringent, and this led to delays in procurement. By consulting other sectors in the country, which were used to working with ADB procedures, this problem was later resolved. The delay in the approval of vendor-submitted design drawings as well as the suppliers' unfamiliarity with shipping to Bhutan added to implementation delays. Although the executing agency had experience with RE prior to the Project, the lack of experience with several types of equipment that were ill suited to Bhutan and the lack of proper training by the international consultants also hampered the timely implementation of the Project.

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[25] Loan 1712-BHU(SF): *Sustainable Rural Electrification Project*, for $10 million, approved on 25 November 1999.

[26] Loan 2009-BHU(SF): *Rural Electrification and Network Expansion Project*, for $9.4 million, approved on 30 September 2003.

[27] The terms of reference for the consultants stipulated that they should inspect equipment and witness factory testing of equipment supplied.

29. As a result of the policy dialogue between DOP and ADB, TA was provided to restructure the former. Following the recommendations of this TA, in July 2002, DOP was unbundled creating the Department of Energy as the governmental planning agency, Bhutan Electricity Authority (BEA) as the sector regulator, and BPC as the transmission, distribution, and supply corporation. Together with RE-3, a TA is being provided to increase the capacity of BEA staff to carry out their mandate. BPC is corporatized under the Company Act of Bhutan and is governed by a 7-member board of directors. The chairman is the minister of Trade and Industry. It comprises six departments (Appendix 1).

30. **Consulting Services.** The consulting services were procured in accordance with ADB's *Guidelines on Consulting Services*. Consultants who were selected by ADB for the feasibility study were selected under advance recruitment procedures by the executing agency (with ADB approval) as implementation consultants. Under the feasibility study, the consultants designed the Project, prepared the tender documents, and designed the 220 kV Baso Chuu to Simtokha II transmission line.[28] They focused on procurement, the design of two 66–33 kV substations, and TA. But the consultants' efforts suffered from various oversights. While they were experienced in the sector, they were not exposed to conditions in Bhutan. Insufficient recognition of aspects of the Bhutan environment led to significant frustration and dissatisfaction by the executing agency and also led to long delays and subsequent service interruptions. The system design was similar to urban designs common in Asia and elsewhere, but had disadvantages when applied to rural areas with low customer density. The consultants failed to take into account the lack of roads and the heavy weight of the transformers made it very difficult to install them on top of mountainous areas. The smaller capacity versions of the 33–0.4 kV units repeatedly failed the factory acceptance testing, but were subsequently cleared by the consultants for purchase. However, these units demonstrated a high rate of initial failure during service (para. 27). No substitution or system design changes were made after these problems became apparent. The OEM believes that the problems of the small transformers were compounded due to an inexperienced vendor and poor quality assurance during construction.

31. The consultant's introduction of auto-reclosers was technically sound, but the necessary analysis of the proper coordination with the main substation circuit breakers was not properly presented to the executing agency personnel. During implementation, the consultants specified that programmable auto-reclosers were to be supplied with advanced solid state electronic controllers contrary to the recommendations of the feasibility study, which specified a less sophisticated version. Similar equipment was available with significantly less sophisticated controllers, which would be more suited to application in Bhutan. After installation, the consultants were unable to properly calibrate the units or to instruct or train the executing agency as to their operation and calibration. Vendor support was not obtained for training. The executing agency is now unable to make most of the units function properly and has bypassed several, causing problems for the first RE project (RE-1) operations (para. 35).

32. The service cable specified was not compatible with ABC[29] and could not be returned. However, the vendor of ABC provided assistance by sending its personnel to Bhutan. They developed a method of utilizing the service cable procured so as to salvage the service cable and avoid additional procurement and increased cost. Even so, the required method of connection was more time-consuming and delayed provision of service connections. The executing agency also complained about the faulty design assumptions as to the stringing of various spans and the resulting shortages of required equipment (in particular dead-end

[28] Financing for the transmission line from Baso Chuu to Simtokha II was found outside of the Project.
[29] The consultant had specified concentric neutral service cables that are not designed to connect with ABC. Twin core service cables should have been specified.

insulators) caused by underestimation of quantities required. The executing agency rated the services of the consultants as unsatisfactory due to the reasons stated above, some aspects of the consultants' billing, and other considerations.

33. **Loan Covenants.** The Government complied with most of the eight loan covenants (Appendix 4). Two covenants, however, were only partially complied with. The first involves the restructuring of the power sector and the corporatization of DOP, while DOP's utility function was unbundled in July 2002 paving the way to the restructuring of the sector. BEA is still to be fully functional. A TA grant attached to the RE-3 project will provide the necessary foundation for BEA to become an effective regulator in the sector including institutional capacity building that is expected to fill the gap for human resource requirements. The TA is expected to be completed in early 2005 and 6 months after, BEA is expected to be fully functional. The OEM believes that this schedule will be met. The second loan covenant that has not been fully complied with involves the revision of the domestic electricity tariff. Tariff structures were formulated under TA 2400-BHU[30] and TA 3112-BHU.[31] Domestic tariffs have been adjusted four times since 1995, but have not kept pace with the suggested increases in the tariff study (para. 48).

III. ACHIEVEMENT OF PROJECT PURPOSE

A. Operational Performance

1. Operations

34. The operation of the RE system of Bhutan is vested with BPC. District offices are responsible for the distribution systems within their service areas. The overall losses for the national system are reported to be about 12% (FY2001–2002).[32] No detailed analysis of the distribution has been made, but given the wire sizes in use and the relatively light loads, it is unlikely that the technical losses are much in excess of 9–12% depending upon the length of the respective feeders. Several possible causes for these loss rates were suggested by district engineers. These included the use of estimated readings by the meter readers, lag times in monthly reconciliation of billings, and the existence of very old meters. Many of the meters in service were reported to be over 15 years old. It is reasonably certain that any mechanical meters over 7–8 years of service would not be accurate. BPC currently has a program to replace old meters starting with urban areas.

35. The various districts reported a significant operational problem in circuit down time. This is due to the design of the RE-1 facilities and the lack of functioning programmable auto-reclosers (para. 31). When a rural feeder circuit suffers a transient or temporary fault,[33] the programmable auto-reclosers should clear these faults. As most of these have been bypassed, faults typically result in the substation 33 kV circuit breaker operating and the entire circuit being de-energized. The necessary procedures to locate the fault and to restore the circuit take time. Similarly, a problem at a distribution transformer requires that the circuit be tripped at the nearest load-break disconnect switch. The linemen are not sufficiently trained to service the transformer, while maintaining the 33 or 11 kV overhead in service. Both situations result in unnecessary outages to consumers. These operational problems are due to a combination of problems in design and implementation and a lack of proper training for the O&M personnel.[34]

[30] The final report of the TA consultant was submitted in March 1997.
[31] TA 3112-BHU: *Policy and Legal Framework for Power Sector Development*, for $500,000, approved on 8 December 1998.
[32] Comparable system losses for Nepal is about 30% and for the Philippines, it is about 21%.
[33] These include ground faults caused by birds, trees, etc.
[34] In 2003, BPC set aside Nu2 million to address its human resource constraints.

2. Maintenance

36. The substations designed and constructed under RE-1 are well maintained. Minor problem areas were noted in both of the substations' 33 kV transformers. They are exhibiting paint failure, but these can be repaired without taking the units out of service. There have been minor oil leaks, but these have been repaired. The transformers are otherwise well maintained, as are the sulfur hexafluoride (SF6) circuit breakers. SF6 replenishment bottles are maintained in stock. In both substations, the original indication metering has failed but has been replaced by a multifunctional solid state metering system. Both substations follow well-designed programs of monthly and annual preventive maintenance including checking the bolts on structural steel, operating the manual switches, and performing SF6 and transformer oil checks.

37. The design of the transformer protection consists of (i) fused disconnect switches, and (ii) the fuses reloaded by hotstick (line stick). This is a common design in developed countries and countries where the linemen are familiar with the use of hotsticks and/or live wire working techniques. While a technically sound design, it appears that the executing agency personnel were not properly familiarized with the necessary techniques required for using the hotsticks nor were they trained in their use. This has resulted in preventing BPC from maintaining the distribution transformers while maintaining service to the remainder of an affected circuit (Appendix 5). Therefore, it is necessary to take sections out of service for routine maintenance tasks as discussed above. The actual O&M costs of the lines are minimal and are estimated on an annual basis to be about 1% of the initial construction costs net of consulting costs and fees.

38. The operation of the RE-1 facilities has been integrated into the general distribution system. This operation is efficient and sustainable but suffers from higher-than-expected losses (para. 34) and avoidable outages (para. 35). Some training in methods of distribution system management and data collection is warranted. The losses can be reduced with a sustained meter replacement effort. The long duration of circuit outages can be approached by two methods. One is to make the programmable auto-reclosers operational and properly calibrated. The second is to train and properly adapt the methods of the line personnel to operate the RE-1 facilities as they are designed to be operated. Maintenance suffers somewhat from a lack of material, but this lack has not resulted in any observable deterioration in the circuits. Guy wires need additional attention. Training and the provision of tools and devices discussed above can improve maintenance, both preventive and restorative. Additional transformers as spares and for the addition of new consumers should be provided to the districts.

B. Performance of the Operating Entity

39. BPC established in July 2002 is still at the initial stage of operation, and is still in transition from a government department to a commercially accountable enterprise. As such, BPC does not yet have a full set of certified financial statements and will produce its first financial statement for 18 months at the end of 2003. Since separate accounts are not maintained for this Project, BPC's overall financial viability is discussed here. Based on the current financial position, forecasted estimates of sales growth, increase in tariffs and increase in operations indicated in the RRP for the RE-3 Project, the 5-year financial forecasts for BPC show it to be financially viable. However, this assumes a low bulk supply price for electricity to BPC, wheeling charges and levies on transmission to India, and substantial cross-subsidy from high- and medium-voltage customers to low-voltage customers.[35] Rural customers typically use low voltage. At present, an Nu2.58/kWh cross-subsidy is provided by medium- and high-voltage consumers to rural low-voltage consumers.

[35] The low bulk supply price for electricity, however, covers the average operating costs.

40. The projected financial statements show a total operating income of Nu509 million and a net profit before tax to be Nu124 million for 2003. Profits after tax of Nu87 million is expected for 2003 (Appendix 6). The debt equity ratio is 19% and the total assets are estimated at Nu4,687 million by the end of 2003. It is necessary for BPC to finalize its corporate strategy and business plan based on the FY2003 financial statements and define financial and operational targets and investments when its financial picture is clearer. Transmission of electricity from the 1,020 megawatts Tala hydropower plant under construction (financed with the help from India) is also expected to generate additional revenues for BPC after 2006.

