People's Republic of China

FY 2016 Ex-Post Evaluation of Japanese ODA Loan Project

"Shanxi Xilongchi Pumped Storage Power Station Project"

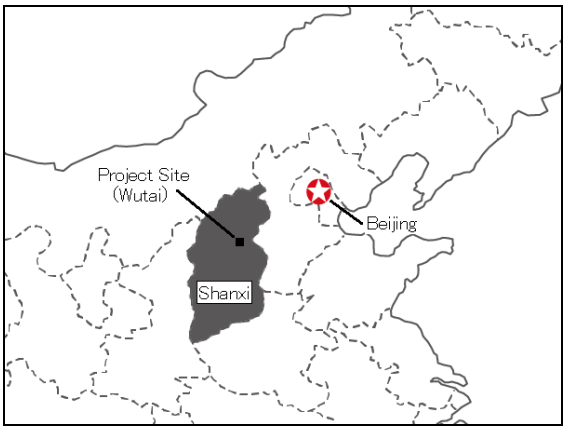
External Evaluator: Toshihiro Nishino, International Development Center of Japan Inc.

0. Summary

The objective of the Project was to improve the peak demand handling capability and the reliability as well as economy of power system operation by constructing a pumped storage power station in Shanxi Province, thereby contributing to the containment of the emission volume of air pollutants. The Project was in line with the electric power and environmental policies of the Government of China as well as the government of the target province, development needs of China to improve air pollution and to increase the stability and economy of power supply and Japan's ODA policy. As such, the relevance of the Project is high. The efficiency of the Project is fair because of the fact that although the project cost was within the planned cost, the project period exceeded the plan. The expected role of the Project (Xilongchi Power Station) has changed as a result of the changing circumstances of the electric power industry in Shanxi Province. In response to such changes, the Xilongchi Power Station currently performs its principal roles of "responding to the peak demand" and "adjusting the power demand and supply for the development of alternative energies (facilitation of air pollution prevention) without fail and various indicators had mostly achieved the target values by the time of this ex-post evaluation. Sufficient positive effects are observed with the anticipated improvement of the stability and economy of power supply. A certain effect of the Project is also confirmed in relation to ① development of the socioeconomy and improvement of poverty in local communities and ② facilitation of the further introduction of Japanese technologies to China. In contrast, the target values set at the time of appraisal were substantially undershot for all indicators of the effectiveness and impacts two years after project completion. In consideration of the foregoing, the effectiveness and impact of the Project are fair. The sustainability of the Project poses no problems in terms of the institutional, technical and financial aspects. As good operation and maintenance conditions were confirmed for the facilities and equipment, the sustainability of the Project is high.

In light of the above, the Project is evaluated as satisfactory.

1. Project Description



Project Locations

Generators

1.1 Background

At the time when the Project was conceived, the Government of China had been emphasizing the development of power sources as the driving force for high economic growth and had actively been promoting investment in the electric power industry. The remarkable results of such efforts included an increase of the installed capacity by 2.3 times (to 320,000 MW) and the power generation amount by 2.2 times (to 1.37 million GWh) in the 10-year period from 1990 to 2000. The power demand maintained its high growth exceeding the rate of economic growth, however, making it essential to further increase the installed capacity. Meanwhile, China's dependence on coal for energy supply at some 70% with a high proportion of coal-fired thermal power generation meant worsening environmental problems in urban areas.

In Shanxi Province located in North China, the development of industries and agriculture relatively lagged behind other provinces despite its rich mining and energy resources. Even though the installed capacity and annual power generation amount for the provincial power grid were 12,700 MW and 62,100 GWh respectively, 97% of the power generation amount relied on coal-fired thermal power generation with a heavy environmental load (Year 2000). The maximum gap in a year between the daily maximum load and minimum load was as large as some 2,500 MW (Year 2000) and this gap showed an increasing trend for the future. In Shanxi Province where thermal power generation had an overwhelming share, the need to adjust the power output to balance the maximum load and minimum load was dealt with by DSS (daily start and stop) of power stations and power output control operation, causing such problems as shortening of the service life of the generating facilities, lowering of the thermal efficiency, increase of the operation and maintenance cost and a further increase of the environmental load. The dust and air pollutants discharged from coal-fired thermal power stations constituted one of the largest

factors for air pollution in Shanxi Province, causing a steady increase of the environmental load.

1.2 Project Outline

The objective of the Project was to improve the peak demand handling capability and the reliability as well as economy of power system operation by constructing a pumped stored power station in Shanxi Province, thereby contributing to the prevention of air pollution through the reduction of the emission of SO_2, NOx and others and also to the containment of the emission volume of Greenhouse Gas (GHG) through the reduction of CO_2 emission.

Loan Approved Amount/Disbursed Amount	23,241 million yen/19,069 million yen	
Exchange of Notes Date/Loan Agreement Signing Date	March 2002 / March 2002	
Terms and Conditions	Interest Rate Repayment Period (Grace Period) Conditions for Procurement	0.75% 40 years (10 years) General untied (Bilateral tied for the consultant)
Borrower/Executing Agencies	The Government of People's Republic of China /State Electric Power Company (SPC)	
Project Completion	August 2011	
Main Contractors	Mitsubishi Electric Corporation (Japan)/ Hitachi Ltd. (Japan)/Toshiba Corporation (Japan)/Mitsubishi Corporation (Japan) (JV); Mitsui & Co. (Japan), Taisei Corporation (Japan), Sumitomo Corporation (Japan)	
Main Consultants	East China Investigation and Design Institute (China)/Tokyo Electric Power Services Co., Ltd. (Japan)	
Feasibility Studies, etc.	F/S by Beijing Engineering Corporation Ltd. (March, 1999)	
Related Projects	-	

2. Outline of the Evaluation Study

2.1 External Evaluator

Toshihiro Nishino, International Development Center of Japan Inc.

2.2 Duration of Evaluation Study

This ex-post evaluation study was conducted with the following schedule.

Duration of the Study: July 2016 - October 2017

Duration of the Field Study: October 16 - 29, 2016 and March 19 - 25, 2017

3. Results of the Evaluation (Overall Rating: B[1])

3.1 Relevance (Rating: ③[2])

3.1.1 Consistency with the Development Policy of China

At the time of project appraisal, the development policy of the Government of China had changed, as indicated in "the 9th Five Year Plan (1996‐2000)", from the conventional policy of stressing an increase of the power generating capacity to a policy of favoring the improvement of the energy utilization efficiency through adjustment of the configuration of power sources, further improvement and enhancement of the transmission and distribution networks, improved capacity to deal with the peak power demand through the construction of pumped storage power stations, etc. and other means, following easing of the supply-demand gap due to an increasing amount of electricity generated in China. As far as environmental consideration was concerned, the containment of harmful emissions and promotion of environmental protection through the expanded use of clean energies and the introduction of new technologies were called for. Subsequent Five Year Plans consistently emphasized environmental consideration and the efficiency supply of energy due to an increase of power generation amount. "The 13th Five Year Plan (2016‐2020)" sets out quantitative targets for various indicators, including "aggregate major pollution emission reduction" and "percentage of non-fossil energy in primary energy consumption", stressing environmental improvement and the development of hydropower generation (target for the output of pumped storage power stations to be newly constructed: 17 million kW).

In response to these national policies, the Shanxi Provincial Government has been adopting its own policies to strengthen the peak demand handling capability and to accommodate environmental consideration. "The 13th Five Year Plan for Shanxi Province (2016‐2020)" emphasizes and promotes the ① improvement of the energy utilization efficiency, ② facilitation of alternative energy development, ③ promotion of low carbon development and ④ increase of the ratio of non-fossil fuel in the energy consumption in view of the currently high level of dependency on coal-fired thermal power generation.

Accordingly, at the time of both appraisal and ex-post evaluation, the contents and objective of the Project are in line with the electric power policy of China in that "the project is an attempt to achieve an efficient energy supply and to address environmental issues through adjustment of the configuration of power sources".

