India

Ex-Post Evaluation of Japanese ODA Loan
Dhauliganga Hydroelectric Power Plant Construction Project (I) (II) (III)

External Evaluator: Keishi Miyazaki and Junko Fujiwara, OPMAC Corporation

0. Summary

This project was implemented to cope with growing power and energy demand in the northern region of India by the construction of a hydroelectric power plant. Its objectives were highly relevant to India's development plan and development needs, as well as to Japan's ODA policy, therefore its relevance is high. Since the key operation and effect indicators such as maximum output, plant load factor, availability factor, and electric energy production met the targets, this project has largely achieved its objectives. Thus its effectiveness is high. However, there were constraints on the evaluation of the extent to which this project contributed to the improvement of the electricity supply in the northern grid due to the fact that the installed capacity of this project makes up less than 1% of the entire grid. Adverse impacts on natural and social environment remained at a minimum thanks to various actions implemented by the executing agency. There were positive impacts such as improvements in the natural environment and in people's living conditions in the upstream area. Although there were some changes in design, such as dam type, the project outputs were realized mostly as planned. Although the project cost was within the plan, the project period slightly exceeded it and therefore the efficiency of the project is fair.

This project's organizational, technical and financial sustainability is high and the project is well operated and the facilities well maintained. In light of the above, this project is evaluated to be highly satisfactory.

1. Project Description

Project Location

Reservoir and Underground Power House

1.1 Background

Electricity demand in India showed rapid growth of as much as an annual average of 5.2% since 1996. The country, however, has suffered from severe electricity shortages due to deterioration of the financial condition of state electricity utilities and sluggish private sector involvement, which has meant that there has not been adequate investment in infrastructure. In response to this, the Indian Government began to concentrate on the effective utilization of the generation facilities owned by the central government in each state, the rehabilitation and modernization of existing power generation plants to secure energy production and to cope with peak demand, the development of new generation facilities with foreign assistance, and the improvement of transmission and distribution networks.

The northern electricity grid of India extends to Uttar Pradesh, Rajasthan, Punjab, Haryana, Himachal Pradesh, Jammu Kashmir and the National Capital Territory of Delhi[1], where electricity deficit has been as severe as anywhere in the entire country. Against 19,240 MW at peak demand, the electricity supply remained at 12,455 MW (64.8%) in 1993[2]. The electricity supply in the same year was 90,106 GWh against the required amount of 102,416 GW (a shortage of 12%). Coping with the growing energy demand thus required immediate action from the Indian Government.

1.2 Project Outline

The objective of this project was to cope with growing power and energy demand in the northern region of India by the construction of a 280 MW (4 X 70 MW) hydroelectric power plant on the River of Dhauliganga, a tributary of Sarda River in Darchula sub-division of Pithoragarh District, Uttarakhand State, thereby contributing to the improvement of people's living standards, to industrial development, employment creation and fuel diversification for power generation in the region.

Loan Approved Amount/ Disbursed Amount	1st Phase: 5,665 million yen / 4,976million yen 2nd phase: 16,316 million yen / 16,312 million yen 3rd phase: 13,890 million yen / 12,048 million yen
Exchange of Notes Date/ Loan Agreement Signing Date	1st Phase: January 1996 / January 1996 2nd phase: October 1997 / December 1997 3rd phase: March 2004 / March 2004
Terms and Conditions Interest Rate, Repayment Period (Grace Period) and Conditions for Procurement	1st Phase: 2.3%, 30 years (10 years), general untied 2nd phase: 2.3%, 30 years (10 years), general untied 3rd phase: 1.3%, 30 years (10 years), general untied
Borrower / Executing Agency	NHPC Ltd. / NHPC Ltd.
Final Disbursement Date	1st Phase: May 2002 2nd phase: September 2004 3rd phase: July 2009
Main Contractor (Over 1 billion yen)	Hindustan Construction Company Ltd (India) / Samsung Corporation (Korea), Kajima Corporation (Japan) / Daewoo Corporation (Korea)
Main Consultant (Over 100 million yen)	Nippon Koei Co., Ltd. (Japan) / Electrowatt Engineering Services Ltd (Switzerland) / Electrowatt Engineering Ltd (Switzerland)
Feasibility Studies, etc.	"Master Plan for the Dhauliganga River Hydro Development" NHPC Ltd., 1985 "Detailed Project Report for the Dhauliganga River Hydro Development" Swedpowser, July 1985
Related Projects	"Northern India Transmission System Project" ODA Assistance Loan

[1] Part of Uttar Pradesh State became an independent state called 'Uttaranchal' in 2000, which was later renamed as Uttarakhand. As of 2011, Uttarakhand State and the Union Territory of Chandigarh are among those connected in the northern grid.
[2] The Indian fiscal year starts in April and ends in March.

2. Outline of the Evaluation Study

2.1 External Evaluator

Keishi Miyazaki and Junko Fujiwara, OPMAC Corporation

2.2 Duration of Evaluation Study

Duration of the Study: August 2011 – June 2012

Duration of the Field Study: 20 November – 10 December 2011. 11 – 21 March 2012

2.3 Constraints during the Evaluation Study

Not applicable.

3. Results of the Evaluation (Overall Rating: A[3])

3.1 Relevance (Rating: ③[4])

3.1.1 Relevance with the Development Plan of India

The Eighth Five Year from 1992/1993 to 1996/1997 laid emphasis on: i) improvements in the operation of the existing generation units and other plants and equipment, ii) reduction of transmission and distribution losses, iii) improvement in the financial performance of central and state electricity bodies, iv) promotion of capacity additions to the existing installed generation capacity, and v) attraction of private investment for power development[5]. Out of a total investment in the public sector of 4,341 billion Indian rupees, investment in the energy sector, 1,155.6 billion rupees, had the biggest ratio of 26.6%. The share of electricity in the energy sector was 795.9 billion rupees, which amounted to 18.3%[6].

The Government of India had the Eleventh Five Year Plan in place (2007/2008 to 2011/2012) at the time of this ex-post evaluation study. The Government projected that the gross electricity requirement by the end of the Eleventh Plan for power would be 1,097 GWh while the peak demand estimation was 158,000 MW. To fulfill the estimated electricity demand requirement, a capacity addition program was planned in order to increase the total by 78,577 MW during the period[7]. Out of 36,447.2 billion rupees of a total investment in the public sector, the Government allocated 8,541.2 billion rupees for the energy sector, which comprises 23.4% of the public sector investment of the Plan[8].

It is thus concluded that this project was highly relevant to India's development plan and its power sector development plan at the time of project appraisal as well as at the time of the ex-post evaluation study.

3.1.2 Relevance with the Development Needs of India

The Central Electricity Board projected that both electricity demand and peak demand would grow annually by as much as 6% on average from 1997/98 to 2012/13. Energy consumption in the northern region was immense with electricity demand and peak demand the biggest of all regions, as shown in Table 1 (129,587 GWh and 24,234 MW respectively). Second to the northern region was the western region.

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3 A: Highly satisfactory, B: Satisfactory, C: Partially satisfactory, D: Unsatisfactory

4 ③: High, ② Fair, ① Low

5 Planning Commission, Government of India. "Eighth Five Year Plan" (1992).

6 Oil (240 billion rupees: 5.5%), coal (105.1 rupees: 2.4%) and renewable energy (14.7 rupees: 0.3%) were also parts of the energy sector.

7 Planning Commission, Government of India. "Eleventh Five Year Plan (2007-2012), Volume I Inclusive Growth" (2008).

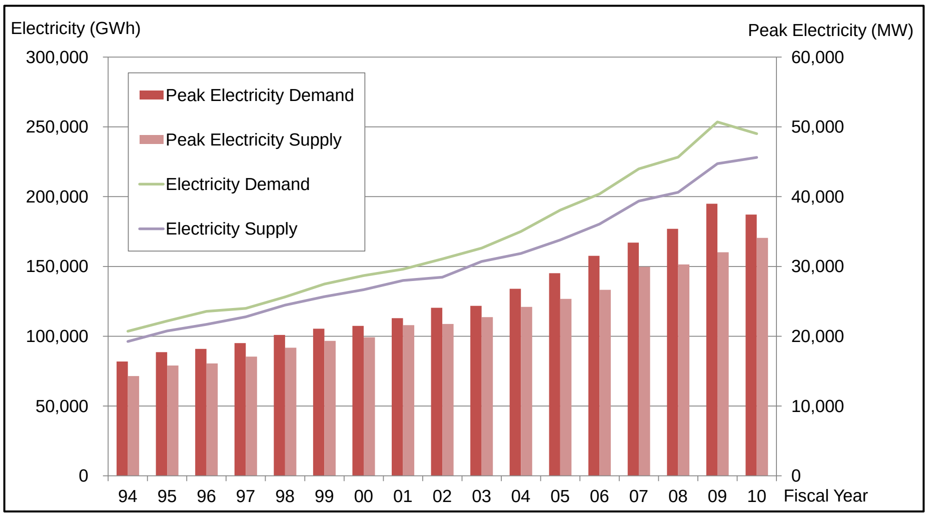
8 The social sector accounts for the biggest amount: 11,234 billion rupees (30.2%) in the Plan.