C. Financial and Economic Reevaluation

41. In calculating the FIRR, the actual capital costs excluding the interest during construction were converted to 2003 second quarter constant values using Bhutan's gross domestic price deflator (Appendix 7). Similar to the appraisal report and the PCR, the Project was assumed to have an economic life of 25 years from 1999 to 2023. Systems losses of 9.5% were used given the data obtained from BPC. Based on a socioeconomic study conducted for the RE-3 project, an average consumption of 119 kWh/household/month was used in the calculations.[36] The actual number of households connected under the Project at the time of the OEM was 3,123 houses, and this was held constant over the life of the Project. Additional connection in the electrified villages would typically be financed from the annual budget of the district and cannot be directly attributable to the Project. The demand for electricity, however, was assumed to grow in the electrified houses due to increased consumption caused by population growth, as well as familiarization and reliance on electrical appliances as time passes by. Actual tariff rates adjusted for inflation are assumed until 2003 and a 5% annual increase in real tariffs is assumed for the next 10 years. Based on these assumptions, the FIRR is negative similar to the appraisal and PCR estimates (see table below).

Summary of Financial and Economic Reevaluation (%)

Item	Appraisal	PCR	PPAR
FIRR	1.1	<0	<0
EIRR	11.9	11.7	12.5

EIRR = economic internal rate of return, FIRR = financial internal rate of return, PCR = project completion report, PPAR = project performance audit report.
Source: Asian Development Bank.

42. Financial costs were converted to economic costs by excluding interest and taxes, and by applying shadow exchange rate to reflect the premium placed on foreign exchange. A shadow wage rate reflects the real cost to the economy of labor used. The economic cost of power is the opportunity cost of exporting power to India. Cost savings for the displaced energy used is valued at border price for kerosene less domestic tariffs. Induced energy consumption is valued according to willingness to pay.

43. Focus group interviews conducted by the OEM (para. 51) indicate that there is a significant improvement in health of household members, especially in women who spend significant time cooking over smoke-filled wood-fire or working with a kerosene lamp. Interviewees indicated that incidence of eye and respiratory ailments were significantly less after the Project. Total health and productivity benefits were estimated at Nu1.27/kWh consumed based on the RE-3 economic analysis. The other benefits mentioned during the focus group interviews were not quantified. The resulting EIRR is 12.5% slightly higher than the PCR's

[36] According to this study, the Department of Energy uses an estimate of 142 kWh/household/month.

estimate. This is mainly due to the inclusion of health and productivity benefits and the higher number of household connections since the PCR.

D. Sustainability

44. The basic structures of the Project are sustainable. The project facilities can be separated into the rural circuits and the 66–33 kV substations constructed under the Project. The substations are well designed and maintainable and are sustainable for the near future. The operation of the rural circuits has been integrated into the general distribution system. This operation is efficient and sustainable but suffers from higher-than-expected losses and avoidable outages. However, the system losses can be reduced with a sustained meter replacement effort.[37] The long duration of circuit outages can be approached by two methods. One is to make the programmable auto-reclosers operational and properly calibrated. The second is to train and properly adapt the methods of the line personnel to operate the RE-1 facilities as they are designed to be operated.

45. The ability to operate and maintain RE at subsidized rates depends on cross-subsidies from high- and medium-voltage consumers to low-voltage consumers as well as BPC financial viability (para. 39). The Government does not subsidize BPC and available indicators show that it is financially viable mainly due to the wheeling charges for transmission. If these charges are revised or price of electricity sold to India becomes more competitive, then BPC would have to bring the weighted average domestic tariff rate up. Despite that, it would prefer to maintain low tariffs and the high lifeline threshold for rural households. Since the low-voltage supply is a small proportion (20%)[38] of the electricity supplied, it may be feasible to continue this cross-subsidy without affecting BPC's financial viability, as long as medium- and high-voltage consumers are willing and able to pay higher tariff rates. Given Bhutan's per capita income of $660 in 2000, this should be feasible.

E. Technical Assistance

46. Under TA 2400-BHU attached to the loan, assistance was provided for (i) the development of financial systems and its computerization, and (ii) a national tariff study. Under the former, the consultants developed a new financial system for budgeting and financial planning. To computerize the financial system, three customized software applications were developed by the same consultants during the TA period for (i) billing and collection and customer accounting, (ii) general ledger accounting, and (iii) fixed asset ledger. Classroom and hands-on training was given to operate the software. However, it was too early to introduce to a government department a financial system suitable for a corporate entity. Therefore, the training for billing system software was retained and the other two modules were neglected.

47. Subsequently, the three financial systems modules had to be updated to eliminate year 2000 related software problems and the source codes had to be obtained (with the help of ADB) to use the highly complicated software that had been developed.[39] The savings from the TA 2912-BHU attached to the RE-2 project were used in 2000 to add five more modules by the same international consultant. As BPC was established as a corporate entity, it was in a position to use a corporate accounting system. However, the consultants had a limited time allocation and the acceptance tests were done on test data and on screen instead of paper. Each of the

[37] Meter replacement has already begun since 2002.
[38] Of the low-voltage supply, 25% is attributable to rural areas.
[39] The TA consultants required an expensive maintenance contract to adjust the parameters of the system, which was not agreed to by the client. The client reports that ADB had to arbitrate on the issue of obtaining the source codes.

eight consultants developing the eight modules had a corresponding local user champion. After the departure of the consultants, some problems and complications remained, as the system could not be fully adapted to the needs of the procedures in Bhutan. Subsequently, BPC hired another long-term regional consultant in March 2002 to readjust the eight modules to suit BPC's requirements. The problems in the billing and collection system were addressed first. The system was being used in 12 district accounting centers at the time of the OEM and is expected to be introduced to all 20 districts by the end of 2003. The regional consultant's 1 year term has now been extended by BPC for another year and he, together with BPC's information technology officer, is expecting to gradually introduce a majority of the modules to the district offices. However, due to design limitations, some modules still have problems in adapting to the clients' needs (i.e., centralized purchase inventory).

48. Under the tariff study, existing pricing structure was reviewed and major consumers and industries were surveyed to determine the willingness and ability to pay. The study developed a tariff policy for cost recovery based on peoples' ability to pay. It recommended an increased system wide average tariff of Nu0.62 in 1997 gradually going up to Nu1.21 in 2001.[40] The proposed tariff increases were not fully implemented within the recommended timeframe. However, the tariff structure has been changed in January 2003 to reflect block tariffs differentiated by kWh and a lifeline tariff has been introduced. A distribution analysis software, the Power System Simulator for Utility from Power Technology Inc., was procured as part of the Project. This is one of several modules of this program, which has transmission, system stability, and other modules. It is considered to be one of the premier softwares of this type circa 1985, and the current versions as well. The reported cost of this software is $20,000. The international consultants used this software to prepare several circuit load flows as mentioned above. However, the executing agency received limited and sporadic training in its use from the international consultants. Subsequent efforts on the part of the executing agency to obtain training from the vendor were thwarted by the high cost of such training. Based on the assessment of the above components, TA 2400-BHU is rated partly successful.

IV. ACHIEVEMENT OF DEVELOPMENT IMPACTS

A. Environmental Impacts

49. Negative environmental impacts of the Project were minimal due to good mitigation efforts. Impact from the electricity substations and the lines were minimized under the Project except for the impact on visual appearance, which is difficult to avoid for overhead wires. During detailed design and construction, land acquisition was minimized with the use of pole-mounted transformers and substations. Where land was acquired, compensation was paid as per the government-specified rates. The lines were erected along the roads to the extent feasible to minimize the impact on agricultural property; they have not impacted the existing land use patterns. Since the project areas were already inhabited, the impact on ecology was also minimal. In addition to the mitigation efforts, the Project provides several positive environmental and health benefits by reducing use of firewood and occurrence of indoor air pollution (para. 51). The focus group interviews revealed that firewood use has reduced by 75% in the electrified areas because firewood is rarely used for cooking after the Project. It is mainly used for heating in poorer households during the cold winter months.

[40] This did not entail an increase in tariff for 80% of the low-voltage domestic customers. According to the OEM calculations, average tariffs in July 2001 was Nu0.78.

B. Socioeconomic Impacts

50. Because of the Project, RE ratio in the country went up from 20% in 1995 to 24% in 1999. About 3,120 households in 110 villages were electrified and 567 electrification kits were provided at a minimal charge. There was unanimous agreement among the beneficiaries that electricity has brought about an overall improvement in their quality of life. Beneficiaries stated that the difference between "having and not having electricity" is like the difference between "the sky and the earth." Beneficiaries who can afford them have begun using electrical appliances such as rice cookers, curry cookers, water boilers, refrigerators, heaters, fans, radios, tape recorders, videos, and chili powder grinders.

51. The focus group interviews revealed that the quality of life had improved for all members of the household (Appendix 8). Children benefited through the extra hours available for study after dark. Adults have enhanced their literacy by attending the nonformal education program organized between 7 pm and 10 pm by the Department of Education in these areas. Women, who previously spent much time in the kitchen, now experience a significant decrease in eye and respiratory ailments that had been caused by excessive indoor smoke emitted from the firewood stoves and kerosene wick-lamps. Electrification has led to reduced cooking time and effort as villagers now just turn on the rice cookers and curry cookers without having to go through the process of lighting up a cold firewood oven and waiting for the food to be cooked. The time saved is spent on other productive activities such as working on their farms. With electricity, beneficiaries feel more secure at night bringing them much needed peace of mind in terms of medical or other emergencies. Cases of theft, burglary, and vandalism in religious temples, monasteries, and structures have decreased in electrified villages as the light acts as a deterrent to thieves and burglars. Electricity has also helped in some instances to protect the harvest from wild animals. In addition, it provided avenues for recreation and relaxation through media, such as radio and television, as well as time to associate with neighbors and relatives.

52. Consumption and usage of kerosene has seen a drastic decrease, where earlier beneficiaries purchased and used about 10 liters of kerosene a month, they now purchase about 1 liter of kerosene monthly, translating to a 90% decrease in kerosene usage. Reduction in the use of firewood and kerosene has meant not only cost savings but also reflect less time and effort spent in collecting firewood and going to replenish their kerosene supplies from the nearest town. The hygiene of beneficiaries has also improved significantly with the cleaner, soot-free environment. In summary, the cost savings reflect that (i) electricity is cheaper than kerosene for lighting, (ii) it decreases smoke and soot within the homes and as such clothes do not have to be washed as often and thus last longer and cost less to maintain, and (iii) interior of houses do not have to be painted as often as before.

53. They also have experienced some enhancement of income by doing income-generating activities at night such as weaving, carpentry, carving, and tailoring. Furthermore, electrically operated rice mills, flour mills, and oil mills have increased supplementary income and employment opportunities in these rural areas. Small shops-cum-bars have sprouted in these areas and remain open even after dark thereby increasing commercial activity and social interaction. During implementation, the villagers contributed labor toward the construction of the Project and they were compensated at the minimum wage rate (Nu50 per day). The work mostly consisted of transportation of poles and wires, clearing land in the path of the line route, digging holes, collection of boulders, erecting the poles, pulling of lines (when sagging), helping to set up transformer on pole-mounted platform, etc.