[1] A: Highly satisfactory, B: Satisfactory, C: Partially satisfactory, D: Unsatisfactory

[2] ③: High, ② Fair, ① Low

Table 1: Main Objectives of Development Plans Related to the Project

Type of Document	At the Time of Appraisal	At the Time of Ex-Post Evaluation
National Level Electric Power Policy and Development Plan	9th Five Year Plan (1996-2000) Proceeds with such policies for the purpose of adjusting the configuration of power sources as ① optimization of the configuration of power sources and improvement of power generation, transmission and distribution, ② power supply to areas of insufficient power supply and improvement of the transmission and peak demand handling capability through the construction of pumped storage power stations, etc. and ③ containment of harmful emissions and environmental protection through the introduction of new technologies.	13th Five Year Plan (2016-2020) Sets quantitative targets for "aggregate major pollutant emissions", "ratio of days of excellent air quality in cities" and "non-fossil energy (percentage of primary energy consumption)", emphasizing environmental improvement and the development of hydropower generation.
Electric Power Development Plan	10th Five Year Plan for Electric Power Industry (2001-2005) Numerical targets: ① installed capacity of newly constructed hydropower stations of 27,300 MW of which 7,400 MW is accounted for by pumped storage power generation during the plan period (the actual figures in the five-year period were 12,700 MW and 1,100 MW respectively) and ② increased share of thermal power generation among power stations of which the rated output is 500 MW or more to some 50% in 2005 (from 38% in 2000).	13th Five Year Plan for the Electric Power Industry (2016-2020) Priority plans: ① to establish an efficient and modern energy system which is low carbon, clean and safe, ② to increase the ratio of non-fossil energy while facilitating the clean and efficient use of fossil fuels and ③ to promote the development of renewable energies. Numerical target: construction of additional pumped storage power stations with a total installed capacity of 17 million kW to reach 40 million kW. Energy Development Strategy Action Plan (2014 - 2020) of the State Council Four strategies: ①Adhere to an "economical, clean and safe" strategy, ② Promote domestic strategy, ③ Realize green and low carbon society and ④ Promote innovation. Numerical targets: ① proportion of non-fossil fuels in primary energy consumption of 15% in 2020 (hydroelectric installed capacity in 2020 of approx. 340 million kW), ② newly installed capacity of operating hydroelectric power stations of approx. 40 million kW with 60 million kW or more installed capacity of power stations under construction ③ 40 million kW of renewable energies in three northern areas (Northwest, North and Northeast).
Provincial Level Development Plan		13th Five Year Plan for Shanxi Province (2016-2020) Emphasizes improvement of the efficiency of energy use, facilitation of the development of alternative energies, promotion of low carbon development and improved ratio of non-fossil fuels.

Source: Documents provided by JICA and plan documents

3.1.2 Consistency with the Development Needs of China

At the time of project appraisal, Shanxi Province almost entirely depended on coal-fired thermal power generation (accounting for 97% of the power generation amount) which was characterized by a large environmental load. In addition, there was a large gap between the maximum daily load and minimum daily load and this gap was predicted to increase (the maximum gap in a year between the maximum daily load and minimum daily load in 2000 was 2,500 MW which was predicted to increase to 4,600 MW in 2010). Because of this, Shanxi Province faced major problems in terms of the reliability and economy of power system operation and environmental load. While this large gap between the maximum and minimum load was handled by DSS and output adjustment of thermal power stations, such mode of operation caused a shorter service life, reduced thermal efficiency and increased maintenance cost of the generating facilities and a further increase of the environmental load. There was a highly urgent need to achieve ① improvement of the operating conditions of coal-fired thermal power stations, ② containment of fuel consumption of coal and oil, ③ prolongation of the service life of thermal power stations, ④ improvement of the reliability of power system operation and the quality of supplied electricity and ⑤ prevention of air pollution and containment of GHG emission. As such, it is safe to say that the Project was relevant to the development needs of China.

Table 2: Historical Changes of Basic Electric Indicators in Shanxi Province

	2000	2009	2011	2013	2015	2016
Installed capacity (MW)	12,749	28,260	37,170	45,590	57,550	62,310
Coal-fired (MW)	11,771	26,590	33,655	39,700	45,550	48,840
Power generation amount (GWh)	62,087	137,050	171,000	197,400	186,100	189,900
Coal-fired (GWh)	60,475	133,950	164,250	186,800	172,600	170,300
Maximum load（MW）	7,614	19,191	21,846	24,654	22,858	24,677
Minimum load（MW）	-	11,202	12,736	14,475	12,503	12,348
Maximum daily range（MW）	2,485	4,797	5,276	6,061	5,999	6,322

Source: Documents provided by JICA and responses to the questionnaire of the executing agency.
Note: “Maximum daily range” indicates the highest value for the maximum gap between the maximum daily load and minimum daily load in the relevant year.

By the time of the ex-post evaluation, the very tight power supply and demand situation has considerably improved due to an increase of the installed capacity following the completion of new power stations and also due to the slowing down of economic growth and the growth of the power demand compared to the period up to around 2011 when the installed capacity lagged behind the rapid increase of the power demand. The capacity to deal with the peak demand has also improved due to ① narrowing of the power supply and demand gap and ② strengthening of the output adjustment function of thermal power stations following the commissioning of new power stations. Nevertheless, further enhancement of the adjustment function is still

necessary to ensure a stable power supply and, therefore, the situation where pumped storage power stations' possession of such adjustment function is highly significant remains unchanged. In recent years, the development of such alternative power sources as wind power has been promoted but the unstable power supply from these sources makes strengthening of the existing adjustment function essential to increase the amount of power generation. In other words, the smooth development of alternative energies is impossible without using the adjustment function of pumped storage power stations. Moreover, the situation of air pollution is still serious in major cities in Shanxi Province. Hydroelectric generation is seen to be an important means of contributing to the prevention of air pollution from three viewpoints: ① clean energy, ② ability to reduce the environmental load through the efficient adjustment of the power supply and demand and ③ essential for the promotion of the development of alternative energies.

3.1.3 Consistency with Japan's ODA Policy

At the time of appraisal, "Japan's Country Assistance Policy for China" (2001, MOFA), "the Medium-Term Strategy for Overseas Economic Cooperation Operations" (2002, JICA) and "the Country Assistance Strategy for China" (2002, JICA) placed priority on ① environmental conservation measures and ② measures designed to improve the standard of living and to reduce poverty in inland China, underlining the relevance of the Project to Japan's ODA policy. The assistance policy for the energy sector as indicated in the "Country Assistance Strategy" clearly spells out the priority to assist the promotion of the development of hydropower generation (pumped storage power generation, etc.) while calling for an integrated approach to take into consideration the situation of the power supply and demand, environmental consideration, capacity to transport coal, private sector investment and other issues.

The Project is highly relevant to China's development plans and development needs at the time of both appraisal and ex-post evaluation as well as to Japan's ODA policies at the time of appraisal. Therefore, its relevance is high.

3.2 Efficiency (Rating: ②)

3.2.1 Project Outputs

The main outputs of the Project were newly constructed upper and lower regulating reservoirs, an underground power station (with four generating units), headrace and tailrace in addition to the installation of a switchyard and procured equipment. As Table 3 shows, the size of both reservoirs was increased by 10% to

20%[3] and minor adjustments were made to the range of equipment to be procured. The actual outputs were, however, generally as planned. The work contents of the consulting service were unchanged. According to the results of the interview survey with the executing agency and some relevant reference materials, changes to the planned outputs were made in accordance with the necessary procedure to respond to the needs of the Project, posing no problems.[4]

Table 3: Planned and Actual Outputs

Item	Planned (at the Time of Appraisal)	Actual
Upper regulating reservoir (effective storage capacity)	Approx.4.2 million m^3	4.6 million m^3
Lower regulating reservoir (effective storage capacity)	Approx.4.2 million m^3	4.8 million m^3
Underground power station	300MW×4 units	As planned
Headrace and tailrace	Penstock x2; branch pipe x4; tailrace x4	As planned
Switch yard	Transformer 340MVA x 4 units; 500kV outgoing system	As planned
Consulting services	Assistance for tender; review of the detailed design; assistance for work supervision	As planned
Procured equipment	Reversible pump-turbine; GIS; cables; auxiliary equipment, etc.	The quantities of monitoring equipment, steel, etc. were slightly changed due to necessary circumstances.

Source: Responses to the questionnaire of the executing agency.

Upper regulating reservoir

Lower regulating reservoir

[3] According to the executing agency, these changes were judged to be minor modifications at the detailed design stage based on the actual conditions of the Project.

[4] At the appraisal stage, the Project was considered to "require careful attention because of its scale and requirement for high (technical) standard." The interview survey with Japanese and Chinese persons involved in the Project found that no problems emerged as the actual situation surrounding the Project remained the same as originally presumed.