Table 1: Forecast of Electricity Demand and Peak Demand by Region (1996/97)

Regions	Electricity (GWh)	Peak Electricity (MW)
Northern	129,587	24,234
Western	121,159	19,587
Southern	103,191	18,150
Eastern	56,011	10,254
North-Eastern	6,169	1,388
Islands	157	43
Country	416,274	73,656

Source: Central Electricity Authority. 14th Electric Power Survey (1991)

According to the data provided by NHPC, electricity demand and peak demand in the northern region continued to increase (Figure 1). Power demand reached 245,137 GWh in 2010/11 while peak demand reached 37,431 MW. The power supply on the other hand saw a deficit of as much as 16,958.8 GWh (6.93%) and peak power lacked 3,360 MW (8.92%). Out of power demand, 31% was for domestic consumers, 29% for industrial consumers, 22% for agricultural consumers, 10% for manufacturing consumers, and 8% for others.



Source: NHPC.

Figure 1 : Growth of Electricity and Peak Electricity and their Gaps

The total installed capacity of the northern region as of the end of March 2012 (Table 2) was 53,925 MW, which was second in size only to the western region. Although dependency on thermal generation is obvious (approximately 66%)[9] for the country as a whole, the hydro ratio in the northern region was approximately 30%, second to the north-eastern region[10]. The Eleventh Five Year Plan suggested the development of additional hydro power generation facilities with 16,533 MW in total[11], and potential hydro power remains one of the most important and abundant sources for power generation, especially to meet peak demand.

[9] Adding thermal power generation to the existing installed capacity was suggested at 58,644 MW in the Eleventh Five Year Plan.

[10] Uttarakhand, Jammu Kashmir and Himachal Pradesh are states where hydro power has a large share among all generation sources.

[11] Eleventh Five Year Plan (2007-2012), Volume III.

Table 2: Sources of Power Generation by Region (as of March 2012)

Regions	Hydro		Thermal		Nuclear		Renewable		Total	
	MW	%	MW	%	MW	%	MW	%	MW	%
Northern	15,122.8	28.04	32,791.8	60.81	1,620.0	3.00	4,391.4	8.14	53,925.9	100.00
Western	7,447.5	11.57	47,196.8	73.29	1,840.0	2.86	7,910.0	12.28	64,394.2	100.00
Southern	11,338.0	21.50	28,512.6	54.06	1,320.0	2.50	11,569.3	21.94	52,739.9	100.00
Eastern	3,882.1	14.77	22,005.1	83.71	0.0	0.00	398.7	1.52	26,285.9	100.00
North-Eastern	1,200.0	48.88	1,026.9	41.83	0.0	0.00	228.0	9.29	2,454.9	100.00
Islands	0.0	0.00	70.0	91.99	0.0	0.00	6.1	8.01	76.1	100.00
Country	38,990.4	19.51	131,603.2	65.84	4,780.0	2.39	24,503.5	12.26	199,877.0	100.00

Source: Central Electricity Authority.

3.1.3 Relevance with Japan's ODA Policy

At the time of the first appraisal in 1996, the Japanese Country Assistance Program for India had not yet been established by the Ministry of Foreign Affairs in Japan. However, based upon preceding studies and research as well as on policy dialogue between the Japanese and Indian governments, economic infrastructure development, particularly for power and transport infrastructure, was among the priority areas of Japan's ODA strategy for India at that time[12].

The current Japan's Country Assistance Program for India, formulated in 2006, also emphasizes economic infrastructure development, in which the power sector takes most priority[13] as seen in the Eleventh Five Year Plan of India.

It is thus concluded that the selection of this project was highly appropriate and relevant to Japan's assistance strategy.

This project has been highly relevant to India's development plan and development needs, as well as to Japan's ODA policy; therefore its relevance is high.

3.2 Effectiveness (Rating: ③)

3.2.1 Quantitative Effects (Operation and Effect Indicators)

Table 3 shows the major operation and effect indicators at Dhauliganga Hydroelectric Power Station from 2005/06 to 2011/12[14].

Although the design energy was 1,134GWh per year[15], the estimated gross electric energy production of Dhauliganga Power Station exceeded that figure. As for net electric energy production, NHPC and JICA agreed to set 1,110 GWh per year as a target. Gross energy

[12] The Ministry of Foreign Affairs. "Japan's ODA White Paper" (1998).

[13] The Ministry of Foreign Affairs. "Japan's Country Assistance Program for India" (2006).

[14] HPC and JICA agreed to apply net electric energy production, maximum output, plant load capacity factor, and forced power outage as the operation and effect indicators in the third appraisal in 2003. In this ex-post evaluation study, in addition to the above indicators, the evaluators also collected gross electric energy production, availability factor, planned outage hours, hydro utilization factor, annual total volume of inflow to the reservoir and volume of sedimentation in the reservoir for a more comprehensive analysis of the project effectiveness.

[15] In the Darchula area of Pithoragarh District where the Dhauliganga Power Station is located, there is a huge difference in rainfall between the monsoon season (June to September) and the dry season (December to March), which gives a seasonal gap in the volume of water inflow from the Dhauliganga River to the Dhauliganga dam. The Power Plant supplies base electricity in the monsoon period, and peak electricity during the dry season, when water inflow declines, according to order by the Northern Regional Load Dispatch Center. Moreover, the potential effect on electric energy production of silt sedimentation in the reservoir was also taken into account in the original design. Out of the designed production (1,134 GWh), 12% is given as free power to the homeland state (Uttarakhand).

production almost reached the estimated amount, except in 2006/07 and 2008/09. Net energy production exceeded the estimated amount except for the above two years. According to NHPC, the reason for lower achievement than the estimate in 2006/07 and 2008/09 was that there were forced outages due to problems with main inlet valve of turbines in 2006/07, while in 2008/09 there was less inflow in the river. In any case, planned production was almost achieved every year.

Table 3: Major Operation and Effect Indicators

Indicator		2005/06(1)	2006/07	2007/08	2008/09	2009/10	2010/1	2011/12(1)
Gross Electric energy Production (GWh per year)	Estimate (2)	279.00	1,191.75	1,197.10	1,191.75	1,155.00	1,144.56	1,151.68
	Actual	314.93	1,093.95	1,186.00	1,116.59	1,134.35	1,134.45	982.00
Net Electric energy Production (GWh per year)	Estimate	1,110.00	1,110.00	1,110.00	1,110.00	1,110.00	1,110.00	1,110.00
	Actual	313.99	1,089.14	1,173.52	1,103.70	1,124.04	1,117.43	967.44
Maximum Output	Estimate	280	280	280	280	280	280	280
	Actual	280	280	280	280	280	280	280
Plant Load Capacity Factor (%)	Estimate	45	45	45	45	45	45	45
	Actual	26.32	45.06	48.74	46.01	46.74	46.75	N/A
Availability Factor (3) (%)	Estimate (2)	94.79	94.79	91.59	92.93	86.97	87.00	93.74
	Actual	97.83	77.27	92.71	89.85	92.62	92.15	99.51

Source: NHPC.

Note 1: Figures for 2005 were collected from 1 October 2005 to 31 March 2006, and those for 2011 from 1 April to the end of October 2011.

Note 2: NHPC sets estimated figures for gross electric energy production and availability factor.