C. Impact on Institutions and Policy

54. TA 2400-BHU had a moderate impact on Bhutan power sector institutions and their policies. According to the sector officials, the tariff study formed the basis for the current tariff structure which incorporates a lifeline tariff, as well as block tariffs differentiated by kWh usage. However, tariff issues are highly political and the recent increases led to a debate in the parliament. The current structure allows a cross-subsidy to low-voltage rural and urban households from medium- and high-voltage consumers. Although the lifeline tariff block is much higher than in the other developing countries, the Government feels that it is justified in Bhutan if its environmental and social objectives are to be met. The Government also intends to transfer a portion of the wealth earned from hydropower to its people by maintaining low tariffs. As per the Energy Act, the authority to increase tariffs further now rests with BEA, and it will reevaluate the tariffs based on the TA attached to RE-3 project.

55. Paras. 30 to 32 discuss the international consultants lapses in adequately training DOP staff regarding programmable auto-reclosers, use of hotsticks, etc. In addition, several of the systems drawings were completed at the home country, and there was little transfer of technology in this area. Inadequate training was also provided under TA 2400-BHU part 1, which developed and installed the financial system software (para. 47). Similarly, training received on the distribution of software analysis (para. 48) was minimal. As a result, this software has gone unused for the most part and replacement analysis software has been obtained by BPC. Subsequent preparation and implementation of the follow-up projects RE-2 and RE-3 has, however, improved the capabilities of the sector officials through learning by doing.

V. OVERALL ASSESSMENT

A. Relevance

56. The Project supported the provision of RE under the Government's Seventh 5-Year Plan (1992–1997). Although not specifically elaborated in the feasibility study, the connection to the grid for this purpose could be justified. Overall, the project design had several positive features: (i) sound environmental management concepts, (ii) social aspects that focused on safe and equitable distribution of electricity, and (iii) a policy dialogue on key sector issues. The technical design was similar to what existed in relatively more urban areas of Bhutan. It did not pay particular attention to the undulating mountain terrain that exists in the rural areas. It also introduced some new equipment to manage the distribution system efficiently. However, due to improper training and purchase of incorrect supplementary parts during implementation, the executing agency found it cumbersome to use them. The Project is assessed as relevant.

B. Efficacy

57. Despite the implementation delays, RE ratio in the country went up from 20% in 1995 to 24% by project closing, and 2,982 households had been electrified including 567 with free electrification kits. About 3,120 households in 110 villages had been electrified by the time of the OEM. It appears that project objectives have been substantially achieved although some of its social development impacts are not quantifiable. Beneficiaries stated that the difference between "having and not having electricity" is like the difference between "the sky and the earth." Beneficiaries who can afford them have begun using various small electrical appliances and consequently reduced the consumption of firewood and kerosene. The Project is assessed highly efficacious.

C. Efficiency

58. The Project is assessed less efficient. Project implementation was delayed by 18 months due to various reasons (para. 24). The main reason for this was the inability of the design and implementation consultants[41] to adapt standard designs to mountain terrain in Bhutan. In addition, DOP personnel's unfamiliarity with some new equipment and inadequate training provided by the consultants added to this delay. Procurement issues were also evident because of improper packaging of items by the consultants and the suppliers' unfamiliarity with shipping to Bhutan. The EIRR recalculated for the Project, which includes health and productivity benefits are slightly higher than EIRR estimates at project approval and completion.

D. Sustainability

59. The Project is very sustainable in a technical sense if appropriate maintenance activities are undertaken. Currently, BPC has the technical and financial capacity to do the necessary O&M. However, the FIRR for the Project is negative. Ability to operate and maintain RE projects at subsidized rates depends on cross-subsidies and BPC's financial viability (para. 40). The Government does not currently subsidize BPC, and it generates income through wheeling charges for transmission. The first financial statements of BPC are expected by end 2003. BEA has the mandate to determine the tariff structure and oversee the sustainability concerns of BPC. The OEM assesses the Project's sustainability as likely.

E. Institutional Development and Other Impacts

60. Under TA 2400-BHU attached to the loan, assistance was provided for the development of financial systems and its computerization and for a national tariff study. However, it was too early to introduce a government department to a financial system suitable for a corporate entity; as such, these applications were not fully utilized. The tariff study developed a tariff policy for cost recovery based on peoples' ability to pay. Although the proposed tariff increases were not fully implemented, it formed the basis for the current tariff structure. In addition to the institutional impact of the TA, the Project itself had a substantial impact on the sector technical staff through learning by doing. Many of the lessons learned by them have already been incorporated in the RE-3 project.

61. The Project has substantial environmental and social impacts that are positive. Firewood consumption is reduced by about 75% in the project areas arresting the forest cover depletion. Air pollution is substantially eliminated with the use of electrical appliances in a majority of households that purchase electricity. This has also led to an improvement in sanitation and prevented smoke-related negative health impacts. Socioeconomic lives of the rural households, the output of the school children, and the safety aspect of the rural areas have also improved. Considering the institutional impacts, environmental, and social benefits of the Project, assessment in this category is considered to be significant.

F. Overall Rating

62. The Project is, therefore, relevant, highly efficacious, and achieved significant institutional development and other impacts. During implementation, it was less efficient in the use of time and resources. Its sustainability is likely. Based on the above considerations, the overall assessment of the Project is rated as successful.

[41] The same company was awarded both contracts to undertake the project preparatory TA and to assist in implementing the Project.

G. Assessment of ADB and Borrower Performance

63. ADB's performance in preparing and supervising the Project was satisfactory. It found a relevant need and developed a good design of the Project in consultation with the Government. During implementation, ADB carried out an inception mission and four review missions spanning the 4 years of implementation. In retrospect, its performance could have been better in monitoring various procurement issues and implementation problems during the early stages of implementation without relying too heavily on the consultants' initiative (para. 30). Due to implementation delays, ADB later decided to recall some members of the consultant team to revisit Bhutan to address the issues related to the auto-reclosers. The TA implementation was smooth regarding the tariff study component, but the financial accounting software installation was saddled with problems partly because DOP was not ready for a corporate accounting systems. ADB followed up the Project with the second and third RE projects approved in 1999 and 2003 (footnotes 25 and 26, respectively) learning lessons from the past experience.

64. The performance of the Government and the executing agency was also satisfactory. Despite the implementation problems and the difficult terrain, the executing agency personnel worked hard to implement the Project. Although it was disappointed with the consultants' performance and frustrated with the implementation difficulties, the executing agency cooperated with the consultants team and learned the work by actually doing it. They have now absorbed many valuable lessons and are using them during the implementation of the subsequent RE projects.

VI. ISSUES, LESSONS, AND FOLLOW-UP ACTIONS

A. Key Issues for the Future

65. **Rural Systems Design.** Technical aspects of the rural systems design need to be revisited prior to any further extension of the facilities. BPC personnel are now aware of successful alternative designs and practices. These include changes in the design of the distribution substations, use of single-phase transformers, and combined circuits of 33 kV feeding to 11 kV extensions among others. Also, the continued expansion will at some point require extensions of the high voltage grid to provide closer points of 33 kV or 11 kV supply.

66. **Poverty Reduction.** The ability of the rural poor to access good infrastructure such as electricity and roads are necessary conditions for poverty reduction. Poverty is a multidimensional concept, and certainly, the many positive impacts provided by the Project facilitate improvements in the standard of living and, therefore, improve non-income poverty aspects. Evidence is sketchy on reducing income poverty as a direct result of the Project. However, it is apparent that provision of rural electricity is a necessary condition for poverty reduction. Despite this, the availability of rural electricity may not be a sufficient condition for the poor to move from poor to nonpoor status, especially in an income poverty sense. This requires the poor's access to supplementary ingredients such as land, microfinance, and skill development. Therefore, if poverty reduction is a key objective, RE projects need to be accompanied by other efforts that increase their access to markets, skills, and seed capital. These may need to be provided under other projects financed by development agencies and/or coordinated bilateral aid in order for them to be effective.

67. **Financial Sustainability.** Revision of the overall tariff rates is crucial for BPC's future financial viability and further electrification of rural areas. Although the Government does not subsidize BPC, it would prefer to continue subsidizing low-voltage consumers. While the Government views on subsidies and transfer of income to rural and poor areas are respected,

the OEM is of the opinion that subsidy element should not be excessive so as to unduly waste electricity. After all, it is also the major foreign exchange earner of the country and wasted energy reflects a revenue loss. While tariffs need to be affordable to low-income groups, they also need to be encouraged to use energy conservation techniques. The Government may need to conduct an economic analysis for power pricing to optimize efficient use of power even by low-voltage, low-income consumers. Simultaneously, public awareness should be further enhanced with respect to long-term repercussions of deforestation. On the other hand, the impact of subsidies on BPC should also be transparent to enable it to function as a corporation. The Government and ADB should ensure the financial sustainability of the sector during discussions of future business plans for BPC.

B. Lessons Identified

68. **BPC Involvement.** BPC technical personnel should be closely involved in all aspects of the design of rural circuits and the specified equipment (para. 65). BPC personnel are aware of many lessons learned during the implementation of previous projects and must be able to impart these to any international consultants in future. Since availability of private domestic technical consultants are limited, this may require substantial participation of BPC personnel in the preparation of feasibility studies to ensure that (i) aspects unique to Bhutan (e.g., terrain, weather) are considered; and (ii) technology is effectively transferred. With the appropriate transfer of technology and design methods, BPC personnel should be enabled to perform RE system design in-house in the future.

69. **Procurement.** Various precautions can be introduced to improve procurement of supplies and shipping to a landlocked country like Bhutan, which is not familiar to many suppliers. Future procurement packages have to be designed for maximum manufacturer participation from all member countries. Equipment warranties of a minimum of 12 months following receipt at the project site should be required for all major equipment items.[42] Prices for and guaranteed availability of spare parts for a reasonable number of years following delivery should be required for this equipment. To minimize the impact of shipping delays after the supplier has submitted the letters of credit, bank guarantees from suppliers should be required.

70. **System Analysis.** System expansion of the RE system (after the RE-3 project) should be pursued only after a detailed system analysis by computerized load flow techniques is performed and all existing system electrical parameters are determined and entered into a computerized database. The future expansion of the rural 33 kV circuits should be limited to a peak demand of about 80% of the conductor regulation capacity. This is to allow for load growth of the already connected loads without premature reconductoring. As the RE system is expanded, a master plan for the siting of additional 33 and/or 11 kV sources is required and should be performed prior to significant extensions of the existing 33 kV lines. The sizing of conductors should be reevaluated in this plan.

71. **Consultant Supervision.** Recruitment of experienced international consultants in the sector for the feasibility study gave ADB and the executing agency confidence that the consultants had adequately grasped the conditions peculiar to Bhutan. As such, they were re-hired under advance recruitment, and their understanding of the circumstances were not reviewed adequately. For first ADB loan in a sector, more attention should be paid by both ADB and the executing agency regarding the consultant's understanding of the country specific context. In cases where the consultants do not have sufficient experience in similar terrain, adequate time needs to be given during the feasibility stage for them to become familiar.

[42] Items such as main power transformers, 33 kV circuit breakers, and other major equipment should be provided with 36-month warranty.