3.2.2 Project Inputs

3.2.2.1 Project Cost

The actual project cost was 69,209 million yen which was within the planned cost of 77,991 million yen (89% of the planned cost) as shown in the following table. The reasons for the lower actual cost than the planned cost were ① active efforts to reduce the consulting services cost payable in local currency, ② containment of the procurement cost of electrical and mechanical equipment through an international competitive tender, ③ containment of the domestic civil engineering cost through a tender and ④ continual appreciation of the yen during the project period. As mentioned earlier, the outputs were achieved as planned. The lower project cost suggests that appropriate efforts to suppress the project cost were made.

Table 4: Planned and Actual Project Costs

Unit: million yen

	Plan (Appraisal)			Actual		
	Foreign Currency	Local Currency	Total	Foreign Currency	Local Currency	Total
Civil engineering works	2,790	28,380	31,170	2,600	25,493	28,093
Electrical and mechanical equipment	16,724	5,190	21,914	13,865	5,558	19,423
Steel structure	1,096	2,010	3,106	2,497	1,213	3,710
Consulting	214	5,865	6,079	107	920	1,027
Taxes, administration cost, etc.	0	10,740	10,740	0	16,956	16,956
Inflation	1,320	510	1,830	0	0	0
Contingency	1,097	2,055	3,152	0	0	0
Grand total	23,241	54,750	77,991	19,069	50,140	69,209

Sources: Documents provided by JICA and responses to the questionnaire of the executing agency.
Note: Planned exchange rate: 1 yuan = 15 yen (September, 2001)
Actual exchange rate: 1 yuan = 14.0 yen (mean exchange rate between 2001 and 2011)

3.2.2.2 Project Period

The actual project period of 118 months (November, 2001 to August, 2011) was much longer than the planned period of 94 months (November, 2001 to August, 2009) (126% of the planned period). The main reason for this over-run of the project period was damage caused to the No. 1 and No. 2 generators during the trial run in October, 2009 which necessitated investigation to identify the cause of the accident and subsequent replacement of the generators. After this accident, a restoration plan was prepared and a steady response was made based on the plan. Nevertheless, the project period exceeded the planned period by 24 months.

Table 5: Planned and Actual Project Periods

	Planned (Appraisal)	Actual
Loan agreement signing date	March, 2002	March, 2002
Project period	November, 2001 - August, 2009 (94 months)	November, 2001 - August, 2011 (118 months)
Preparatory work	November, 2001 - June, 2003	November, 2001 - August, 2003
Upper regulating reservoir	June, 2003 - March, 2006	December, 2003 - September, 2008
Lower regulating reservoir	February, 2003 - May, 2007	August, 2003 - September, 2010
Power station	May, 2003 - December, 2006	September, 2003 - August, 2011
Electrical machinery	January, 2004 - August, 2009	March, 2006 - July, 2009
Consulting	October, 2002 - June, 2008	March, 2003 - November, 2008
Completed trial run of No.1 unit	August, 2009	May, 2011
Completed trial run of No.2 unit	August, 2009	August, 2011
Completed trial run of No.3 unit	August, 2009	April, 2009
Completed trial run of No.4 unit	August, 2009	November, 2008

Sources: Documents provided by JICA and responses to the questionnaire of the executing agency.
Note: As part of the Project started using Chinese funding before the signing of the loan agreement, the commencement of the Project was before this signing.

3.2.3 Results of Calculations of Internal Rates of Return (Reference only)

Financial Internal Rate of Return

At the time of appraisal, only the financial internal rate of return (FIRR) was calculated. In this ex-post evaluation, the FIRR is recalculated. At the time of appraisal, the items considered to be costs were the construction cost of the Project, cost of electricity purchase for pumping, operation and maintenance cost and taxes while the revenue from the sale of electricity was considered to be the benefit. The calculated FIRR for the period of 30 years was 8.06%. The recalculated FIRR[5] at the time of ex-post evaluation using the same cost, benefit and project period assumed at the time of appraisal was -4.45%. The reasons for this negative FIRR were that ① the actual revenue from the sale of electricity significantly lowered than the planned (from 102.8 million yuan/year at the time of appraisal to approximately 45.5 million yuan/year at the time of ex-post evaluation; 44% of the revenue assumed at the time of appraisaland ② delayed completion of the Project (longer construction period than planned) which delayed the start of operation (to generate revenue). Meanwhile, the operating cost after the completion of the Project is slightly lower

[5] For recalculation of the FIRR, it was assumed that the averaged actual values for the last three years would be maintained as the benefit (revenue for the sale of electricity), costs (cost of purchased electricity and personnel cost, etc.) and taxes.

than the planned cost at the time of proposal (36.2 million yuan/year at the time of ex-post evaluation compared to 40.2 million yuan at the time of appraisal; 90% of the planned cost).

Although the project cost was within the planned cost, the project period exceeded the plan. Therefore, the efficiency of the Project is fair.

3.3 Effectiveness[6] (Rating:②)

For evaluation of the effectiveness, major changes of the environment surrounding the Project and the status of the Project were taken into full consideration.

3.3.1 Quantitative Effects (Operation and Effectiveness Indicators)

Table 6 shows the historical performance of the operation and effectiveness indicators which were set at the time of appraisal to indicate the quantitative effects of the Project.

Table 6: Historical Performance of Operation and Effectiveness Indicators

	Target	Actual						
	(2011)	2011	2012	2013	2014	2015	2016	Average between 2013 and 2016
	2 years after project completion	Year of project completion	1 year after project completion	2 years after project completion	3 years after project completion	4 years after project completion	5 years after project completion	
【Operation Indicators】								
Installed capacity（MW）	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200
Operating hours (generating hours/year)	4,811	1,704	148	609	1,802	2,591	4,768	2,443
Operating hours (pumping hours/year)	4,201	1,797	170	541	1,780	2,793	5,530	2,661
Operating rate (%)	91.6	29.2	2.5	10.4	30.9	44.4	81.6	33.2
Utilization factor (%)	91.6	21.7	1.8	6.5	22.9	35.4	64.3	25.4
Comprehensive circulating efficiency (%)	75	75	59	70	75	73	74	73
Unplanned stoppage hours (hours/year)	12	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
【Effectiveness Indicator】								
Annual power generation amount (GWh)	1,796	381	31	114	401	620	1,638	693

Sources: Documents provided by JICA and responses to the questionnaire of the executing agency.
Notes: ”operating rate” = (actual power generating hours) /(4 units x 4 hours x 365 days); “utilization factor” = (actual power generation amount）/(4 units x 4 hours x 300 MW x 365 days); “overall cycle efficiency” = (sending-end power generation amount”/”power consumption for pumping operation) x 100.

[6] Sub-rating for Effectiveness is to be put with consideration of Impact.

The performance of the indicators in 2013, two years after project completion and for which the target values were set at the time of appraisal, showed that while the target for installed capacity was achieved, the operating hours (generating hours) and annual power generation amount were considerably below their targets. The former was 13% of the target value (609 actual hours compared to 4,811 target hours) and the latter was 6% of the target value (114 actual GWh compared to 1,796 target GWh). As such indicators as the operating rate, utilization factor and comprehensive circulating efficiency were affected by the operating hours (generating hours) and power generation amount, their actual performance levels were low, failing to achieve the respective targets.[7] However, the actual performance of both the operating hours (generating hours) and annual power generation amount has shown a rapid recovery trend in recent years. The actual figures in 2016 representing the latest figures at the time of ex-post evaluation show that the operating hours (generating hours) achieved 99% of the target value (4,768 actual hours compared to 4,811 target hours) and the annual power generation amount achieved 91% of the target value (1,638 actual GWh compared to 1,796 target GWh). As a result, many of the quantitative indicators reached the level of roughly achieving the target.

Regarding pumped storage power stations, the operating hours (generating hours) and annual power generation amount generally tend to greatly fluctuate from one year to another[8] and it is inappropriate to evaluate the performance of a station based on a single year. As such, the present ex-post evaluation has examined the average values for the actual performance for a period of two years after project completion to the time of ex-post evaluation (from 2013 to 2016). On this basis, the operating hours (generating hours) and annual power generation amount achieved 51% of the target for the former (2,443 actual hours compared to 4,811 target hours) and 39% of the target for the latter (693 actual GWh compared to 1,796 target GWh). When compared to the performance in 2013, i.e. two years after project completion, these average figures show much improvement reflecting the recent trend of recovery but are still below the target values.