Note 3: Plant Load Factor = Net Electric energy Production / (Maximum Output X Hours per Year) X 100
Availability Factor = (Operation Hours per Year / Hours per Year)

The maximum output met the figures planned every year, and the plant load factor almost reached or exceeded the planned figures. The availability factor also almost reached the target except in 2006. The figures for the most recent two years were 92.62% in 2009/10 and 92.15% in 2010/11. According to the NHPC annual report, the average availability factor among all hydroelectric power plants owned by NHPC was 84.1% in 2009/10 and 85.2% in 2010/11. Those for Dhauliganga Power Station far exceeded these.

The total unplanned outage hours from 2007/08 to 2009/10 remained within the estimated hours (Table 4). Electric energy production reached around 90% of the estimate every year (Table 3) and exceeded the designed figure (1,134 GWh per year), so there has been no major effect seen on the operation of the power plant.

The major reasons for forced outages were mechanical failures: the non-opening of the wicket gate of the francis-type turbine[16], malfunction of resistance temperature detectors (RTDs)[17], and shear pin failure[18]. There were no unplanned outages due to human errors or other factors.

16 Spiral shaped inlet at the entry of the francis turbine. This adjusts the amount of water flow by changing the degree of openness to allow efficient turbine operation.

17 Wire wound and thin film devices that measure temperature. The hotter they become, the larger or higher the value of their electrical resistance.

18 A safety device designed to shear in the case of a mechanical overload preventing other parts from being damaged.

Table 4: Unplanned and Planned Outage Hours

Indicators			2005/06(1)	2006/07	2007/08	2008/09	2009/10	2010/1	2011/12(1)
Unplanned Outage Hours		Estimate (2006)	Actual						
		100 hrs/year	200.31	777.04	92.20	82.30	86.07	130.59	250.35
	Mechanical	90 hrs/year	200.31	777.04	92.20	82.30	86.07	130.59	250.35
	Human errors	0 hrs/year	0	0	0	0	0	0	0
	Others	10 hrs/year	0	0	0	0	0	0	0
Planned Outage Hours		Estimate(2)	1825:35:00	1825:35:00	2946:50:00	2477:20:00	4565:45:00	4551:10:00	2193:30:00
		Actual	277:42:00	8150:05:00	4104:50:00	5036:00:00	3834:15:00	3801:30:00	789:10:00

Source: NHPC.

Note 1: Figures for 2005 were collected from 1 October 2005 to 31 March 2006, and those for 2011 from 1 April to the end of October 2011.

Note 2: Total Planned Outage Hours refer to the total hours of planned outage of the four generation units. This estimate was set by NHPC.

Although the total outage hours far exceeded the plan from 2005/06 to 2008/09, they have been lower than estimate since 2009/10 (Table 4). This did not affect the amount of energy production. Major reasons for the planned outages were the annual maintenance of four units of generation facilities, less demand for power generation during the dry season, miscellaneous maintenance of breakdown equipment / parts and silt flushing of the reservoir every 15 days during the monsoon period. In some years the replacement of equipment parts was also among the reasons for planned outages.

The total volume of water inflow to the reservoir of the Dhauliganga Power Station remained at approximately 70 to 90% of the estimates (Table 5). The hydro utilization factor stayed at 64.9% (2010/11) to 84.55% (2009/10) against the estimate (61.26%). There has been no major effect up to now, and the annual energy production has almost been achieved.

The volume of silt in the reservoir was beyond estimate in 2006/07 and 2007/08, but has remained only 10% of the estimate since 2009/10. According to NHPC, the sharp decline in sedimentation since 2009/10 results from successful implementation of the catchment area treatment works, soil conservation works, river bank protection works, check-dam construction etc. (which were planned at the beginning of project design) together with a reduction of deforestation though improvements in local people’s traditional ways of living and means of making a livelihood. Silt reduction in the reservoir is essential to secure full functioning power plants and electric energy production, which significantly contributes to the project sustainability.

Table 5: River Water Flow, Hydro utilization Factor and Sedimentation in the Reservoir

Indicators		2005/06(1)	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12(1)
Annual Total Volume of Inflow to the Reservoir (m^3 / year)	Estimate(2)	2,546.50	2,546.50	2,546.50	2,546.50	2,546.50	2,546.50	2,546.50
	Actual	258.57	2,202.33	2,224.86	2,170.33	1,865.75	2,430.65	N/A
Hydro Utilization Factor(3) (%)	Estimate(2)	N/A	61.26	61.26	61.26	61.26	61.26	61.26
	Actual	N/A	69.08	74.13	71.53	84.55	64.90	66.86
Volume of Sedimentation in the Reservoir (m^3 / year)	Estimate(2)	N/A	300,000	300,000	300,000	300,000	300,000	300,00
	Actual	N/A	410,000	340,000	180,000	30,000	30,000	N/A

Source: NHPC.

Note 1: Figures for 2005 were collected from 5 November 2005 (start of commercial operation of all four generation units) to 31 March 2006, and those for 2011 from 1 April to the end of October 2011.

Note 2: NHPC sets estimated figures.

Note 3: hydro utilization factor = Net electric energy production / electric energy which could have been generated during the particular year ×100

3.2.2 Qualitative Effects

This project was intended to deal with growing power and energy demand in the northern region. However the installed capacity of the Dhauliganga Power Station (280 MW) had a share of only 0.86% at the start of its commercial operation in 2005/06, and this declined to 0.62% in 2009/10. The effect therefore was limited.

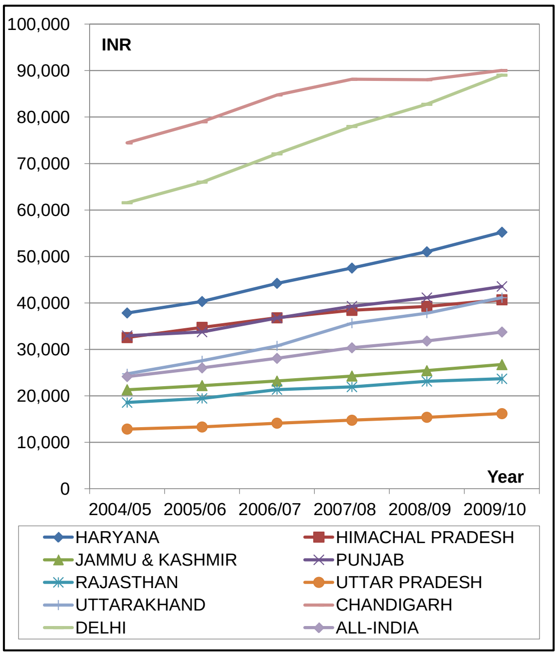
3.3 Impact

3.3.1 Intended Impacts

(1) Impact on Economic Development such as Employment Creation in the Northern Region

Figure 2 shows the per capita net state domestic product (NSDP) at constant prices and the per capita national net domestic product (NNDP). Delhi, Chandigarh, Haryana, Uttarakhand are among the fastest growing economies in the region. The per capita NSDP of Uttarakhand, where the Dhauliganga Power Station is located, was 24,740 rupees, which was almost same as NNDP (24,143 rupees). This grew as much as 41,126 rupees in 2009/10, which far larger than NNDP (33,731 rupees).

However, as described in the above 3.2.2, the installed capacity of the Dhauliganga Power Station had a share of 0.86% in 2005/06 and 0.62% in 2009/10, and therefore the impact in the northern region has been limited.