C. Follow-Up Actions

72. **Capacity Building.** Capacity building is required for some specific technical aspects, such as relay and fuse coordination and basis of protection engineering (Appendix 4). In addition to learning by doing, training in the technical theory is needed. Such training of key personnel in BPC needs to be completed by end 2004.

73. **Auto-Reclosers.** Similarly, BPC personnel should be properly versed in the calibration and maintenance of the programmable auto-reclosers by July 2004 as these are a necessary design feature of the installed distribution system. BPC should ensure that the existing units also need to be returned to functional condition by the same time and additional units should be installed as the system expands.

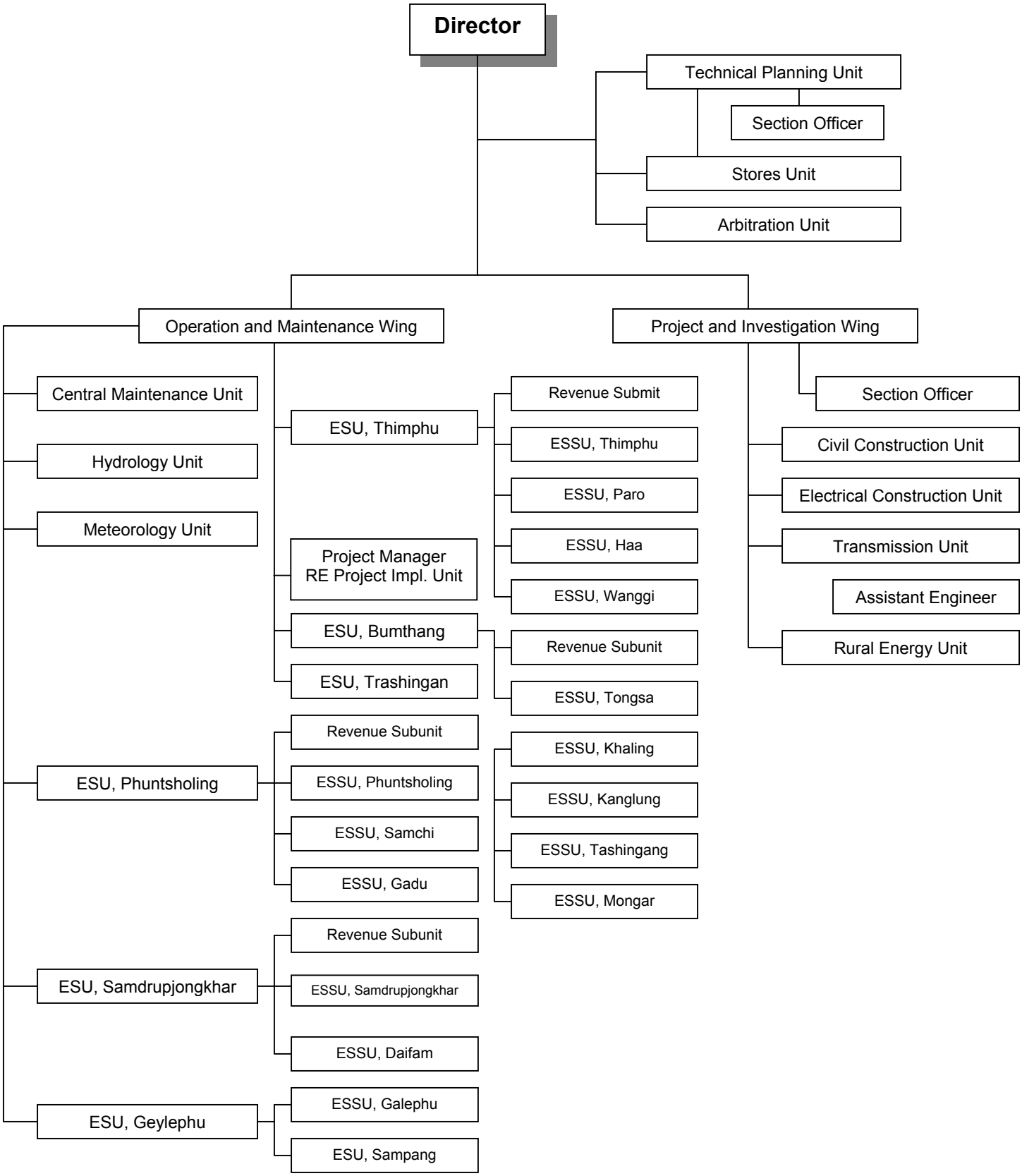
74. **Financial Statements.** BPC financial statement should be ready by end December 2003 as envisaged. They should be certified by June 2004 and provide a basis for BPC's corporate strategy.

75. **Tariffs.** Within 12 months after completion of the TA for capacity building for BEA,[43] BEA should review the tariff structure to ensure that overall tariffs are adequate for BPC's financial viability and cross-subsidies provided for RE have not become a disincentive for consumers to be energy efficient.

[43] TA 4188-BHU: *Capacity Building of the Bhutan Electricity Authority*, for $400,000, approved on 30 September 2003.

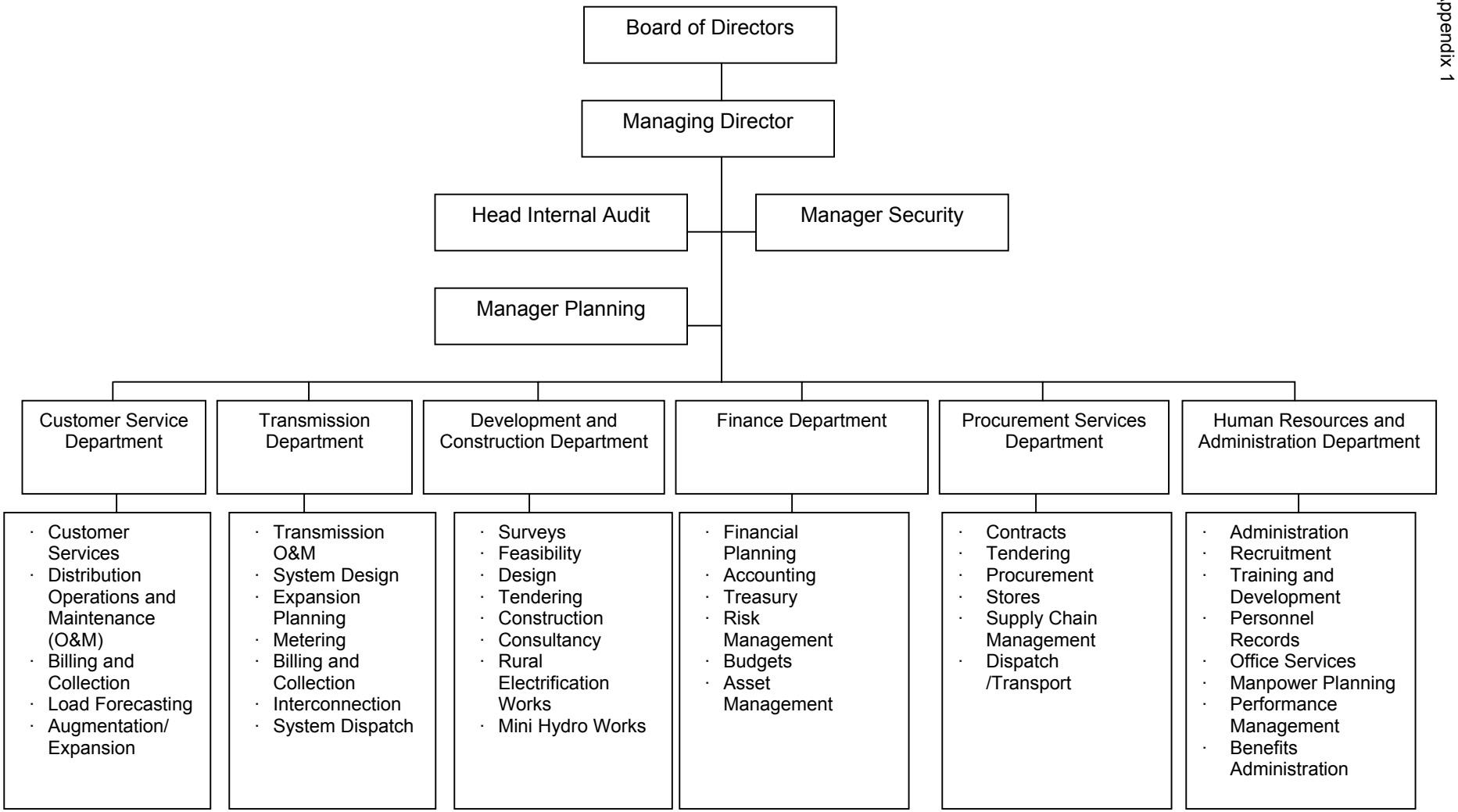
ORGANIZATIONAL CHARTS

Figure A1.1: Division of Power as of August 1995



ESU = Electric Supply Unit, ESSU = Electric Supply Subunit, RE = rural electrification.
Source: Asian Development Bank. 1995. *Report and Recommendation of the President to the Board of Directors on a Proposed Loan and Technical Assistance Grant to the Kingdom of Bhutan for the Rural Electrification Project*. Manila.

Figure A1.2: Bhutan Power Corporation Organization Chart as of September 2003



Source: Asian Development Bank. 2003. *Report and Recommendation of the President to the Board of Directors on a Proposed Loan and Technical Assistance Grants to the Kingdom of Bhutan for the Rural Electrification and Network Expansion*. Manila.

TECHNICAL NOTE ON PROJECT DESIGN

A. Project Description

1. Project Feasibility Study

1. Technical assistance (TA) 2043-BHU[1] was to be the basis for the feasibility of the Project as well as preparation of basic design and procurement documents. The scope included the design development of the rural electrification (RE) schemes and the conceptual design and routing of a 220 kilovolts (kV) transmission line to connect the Baso Chuu hydropower station to the grid.[2] Although the consultant for the feasibility study was to design and specify a distribution system, including its source of generation, "from scratch," the costs and benefits source of generation was not effectively analyzed. The design development activities carried out under the feasibility study included a least-cost determination and the system design, including system voltage(s) selection. Other activities included the conductor selection and sizing for the medium voltage feeder circuits, low voltage distribution and service connections, distribution transformer rating determination, pole height and material design, and all other aspects of a distribution system intended for rural application in the Bhutan terrain were pursued.