The reasons for these results are ① considerable changes of the socioeconomic environment surrounding the Project and ② significant change of the status of the Project following changes of its environment (see Table 7).

---

[7] No data was obtained for unplanned stoppage hours but those in charge at the executing agency replied in an interview that the target was achieved.

[8] Taking such characteristics of pumped storage power generation into consideration, Shanxi Xilongchi Pumped Storage Power Generation Co., Ltd. (Xilongchi Pumped Storage Power Station) and Shanxi Electric Power Group Co, Ltd. (Shanxi Electric Power Company) have signed "a fixed amount contract based on the installed capacity regardless of the power generation amount" to ensure stable revenue for the former.

Table 7: Changing Roles of the Project

	2001(Time of Appraisal)	2012-14 (1-3 years after Completion)	2015-16 (Time of Ex-Post Evaluation)
Socioeconomic situation	・Tightening of power supply due to a rapid increase of power demand ・Insufficient adjustment function due to the widening of the gap between the maximum and minimum loads	・Slowdown of the increase of power demand due to sluggish economy ・Decline of the necessity for the adjustment function due to narrowing of the gap between the maximum and minimum loads	・Increasing necessity for the function to adjust the gap between the maximum and minimum loads following the improvement of the economy ・Necessity to strengthen the adjustment function following the development of alternative energies
Expected roles of the Project	・Response to the peak demand (strong need) ・Power supply source for intermediate-load to combat power shortage	・Response to the peak demand (decline of the need)	・Handling of the peak demand (increase of the need to do so) ・Adjustment of demand and supply following the development of alternative energies

Source: Prepared by the evaluator

At the time of appraisal (2001), the power supply in Shanxi Province was insufficient to meet the demand while the supply-demand adjusting capacity was poor. Because of this, it is safe to assume that the Project was expected to partly play the role of an intermediate power source in addition to boosting the capacity to deal with the peak demand.[9] At that time, the target operating hours (generating hours) was set at approximately 4.1 hours a day.[10] The above assumption is backed by ① the comparable performance of a pumped storage power station in Japan shows average daily operating hours of 0.43 to 1.57 hours in the case of Kansai Electric Power Co., Inc. (a pumped storage power station with an installed capacity of 5,060 MW and annual power generation amount of 800 - 2,900 GWh)[11] and ② in China, the actual average operating hours for pumped storage power stations are less than two hours except in 2016 as shown in Table 8 and, therefore, the target operating hours of 4.1 hours for the Xilongchi Power Station were beyond the normal operating hours to deal with the peak demand.

[9] This idea was confirmed by those in charge of the Project at the executing agency.

[10] Target annual power generation amount ÷ (installed capacity x 365 days) = 1,796,000 MWh ÷ (1,200 MW x 365 days) = 4.1 hours

[11] From the website of Kansai Electric Power Co., Inc. (http://www.kepco.co.jp/corporate/profile/data/dengen.html)

Table 8: Historical Changes of Power Generation by Pumped Storage Power Stations in China and under the Project

		2011	2012	2013	2014	2015	2016
China	Annual power generation amount (GWh)	10,900	9,300	10,700	13,200	15,800	30,600
	Installed capacity (MW)	18,380	20,330	21,530	22,110	23,030	26,690
	Average daily operation hours (hours)	1.62	1.25	1.36	1.64	1.88	3.13
Xilongchi	Annual power generation amount (GWh)	381	31	114	401	620	1,638
	Installed capacity (MW)	1,200	1,200	1,200	1,200	1,200	1,200
	Average daily operation hours (hours)	0.87	0.07	0.26	0.92	1.42	3.73

Source: Prepared by the evaluator using documents provided by JICA, the 13th Five Year Plan for the Electric Power Industry and the list of basic statistical data for the power sector in 2015

Since 2012, one year after project completion, the slowing down of the economic growth greatly reduced the growth of the power demand while the construction of many new power stations, primarily thermal power stations, was completed (including those with a high-power supply adjusting capacity). As a result, the power supply and demand situation in Shanxi Province greatly improved, restricting the role of Xilongchi Power Station to that of handling the peak demand which is the essential role of a pumped storage power station. The gap between the maximum load and minimum load was reduced, making a strong capacity to deal with the peak demand less necessary. As such, the utilization level of the Xilongchi Power Station was low in 2013, two years after project completion.[12] When compared to the target value based on approximately 4.1 operating hours (generating hours) a day, the actual operating hours of the Xilongchi Power Station for 2013 through 2015 were lower than the target.[13] Nevertheless, it is judged that this power station sufficiently fulfilled its role of handling the peak demand due to the facts that ① it maintained a reasonable level of the annual power generating amount when compared to the actual performance of

[12] If the Project had been completed in 2009 as planned, the year of 2011 which was two years after project completion would have been a year in which adjustment between the maximum load and minimum load was most required because of the tightest power supply and demand situation in Shanxi Province, surely achieving the target values. In view of this scenario, the delay of project completion greatly affected the achievement status of the effectiveness indicator for the Project. A person in charge of the power grid of Shanxi Province at the Shanxi International Electricity Group Limited Company (hereinafter referred to as "Shanxi Electricity Company") expressed the opinion that "it was highly regrettable that the Project had not been completed by 2010-2011 when the power supply and demand adjusting capacity was most needed.

[13] It must be fully noted for the present evaluation of the Project that a small power generation amount does not necessarily mean a low level of effectiveness of the Project as the actual power generation amount greatly fluctuates from one year to another in the case of pumped storage power generation. This statement is supported by the facts that ① the JICA Operation Indicator and Effect Indictor Reference in ODA Loan Projects (July, 2014) spells out that (in view of its characteristics) not reaching the targets for the operating hours (generating hours) and power generation amount does not always lead to a low evaluation in the case of pumped storage power generation, ② China's 13th Five Year Plan for the Electric Power Industry does not set a target power generation amount for pumped storage power generation and ③ in the power sales contract related to the Project, a fixed charge based on the installed capacity is agreed upon regardless of the actual power generation amount.

pumped storage power stations in China as shown in Table 8 and ② it was primarily used in winter when the power supply and demand tends to be tight in Shanxi Province.

Since 2015, China has achieved the development of environment-friendly alternative energies and Shanxi Province has witnessed a great increase of the amount of development as well as the power generating amount of wind and photovoltaic power generation. Because of the unstable nature of the power supply from these alternative energy sources, however, further enhancement of the adjusting capacity is required, prompting the active use of the Xilongchi Power Station and resulting in an increase of the operating hours (generating hours) and power generation amount. The role of the Project has changed again to emphasize its function of adjusting the power supply and demand with a view to facilitating the development of alternative energies in addition to its conventional function of dealing with the peak demand. This new trend is commonly observed with pumped storage power stations throughout China and their annual power generating amount notably leaped in 2016 as shown in Table 8. Given the current national policy of continually developing alternative energies along with the plan to construct new pumped storage power stations, the importance of the Project and its pumped storage power station will remain high. Because of such prospect, those in charge of the Project at the executing agency assert that the Xilongchi Power Station will be operated above the target level with its new role.

3.3.2 Qualitative Effects

The assumed qualitative effects at the time of appraisal were ①containment of the fuel consumption and ② improvement of the reliability and economy of power supply system operation due to the mitigation or reduction of DSS operation.

According to the results of the interview survey with Shanxi Electricity Company, the number of DSS operation has drastically fallen since 2012 and is now hardly put into practice except at special times such as Chinese New Year. A situation requiring DSS operation now seldom occurs (several times a year), illustrating a massive improvement in this regard. The reasons for such improvement include alleviation of the tight power supply and demand situation since 2012 and overall decreasing trend of the gap between the maximum load and minimum load as described earlier in addition to the increased adjusting capacity due to the completion of the Project. Even today when the environment of the power generating business has changed in that the power supply and demand gap is increasing due to an increasing power demand and the capacity to adjust the power supply and demand is increasing due to the expansion of power generation using alternative energy sources, DSS operation is no longer necessary, suggesting a major contribution by the Project.

Officials of Shanxi Electricity Company who were interviewed for this ex-post evaluation expressed their understanding that the reduction of inefficient operation of power plants and improvement of the thermal efficiency due to a stable output, both of which were the result of mitigated or reduced DSS operation, had achieved ① "a reduction of the fuel consumption". Regarding ② "improvement of the reliability (stability) and economy of power supply system operation", although no data indicating the voltage, frequency, etc. of the power grid to show the relevant situation was not obtained, their understanding was that mitigated or reduced DSS operation had contributed to the reduction of the power station operation and maintenance cost and prolongation of the service life of the generating equipment.[14]

Two further matters can be pointed out as described below.