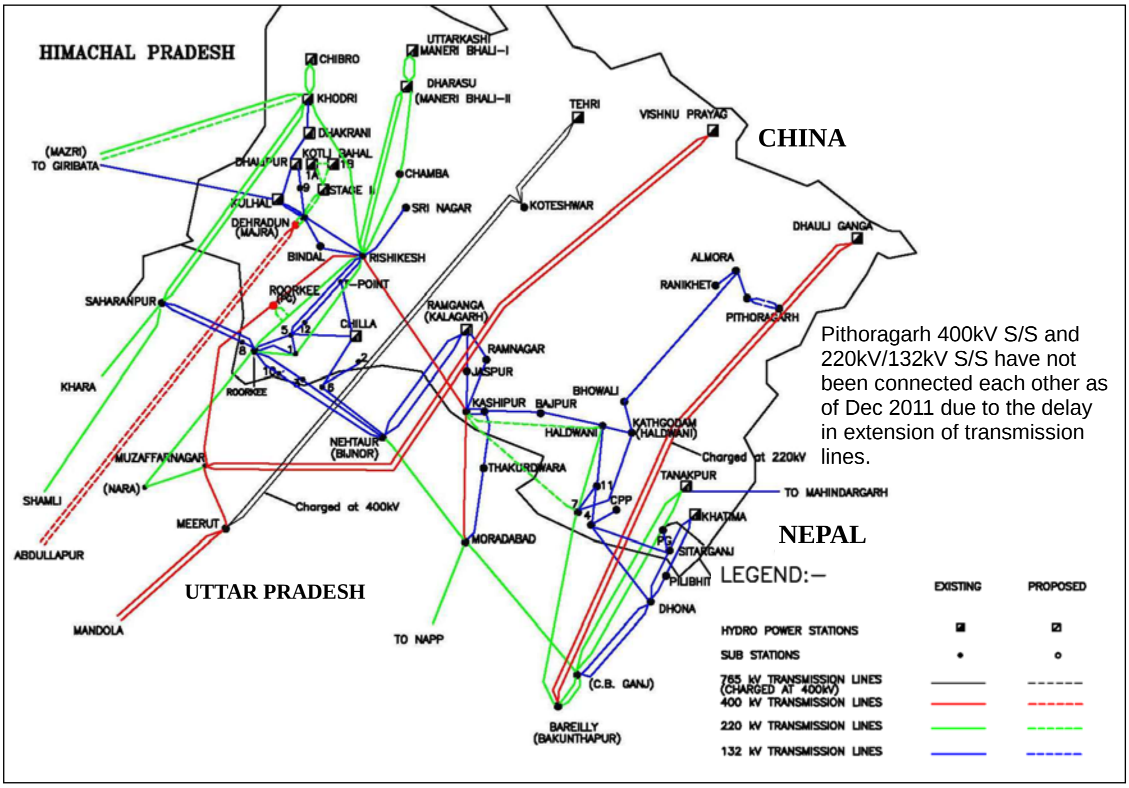
Source: Reserved Bank of India. "Handbook of Statistics on Indian Economy 2010-2011" (2011).

Figure 2: Per Capita Net State Domestic Product at Factor Cost - State-wise (At Constant Prices)

The electric energy produced at the Dhauliganga Power Station is supplied to the Bareilly 400 kV Substation [19] in Uttar Pradesh which is 233 km away through two double circuit lines (Figure 3). One of the two lines is connected to the Pithoragarh 220 kV Substation at a point 59 km from the power station, but as of December 2011, the substation had not yet started supplying electricity directly to the Pithoragarh District since the PGCIL had not completed the extension of transmission lines to reach the Pithoragarh 132 kV S/S from which the surrounding people should have received electric energy. The electric energy therefore goes through Bareilly S/S, Haldwani S/S and other substations to reach entire northern region including Pithoragarh. It is therefore not possible to see the degree of the project's contribution to the Uttarakhand State itself.

The impact on economic development such as employment creation in the northern region has thus not been analyzed due to difficulties in measurement.

[19] The transmission line between the Dhauliganga Power Station and Bareilly 400 kV Substation was extended by the Northern India Transmission System Project with the JICA ODA assistance loan of 1996 (disbursed amount: 3,726 million yen). The executing agency was the Power Grid Corporation of India Limited (PGCIL). JICA conducted an ex-post evaluation for the project in 2008 by employing a third-party evaluator.



Source: Power System Operation Corporation Ltd., Northern Regional Load Dispatch Centre (2011). Annual Report 2010-2011.

Figure 3: Power Map of Uttarakhand State

(2) Impact on Industrial Development in the Northern Region

As stated above (1), the impact on industrial development in the northern region has not been analyzed due to difficulties in measurement.

(3) Impact on the Improvement of People's Living Standards in the Northern Region

As of December 2011, the electric energy produced at the Dhauliganga Power Station has not directly been supplied to the surrounding area in the Pithoragarh District. It instead goes to the Bareilly 400 kV Substation, the Haldwani Substation, and thence to other substations to be distributed to the entire northern region. It is therefore difficult to identify particular beneficiaries. The impact on the improvement of people's living standards in the northern region has thus not been analyzed due to difficulties in measurement.

(4) Impact on Fuel Diversification for Power Generation in the Northern Region

As described above, the share of the installed capacity of the Dhauliganga Power Station is negligible, and therefore the impact on fuel diversification for power generation in the northern region has been limited.

As of March 2012, the installed capacity of hydro and thermal generation facilities accounted for 30% and 60% of the total capacity of the northern region.

3.3.2 Other Impacts

(1) Impacts on the Natural Environment

・ Impact on the entire catchment area

Although the project site was located in a sanctuary as stipulated by the Ministry of

Environment and Forests, there no valuable fauna and flora existed in the project site itself[20], and NHPC and the contractors were aware of the importance of minimizing adverse impacts on animals and plants during explosion works in the construction period. Contractors undertook landscaping and restoration works for muck disposal sites and quarry areas, as stipulated in the contract agreement, both in and around the dam and power house.

Based on the Environmental Action Plan completed by NHPC in March 1995, NHPC implemented i) a compensatory afforestation scheme, ii) a catchment area treatment plan, and iii) a rehabilitation & resettlement plan as follows. They also focused on the reduction of silt sedimentation in the reservoir.

i) Compensatory Afforestation Scheme

Prior to project implementation, the Uttar Pradesh Social Forest Department implemented a 7.4 million rupee compensatory afforestation scheme in 140 ha of non-forest land during 1994 and 1996. Seedlings / saplings were provided by the department.[21].

ii) Catchment Area Treatment Plan

1,571 ha of plantation with 1.85 million of seedlings, soil conservation works, check-dams (1,940 nos in total), agricultural terraces (370 ha), river training works, water detention tanks (167 nos), river bank protection (64 km in total) were planned and implemented by the Forest Department of Dehradun and implemented from 2001 to 2006, which at a cost of approximately 70 million rupees.

Life improvement programs, technical training in agriculture and free fuel supplies of LPG, diesel stoves, and electric heaters to replace firewood were also provided for local people living in upstream and in the area surrounding the dam, powerhouse and colonies.

iii) Rehabilitation and Resettlement Plan

NHPC improved the basic infrastructure required for a better living environment for local people, and it provided direct employment opportunities to members of the 37 fully affected families out of the total 581 project affected households (See (2) below for details).

A comparison of the remote sensing data[22] from 1999 and 2004 obtained during the site survey in this ex-post evaluation indicates that forest areas had rapidly increased in the catchment area and that soil erosion had been mitigated. Such positive impacts in the catchment area also had helped reduce the suspended load inflow into the reservoir consequently.

Forestry activity has been succeeded and integrated into the CSR program for the Dhauliganga Power Station. Between 2007 and 2011, 32,000 of trees, flowers and fruit trees have been planted in around the upstream area and in the areas surrounding area of the dam, powerhouse and colonies from 2007 to 2011.

・ Impact on Water Quality

NHPC regularly conducts water quality tests at the following six sites around the dam and power house area of the Dhauliganga Power Station: i) the confluence point of tailrace tunnel (TRT) with the main river channel, ii) downstream of the dam, iii) at the dam gallery, iv) at the tail end of the reservoir, v) at the service bay of the power station, and vi) upstream of the dam reservoir. The test parameters are: temperature, conductivity, salinity, pH, turbidity, total

[20] Confirmed at the first appraisal in 1995, another environmental appraisal was carried out in the third appraisal in 2003. It was then concluded that there was no such protected or endangered species (JICA appraisal documents).
[21] Managed by Uttar Pradesh State as Uttarakhand Sate was separated in 2000.
[22] Provided by NHPC.

dissolved solids, chlorides, Ca, Mg, alkalinity, Nitrate- nitrogen, DO, COD, Iron, and bacteria etc. There have been no major problems in the water quality tests, and thus no negative impact has been observed.

(2) Land Acquisition and Resettlement

The total land acquired for the project was 166.7 ha (138.6 ha of forest land and 28.15 ha of private owned land), and the submergence area was 28.6 ha. 581 families around the reservoir and dam site were affected in the execution of the project ("project affected households"), out of whom 37 were "fully affected families for resettlement" (22 lost more than 50% of their lands / houses and 15 became houseless).