2. Least-Cost Determination

2. The feasibility study was to determine the least-cost method of providing electric service to the rural areas of Bhutan. The feasibility study concluded that the extension of the existing grid was the least-cost method. The Asian Development Bank report and recommendation of the President (RRP) reflects and restates this conclusion and offers more discussion on the matter than the feasibility study. The RRP discusses the difficulties of transportation of diesel fuel in many areas of the RE schemes and the fact that diesel fuel use would require foreign exchange and was not environmentally friendly. But no computations were presented in the RRP or the feasibility study. The sole alternative cited in the feasibility study was diesel generation. There was no discussion of solar, wind, or additional mini-hydro schemes. While the feasibility study did not offer anything in the way of cost comparisons or a listing of advantages, the conclusion was sound. The cost and transportation problem of diesel fuel is a distinct disadvantage as compared to indigenous hydroelectric generation. The environmental benefits are clearly on the side of extending the existing grid when the source of generation is hydropower, particularly as Bhutan's development consists of run-of-river designs. Solar or photovoltaic generation, circa 1994, had a relatively high initial cost. In order to provide a reasonable amount of power and (fairly) constant supply, solar panels must be combined with significant battery storage. In colder ambient temperatures, which are normal in most areas of Bhutan, such batteries require frequent replacement, which adds to the cost of the system. Also, in order to provide power to commonly available appliances, which are designed to utilize alternating current at 230 volts (V), a device to convert the (typically) 12 or 24 V direct current output of solar cells to alternating current of suitable voltage would be required. This device adds to the initial and operating cost of a solar system comparable to grid extension. Wind generation is site specific and does not offer high reliability in most applications. These are significant and probably telling considerations justifying the extension of the existing grid for the Project.

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[1] TA 2043-BHU: *Power System Development*, for $245,000, approved on 29 December 1993.
[2] The transmission line was later constructed but not as a part of the Project, as grant funding was obtained for it.

3. Rural Distribution System Design

3. The terms of reference for the feasibility study contemplated that the consultants consider the relevant factors and produce a distribution system design. There was some distribution in service in Bhutan at that time. These were located in the more urban areas of population centers, i.e., towns and villages, and were typical of the standard design popular in the towns and villages of much of Southeast Asia. This design's main features include an overhead three-phase delta primary circuit, usually of 11 kV design, with three-phase distribution transformers located at intervals along the primary circuit. The distribution transformers are of delta-wye configuration so as to supply three-phase, four-wire service to groups of single-phase consumers, as well as three-phase service to larger users where required. The consultant chose to extend this design for the RE project. There is no discussion or inference that alternative designs were considered. This is a considerable weakness in the design effort that resulted in several difficulties in implementation and limited the flexibility of the resulting system. The extension of the existing design was considerably more expedient to utilize, as the design is very standardized and Indian manufacturers could be expected to be able to provide all the necessary components. Also, the Division of Power technical and maintenance personnel could be expected to be familiar with operation and maintenance requirements of this design, as it was already in use. Alternative designs incorporating single-phase circuits and distribution transformers, combinations of three and single-phase circuits, etc., are also common in Asia in rural and in some urban service areas.[3] The advantage of a design, which incorporates three-phase distribution transformers, is that concentrated mixes of single-phase residential and three-phase commercial requirements can be served from the same transformer. If the loading on each of the three phases can be balanced, there is no current in the ground return, which results in lower total circuit losses compared to single-phase service. However, the advantage diminishes as the loads served become of lower capacity, contain few, if any, three-phase consumers, and are more diverse in location, i.e., a rural distribution service area. Further, indicative of its urban origins with easy road access, the standard three-phase design tends to require much heavier components than the equivalent single-phase system. The weight advantage of the single-phase or combinations of three-phase and single-phase circuits[4] also tends to favor its use in rural areas and where most installation will be performed without mechanized equipment.

4. System Voltage Determination

4. While the consultant chose to proceed with the existing distribution design configuration, the feasibility study did consider the use of alternative primary voltages. The existing primary voltage was 11 kV or 33 kV was utilized as subtransmission. The consultant discussed various alternatives including extending the existing and new circuits for the Project at 11 kV; discontinuing the use of 11 kV with all new distribution at 33 kV, with the eventual replacement of the 11 kV; the introduction of 22 kV as the standard distribution voltage; and the extension of the existing 11 kV where suitable with new circuits and sources established at 33 kV. There was

[3] These designs, which places emphasis on single-phase circuits utilizing 11 kV and 22 kV as the primary distribution voltage, are in use in the Philippines, Thailand, and in the rural areas of Bangladesh among other locations. They are the standard design for all parts of North America.

[4] The use of the term "single-phase" should be in context. Rural "single-phase designs" refer to the use of a combination of three-phase main circuits with single-phase transformers used to service consumers along the main roadways. Single-phase "spur" or branch circuits are fed from the main to more isolated loads. As the need or use of three-phase utilization is rarely remote from a roadway, single-phase circuits can supply remote loads of low to moderate demand (to about 1,000 kilovolt-ampere at 11 kV) at significantly lower installed cost.

no detailed cost-benefit examination of these alternatives presented. Discussion centered on a listing of the perceived advantages and disadvantages of each alternative. The recommended configuration was that the new circuits for the Project would be 33 kV. However, the subsequent installation consisted of extending the existing 11 kV with two new sources and project circuits at 33 kV. It is not clear in the various reports as to what led to the decision to extend the 11 kV during implementation. However, the Operations Evaluation Mission (OEM) believes this was a proper course of action.

5. System Conductor and Equipment Selection

5. The overhead conductors were selected based upon a life cycle analysis considering the design assumptions as to loading and span length and loss evaluation. Aluminum conductor steel reinforced (ACSR) conductors were selected[5] and a horizontal profile for overhead conductors was assumed. For the evaluation of losses, to select the size of the conductors, the consultant introduced a "rule of thumb" that the most economical conductor size occurs when the annual losses are equal to the annual capital cost. On the basis of the most economical combinations of conductor strength and losses, "dog" and "wolf" (ACSR) conductors of 100 square millimeters (mm^2) and 150 mm^2, respectively, were to be used depending upon the specific circuit. The consultants introduced and recommended that the Project utilize aerial bundled conductor (ABC) for the low voltage low-tension 230/400 V distribution circuits. This recommendation was predicated upon certain advantages assumed for ABC compared to the existing low-tension design of bare conductors (four wires in a vertical configuration) in current use. The methodology of this selection appears to be proper. The version estimated in the feasibility study to represent the lowest installed cost was the low-tension design of bare conductors in a conductor size similar to ABC. However, the estimated cost differential was slight and the OEM endorses the use of ABC design.

6. Other significant design innovations (for Bhutan) were the use of pole-mounted programmable auto-reclosers and the use of fused load-break switches designed for operation with hotsticks (line sticks)[6] for the isolation of distribution transformers.[7] The inclusion of auto-reclosers was a proper addition to the system. The feasibility study recommended that the more easily set and maintained hydraulic controller models be utilized in the Project. This was apparently lost during implementation, as the more complicated microprocessor models were procured. This unfortunately resulted in both the consultant and the implementing agency being unable to properly utilize the programmable auto-reclosers. Operational continuity has suffered as a result. The design of the distribution substations was intended for operation and maintenance with hotsticks, which was an unknown technique in Bhutan. This is contrary to the design of the basic system configuration that could be justified on the basis that it was familiar to the Division of Power. Then, to include a totally unfamiliar feature such as the use of dropout fuses as the transformer disconnecting means is not a consistent design philosophy. The linemen received unenthusiastic training and demonstrations on the use of hotsticks with the

[5] The recommendation of ACSR appears to have been on the basis of its higher strength as compared to all aluminum conductor of similar ampere capacity. The OEM concurs with this as the additional protection from conductor breaking under winter tension provided by the ASCR negates the very slight energy loss and weight advantage of the all aluminum conductor considered.

[6] A telescoping pole or rod which is nonconductive (usually fiberglass) which can be equipped with an assortment of end-mounted fixtures, i.e., hooks for operating switches, holders for meters, etc. Such sticks are available in varying lengths up to about 10 meters and are very commonly used in other countries, i.e., Bangladesh, Sri Lanka, and Thailand.

[7] A pole-mounted distribution transformer of 33–0.4 kV or 11–0.4 kV is considered a substation by the Bhutan Power Corporation personnel. Such a designation would not normally be used in other locales.

result being that they now refuse or are unable to properly switch and refuse the transformers as needed.

7. Distribution transformers of 25, 63, and 100 kilovolt-ampere ratings[8] were standardized for the Project. These were to be platform mounted on two-pole structures. The consultant utilized a model for selection of transformer ratings that is intended to size transformers for urban residential neighborhoods based upon the typical lot frontage. This was not the proper application of the model but, as the ratings of 33–0.4 kV are limited in the smaller sizes, the model worked. Therefore, these ratings were properly determined bearing in mind that they are exclusively three-phase values (see above) and can, therefore, be endorsed.

8. System load flow studies were not made in any detail for the Project.[9] It may be that these types of studies could not be made due to a lack of system data. Accepting such a lack of data, the effort is acceptable for the time frame of the Project.

[8] In addition, a 40 kilovolt-ampere rating was discussed, but the OEM was unable to confirm that these were utilized in the Project.

[9] Some sample runs (4) of load flows were presented in the feasibility study, but these did not include the Project in conjunction with the grid, but compared voltage regulation and other aspects of individual circuits to be added.

PROJECT COST AND LOAN UTILIZATION

Table A3.1: Project Cost by Component
($ million)

Item	Appraisal Estimate	Actual	Overrun/ (Underrun) (%)
Base Cost			
Civil Works and Equipment	7.10	7.34	3.38
Consulting Services	0.40	0.37	(7.50)
DOP Administrative and Overhead	0.20	0.34	70.00
Subtotal	**7.70**	8.05	**4.55**
Contingencies			
Physical Contingencies	0.80	0.00	(100.00)
Price Contingencies	0.80	0.00	(100.00)
Subtotal	**1.60**	**0.00**	**(100.00)**
Service Charge	**0.20**	**0.16**	**(18.50)**
Total	**9.50**	**8.21**	**(13.55)**

DOP = Division of Power.
Source: Operations Evaluation Mission.

Table A3.2: ADB Loan by Category
($ million)

Item	Original Allocation	Revised Allocation	Net Amount Disbursed	Undisbursed % from Revised Allocation
Civil Works	0.20	0.17	0.04	76.30
Equipment	5.74	5.16	6.07	(17.67)
Consulting Services	0.30	0.27	0.37	(34.07)
Service Charge	0.20	0.18	0.16	6.32
Unallocated	1.06	0.91	0.00	100.00
Total ADB Loan	**7.50**	**6.69**	**6.64**	**0.78**

ADB = Asian Development Bank.
Source: Operations Evaluation Mission.