Realization of a stable power supply, including the prevention of large-scale outages: A stable power supply is essential for Shanxi Province to achieve stable as well as sustained socioeconomic development. A wide range of stakeholders, including those responsible for the electric power policy of the provincial government of Shanxi, have expressed their understanding that both the level of contribution and the role played by the Project have been great (despite the small power generation amount) from the viewpoint of improving the reliability of power supply system operation, including the prevention of large-scale outages, against the background of a continual increase of the power demand.

Improvement of the adjustment of the power supply and demand in wider North China: Geographical widening of the power network management in China is being promoted to facilitate improvement of the stability and economy of the power supply system. Since 2016, the Xilongchi Power Station has been incorporated in not only the provisional power supply network of Shanxi but also in the North China power supply network, contributing to the improvement of the stability and economy of the power supply system through its involvement in the adjustment of the power supply and demand in a much wider area.

[14] Even in 2011 when the power supply and demand situation was very tight, there were neither any accidental nor planned outages. Because of this, no clear opinion of the achievements of the Project were expressed during the interview survey.

3.4 Impacts

For evaluation of the impacts, resetting of the target values and other changes were made as described later in consideration of the improved environmental measures and technological innovation in China.

3.4.1 Intended Impacts

The identified quantitative impact was "the air pollution prevention effect" while the identified qualitative impacts were "contribution to the socioeconomic development and poverty reduction in a local area" and "facilitation of the development of alternative energies in Shanxi Province".

(1) Air Pollution Prevention Effect

The impacts (quantitative indicators) assumed at the time of appraisal were ① annual reduction volume of coal combustion and ② reduction of the emission of air pollutants, etc. (NOx, SO_2, dust and CO_2). The target values for the air pollution prevention effect of the Project were calculated by the method explained in the box below.

Item	Calculation Method
Coal combustion/ reduction volume	• The case where the power station constructed under the Project (with-case) is compared to the case where an additional thermal power station is constructed instead of the planned power station under the Project (without-case) to calculate the reduction amount of coal combustion under the Project (reduction amount per one KWh of power generated under the Project). • For calculation of the reduction amount of coal combustion, the "coal consumption curve" which takes the scale of power generation and situation of use of provincial power generation into consideration and other information are used. • The operating hours (generating hours) of a pumped storage power station are assumed to be 5.5 hours a day (annual power generation amount of 2,409 GWh).
Reduction volume of air pollutants, etc.	• Based on the actual coal consumption and emission volume of air pollutants by thermal power generation in Shanxi Province, the emission volume of air pollutants, etc. per one ton of coal combustion is calculated to determine the target value for the Project.

At the time of appraisal, however, the assumed operating hours (generating hours) of 5.5 hours/day (annual power generation amount of 2,409 GWh) was used for calculating the coal combustion reduction volume, and the subsequently expected "coal combustion reduction volume" and "reduction volume of air pollutants, etc." were set as the target values of air pollution prevention effect of the Project. Meanwhile, the target values for the power generation amount set for the Project were based on the operating hours of approximately 4.1 hours and annual power generation amount of 1,796 GWh, creating discrepancies in the target values relating to the air pollution prevention effects. For the present ex-post evaluation, these "target values" were

revised as shown in Table 9.

Table 9: Target Values Relating to the Air Pollution Prevention Effect of the Project

	At Time of Appraisal (before revision: annual power generation amount 2,409 GWh)	At Time of Ex-Post Evaluation (after revision: annual power generation amount 1,796 GWh)
Annual reduction volume of coal combustion	259,000 tons	193,000 tons
Reduction volume of NO_X	3,000 tons	2,236 tons
Reduction volume of SO_2	6,100 tons	4,547 tons
Reduction volume of coal dust	2,700 tons	20,130,000 tons
Reduction volume of CO_2	700,000 tons	522,000 tons

Source: Prepared by the evaluator using documents provided by JICA

For estimation of the actual values, it was attempted to reset the calculation formula to reflect the current conditions because the degree of impact of power generation on the environment had changed as a result of improved environmental measures and technological innovation since the original appraisal. However, for "the reduction volume of coal combustion per GWh of power generation", the coal consumption curve, etc. calculated at the time of appraisal were used due to the lack of the latest versions of such information. In the case of "the reduction volume of air pollutants, etc. per ton of coal combustion reduction volume", it was decided to use the latest relevant performance in entire China as shown in such obtainable reference materials as "the 13th Five Year Plan for the Electric Power Industry" for calculation. The results are shown in Table 10. "The actual values" were then calculated using this set of two standards.[15]

Table 10: Air Pollution Prevention Effect per 1 GWh of Power Generation

	Standards at Time of Appraisal	Standards at Time of Ex-Post Evaluation
Saved amount of coal combustion	Approx.107.51 tons	Approx. 107.51 tons (no change)
Reduction volume of NO_X	Approx.1.25 tons	Approx.0.96 tons
Reduction volume of SO_2	Approx.2.53 tons	Approx.0.92 tons
Reduction volume of coal dust	Approx.1.12 tons	Approx.0.73 tons
Reduction volume of CO_2	Approx.290.58 tons	Approx.89 tons

Source: Prepared by the evaluator using documents provided by JICA, the 13th Five Year Plan for the Electric Power Industry and the list of basic statistical data for the power sector in 2015

Note: The principal reasons for the change of the air pollution prevention effect per GWh of power generated between the time of appraisal and the time of ex-post evaluation are ① the progressive introduction of power generating facilities producing less environmental load and ② the promotion of environmental measures at existing power stations.

[15] When the emission reduction volume of air pollutants, etc. (per ton of coal combustion reduction volume) was calculated at the time of appraisal, data for entire Shanxi Province was used. For recalculation this time, data for entire china was used as data for Shanxi Province was unavailable.

Accordingly, the situation of air pollution prevention effect of the Project can be summarized as shown in Table 11.

Table 11: Situation of Air Pollution Prevention Effect of the Project

		Revised Target	Actual						
		(2011)	2011	2012	2013	2014	2015	2016	2016
		2 years after project completion	Year of project completion	1 year after project completion	2 years after project completion	3 years after project completion	4 years after project completion	5 years after project completion	Target achievement ratio
	Annual electric power sold (GWh)	1,796	381	31	114	401	620	1,638	91%
Standards at the time of appraisal	Annual reduction volume of coal combustion (,000 tons)	193	41	3	12	43	67	176	91%
	Reduction volume of NO_X (tons)	2,236	474	39	142	499	772	2,040	91%
	Reduction volume of SO_2 (tons)	4,547	965	78	289	1,015	1,570	4,147	91%
	Reduction volume of coal dust (tons)	2,013	427	35	128	449	695	1,836	91%
	Reduction volume of CO_2 ('000 tons)	522	111	9	33	117	180	476	91%
Standards at the time of ex-post evaluation	Annual reduction volume of coal combustion (,000 tons)	193	41	3	12	43	67	176	91%
	Reduction volume of NO_X (tons)	2,236	364	30	109	384	593	1,566	70%
	Reduction volume of SO_2 (tons)	4,547	351	29	105	369	571	1,508	33%
	Reduction volume of coal dust (tons)	2,013	278	23	83	293	453	1,196	59%
	Reduction volume of CO_2 ('000 tons)	522	34	3	10	36	55	146	28%

Source: Prepared by the evaluator using documents provided by JICA and responses to the questionnaire of the executing agency.

The standards at the time of appraisal basically linked the state of any achievement of each indicator related to the air pollution prevention effect to the power generation amount of the Xilongchi Power Station. Therefore, for the year of 2013 which was two years after project completion and the target values were set at the time of appraisal, all of the indicators failed to achieve their targets because the target value for the power generation amount was not achieved (target achievement ratio of 6%). In subsequent years, the power generation amount increased each year, nearly reaching the target level in 2016. Accordingly, each indicator related to the air pollution prevention effect also reached the 91% level of the original target. However, when the actual average annual performance for the period of four years from 2013 to 2016 is compared to the original target, the actual achievement ratio is as low as 39%.[16]

[16] As described later, the Project is believed to have the effect of facilitating the development of alternative energy sources (even though quantitative evaluation of this effect cannot be done) and, therefore, the air pollution prevention effect of the Project should be better than this figure.