NHPC was open and shared all manners of information related to these families, and examined alternatives for the project affected households to choose which type of compensation they preferred. The local government also extended affirmative actions to the project affected people. As a result of a long-term comprehensive consultation process, 35 families out of 37 fully affected families for resettlement decided to resettle and rehabilitate their own livelihoods by themselves and received cash compensation for their land and property. The remaining two asked NHPC to provide accommodations to their satisfaction. NHPC provided job opportunities at the Dhauliganga Power Station to 37 members from the 37 families. The remaining 545 project affected households were provided with compensation for their land and property through the Land Acquisition Officer of the District. The total amount spent on compensation amounted to 66.99 million rupees (land: 29.5 million, houses: 17.4 million, fruit trees: 5.9 million, others: 13.19 million, and registration costs: 20,000 rupees).

The land acquisition and resettlement were executed as planned, and there was no delay to or effect on the project design caused by social impacts.

NHPC continued CSR activities after the construction was over, to sustain / promote further communication with project affected people and other people in the local area. Various assistances have been provided such as scholarships for children, eye camps, river bank improvement, blankets during wintertime and rice for poor villagers.

(3) Impact on Local People in Downstream of the Dam

A series of local surveys, focus group discussions, in-depth interviews and household interviews with the project affected people, was conducted in this ex-post evaluation. The survey outcomes suggested significant positive effects on the affected households and the community as a whole. Those surveyed reported a significant overall improvement in hygiene in their living environment, an increase in their income levels through new employment opportunities given to them, and improvements in their children's educational environment.

25 of 28 households said that resettlement had had good impact on their lifestyles and livelihoods, and 16 households felt very comfortable in their new neighborhoods. NHPC says that they reflect local people's views and take their opinions into the CSR plan every year. Consultation is on-going and actions taken when required.

Interview Survey with the Project Affected People

Survey Date: November 2011
Venue: Nigalpani, Chirkela, Tapovan, Jamuka villages of Dharchula town
Survey Method: The survey used household interviews, focus group discussions, and case studies to gather information.

The main focus of this survey was 37 "fully affected" and displaced households. However, nine of these households had moved out of their original villages and could not be reached.

Of the remaining 28 households covered, 18 household members were still employed at NHPC, while10 households had retired from jobs provided by NHPC. All the project-affected households were well compensated in the form of cash and employment as per the restoration and rehabilitation commitment of the project. They restored their livelihoods by purchasing new land and building houses which had the basic infrastructure of LPG and electricity supply facilities ready and available. Income stream analysis suggested that all 28 households had annual incomes above 300,000 rupees per annum.

90% of the interviewed households agreed that resettlement has had a good impact on their lifestyle and livelihood. In the rehabilitation sites, around 60% of households felt very comfortable in their neighborhoods, and felt very secure while outside their homes. This indicates that project-affected households felt socially secure in the post-displacement period. Roads in and around the study villages however are in need of repair.

This project has largely achieved its objectives; therefore its effectiveness is high. However, there were constraints in evaluating to what extent this project contributed to the improvement of the electricity supply in the northern grid due to the fact that the installed capacity of this project made up less than 1% of the total. Adverse impacts on natural and social environment have remained at a minimum through a series of actions implemented by the executing agency. There have been positive impacts such as improvements in the natural environment and in people's living conditions in the upstream area.

3.4 Efficiency (Rating: ②)

3.4.1 Project Outputs

The aim of this project was to construct a 280 MW hydroelectric power station in the Pithoragarh District of Uttarakhand State. The major planned outputs were: reservoir (gross storage volume: 6.2 million m^3, max reservoir level: 1,348.5 above sea level), rock-fill dam (max height above river bed level 56 m, length of dam crest 270 m), spillway with three gated sluices (10 m high X 6 m wide), river diversion tunnel, headrace tunnel intake structure, de-silting chamber, surge shaft, pressure shaft, underground power house (4 X 70 MW with francis type of turbine, rated net head: 297 m), tailrace tunnel, tailrace surge gallery, consulting services (117 man/month), and a Panel of Experts (45 man/month).

Major changes in the actual outputs were of dam type and the number of gated sluices of the spillway[23]. Other changes were minor ones and most outputs were realized as planned.

Source: Evaluation Study Team

Picture 1: Spillway

As for the manning schedule of consulting services, 115 man/month was used against the planned 117, in which consultants conducted technical reviews and the finalization of the bid level of the project and of the tender documents. NHPC built a project office for supervision with in-house units for design, construction, quality control and monitoring.

[23] The dam type was changed to a concrete faced rock-fill dam mainly because of the physical difficulty in obtaining construction materials (clay core) around and in the suburbs of the project site, and because of the financial inefficiencies in purchasing and transporting raw materials from remote areas. Based on the technical advice of the POE, the dam design was changed, its technical viability confirmed. Slope failure on the right bank due to unforeseeable physical conditions also meant changes in spillway design. A two-bay spillway was constructed in place of a three-bay, and the requirement for the last bay was fulfilled by modifying an existing diversion tunnel into a tunnel spillway.

The Panel of Experts was comprised of foreign engineers: a geologist, a hydro-mechanical engineer, an electro-mechanical engineer, a civil engineer, an environmental expert, a hydrologist, and a hydraulist. Five of these were expected to visit the project site four times a year on average to solve any technical problems occurring during the construction period, to maintain quality management, and to give technical advice for smooth implementation. For this, 6.5 man/month was used against the planned 45. According to NHPC, the POE played a significant role in solving technical obstacles. They examined and confirmed technical viability in changing the dam type, and modifying the third spillway design. They gave technical advice on various issues of the plan, design and execution of the project, which significantly promoted the smooth project implementation process.

3.4.2 Project Inputs

3.4.2.1 Project Cost

The actual project cost was 47,541 million yen, which was 89.8% of the planned cost of 52,968 million yen[24]. The disbursed amount of ODA loan was 33,336 million yen in total against 35,871 million yen, which was also within the plan (92.9%).

Table 6: Planned and Actual Project Cost

	Plan			Actual
	Foreign Currency (Mil. Yen)	Local Currency (Mil. INR)	Total (Mil. Yen)	Total (Mil. Yen)
1. Preparation works	-	1,410	4,075	686
2. Civil work	12,361	1,390	16,380	25,191
3. Metal work	523	-	523	
4. Electro-mechanical work	8,033	-	8,033	6,146
5. Land acquisition	-	119	344	562
6. Administration costs	-	1,259	3,637	9,476
7. Tax and duties	-	857	2,476	
8. Price escalation	2,746	2,266	9,293	
9. Contingency	1,875	441	3,151	2,028
10. Consulting services / Panel of Experts	669	18	721	482
11. Interest during construction	4,355	-	4,335	2,970
Total	30,542	7,760	52,968	47,541

Source: JICA appraisal documents and NHPC.

Note 1: The cost estimate at the first appraisal in 1995 was deemed as the planned cost for plan-actual comparison in this ex-post evaluation. The exchange rate was INR 1 = JPY 2.89 (April 1995).

Note 2: Taking into consideration the fact that there had been wide ranges of fluctuation between the INR and USD, and the JPY and USD exchange rates during the project period, exchange rates applied for converting the actual cost into Japanese yen were taken from the average annual rates issued by IMF at the International Financial Statistics; Yearbook from 1995 to 2005.

Note 3: As there was no common definition of the expenditures of foreign currency and local currency, a comparison between planned and actual cost in two currencies was not viable.

Due to additional civil work after the slope failure on the right bank and construction of the tunnel spillway, together with road widening and the strengthening of bridges for the transportation of construction equipment and heavy machinery, the actual cost in Indian rupees, 18,589 million rupees, exceeded the planned project cost of 15,783 million rupees sanctioned by the Indian Government in 2000. However, the yen value steadily appreciated against the Indian rupee throughout the project implementation period, which resulted in a lower cost than planned when converted into Japanese yen.

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[24] The cost estimate at the first appraisal in 1995.

3.4.2.2 Project Period

The actual project implementation period was 119 months from January 1996 (project start[25]) to November 2005 (project completion[26]) against the 105 months of planned project period from January 1996 to September 2004 (113%). This was slightly longer than planned.