STATUS OF COMPLIANCE WITH LOAN COVENANTS

Nature of Covenant	Status of Compliance
1. The Government will acquire land, including rights to land, required for the Project on a timely basis. The Government will offer adequate land sites to land owners affected by land acquisition.	Complied with
2. The Division of Power (DOP) will establish a project implementation unit in its operation and maintenance wing to ensure timely implementation.	Complied with
3. The Government will finalize an action plan to be agreed upon with the Asian Development Bank (ADB) for a two-phase restructuring of the power sector. The first phase will consist of introducing a commercial accounting system in DOP and establishing an appropriate tariff structure. The second phase will involve the corporatization of DOP.	Partly complied with. The unbundling of DOP in July 2002 when the Department of Energy and the Bhutan Electricity Authority (BEA) were spun off paved the way for the restructuring of the power sector. However, BEA is still to be fully functional. A technical assistance (TA) grant that is attached to the ongoing third rural electrification project will provide the necessary foundation for BEA to become an effective regulator. The computerized accounting system developed under TA 2400-BHU[a] and TA 2912-BHU[b] is still undergoing development and may be installed only in FY2005.
4. The Government will carry out a tariff study to determine the appropriate tariff structure during the first phase of the restructuring of the power sector, and thereafter the Government will revise the domestic electricity tariff based on the findings of the study and on an action plan to be agreed upon by the Government and ADB.	Partly complied with. A national tariff study completed under TA 2400-BHU forms the basis for the current domestic electricity price structure. Since the completion of this study, tariff rates have been adjusted four times.
5. The Government will furnish ADB with quarterly reports on project implementation and will indicate, among other things, progress made, problems encountered, and steps taken.	Complied with
6. DOP will monitor the Project with benchmark information agreed upon with ADB. During project implementation, DOP will furnish ADB with annual performance reports on monitoring the Project.	Complied with
7. DOP will evaluate the benefits of the Project after project completion in accordance with the time schedule and terms of reference to be agreed upon with ADB.	Complied with
8. DOP will submit to ADB, not later than 9 months after the end of the fiscal year (30 June), certified copies of the audited financial statements.	Complied with

[a] TA 2400-BHU: *Institutional and Financial Development of Department of Power,* for $400,000, approved on 19 September 1995.
[b] TA 2912-BHU: *Second Rural Electrification*, for $600,000, approved on 19 November 1997.

TECHNICAL NOTE ON OPERATION AND MAINTENANCE CONSIDERATIONS

A. Operations

1. The operation of the rural electrification (RE) system of Bhutan is vested in the Bhutan Power Corporation. District offices are responsible for the distribution systems within their service areas. No distinction is made between the circuits and consumers connected under the two RE projects[1] and the distribution within the more urbanized areas, which predates the Project (RE-1). District offices' functions include billing, customer service activities, and maintenance. The districts submit a request for an annual budget, which sustains operation, maintenance, and an amount for improvement and expansion. Funding for expansion and improvements are expected to be justified on a cost-benefit basis.

2. The indicated losses of the distribution system are higher than what would be expected. While the overall losses for the national system are reported to be about 12% for FY2001–2002, 15 of the districts appear to have annual losses in excess of this with about half indicating losses in excess of 20%. No detailed analysis of the distribution has been made, but given the wire sizes in use and the relatively light loads, it is unlikely that the technical losses are much in excess of 9–12% depending upon the length of the respective feeders. The large discrepancy in system annual losses and the individual districts is somewhat accounted for by the large ratio of industrial usage to the residential use. For FY2001–2002, industrial usage was 70% of total sales to basically four users. These services are at medium voltage and well metered. This implies that the large levels of losses in the distribution to the domestic (13% of total sales) and commercial (3.6% of total sales) can be in part attributed to metering errors or incorrect readings.

3. Several possible causes for the high loss rates were suggested by district engineers. These included estimated readings by the meter readers, lag times in monthly reconciliation of billings, and meters of very advanced age. Lag times in billing over more than 13 months cannot account for consistently high losses on an annual basis. Many of the meters in service were reported to be in excess of 15 years service. It is reasonably certain that any mechanical meters over 7–8 years of service are not accurate. Also, given the very light loads of many of the domestic consumers, especially during off-peak times, the meters in use may not be able to function accurately.[2] It would appear that the metering in the distribution system is not functioning well and is the cause of the large reported losses.

4. The reliability of the rural circuits has been decreased by the lack of proper operation of the programmable auto-reclosers. With these units in a bypassed mode, transient faults that would have otherwise been cleared by the programmable auto-reclosers are now causing the main substation circuit breaker to operate, which results in both feeders being out of service until the fault can be located and service restored. This operation can consume several hours. In addition, the inability of the linemen to utilize the designed dropout fuses to deenergize single transformers for maintenance. The maintenance procedure without utilizing the dropouts requires that the nearest load-break switch is operated. Instead of an individual transformer being out of service during the maintenance, this results in multiple transformers being out

[1] There have been two separate projects funded by the Asian Development Bank to extend electric service into the rural areas. These are Loan 1375-BHU(SF): *Rural Electrification Project*, for $7.5 million, approved on 19 September 1995, and Loan 1712-BHU(SF): *Sustainable Rural Electrification Project*, for $10 million, approved on 25 November 1999 (referred to as RE-1 and RE-2, respectively). In most districts, the constructions are now integrated. RE-1 was the subject of the Operations Evaluation Mission.

[2] Mechanical or electromechanical meters have a certain inertia, which must be overcome for them to rotate and record usage. The rotational power to a meter is provided by the usage of the connected loads. At low levels of demand, older mechanical meters tend to under-register the usage.

which significantly increases the consumer outage time. Further compounding the problems with reliability, the use of steel cross arms was a design error.

5. Two 66–33 kilovolt (kV) substations were constructed as a part of the Project. Both of these substations are operated well by knowledgeable staff. Tap changes are performed manually by the operators as are switching operations for planned shutdowns of the lines. Both of the substations' officers-in-charge demonstrated a high level of knowledge as to the operation and necessary data maintenance of the stations. As discussed above, the lack of functional programmable auto-reclosers has resulted in operational problems. Watsa substation has two operating programmable auto-reclosers, one on each of its outgoing 33 kV feeders. Lobeysa substation is of similar design, but its two programmable auto-reclosers are not in service. As an illustration of the operational problems with the nonfunctioning programmable auto-reclosers, the main circuit breaker at Lobeysa has had 1,361 operations. Watsa circuit breaker has had 438. As the two substations are of similar age and one would not expect that the feeders from Lobeysa are more prone to faults than Watsa, it is reasonable to conclude that the operating programmable auto-reclosers at Watsa have prevented a great number of outages of its feeders compared to Lobeysa. This prevented a loss of service to the consumers and the related loss of sales.

6. The districts do not maintain circuit or distribution transformer loading records at present. The data for a transformer and circuit loading program can be obtained by a software addition to the billing program and the consumers coded as to their serving transformer and circuit. The software then collects the monthly customer usage and a report is generated. Periodic analysis of this report can allow the districts to schedule transformer and conductor replacements and additions and avoid premature loss of life and failure due to overloads.

B. Maintenance

7. The substations designed and constructed under the Project are well maintained. Problem areas were noted in that both of the substations 33 kV transformers are exhibiting paint failure, but these are minor at present and can be repaired without taking the units out of service. There have been minor oil leaks, but these have been repaired. The transformers are otherwise well maintained, as are the sulfur hexafluoride (SF6) circuit breakers. SF6 replenishment bottles are maintained in stock. In both substations, the original indicating metering has failed but has been replaced by a multi-functional solid state metering system. Both substations follow well-designed programs of monthly and annual preventive maintenance including checking the bolts on structural steel, operating the manual switches, and performing SF6 and transformer oil checks. At Watsa, the SF6 33 kV circuit breaker had experienced an SF6 gas leak, but this has been corrected and the unit refilled. Common tools and spare gas for use at both of the substations circuit breakers are maintained at Lobeysa.

8. Distribution maintenance at the district office level is more problematic. There is a shortage of spare materials including overhead conductor, aerial bundled conductor, and transformers. Some district engineers expressed a belief that the surplus materials from the Project had not been released as planned from the Construction Division of the Bhutan Power Corporation. If true, this should be corrected and a level of spare materials maintained at the district offices. Connectors for the aerial bundled conductor are said to be in short supply. This must also be corrected so as not to delay the connection of new consumers or to delay any replacements should they be required. A singular problem with the maintenance of the rural circuits is the lack of training and/or the ability of the linemen to maintain the project circuits and transformer installations. While this is also a design problem, the design is as it is and proper maintenance is a priority.

9. The maintenance of the rural circuits consist of periodic transformer checks; replacement of fuses; repairs of broken insulators; reattaching conductor; and replacement of other damaged items, including poles. The linemen are unable or unwilling to perform most of these tasks as the design intended. The design assumed that many of these tasks would be performed using hotsticks and climbing the poles would be rare. If it would be required to access the transformer platforms, the transformer and the secondary low-voltage would be de-energized by using the hotsticks. However, even at this, the design does not allow for workspace on the transformer poles indicating that the design was adapted from one where the bulk of maintenance is performed from lift or bucket trucks, which are not practical in Bhutan.

10. The steel poles as specified for the Project are not equipped with steps. The districts have complained about this, as many of the poles are too far from road access to carry the required ladders to the poles. Sets of strap-on climbing steps are available from a wide variety of vendors or could be fabricated in Bhutan. The lack of steps should not be deterrence to maintenance. The districts have also cited the diameter of the poles as being too large for the linemen to climb. Again, climbing steps can be carried by the linemen and strapped to the poles as and when needed. Permanent steps are not recommended for electric utility poles due to the likelihood of unauthorized access.

11. There is a shortage of tools in the districts for the use of the line maintenance personnel. Each line maintenance personnel should be equipped with the necessary basic hand tools, a tool belt, hardhat, 600-volt rated safety gloves, safety glasses, a safety belt, secondary grounding leads, and other apparatus and tools which may be unique to Bhutan methods and conditions. Observations of the lines indicated that with one exception, the maintenance is being performed. The problems cited would tend to increase the outage time rather than result in a deterioration of the facilities. The one exception is that several guy lines were observed to be in need of tensioning. Lack of maintaining proper guy wire tension can result in the failure of a pole and the loss of several spans of line. This can damage insulators and conductors beyond repair.

12. Other items of concern to the district personnel included the claim that the cross-arms are too long, the outer conductor and insulators cannot be reached from the pole, and that the medium-voltage insulators are not sufficient to prevent birds from causing faults from the conductors to the cross-arms. The cross-arm length is probably a standard from a design typically worked from lift trucks and was not meant to be reached from the pole. This will remain a problem, but it is rare that one needs to reattach a conductor. The evidently common occurrence of birds contacting the overhead wire and the pole or cross-arm and causing a fault is not easily solved. It is unlikely to be prevented by any standard 33 kV or 11 kV pin insulator. One method that has had some success elsewhere is to place guards on the cross-arm to prevent birds from landing.

13. The operation of the project facilities has been integrated into the general distribution system. This operation is efficient and sustainable but suffers from higher-than-expected losses and avoidable outages. Some training in methods of distribution system management and data collection is warranted. The losses can be reduced with a sustained meter replacement effort. The long duration of circuit outages can be approached by two methods. One is to make the programmable auto-reclosers operational and properly calibrated. The second is to train and properly adapt the methods of the line personnel to operate the project facilities as they are designed to be operated. Maintenance suffers somewhat from a lack of material, but this lack has not resulted in any observable deterioration in the circuits. Guy wires need additional attention. Training and the provision of tools and devices discussed above can improve maintenance, both preventive and restorative. Additional transformers as spares and for the addition of new consumers should be provided to the districts.