When the standards reflecting the improvement of environmental measures and technological innovation after appraisal are used to evaluate the air pollution prevention effect of the Project, the general trend is similar to that with the standards adopted at the time of appraisal. However, the actual air pollution prevention effect has been much lower. Even in 2016 when the power generation amount almost reached its original target, some indicators greatly undershot their respective targets. The level of achievement was quite low at around 30% for the reduction of SO_2 and CO_2 for which measures to reduce these emissions had made great progress.[17]

(2) Contribution to Local Socioeconomic Development and Improvement of Local Poverty

The Project made a certain contribution to the increase of the fiscal revenue of the county government. Shanxi Xilongchi Pumped Storage Power Station Co., Ltd. (hereinafter referred to as "Xilongchi Power Company") was the third highest tax payer in Wutai County in 2015/2016 and the amount of its paid tax exceeded 5% of the county's revenue. Against the background of sluggish tax revenue under the recent low economic growth, the tax revenue from Xilongchi Power Company was highly significant for a state-designated poor county like Wutai (against the planned revenue of Wutai County of 65.31 million yuan in 2011 at the time of appraisal, the actual revenue was 317.34 million yuan in 2010 and 711.72 million yuan in 2015, showing much greater revenue than planned). In this county, the improvement of social infrastructure and services has been in progress using the increased fiscal revenue, including tax revenue from project-related business operations. While the actual monetary amount and other details are unknown, the construction work under the Project produced employment for construction workers, those providing accommodation for project-related personnel and food and beverage services in areas around the project site. At the time of the ex-post evaluation, many trucks were seen transporting coal using the road constructed for the Project. Accordingly, it is reasonable to assume that the Project had made a certain contribution to the development of the local socioeconomy.

Although Wutai County is still a state-designated poor county, the number of poor people has declined (currently some 7,000 - 8,000) and the county aims at eliminating all poor people by 2020. The increased fiscal revenue has made it possible for the county to strengthen such measures designed to reduce poverty as the fostering of and assistance for side businesses and infrastructure development. The interview survey

[17] It must be fully noted that the improvement of environmental measures and technological innovation after appraisal are considered to be external conditions from the viewpoint of project management.

with county officials confirmed that the tax revenue from project-related business operations contributes to the implementation of poverty reduction measures to a certain extent.[18]

(3) Promotion of the Development of Alternative Energies in Shanxi Province

As mentioned earlier, both the Government of China and Shanxi Provincial Government stress and promote the development of alternative energies from the viewpoint of environmental protection (while no alternative energy sources existed in the province in 2012, the installed wind power and photovoltaic power generation capacities stood at 7,300 MW and 2,700 MW respectively in 2016 (hydropower generation 2,300MW). Power supply from alternative energy sources (wind power, photovoltaic power, etc.) is rather unstable, making it difficult to generate power in response to the power demand. Moreover, the hours of high level power generation by these alternative energy sources do not necessarily coincide with the hours of a high power demand. As such, there is always the possibility of wasting the generated electric power when the power generation exceeds the demand. This means that an increase of the power supply and demand adjusting capacity is essential for an increase of the installed capacity of alternative energy sources. Here is one reason for the growing expectation of the role to be played by pumped storage power stations. Accordingly, officials of State Grid Xinyuan Company[19] and Shanxi Electricity Company interviewed for the ex-post evaluation believe that it is possible to utilize the surplus electric power generated by wind power (portion exceeding the demand) without waste by means of using this portion of generated electric power for pumping operation (conversion of 1.25 KWh of electric power generated by wind power to 1 KWh of pumped storage power generation). It is assumed that some 70% of the installed capacity of pumped storage power stations will be used for adjustment of the power supply and demand in connection with the development of alternative energy sources. Shanxi Province has an installed ordinary hydroelectric power generation capacity of some 1,100 MW. The large seasonal fluctuation of the discharge of rivers used for power generation, however, means that ordinary hydroelectric power generation cannot be expected to perform a sufficient adjustment function, raising high expectations that the Xilongchi Power Station will perform this function. The rapid growth of the amount of power generated by the Xilongchi Power Station in recent years is believed to reflect such situation, illustrating the strong contribution of the

[18] Partly because of the commitment of the central government to promoting the development of social infrastructure in rural areas, the communication, road and power supply networks fully cover even poor areas.

[19] This company manages and supervises all pumped storage power stations in China.

Project to facilitation of the development of alternative energies (and air pollution prevention through such development) in Shanxi Province.

3.4.2 Other Positive and Negative Impacts

(1) Impacts on the Natural Environment

The Environmental Bureau of the county government conducted monitoring of the natural environment in association with the implementation of the Project in addition to its ordinary environmental monitoring for a period of three years during which the impacts on the natural environment were thought to be great, if any, on three items, i.e. air quality, noise and dust. The interview survey with officials of the county's Environmental Bureau found that all of the monitoring results for these three items were within the respective standards, posing no significant problems. There were cases where a minor problem involving dust, etc. occurred during the construction period but appropriate measures were implemented through consultations with the contractors. In regard to the river water quality, the ordinary monitoring regime (checking of the state of water pollution in the downstream of the river four items a year) which is still implemented at the time of ex-post evaluation checks the water quality and no deterioration of the water quality has been found.[20] At the time of project planning, human sewage from the power station complex was thought to pose the biggest problem. However, sewage treated on site to meet the relevant standards is mostly used for greening of the site, etc. As such, hardly any treated sewage is currently discharged to the river. Accordingly, it is safe to judge that the Project has caused hardly any negative impacts on the natural environment.

(2) Resettlement and Land Acquisition

The actual situation of resettlement and land acquisition necessitated by the implementation of the Project is summarized in Table 12 and the actual figure exceeds the planned figure for both resettlement and land acquisition. The actual number of resettled residents represents the revised figure based on the results of the survey on the intentions of residents which was conducted again at the implementation stage. The increase of the scale of land acquisition was, in fact, the acquisition of waste land (the size of housing plots and farmland to be acquired remained the same as planned) to fulfill the operational needs of the power station. As such, no special problems are observed in regard to these matters.

[20] Water required for pumping operation is taken from the river but the actual intake volume is limited to replenishing the amount of water lost due to evaporation, etc. from the two regulating reservoirs, causing hardly any impact on the river flow.

Table 12: Implementation Situation of Resettlement and Land Acquisition

Item	Target Area	Planned	Actual
Land acquisition	Xihe Village (administrative village) and Xilongchi Village (natural village)	240 ha (of which 7.5 ha is housing plots and 92 ha is farmland)	330 ha (of which 7.5 ha is housing plots and 92 ha is farmland)
Resettlement	Construction site for the upper regulating reservoir (Xilongchi Village (natural village))	630 persons	55 persons (Done in 2003) On the basis of the resident survey results, 44 persons were moved to homes of relatives or friends, including those outside the village, and 11 persons were individually moved to other areas.
	Construction site for the lower regulating reservoir (Xihe Village (administrative village))		620 persons (Done in June, 2003) Collectively moved to a site near the center of the village

Source: Documents provided by JICA and responses to the questionnaire of the executing agency

Residents of Xihe Village (construction site of the lower regulating reservoir) were collectively resettled at a former agricultural experiment station site.[21] In accordance with the national standards, the amount of the compensation for each household was decided taking the conditions of the cultivated land, crops cultivated and farming income into consideration (the farming area per person was increased from 0.5 mu (shimu)[22] to 1 mu). In addition, 600 yuan is offered every year for 20 years from 2003. A visit to the resettled area and interview results with officials and residents of Xihe Village confirmed that the income and standard of living of these resettled residents have clearly improved. While some residents purchased a house (floor area of 90 m^2 at a price of 40,000 yuan) using the financial compensation, etc., those residents which could not afford the price immediately were given the facility of installment payments. Therefore, the residents did not experience any financial problems following their resettlement. Because the resettled site enjoy a good location being near to the center of the town, business opportunities other than farming (and the income from them) have increased (the annual income per capita has doubled from 3,000 yuan to 6,000 yuan and approximately two-thirds of this income comes from businesses other than farming). While the previous residential site did not have a full range of social infrastructure, the new site has such lifelines as water supply, sewerage and gas supply which have greatly contributed to the improved standard of living. The village authority has constructed apartment blocks on vacant land. The resulting favorable living environment has attracted purchasers from outside the village, increasing the village population to as many as 1,100 at present. The conversion of farming from dry

[21] The acquisition of the resettlement site did not pose any problems.
[22] Mu (shimu) is a Chinese unit for agricultural land and is equivalent to approximately 666 m^2.

field farming to rice cultivation planned at the time of appraisal has been implemented as planned with the guidance of nearby farming households with experience of rice cultivation and the county's Agricultural Bureau. As a result, the newly settled farming households have been capable of cultivating rice without assistance since the second year. However, the rice acreage is showing a declining trend because although rice cultivation produces a slightly higher income per unit of land than maize cultivation, it requires much greater care than the latter (at the time of ex-post evaluation, rice and maize are cultivated on some 20% and 70% respectively of the arable land). The resettlement of the residents of Xihe Village is recognized as a successful example of a resettlement project and the new site accepts study visits from those involved in similar projects.