Table 7: Comparison of Planned and Actual Project Period

	Plan	Actual
Signing of first loan agreement	Jan 1996	Jan 1996
Selection of consultants	Jan 1996 to July 1997	Sep 1996 to Jun 1997
Detailed Design Study	Jul to Dec1997	Jul 1997 to May 1998
Review of pre-qualification and tender documents	Sep to Dec 1997	
Preparation for tender	Dec 1997 to Jun 1999	Oct 1998 to Dec 1999
Services of Panel of Experts (POE)	Oct 1998 to Sep 2004	May 1998 to Oct 2005
Prequalification	Oct 1997 to Feb 1998	May to Oct 1998
Tender / contracts	Feb 1998 to Jun 1999	Oct 1998 to Feb 2000
Supplemental survey on Glacier Lake Outburst Flood (GLOF)	Jun 1997 to Mar 1998	2000 to 2001
Preparation works	Apr 1995 to Mar 1997	1998 to 2000
Civil works	Aug 1998 to Nov 2003	Jan 2000 to Jan 2005
Hydro-mechanical works	Jun 1999 to Feb 2003	Feb 2000 to Oct 2005
Electro-mechanical works	Jun 1999 to Oct 2001	Feb 2000 to Nov 2005
Extension of transmission lines and substation	Jun 1999 to May 2003	Dec 1997 to Jul 2005
Commissioning	Unit 1: Dec 2003 Unit 2: Mar 2004 Unit 3: Jul 2004 Unit 4: Sep 2004	Unit 1: Nov 2005 Unit 2: Nov 2005 Unit 3: Oct 2005 Unit 4: Nov 2005

Source: JICA appraisal documents and NHPC.

The major factor causing delay in construction start was the receipt of clearances from Central Government. NHPC was required to receive various clearances from relevant authorities: the Techno Economic Clearance (TEC) was issued in 1988 from the Central Electricity Authority (CEA) prior to JICA's involvement. Another clearance from the Public Investment Board (PIB) was issued in 1991. The last clearance from the Cabinet Committee on Economic Affairs (CCEA) was issued in 2000.

Time overrun of the construction period was caused by a delay of eight months in the spillway construction works due to slope failure on the right bank and the resulting design change. Delays were also caused by the change in surge shaft type, and the delay in the extension of transmission lines. Leakages were observed from the headrace tunnel when it was tested in March 2005, and repair works there lasted until July in the same year. The Power Grid Corporation of India Ltd (PGCIL) completed the extension works of the transmission lines to the Dhauliganga Power Station at the end of July 2005.

3.4.3 Results of Calculations of Internal Rates of Return (IRR) (for ODA Loan project)

3.4.3.1 Financial Internal Rate of Return

FIRR as calculated at the first appraisal (1995) and at the second appraisal (1997) was 7.24%. At the third appraisal (2003), it was recalculated as 8.5%. FIRR calculations were based upon the preconditions below. The result of recalculation of FIRR for the project at the

[25] The project start was defined as the signing of the first loan agreement.

[26] The project completion was defined as the commissioning date of commercial operation of all four generation units.

time of the ex-post evaluation was 8.93%[27].

	1st Appraisal and 2nd Appraisal	3rd Appraisal
FIRR	7.24%	8.5%
Cost	Construction cost, O&M cost	Construction cost, O&M cost
Benefit	Revenue of electricity sales	Revenue of electricity sales
Project Life	25 years after commencement of commercial operation	25 years after commencement of commercial operation

3.4.3.2 Economic Internal Rate of Return

EIRR as calculated at the first and the second appraisals was 12.83%. It was recalculated as 15.6% in the third appraisal.

Due to difficulties in collecting the necessary information and data regarding the benefits for the recalculation of EIRR, the ex-post evaluation did not undertake a recalculation of EIRR. The EIRR calculations at appraisals were based upon the preconditions below:

	1st Appraisal and 2nd Appraisal	3rd Appraisal
EIRR	12.83%	15.6%
Cost	Project cost	Construction cost excluding taxes and duties, O&M cost
Benefit	Cost required for alternative project implementation (construction cost and O&M cost of a coal thermal power plant at same scale)	Long-term marginal cost
Project Life	25 years after commencement of commercial operation	25 years after commencement of commercial operation

Although the project cost was within the plan, the project period slightly exceeded it, therefore the efficiency of the project is fair.

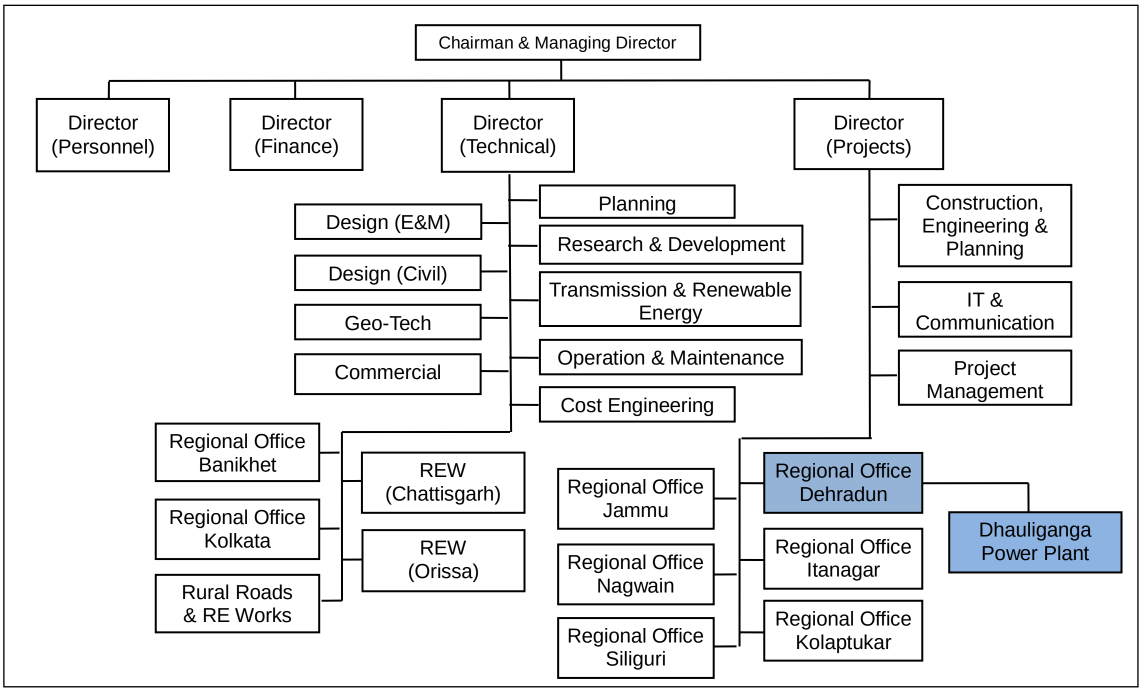
3.5 Sustainability (Rating: ③)

3.5.1 Structural Aspects of Operation and Maintenance

The operation and maintenance (O&M) agency of this project is NHPC Ltd. The total number of employees at NHPC was 11,000 as of November 2011, topped by the Chairman and Managing Director, Directors in personnel, finance, technical and projects departments were allocated and underneath them were regional offices and power stations. The total electric power generated by NHPC power stations increased year by year, from 12,567 GWh (2005/06) to 18,606 GWh in 2010/11. The following figure shows NHPC's organizational structure.

NHPC owned twelve power stations nationwide as of March 2011. Out of these, the Dhauliganga Power Plant was supervised by the Dehradun Regional Office located in the Uttarakhand State capital. The power station had 303 employees as of the end of November 2011: 68 executives including the general manager, chief engineer, senior managers, managers and others; 26 supervisors such as junior engineers; 201 highly skilled, skilled and unskilled workmen and eight paramedic staff. In addition, 270 local residents were also employed.

[27] NHPC submitted a project completion report to the Planning Commission of the Central Government at the end of October 2009, in which they calculated FIRR and EIRR as 9.05% and 9.27% respectively.



Source: NHPC
Note: Concerned departments are extracted related to this project.

Figure 4: Organizational Structure of NHPC

3.5.2 Technical Aspects of Operation and Maintenance

NHPC has received both international and domestic awards in the past. Thorough quality management, environmental management, and safety and health management has been applied at NHPC corporate office in Faridabad, at regional offices and power stations, and it has been certified for ISO9001:2008 (Quality Management System), ISO14001:2004 (Environmental Management System), OHSAS 18001:2007 (Occupational Health and Safety Management Systems) for its corporate office in Faridabad and for 14 locations including all power stations and a number of regional offices. NHPC has further gone ahead to integrate the above systems under the Integrated Management System (IMS)/PAS 99. NHPC was awarded 'Best Human Resource Management' in 2011 and others in India.