FINANCIAL PERFORMANCE OF BHUTAN POWER CORPORATION

Table A6.1: Profit and Loss
(Nu million)

Item	2003
Revenues	
Transmission Income	216
Total Sales	504
Less Purchases	221
Gross Margin	283
Other Operating Income	10
Total Operating Income	**509**
Less Operating Expenditure	223
Less Bad Debts Expense	1
Earnings Before Interest, Tax, Depreciation, and Amortization	285
Depreciation	161
Earnings Before Interest and Tax	124
Finance Expense (interest)	0
Net Profit Before Tax	124
Tax Expense	37
Net Profit After Tax	87
Retained Earnings	
Opening Balance	0
Net Profit After Tax	87
Dividends Paid	26
Closing Balance	61
Dividends/Equity	**0.7%**

Source: Asian Development Bank. 2003. *Report and Recommendation of the President to the Board of Directors on a Proposed Loan and Technical Assistance Grants to the Kingdom of Bhutan for the Rural Electrification and Network Expansion* . Manila.

Table A6.2: Balance Sheet

Item	2003
Current Assets	
Cash (overdraft)	337
Receivables	50
Other	22
Total	**409**
Non-Current Assets	
Net Fixed Assets (including work in progress)	
Transmission	2,272
Distribution	1,199
Generation	584
Buildings	108
Land	27
Other Assets	88
Total	**4,278**
Total Assets	**4,687**
Liabilities (creditors equity)	
Creditors	22
Provisions	3
Term Loans	710
Provision for Tax	37
Total	**772**
Shareholders' Equity	
Beginning Balance Forwarded	3,654
Equity Injections	200
Closing Balance	3,854
Retained Earnings	61
Net Equity	3,915
Total Liabilities and Equity	**4,687**

Source: Asian Development Bank. 2003. *Report and Recommendation of the President to the Board of Directors on a Proposed Loan and Technical Assistance Grants to the Kingdom of Bhutan for the Rural Electrification and Network Expansion* . Manila.

FINANCIAL AND ECONOMIC ANALYSES

A. Background and Basic Assumptions

1. Loan 1375-BHU(SF): Rural Electrification Project (RE-1, the Project) is the first of three RE projects financed by the Asian Development Bank in Bhutan. The second (RE-2)[1] and the third (RE-3)[2] are both under implementation. RE-1 was designed to address the need for reliable power supply to the rural areas of the country where majority of the people depended on imported kerosene, pine sap, and wood for cooking, heating, and lighting. Bhutan has vast hydropower resources and is a net exporter of energy to India.

2. The economic life of the Project is assumed to be 25 years from 1999 to 2023, the same as in appraisal and project completion report. An average consumption of 119 kilowatt-hour (kWh)/household/month was used.[3] This is plausible given the low tariffs, lack of energy efficiency in the rural areas, and the high lifeline tariff of 80 kWh/month. All prices and costs are expressed in second quarter 2003 constant values. The prices and costs were adjusted for inflation using Bhutan's gross domestic price deflator. The exchange rate at the time of the Operations Evaluation Mission (OEM) was at $1 = Nu45.74.

B. Financial Performance

3. The financial internal rate of return (FIRR) was evaluated by comparing revenues and costs during the life of the Project. Interest during construction is excluded from actual capital costs. The number of houses connected under RE-1 from 1999 to 2003 is actual connections. Actual number of connection as of the OEM, which is 3,123 houses, is held constant for the rest of the life of the Project. This is just about the target number of connections at appraisal, and the analysis assumes this is just about the maximum number of connections the facilities constructed under the Project could take. The demand for kWh per house is assumed to grow by 7% annually until 2009, 10 years after the commissioning of the project facilities. This represents population growth and the use of additional electrical appliances and lighting and increased number of hours per household, as they get accustomed to electrification conveniences. After 2009, demand for kWh per house is assumed to grow by 3.5% representing population growth. The actual tariff rates are assumed until 2003 adjusted for inflation. From 2004 until 2013, a 5% increase in real tariff rates is assumed. Operation and maintenance is assumed to be 1% of capital cost and purchase price of power takes the actual purchase price of around Nu40/kWh until 2003, adjusted for inflation. Based on these assumptions, the FIRR is less than zero, similar to estimates at appraisal and project completion (Table A7.1). The OEM computations indicate that the weighted average cost of capital for Bhutan was 1.4% at project approval.

C. Economic Performance

4. The analysis to estimate the economic internal rate of return (EIRR) draws from the assumptions used in estimating the EIRR for RE-3. The economic project costs were derived from the financial costs and converted to economic cost by applying a shadow exchange rate to

[1] Loan 1712-BHU(SF): *Sustainable Rural Electrification Project*, for $10 million, approved on 25 November 1999.
[2] Loan 2009-BHU(SF): *Rural Electrification and Network Expansion Project*, for $9.4 million, approved on 30 September 2003.
[3] Taken from the supplementary appendix (economics report) for the report and recommendation of the President of RE-3. It drew this estimate from socioeconomic studies. The same supplementary appendix also mentions that the Department of Energy analysis suggests an average consumption of 142 kWh/household/month.

reflect the premium placed on foreign exchange and a shadow wage rate to reflect the real cost to the economy of the labor used.[4] The economic cost of the power purchase is the opportunity cost of exporting the energy to India, which at the time of the OEM was at Nu1.5/kWh.[5]

5. Displaced energy represents the displaced energy consumption and estimated at 9 liters per month per house in terms of kerosene. This was valued using the border price of imported kerosene from India and adding average transport cost. The cost savings from displaced firewood was valued at zero cost because firewood is available free of charge. Induced benefit represents energy sales with Project less displaced energy and valued at willingness to pay based on the alternative costs of providing similar energy-related services. It is assumed that a household with an average consumption of 119 kWh/month households under present tariffs would be paying an average of Nu101 per month.

6. Health and productivity benefits are derived from electrification. The OEM gathered from focus group discussions it conducted that there has been a significant improvement in health of household members, especially women who spend significant amounts of their daily time in the kitchen where firewood stoves and kerosene wick lamps were in use before RE-1. The incidence of eye and respiratory ailments was significantly less after RE-1. As a result of improved health, productivity has also gone up. This improvement in productivity, coupled with greater opportunities to take up income-generating activities at night (such as weaving and carpentry), has increased household income in some. Children also benefited through the extra hours available for study after dark resulting in better performance in school. Overall, beneficiaries of RE-1 confirm that electrification has brought a definite improvement in their quality of life.

7. The total health and productivity benefits have been estimated at Nu1.27/kWh consumed. The other benefits mentioned above, apart from health and productivity, were not quantified. The resulting EIRR is 12.5% (Table A7.2), slightly higher than the 11.7% estimate at the project completion report.

[4] The conversion factors used were 1.11 for foreign components of costs and .0.75 for domestic unskilled labor component of capital costs. All other components had a conversion factor of 1.0.

[5] Generation costs are not deducted, as all available electricity not sold in the domestic market can be sold to India.

Table A7.1: Financial Internal Rate of Return

Year	Total Purchases (MWh)	Systems Losses (%)	No. of Houses	Sales (MWh)	Electricity Tariff (Nu/kWh)	Gross Benefit (Nu mn)	Capital Cost (Nu mn)	O&M (Nu mn)	Power Purchase Cost (Nu mn)	Total Cost (Nu mn)	Benefit Stream (Nu mn)
1996							1.3	0.01		1	(1)
1997							177.3	1.19		178	(178)
1998							162.2	2.46		165	(165)
1999	3,468	9.5	2,198	3,139	1.10	3	40.2	2.95	2	45	(41)
2000	5,018	9.5	2,972	4,541	1.01	5	18.2	3.35	2	24	(19)
2001	5,476	9.5	3,031	4,956	0.95	5		3.35	2	6	(1)
2002	5,977	9.5	3,092	5,409	0.89	5		3.35	3	6	(1)
2003	6,459	9.5	3,123	5,846	0.85	5		3.35	3	6	(1)
2004	6,911	9.5	3,123	6,255	0.89	6		3.35	3	6	(1)
2005	7,395	9.5	3,123	6,693	0.94	6		3.35	3	6	0
2006	7,913	9.5	3,123	7,161	0.98	7		3.35	3	7	1
2007	8,467	9.5	3,123	7,662	1.03	8		3.35	3	7	1
2008	9,060	9.5	3,123	8,199	1.08	9		3.35	4	7	2
2009	9,694	9.5	3,123	8,773	1.14	10		3.35	4	7	3
2010	10,033	9.5	3,123	9,080	1.20	11		3.35	4	7	3
2011	10,384	9.5	3,123	9,398	1.26	12		3.35	4	8	4
2012	10,748	9.5	3,123	9,727	1.32	13		3.35	4	8	5
2013	11,124	9.5	3,123	10,067	1.38	14		3.35	4	8	6
2014	11,513	9.5	3,123	10,419	1.38	14		3.35	5	8	6
2015	11,916	9.5	3,123	10,784	1.38	15		3.35	5	8	7
2016	12,333	9.5	3,123	11,161	1.38	15		3.35	5	8	7
2017	12,765	9.5	3,123	11,552	1.38	16		3.35	5	8	7
2018	13,212	9.5	3,123	11,956	1.38	16		3.35	5	9	8
2019	13,674	9.5	3,123	12,375	1.38	17		3.35	5	9	8
2020	14,153	9.5	3,123	12,808	1.38	18		3.35	6	9	9
2021	14,648	9.5	3,123	13,256	1.38	18		3.35	6	9	9
2022	15,161	9.5	3,123	13,720	1.38	19		3.35	6	9	10
2023	15,691	9.5	3,123	14,200	1.38	20		3.35	6	10	10
										FIRR =	**< 0**
										WACC =	**1.36**

FIRR = financial internal rate of return, kWh = kilowatt-hour, MWh = megawatt-hour, O&M = operation and maintenance, WACC = weighted average cost of capital.
Source: Operations Evaluation Mission.