In the case of Xilongchi Village (the construction site of the upper regulating reservoir), 44 people were moved to the home of relatives or friends, including those outside the village, while 11 people were individually moved to other areas, following the results of the survey on the intentions of residents. As in the case of Xihe Village, compensation was provided based on the national standards but the amount of financial compensation was slightly higher than the level paid to the residents of Xihe Village in view of individual resettlement rather than collective resettlement. The interview survey with resettled villagers of Xilongchi Village found that the living conditions, etc. of those moving to other areas had improved compared to the poor conditions experienced at the previous village site located in a mountain area. A high level of satisfaction was confirmed particularly in regard to improvement of the educational environment and conditions for children. The situation of those who resettled within the same village area is unclear as an interview survey with these people could not be conducted. However, it is reasonable to assume that the standard of living has improved to a certain extent because of ① the assistance provided by Xilongchi Power Company in the form of dug wells and assistance for farmland improvement in areas near the power station and ② much improvement of access to outside the village due to the improvement of roads linking the power station and other areas under the Project.

According to the interview survey results with the county government, the factor for the successful resettlement of residents was the well-thought out advance preparations by the county government, including the establishment of a resettlement office dedicated to the Project and served by 14 staff members. The deputy governor of the county played a leading role, including on-site coordination, and a survey on the intentions of residents and explanatory meetings were actively organized. Although the office dedicated to the Project has already been closed, the county government's Immigration Office provides such follow-up services for resettled residents as

consultations on daily life and consumer affairs.

Housing for resettled villagers
(Xilongchi Village)

Rice cultivation at the resettled site
(Xilongchi Village)

(3) Development of Other Pumped Storage Power Stations in China and Facilitation of Business Orders Placed to Japanese Companies

The interview survey with officials of State Grid Xinyuan Company which manages pumped storage power stations in China found that the Project is considered a successful model for pumped storage power stations partly because of its employment of advanced technologies. Following the success of the Project, Shanxi Province plans to promote the construction of further pumped storage power stations. The utilization of state-of-the-art technologies at the Xilongchi (Pumped Storage) Power Station has been attracting many visitors involved in hydropower generation in China. As such, the Project has had a certain impact on the development of pumped storage hydropower generation in other parts of China.

For the construction of the Xilongchi Power Station, Japanese companies delivered a number of main equipment, including generators and pump turbines. Those Japanese manufacturers involved in the Project subsequently succeeded in winning orders mainly through their local subsidiaries for equipment, etc. (four sets of 320,000 kW pump turbines, generators and accessories) for the Qingyuan Pumped Storage Power Station (Guangdong Province) in April, 2010. The underlying reasons for this success were ① the Chinese stakeholders in pumped storage hydropower generator were greatly impressed by the excellent equipment produced by Japanese manufacturers (including the aspects of noise, vibration, etc.) and ② Xilongchi became an actual showpiece of Japan's successful contract to build a pumped storage power station in China.[23] The Qingyuan Power Station was the first order for a pumped storage power

[23] It was possible for Japanese companies with both advanced technical capability and competitiveness over other companies to win the contract for the Project because of the facts that " the Project would involve a

station successfully won by Japanese manufacturers involved in the Project in a domestic tender in China.[24] The staff members of these Japanese manufacturers interviewed for the ex-post evaluation said that the receipt of an order for the Project undoubtedly contributed to new orders and that they are planning to continue to compete for orders as pumped storage power generation is one of the few fields in which Japanese companies enjoy better competitiveness over Chinese companies.[25] Accordingly, the Project is believed to have contributed to facilitate the winning of orders for pumped storage power generation projects in China by Japanese companies.

As far as the quantitative effects relating to the effectiveness and impacts of the Project are concerned, the Xilongchi Power Station performs the roles of "handling the peak demand" and "adjusting the power supply and demand for the development of alternative energies (promotion of air pollution prevention)" in line with the changing roles expected of the Project. At the time of ex-post evaluation, the target values for various indicators are mostly achieved. The expected qualitative effects (① reduction of fuel consumption and ② improved reliability and economy of power system operation through the mitigation or reduction of DSS operation) are also achieved. Other positive impacts include its contribution to the socioeconomic development and poverty reduction of local communities, development of pumped storage hydropower generation in other areas of China and facilitation of the winning of orders by Japanese companies. No significant problems are observed in such aspects as impact on the natural environment, resettlement of residents and land acquisition. However, all the indicators relating to the effectiveness and impacts considerably undershot their respective target values for two years after project completion set at the time of appraisal.

This Project has achieved its objectives to some extent. Therefore, the effectiveness and impact of the Project are fair.

---

large head which was unprecedented in China" and that "the ODA loan project (international competitive bidding) meant that Japanese companies were able to bid without the obligation of technology transfer".

[24] One important factor for the successful bid was the China's shifting of the emphasis when deciding the contractor for a pumped storage power generation project in China on "technology transfer" to "a domestic company (private tender)" and further to "a domestic company in general (including a foreign subsidiary)".

[25] The 13th Five Year Plan for the Electric Power Industry plans to commence the construction of pumped storage power stations with a total installed capacity of 60 million kW throughout China in the five year period up to 2020.

3.5 Sustainability (Rating: ③)

3.5.1 Institutional Aspects of Operation and Maintenance

As a result of the Chinese government policy of placing all pumped storage power stations in the country under the control of State Grid Xinyuan Company (established in March, 2005 under State Grid Corporation of China) for the purpose of the expert as well as central management of these power stations, the superior organization and shareholder composition of Xilongchi Power Company has changed as shown in Table 13. At the time of appraisal, it was planned that Shanxi Electricity Company would be responsible for the operation and maintenance of the power station and Xilongchi Power Company would be responsible for managing its assets. Following the change of the systems, State Grid Xinyuan Company and Xilongchi Power Company are currently responsible for the management of assets and the operation and maintenance of the power station respectively. Despite such partial changes of the systems due to the Chinese government policy, etc., no problems have consequently emerged as these changes apply to all pumped storage power stations in China. The shareholder ratio of local organizations of Shanxi Province has dropped compared to the original plan but power generation operation is conducted under the instruction of Shanxi Electricity Company as originally planned from the viewpoint of the central operation of the power system.

Table 13: Shareholders and Operation and Maintenance System of Xilongchi Power Company

	At Time of Appraisal		At Time of Ex-Post Evaluation	
Shareholders	Shanxi Electricity Company Shanxi Local Electric Power Group Company	73% 27%	State Grid Xinyuan Company China International Energy Group State Grid Jibei Electric Power Company State Grid Shanxi Electric Power Company Shanxi Electricity Company	43% 17% 16% 14% 10%
System	Supervising agency	State Electric Power Company	Supervising agency	State Grid Xinyuan Company
	Operation and maintenance	Shanxi Electricity Company	Operation and maintenance	Xilongchi Power Company
	Asset management	Xilongchi Power Company	Asset management	State Grid Xinyuan Company
	Instruction of power generation	Shanxi Electricity Company	Instruction of power generation	Shanxi Electricity Company

Source: Documents provided by JICA and responses to the questionnaire of the executing agency

As of March 2017, Xilongchi Power Company employs 79 persons (of which 51 are engineers). According to the results of interviews with officials of this company, the current staff strength is satisfactory and there are no personnel-related problems.

3.5.2 Technical Aspects of Operation and Maintenance

The basic common system for the operation and maintenance of pumped storage power stations nationwide in accordance with the policy of State Grid Xinyuan Company is to entrust much of the equipment maintenance (mainly routine work) to an external specialist company[26] and for in-house engineers of the power station (employees of Xilongchi Power Company in the present case) to conduct work requiring high level technical skills and to supervise the entrusted external company. One reason for such an arrangement is that the upper limit of employees is set forth by State Grid Xinyuan Company.