NHPC has provided training opportunities for its employees. A total of 145 staff participated in outside training courses, and 894 staff joined internal training programs in 2010/11. Courses vary from technical skill improvement, to those covering environmental aspects, financial management, labor law etc. In 2010/11, 98.5% of O&M staff at the Dhauliganga Power Plant enrolled and completed training courses on O&M. NHPC even provides African trainees with training courses on operation and maintenance of hydroelectric power stations

Therefore, there is no particular problem in the technical aspects of NHPC.

3.5.3 Financial Aspects of Operation and Maintenance

Table 8 shows the O&M budget and expenditure of the Dhauliganga Power Plant from 2005/06 to 2011/12. According to Dhauliganga, they request budget allocation with minimum amount, and its corporate office then allocates the approved amount, which is part of reason for the fact that the actual expenditure exceeds budget every year. However, the Dhauliganga Power Station sells electric energy to the power utilities throughout the northern region, and its sales revenue is large enough to settle all the O&M cost.

Table 8: O&M Budget and Expenditure of Dhauliganga Power Station

Unit: Million Rs.

2005/06		2006/07		2007/08		2008/09		2009/10		2010/11		2011/12*	
Plan	Actual	Plan	Actual	Plan	Actual	Plan	Actual	Plan	Actual	Plan	Actual	Plan	Actual
453.4	592.6	1,207.1	1,292.8	1,228.8	2,188.5	1,308.5	3,046.3	2,146.9	2,288.1	2,180.3	3,968.6	2,258.9	1,628.4

Source: NHPC

Note: Figures for 2011were collected from 1 April to the end of October 2011.

As of 2011, the Dhauliganga Power Station sold electricity to eight states and two union territories (Delhi, Chandigarh, Uttar Pradesh, Jammu & Kashmir, Punjab, Jaipur, Rajasthan, Uttarakhand, Haryana, and Himachal Pradesh)[28]. Energy sales had increased steadily for consecutive six years, reaching 3,116 million Rs. in 2010/11 (Table 9).

The electricity tariff is decided based on the regulations of the Central Electricity Regulatory Commission[29], and the tariff for the electricity sold from Dhauliganga was Rs. 2.68 / kWh as of November 2011.

Table 9: Profit and Loss of Dhauliganga Power Station

Unit: Million Rs.

	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11
Income	939.6	1,794.9	3,039.6	3,810.1	3,010.3	5,187.3
Of which energy sales	*903.8*	*1,744.8*	*2,028.9*	*2,265.7*	*2,837.1*	*3,116.2*
Expenditure	592.6	1,292.8	2,188.5	3,046.3	2,288.1	3,968.6
Of which generation administration and other expenses	*80.6*	*199.6*	*134.4*	*24s6.4*	*389.2*	*297.1*
Of which Depreciation	*200.0*	*410.8*	*403.9*	*471.6*	*976.5*	*938.7*
Profit before Tax	347.2	502.1	851.1	763.9	722.2	1,218.7
Profit after Tax (Net Profit)	347.0	494.5	794.2	761.6	721.6	1,150.7

Source: NHPC.

Profit and loss figures for NHPC and its subsidiary companies including Dhauliganga, shows that the whole group has increased sales and income as well as profit (Table 10). Return on Assets (ROA) has remained at around 4 to 5% (Table 11), which indicates that long-term profitability is secured.

28 Energy sales to the Uttar Pradesh Power Corporation Ltd. and the Punjab State Electricity Board account for over 40%.

29 The Central Government and State Governments have worked since late 1990 on power sector reforms resulting in the establishment of regulatory bodies, improvements in transparency and avoidance of political intervention in regulating tariff structures, improvements in the management of distribution companies by utilizing private investments, and the abolition of state subsidies. The Central Electricity Regulatory Commission (CERC) was established in July 1998, and the current electricity sales price follows a tariff structure for 2009 to 2014 as stipulated in the Notification No.L-7/145(160)/2008-CERC (dated 19 Jan 2009).

Table 10: Profit and Loss of NHPC Group

Unit: Million Rs.

	2007/08	2008/09	2009/10	2010/11
Income	34,298.3	40,720.4	57,945.5	59,507.4
Of which energy sales	*29,821.0*	*35,334.9*	*51,638.7*	*49,166.6*
Expenditure	18,984.9	25,802.7	30,392.5	33,499.9
Of which generation administration and other expenses	*3,235.7*	*3,690.8*	*2,919.0*	*5,851.5*
Of which depreciation	*5,455.4*	*6,440.7*	*12,683.5*	*11,665.5*
Profit before Tax	15,313.4	14,917.7	27,553.0	26,007.5
Profit after Tax (Net Profit)	12,994.4	13,310.9	22,775.6	24,627.7

Source: NHPC. Annual Report (2008-09, 2009-10, 2010-11)

NHPC and its subsidiary companies have shown favorable figures in their current ratio and fixed ratio. Total equity has exceeded total liabilities, and the equity to assets ratio also shows good figures, which indicates a high solvency of the NHPC group. Budget allocation and financial back-up for the Dhauliganga Power Station is thus secured in the long-run.

Table 11: Major Financial Indicators of NHPC Group

	2007/08	2008/09	2009/10	2010/11	2011/12	Notes
Current Ratio	145.86%	135.68%	208.31%	142.87%	N/A	Current Assets / Current Liabilities
Fixed Ratio	143.44%	151.35%	128.78%	134.01%	N/A	Fixed Assets / Equity
Equity to Assets Ratio	57.58%	54.29%	56.95%	56.29%	N/A	Equity / Assets
Return on Assets	4.08%	3.57%	5.56%	4.92%	N/A	Ordinary Profit / Assets

Source: NHPC Annual Report (2008-2009, 2009-2010, 2010-2011)

The profit and loss, and financial status of NHPC and the Dhauliganga Power Station are deemed firm. There is no particular problem with financial self-sustainability since the operation and maintenance budget is firmly secured for this project

3.5.4 Current Status of Operation and Maintenance

(1) Power Station Facilities

Based on the technical manual, there are 211 check items including 49 items for generators and 27 for rotors. Routine and major maintenance is conducted monthly and yearly respectively.

Routine and preventive maintenance is conducted daily, weekly and monthly, and major maintenance is conducted yearly at both power house and dam. As for annual maintenance for generators in 2010, for instance, 28 days were spent on maintenance for Unit 1, 25 days for Unit 2, 22 days for Unit 3, and 18 days for Unit 4.

It was confirmed during the field survey of this ex-post evaluation that Dhauliganga technical staff members continue to record data on O&M for all facilities of the power house and dam, and the condition remains good.

(2) Countermeasures for Sedimentation

NHPC and other state power bodies with hydroelectric power plants are fully aware of the serious operation risk caused by accumulated silt in reservoirs. Countermeasures were taken in the design of the Dhauliganga Power Plant with the addition of a de-silting chamber and silt ejector, and in the catchment area treatment works. Compensatory afforestation and technical guidance given to the local people were commenced prior to the construction of the Power Station, which also helped reduce the amount of the suspended load inflow from the upstream area.

In the site survey of this ex-post evaluation, it was seen that the volume of sedimentation in the reservoir has sharply declined from 410,000 to the present 30,000 m^3 (see 3.2.1). In addition to the collection of silt at the de-silting chamber, silt is ejected in the upstream area before full operation of dam during monsoon season, and silt in the reservoir is flushed every fifteen days during the same period. The Dhauliganga Power Station monitors and keeps records of the suspended sediment upstream of the silt ejector and tailrace tunnel every day in order that quick action may be taken in the case that any abnormal condition is found.

(3) Monitoring of Glacier Lakes

It was confirmed that there seven glacier lakes existed in the upstream tributary and the Dhauliganga river basin at the time of the first appraisal in 1994. In response to the suggestion that countermeasures against glacier lake outburst floods be taken immediately, JICA conducted the Dhauliganga Hydroelectric Power Project Special Assistance for Project Implementation (SAPI) in 2001. Then, the volumes and transitions of glacier lakes were observed and analyzed using digital satellite images from 1994 and 2000 taken by the National Remote Sensing Agency (NRSA). It was found that the size of the glacier lakes remained 1.0 to 1.2 million m^3, and that their volumes did not change very much. Since the inventory did not indicate any imminent potential hazard, it seemed that no immediate action was required, for example, in developing a detection system. However, it was recommended that inventories and analysis of the glacier lakes should be carried out periodically as this was not indicative of longer-term trends. In the case that a significant potential hazard in any of the glacier lakes in the Dhauliganga river basin be revealed, then the GLOF forecast warning system would be implemented without delay.