Table A7.2: Economic Internal Rate of Return

Year	Total Purchases (MWh)	Systems Losses (%)	Annual Sales (MWh)	Tariff (Nu/kWh)	Displaced Energy (MWh)	Induced Consumption (MWh)	Induced Benefit (Nu mn)	Econ and Resource Benefit (Nu mn)	Gross Benefit (Nu mn)	Capital Cost (Nu mn)	O&M (Nu mn)	Purchase Power (Nu mn)	Total Cost (Nu mn)	Net Benefit (Nu mn)
1996										1	0.014		1	(1)
1997										188	1.889		189	(189)
1998										172	3.604		175	(175)
1999	3,468	9.5	3,139	1.10	171	2,967	9	1	10	42	4.029	7	53	(43)
2000	5,018	9.5	4,541	1.01	232	4,309	44	3	47	19	4.222	9	32	15
2001	5,476	9.5	4,956	0.95	236	4,720	46	3	49		4.222	9	13	35
2002	5,977	9.5	5,409	0.89	241	5,168	57	3	61		4.222	9	14	47
2003	6,459	9.5	5,846	0.85	244	5,602	66	3	69		4.222	10	14	55
2004	6,911	9.5	6,255	0.89	244	6,011	70	3	74		4.222	10	15	59
2005	7,395	9.5	6,693	0.94	244	6,449	75	3	79		4.222	11	15	63
2006	7,913	9.5	7,161	0.98	244	6,918	80	3	84		4.222	12	16	68
2007	8,467	9.5	7,662	1.03	244	7,419	86	3	89		4.222	13	17	72
2008	9,060	9.5	8,199	1.08	244	7,955	92	3	95		4.222	14	18	77
2009	9,694	9.5	8,773	1.14	244	8,529	98	3	101		4.222	15	19	83
2010	10,033	9.5	9,080	1.20	244	8,836	101	3	104		4.222	15	19	85
2011	10,384	9.5	9,398	1.26	244	9,154	104	3	107		4.222	16	20	88
2012	10,748	9.5	9,727	1.32	244	9,483	107	3	111		4.222	16	20	90
2013	11,124	9.5	10,067	1.38	244	9,823	110	3	114		4.222	17	21	93
2014	11,513	9.5	10,419	1.38	244	10,176	114	3	118		4.222	17	21	96
2015	11,916	9.5	10,784	1.38	244	10,540	118	3	122		4.222	18	22	100
2016	12,333	9.5	11,161	1.38	244	10,918	123	3	126		4.222	18	23	103
2017	12,765	9.5	11,552	1.38	244	11,309	127	3	130		4.222	19	23	107
2018	13,212	9.5	11,956	1.38	244	11,713	132	3	135		4.222	20	24	111
2019	13,674	9.5	12,375	1.38	244	12,131	136	3	140		4.222	21	25	115
2020	14,153	9.5	12,808	1.38	244	12,564	141	3	145		4.222	21	25	119
2021	14,648	9.5	13,256	1.38	244	13,013	146	3	150		4.222	22	26	123
2022	15,161	9.5	13,720	1.38	244	13,477	151	3	155		4.222	23	27	128
2023	15,691	9.5	14,200	1.38	244	13,957	157	3	160		4.222	24	28	132
											EIRR =	**12.50%**		

EIRR = economic internal rate of return, kWh = kilowatt-hour, MWh = megawatt-hour, O&M = operation and maintenance.
Source: Operations Evaluation Mission.

THE SOCIOECONOMIC IMPACTS OF RURAL ELECTRIFICATION PROJECT

A. Background

1. The Operations Evaluation Mission visited four villages electrified under the Rural Electrification Project[1] to assess its socioeconomic impacts. The villages were from four districts: two in western Bhutan and two in eastern Bhutan. The four villages were selected through consultation with officials of the Department of Energy and Bhutan Power Corporation. The villages selected were Changkha in Wangdue Phodrang district, Gangkha in Chhukha district, Isuna in Paro district, and Lakhu in Punakha district. Focus group discussions were held with project beneficiaries at each village. A total of 157 beneficiaries, 80 females and 77 males, participated in the focus group discussions. The discussions were held in outreach clinics, rural houses, and out in the open. On an average, the discussions and interviews lasted between 1.5 to 2 hours.

Location and Number of Participants at the Focus Group Discussions

Village	District	No. of Male Participants	No. of Female Participants	Total No. of Participants
Changkha	Wangdue Phodrang	14	17	31
Gangkha	Chhukha	17	5	22
Isuna	Paro	26	20	46
Lakhu	Punakha	20	38	58
Total		**77**	**80**	**157**

B. Findings of the Focus Group Discussions

2. **Improvement in Overall Quality of Life.** Beneficiaries stated unequivocally that electricity has brought about a definite improvement in their overall quality of life. Beneficiaries expressed that the difference between "having and not having electricity" is like the difference between "the sky and the earth."

3. **Improvement in Education.** Children benefited through the extra hours available for study after dark. Apart from the extra hours available through electricity, it was the quality of light that enabled them to study longer and helped them retain what they studied as compared to pre-electrification days when poor lighting from the use of kerosene wick-lamps hampered their studying after dark. They are now able to complete and submit their homework on time and beneficiaries stated that their children are performing much better at school.

4. Electricity has played an instrumental role in enhancing adult literacy in these rural villages. The Department of Education, in an effort to promote literacy, conducts nonformal education (NFE) programs in rural villages. Villagers are taught simple arithmetic, basic reading, and writing. These NFE classes are conducted between 7:00 pm and 10:00 pm. Beneficiaries said that electricity has enabled them to enroll in the NFE classes.

5. **Improvement in Health and Hygiene.** Health has improved for all members of the household. Beneficiaries, especially women, who previously spent much of their time in the kitchen, now experience a significant decrease in eye and respiratory ailments that had been

[1] Loan 1375-BHU(SF): *Rural Electrification Project*, for $7.5 million, approved on 19 September 1995.

caused by excessive indoor smoke emitted from the firewood stoves and kerosene wick-lamps, particularly during winter when it is cold and moisture levels are low. Children have also benefited, as they do not have to strain their eyes in an effort to read at night. Beneficiaries also stated that before electrification, they frequently suffered from cough and cold resulting from the smoke in their homes, but now they have fewer incidences of cough and cold. The hygiene of the beneficiaries has also improved significantly; they find that it is now much easier and requires less time and effort to keep themselves and their homes and clothes cleaner, leading to better hygienic environment.

6. **Safety and Health Hazards.** Participants mentioned instances in the past of children drinking kerosene by mistake and endangering their lives. Villagers also cited instances when children accidentally toppled kerosene lamps and burn themselves, such an accident made headlines in the national newspaper about a year ago.[2] There have also been instances when a kerosene lamp is accidentally toppled leading to outbreak of fire within the house. The frequency of such accidents has decreased after electrification.

7. **Decrease in Dependency and Consumption of Firewood and Kerosene.** Beneficiaries claimed that firewood consumption has dropped by as much as 75% after electrification. Prior to electrification, beneficiaries used about four truckloads of firewood annually; after electrification, they now use about one truckload annually. This has reduced pressure on forestry resources and the environment. Consumption and usage of kerosene has also seen a drastic decrease, where earlier beneficiaries purchased and used an average of about 10 liters of kerosene a month, they now purchase about one liter of kerosene monthly, translating to a 90% decrease in kerosene usage.

8. **Increase in Income and Employment Opportunities.** Beneficiaries have experienced some enhancement of income by taking up income-generating activities at night such as weaving, carpentry, carving, and tailoring. In some instances, income from such activity, especially weaving has increased by over 50%. Some wealthier households employ poor villagers as weavers on a contract basis, thus providing employment to the needy. Furthermore, electrically-operated rice mills, flour mills, and oil mills have increased income and employment opportunities in these rural areas. Small shops-cum-bars have sprouted in these areas and remain open even after dark thereby increasing commercial activity and social interaction. Beneficiaries have begun using electrically operated “chili powder grinders” to produce chili powder that they sell in urban centers and towns.

9. **Increase in Savings.** Savings has increased and are reflected as

(i) electricity is cheaper than most other fuel, including kerosene (this includes the opportunity costs of traveling to urban centers and towns to purchase kerosene and other fuel, which often takes half a day or more, and very often returning empty handed due to fuel shortages);
(ii) decrease in smoke and soot within the houses has meant that houses do not have to be painted as often as before; and
(iii) clothes do not have to be washed as often and thus lasts longer and cost less to maintain. Consequently, less washing has led to decrease in the use and purchase of soap and detergent.

[2] Quoted from *“Facilitating Capacity Building and Participatory Activities II”* report, TA 5894-REG, 2001, funded by the Asian Development Bank.

10. **Increase in Productivity.** Reduction in the use of firewood and kerosene has meant that beneficiaries now spend less time and effort in collecting firewood and going to replenish their kerosene supplies from the nearest town. Electricity has enabled beneficiaries to use cost- and labor-saving appliances. Beneficiaries who can afford them have begun using electrical appliances such as rice cookers, curry cookers, water boilers, refrigerators, heaters, fans, radios, tape recorders, videos, chili powder grinders, etc. This has led to reduced cooking time and effort, as villagers now just turn on the rice cookers and curry cookers without having to go through the process of lighting up a cold firewood oven and waiting for the food to be cooked. They can often leave the rice cooker on and go and attend to other responsibilities. The time saved is spent on other productive activities such as working on their farms or carrying out income-generating activities.

11. **Recreation, Relaxation, and Security.** Electricity has helped beneficiaries feel more secure at night bringing them much needed peace of mind, for example, in times of medical or other emergencies they know that they just have to flick the switch on and they have light, rather than grope for matches, lamps, etc., in the dark. Cases of theft, burglary, and vandalism in religious temples, monasteries, and structures have decreased in electrified villages as light acts as a deterrent to thieves and burglars. Electricity has also provided avenues for recreation and relaxation through media such as radio and television as well as time to associate and socialize with neighbors and relatives.

12. **Pest Management.** Electricity does not seem to have had very much of an impact on agriculture in rural areas as land holdings are small and most of the rural masses cannot afford to set up electrical pumps for irrigation purposes. However, some of the participants stated that electricity assisted them in protecting their harvest from wild animals. For example, wild boar and deer are common pests found all over the country. Villagers stated that way before the harvesting season began they would have to stay up all night keeping vigil on their crops and chasing away wild animals from their fields to avoid their crops from being consumed or damaged by these pests. Some studies estimate that crop loss due to pests is as high as 40% in certain regions. In order to protect their crop, most villagers build a small bamboo-matted shelter on stilts in their fields and spend the nights there to ensure that their crop is safe from the animals. This, villagers said, was tiring and villagers were deprived of their sleep as they stay up all night especially during the harvest season. With electricity, villagers have begun extending the electrical lines outside such shelters and lighting up a bulb or two. This seems to deter pests from coming to their fields and destroying their crop.

13. **Disadvantages of Electricity.** Villagers strongly felt and expressed that, in general, electricity was beneficial and the only disadvantages they mentioned were

(i) Some of the villagers stated that “electricity was like fire, if one knew how to handle electricity it could be put to tremendous use. However, if one did not, it would burn you.” Most of the new rural consumers are illiterate and unaware on the proper usage, handling, and safety aspects of electricity. Some of the beneficiaries hurt themselves when dealing with electricity or while conducting minor electrical repairs themselves.

(ii) A participant from an electrified village mentioned that electricity brought with it unrealistic demand for commodities that they were not used to until the arrival of

electricity.[3] He stated that prior to electrification, his family's wants were very few and genuine, and that even though they were relatively poor they were happy. Now, with electricity, his wife wanted a rice cooker and a refrigerator, his children want a music set and a television, and he just wants peace. He said that he could not afford to purchase these appliances but just because some of the villagers had these appliances, he too was being pressured by his family to get them as well. He stated a case where a villager exchanged a piece of land for a television, as he had no cash to purchase them. Was he to sell part of his meager land as well to purchase these appliances or take a loan that he knows he cannot repay, in order to keep his family happy?

C. Conclusion

21. Electricity has brought many benefits to the beneficiaries. Beneficiaries at all four locations were overwhelmed with the positive changes electricity bought to their lives and thanked the Government and the Asian Development Bank for providing them with electricity.

[3] Quoted from the study of phase I of Loan 2009-BHU(SF): *Rural Electrification and Network Expansion Project*, for $9.4 million, approved on 30 September 2003, funded by the Asian Development Bank.