Many engineers of Xilongchi Power Company are officially qualified advanced engineers or engineers who, therefore, have a sufficient technical capability and experience. Staff members of Xilongchi Power Company undergo not only common training designated by State Grid Xinyuan Company for those working at pumped storage power stations nationwide but also the company's own training which is planned by the specialized section and periodically as well as methodically conducted. External companies to which maintenance, etc. is entrusted are periodically selected by the tender process. These companies must have sufficient experience of the work at pumped storage power stations throughout China based on common nationwide criteria. Maintenance work is conducted on the basis of uniform standards which are applicable to all pumped storage power stations in China. As a result, both Xilongchi Power Company and the external company entrusted with the maintenance work of the Xilongchi Power Station have the necessary operational and maintenance skills. As the maintenance of equipment and handling of problems have been properly conducted, no serious problems have occurred since the commissioning of the power station. The system in place to deal with a major operational or maintenance problem is that such a problem is dealt with by the assistance of the equipment manufacturer(s) and State Grid Xinyuan Company. If necessary, the assistance of another pumped storage power station is sought. When the No. 4 unit of the Xilongchi Power Station malfunctioned in 2011, a swift response was made with the assistance of the manufacturer with operation restarting within one month.

[26] Each work is graded as one of four grades (A through D) based on the required technical level. Grade B work through Grade D work requiring a relatively low level of technical skills, etc. are externally entrusted (Grade A work: total overhaul, inspection and repair of equipment; Grade B work: solving of problems which cannot be eliminated by Grade C work; Grade C work: standard inspection and repair of damaged or deteriorated equipment; Grade D work: handling of minor problems of equipment which is mainly running smoothly).

3.5.3 Financial Aspects of Operation and Maintenance

As mentioned earlier, Xilongchi Power Company conducts power generating operation under the instruction of Shanxi Electricity Company which operates the power system. The entire amount of generated electricity is purchased by the latter. These two companies have concluded a contract by which a fixed amount based on the installed capacity is paid by the latter to the former irrespective of the generated amount of power as planned at the time of appraisal. Since 2012 when all four generating units became operational, Xilongchi Power Company has received some 450 million yuan or more annually. As a result, its annual account has been in surplus and its financial status has been stable even though the actual revenue changes from one year to another.

The financial performance of Xilongchi Power Company is shown in Table 14. As already described in the section on the FIRR (see 3.2.3), the size of the revenue is around half of the planned revenue at the time of appraisal. Because of this, the profitability is lower than planned. However, the financial status of the company is stable at present. Unlike the plan prepared at the time of appraisal (the power purchase contract is to be revised every three years), the contract is now due for revision every year. However, as this revision follows an appropriate procedure based on regulations set by the Government of China and also as the contracted amount has remained unchanged, no financial problem has so far occurred. The provincial government and other stakeholder organizations intend to continue their support so that Xilongchi Power Company can conduct its business in a stable manner.[27]

Table 14: Historical Financial Performance of Xilongchi Power Company

(Unit: million yuan)

	2010	2011	2012	2013	2014	2015	2016
Revenue	227.2	311.6	455.3	454.9	454.5	455.3	454.2
Expenditure	292.7	338.9	302.7	147.8	315.5	450.9	409.9
Profit	-65.5	-27.3	152.7	307.1	139.0	4.4	44.3

Source: Responses to the questionnaire of the executing agency

3.5.4 Current Status of Operation and Maintenance

The monitoring, maintenance and periodic inspection of equipment at the Xilongchi Power Station are properly conducted by the external company entrusted with this work. The operation of this power station is monitored on-line for 24 hours a day by

[27] The balance sheet of Xilongchi Power Company for the 2016 business year shows 3,410 million yuan of assets (3,310 million yuan of fixed assets and 1,000 million yuan of current assets), 2,040 million yuan of liabilities (1,490 million yuan of fixed liabilities and 550 million yuan of current liabilities) and 1,360 million yuan of capital, posing no problems.

State Grid Xinyuan Company and no serious problem has occurred since its commissioning to the time of the ex-post evaluation. There have been no problems in regard to the procurement of spare parts. The field reconnaissance conducted as part of the ex-post evaluation has confirmed that ① each equipment is tidily as well as cleanly maintained and ② guidance and awareness raising for in-house engineers as well as for workers of the entrusted company are actively conducted using instruction posters, etc. designed to ensure smooth operation and maintenance. Measures and cautionary notices to ensure safety are specially emphasized. According to officials of the executing agency, the handling of any equipment breakdown or abnormality is smoothly conducted in cooperation with the entrusted company. As such, the conditions of the main facilities and equipment are generally good. It is safe to assume that the operation and maintenance of the Xilongchi Power Station are properly conducted based on the relevant national rules for pumped storage power stations and those of Xilongchi Power Company.

While the operating rate of the Xilongchi Power Station was low for several years after project completion as described earlier it has been increasing in recent years in response to the growing need for the power supply and demand adjustment function of this power station following the development of alternative energy sources.

No major problems have been observed in the institutional, technical and financial aspects and current status of the operation and maintenance system. Therefore, the sustainability of the Project effects is high.

4. Conclusions, Lessons Learned and Recommendations

4.1 Conclusions

The objective of the Project was to improve the peak demand handling capability and the reliability as well as economy of power system operation by constructing a pumped storage power station in Shanxi Province, thereby contributing to the containment of the emission volume of air pollutants. The Project was in line with the electric power and environmental policies of the Government of China as well as the government of the target province, development needs of China to improve air pollution and to increase the stability and economy of power supply and Japan's ODA policy. As such, the relevance of the Project is high. The efficiency of the Project is fair because of the fact that although the project cost was within the planned cost, the project period exceeded the plan. The expected role of the Project (Xilongchi Power Station) has changed as a result of the changing circumstances of the electric power industry in Shanxi Province. In response to such changes, the Xilongchi Power Station currently performs its principal roles of

“responding to the peak demand” and “adjusting the power demand and supply for the development of alternative energies (facilitation of air pollution prevention) without fail and various indicators had mostly achieved the target values by the time of this ex-post evaluation. Sufficient positive effects are observed with the anticipated improvement of the stability and economy of power supply. A certain effect of the Project is also confirmed in relation to ① development of the socioeconomy and improvement of poverty in local communities and ② facilitation of the further introduction of Japanese technologies to China. In contrast, the target values set at the time of appraisal were substantially undershot for all indicators of the effectiveness and impacts two years after project completion. In consideration of the foregoing, the effectiveness and impact of the Project are fair. The sustainability of the Project poses no problems in terms of the institutional, technical and financial aspects. As good operation and maintenance conditions were confirmed for the facilities and equipment, the sustainability of the Project is high.

In light of the above, the Project is evaluated as satisfactory.

4.2 Recommendations

4.2.1 Recommendations to the Executing Agency

None

4.2.2 Recommendations to JICA

None

4.3 Lessons Learned

None

Comparison of the Original and Actual Scope of the Project

Item	Original	Actual
1.Project Outputs	1) Upper regulating reservoir: 4.2 millionm^3 2) Lower regulating reservoir: 4.2 millionm^3 3) Underground power station: 300MW x 4 units 4) Headrace and tailrace 5) Switchgear: transformers 340MVA × 4, 500kV outgoing system 6) Consulting service: Assistance for tender; review of the detailed design; assistance for work supervision 7) Procured equipment: Reversible pump-turbine, GIS, cables, auxiliary equipment, etc.	1) Upper regulating reservoir: 4.6 millionm^3 2) Lower regulating reservoir: 4.8 millionm^3 3) As planned 4) As planned 5) As planned 6) As planned 7) Quantities, etc. of monitoring equipment, etc. were slightly changed due to necessary circumstances.
2. Project Period	November, 2001 – August, 2009 (94 months)	November, 2001 – August, 2011 (118 months)
3. Project Cost Amount Paid in Foreign Currency Amount Paid in Local Currency Total ODA Loan Portion Exchange Rate	23,241 million yen 54,750 million yen (3,650 million yuan) 77,991 million yen 23,241 million yen 1yuan =15 yen (As of September, 2001)	19,069 million yen 50,140 million yen (3,581 million yuan) 69,209 million yen 19,069 million yen 1yuan =14.0 yen (Average between 2001 and 2011)
4. Final Disbursement	October, 2015	