Up to present, NHPC has conducted remote sensing data collection every five years since 1994, but there has been no detection of any indicative features of outburst flood, or of increases or decreases in the area of glacier lakes. These lakes at present are not significant enough to have an adverse impact on the Dhauliganga Power Station. NHPC will continue to monitor the condition of the glacier lakes based on the recommendation drawn up in the SAPI study.

No major problems have thus been observed in the operation and maintenance system, therefore the sustainability of the project effect is high.

4. Conclusion, Lessons Learned and Recommendations

4.1 Conclusion

This project was implemented to cope with growing power and energy demand in the northern region of India by the construction of a hydroelectric power plant. Its objectives were highly relevant to India's development plan and development needs, as well as to Japan's ODA policy, therefore its relevance is high. Since the key operation and effect indicators such as maximum output, plant load factor, availability factor, and electric energy production met the targets, this project has largely achieved its objectives. Thus its effectiveness is high. However, there were constraints on the evaluation of the extent to which this project contributed to the improvement of the electricity supply in the northern grid due to the fact that the installed capacity of this project makes up less than 1% of the entire grid. Adverse impacts on natural and social environment remained at a minimum thanks to various actions implemented by the executing agency. There were positive impacts such as improvements in the natural environment and in people's living conditions in the upstream area. Although there were some changes in design, such as dam type, the project outputs were realized mostly as planned. Although the project cost was within the plan, the project period slightly exceeded it and therefore the efficiency of the project is fair.

This project's organizational, technical and financial sustainability is high and the project is well operated and the facilities well maintained. In light of the above, this project is evaluated to be highly satisfactory.

4.2 Recommendations

4.2.1 Recommendations to the Executing Agency

Not applicable.

4.2.2 Recommendations to JICA

Not applicable.

4.3 Lessons Learned

(1) Project implementation mechanism with technical expertise fully utilized

A Panel of Experts was formed, comprising of a geologist, a hydro-mechanical engineer, an electro-mechanical engineer, a civil engineer, an environmental expert, a hydrologist and a hydraulist. There was slope failure on the right bank, which caused design changes. The POE provided various technical advices on countermeasures and modifications in the project design, and the executing agency took immediate action.

The establishment of POE within the implementation mechanism of the project helped to manage risks during the construction period, and to prevent further unexpected accidents. This contributed to smooth project implementation in terms of time management and technical process management. Transparency and accountability was also secured by making use of third-party people with technical backgrounds. This kind of technical mechanism can be taken into consideration at the project planning stage, and can be applied in other future projects.

(2) Holistic mitigation measures in land acquisition and resettlement, and coordination mechanism with relevant authorities and affected people

The executing agency of this project coordinated and cooperated well with the State Forest Department and other local government agencies. All information and required procedures for land acquisition and resettlement was disclosed to the affected people, and their opinions reflected into the plans. Thus people's understanding and cooperation was gained. Affected households received individual compensation, and basic infrastructure which improved their living conditions (road, water supply, electricity supply and LPG supply). All fully affected households obtained employment opportunities, with which they built stable livelihoods in the long run. Such efforts by the executing agency meant that there was no delay caused by land acquisition or resettlement.

When planning and implementing similar projects in the future, it is desirable that a suitable and comprehensive approach is examined and introduced as it was in this project where there was an emphasis on building firm relationships with local government agencies and with people in the project area.

Comparison of the Original and Actual Scope of the Project

Item	Original	Actual
1. Project Outputs	(1) Reservoir ・ Max level: 1,348.5m asl ・ Full level: 1,345m asl ・ Minimum level: 1,330m asl ・ Gross storage volume: 6.2 million m^3 ・ Live storage volume: 1.54 million m^3	(1) Reservoir As planned
	(2) Dam ・ Type: rockfill dam ・ Max height above river bed level: 56m ・ Length of dam crest: 270m (elevation: 1,351m asl)	(2) Dam ・ Type: concrete faced rockfill dam (changed) ・ Max height above river bed level: as planned ・ Length of dam crest: as planned
	(3) Spillway ・ Type: gated sluices with open chute and flip bucket ・ Design flood: 3,210m / s ・ Invert level of gated sluices: 1,307m ・ No and size of sluices: three (10 m high X 6 m wide)	(3) Spillway ・ Type: as planned ・ Design flood: as planned ・ Invert level of gated sluices: as planned ・ No and size of sluices: Two (changed) (10 m high X 6 m wide) and the existing diversion tunnel was modified to one tunnel spillway (crest level: 1,332.87 m, radial gate size: 9 m X 16 high).
	(4) River diversion tunnel at dam site ・ Shape: horseshoe ・ Diameter: 10m ・ Length between portals: 750m	(4) River diversion tunnel at dam site ・ Shape: as planned ・ Diameter: as planned ・ Length between portals：753.56 m (changed)
	(5) Headrace tunnel intake structure ・ Invert level：1,307m ・ No and sizes of inlets: Two (5m high X 5m wide)	(5) Headrace tunnel intake structure As planned
	(6) De-silting chamber ・ Length: 300m ・ No and size: Two (13.0m X 16.2m) ・ Minimum particle size to be removed: 0.2mm	(6) De-silting chamber ・ Length: 315m (changed) ・ No and size: as planned ・ Minimum particle size to be removed: as planned
	(7) Headrace tunnel (concrete lined) ・ Shape: horseshoe ・ Diameter: 6.5m ・ Length: 5,400m ・ Discharge capacity: 107 m^3 / s	(7) Headrace tunnel (concrete lined) As planned
	(8) Surge shaft (concrete lined) ・ Type: vertical shaft with a short riser shaft ・ Internal diameter: 15m ・ Depth: 95m	(8) Surge shaft (concrete lined) ・ Type: Restricted orifice (changed) ・ Internal diameter: 14m (changed) ・ Depth: 96m (changed)
	(9) Pressure shafts ・ No and type: two circular vertical shafts, partly concrete and partly steel lined ・ Diameter: 4.0m ・ Depth: 250m	(9) Pressure shafts As planned

Item	Original	Actual
	(10) Underground power house • Type of turbine: francis, vertical axis • Installed capacity: 280MW (70MW X 4 units) • Normal tail water level: 1,034m • Max gross head: 311m • Rated net head: 297m • Dimension of machine hall: 16.5m X 103m X 39m • Dimension of transformer cavern: 12m X 76m X 10m • Dimension of GIS cavern: 9m X 27m X 11m (11) Tailrace tunnel (concrete lined) • Type: Horseshoe • Diameter: 6.5m • Length: 445m (12) Tailrace surge gallery • Type: D-shaped curved • Diameter: 6.0m • Length: 280m (13) Consulting Services Foreign engineers: Total 117M/M (14) Panel of Experts Foreign engineers: Total 45M/M	(10) Underground power house • Type of turbine: as planned • Installed capacity: as planned • Normal tail water level: as planned • Max gross head: as planned • Rated net head: as planned • Dimension of machine hall: as planned • Dimension of transformer cavern: as planned • Dimension of GIS cavern: 10m X 27m X 11m (changed) (11) Tailrace tunnel (concrete lined) As planned (12) Tailrace surge gallery As planned (13) Consulting Services Foreign engineers: Total 115M/M (reduced) (14) Panel of Experts Foreign engineers: Total 6.5M/M (reduced)
2. Project Period	January 1996 to September 2004 (105 months)	January 1996 to November 2005 (119 months)
3. Project Cost		
Amount paid in Foreign currency	30,542 million yen	N/A
Amount paid in Local currency	22,246 million yen (7,760 million INR)	N/A (N/A)
Total	52,968 million yen	47,541 million yen
Japanese ODA loan portion	35,871 million yen	33,336 million yen
Exchange rate	1INR = 2.89 yen (As of April 1995)	1INR = 2.73yen (Average from 1995 to 2005)