Republic of Armenia

FY2015 Ex-Post Evaluation of Japanese ODA Loan

"Yerevan Combined Cycle Co-Generation Power Plant Project"

External Evaluator: Kenichi Inazawa, Octavia Japan Co., Ltd.

0. Summary

This project constructed a new combined cycle co-generation power plant (hereafter referred to as "CCPP") in a suburb of the capital Yerevan, with a view to enhancing the power supply capacity. This project is consistent with power sector development policies in Armenia, such as the "Integrated Financial Rehabilitation Plan for Public Utilities" (2003-2007) and the "Main Direction for Developing the Energy Sector in the Period up to 2036" (2015). Before the start of the project, the Yerevan Thermal Power Plant, which had been operational since early 1960s, was aging, and there was a need to construct new power facilities in order to stabilize the power supply. At the time of the ex-post evaluation, the Armenian government plans to develop and attract investments for new power sources; and thus this project is consistent with the development needs of the country. Additionally, given that this project is also harmonized with the assistance policy of Japan, the relevance of this project is high. The actual project costs fell within the planned budget, as did the project period; the efficiency is also therefore high. With regard to the project effectiveness, the maximum output, capacity factor (power generation), availability factor, auxiliary power ratio, forced outage hours and frequency by cause, as well as net generation, either met or exceeded the initial expectations, on the whole. On the other hand, the maximum heat output per hour, plant capacity factor (heat supply portion), gross thermal efficiency and heat supply did not reach the initial targets, mainly due to the shutdown of the Nairit Chemical Plant. Therefore, the effectiveness and impact are fair. Since no particular problems are observed in the institutional, technical and financial aspects of operation and maintenance, the sustainability of the effects of this project is high.

In light of the above, this project is evaluated to be highly satisfactory.

1. Project Description

Project Location

Yerevan Combined Cycle Co-Generation Power Plant

1.1 Background

In Armenia, since many of the power generation facilities were deteriorated with decreasing reliability of the power facilities and supply capacity, there was a need to increase the capacity of the power supply and to address the issue of power shortages by developing new power supply facilities. Yerevan Thermal Power Plant, located in a suburb of the capital Yerevan, began its operation in the 1960s as a co-generation thermal power plant using natural gas as fuel. The plant was becoming old and operating with a significantly decreased power supply capacity. Since the capital Yerevan roughly accounts for one third of the national population[1] and about half of the country's demand for power, there was a need to develop new power generation facilities near Yerevan, as the area of highest demand, thereby stabilizing the power supply in and around the city.

1.2 Project Outline

The objective of this project is to increase the country's power supply capacity by constructing a new CCPP near the capital, Yerevan, thereby contributing to the alleviation of future electricity shortages and to sustainable economic growth.

Loan Approved Amount/ Disbursed Amount	26,409 million yen / 26,399 million yen
Exchange of Notes Date/ Loan Agreement Signing Date	March, 2005 / March, 2005

[1] Approximately 3.2 million (2004 data; Source: International Monetary Fund)

Terms and Conditions	Interest rate: 0.75% Repayment Period: 40 years (Grace Period: 10 years) Conditions for Procurement: General Untied
Borrower / Executing Agency(ies)	The Government of the Republic of Armenia / Yerevan Thermal Power Plant Closed Joint Stock Company (hereafter referred to as "YTPP")
Final Disbursement Date	July, 2013
Main Contractor (Over one billion yen)	Mitsui & Co., Ltd. (Japan) / GS Engineering and Construction Corporation (South Korea)
Main Consultant (Over 100 million yen)	Tokyo Electric Power Services Co., Ltd. (Japan)
Feasibility Studies, etc.	F/S (January, 2003)
Related Projects	【ODA Loan Projects】 ・ "Electricity Transmission and Distribution Project[2]" (The loan agreement was signed in 1999)

2. Outline of the Evaluation Study

2.1 External Evaluator

Kenichi Inazawa, Octavia Japan Co., Ltd.

2.2 Duration of Evaluation Study

Duration of the Study: September, 2015 – October, 2016

Duration of the Field Study: January 16 – January 30, 2016; and
April 2 – April 8, 2016

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

3.1 Relevance (Rating: ③[4])

3.1.1 Relevance to the Development Plan of Armenia

[2] It was co-financed by the World Bank and aimed to develop electricity transmission and distribution networks in all parts of Armenia, to stabilize electricity power and improve reliability, and to strengthen the management capacity of the power transmission and distribution company.

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

[4] ③: High, ② Fair, ① Low

Before the start of this project, the government of Armenia had formulated a national plan for public services entitled “The Integrated Financial Rehabilitation Plan for the Public Sector” (2003-2007), which prioritized energy security and planned the construction of new power generation facilities. The plan stated that this project would be given priority and executed as a national project from the perspective of energy security.

At the time of the ex-post evaluation, the government of Armenia has formulated the document “Long-Term Development Program/Plan for Energy Sector through 2036” (2015), which has set out the future direction of the power sector and highlighted the importance of energy security - increasing power supply by importing more natural gas.

Based on the above, the development of the power sector formed an important part of Armenia’s national development plan at the time of the appraisal as well as at the time of ex-post evaluation. Therefore, this project has been consistent with the country’s policy.

3.1.2 Relevance to the Development Needs of Armenia

Before the start of this project, many of the power generation facilities in Armenia had been in operation for more than 30 years. Power supply capacity and the reliability of the facilities were markedly decreasing. There was therefore a need to promote the development of new power generation facilities, thereby increasing the power supply capacity and alleviating power shortages. In particular, Yerevan Thermal Power Plant, a co-generation thermal power plant using natural gas as fuel, which had 550MW capacity when it began operating in the 1960s, had become outdated. Due to aging power generation unit, its maximum capacity was only 85MW before the start of this project. It was therefore predicted that demand for power would not be met by the existing generation facilities in the future. In particular, there was a need to construct new power facilities and stabilize power supply to the capital Yerevan, which roughly accounts for one third of the national population and about half of the country’s demand for power. Heat supply was managed in accordance with the operation status of the largest energy-consuming entity Nairit Chemical Plant (accounting for more than 90% of the heat supply)[5]; and it was projected that the heat supply would not meet future demand. Thus, there was a need to construct the combined heat and power facilities to replace the existing power plant which was expected to stop operation in the future.

[5] Located near YTPP, this large chemical factory mainly produces synthetic rubbers such as latex and chloroprene. It was a state-owned company during the era of the former Soviet Union and later became a private company, having been acquired by a Russian corporation. At the time of the appraisal, products from this factory were sold domestically and internationally, including Russia and Ukraine.

It has been confirmed at the time of the ex-post evaluation that this project is contributing to the stabilization of power supply within the country and is exporting electricity to neighboring countries, as a result of the construction of the 220MW CCPP, with lower environmental impact and more heat efficiency under this project[6]. Out of the net power generation of the entire country in 2015[7] (7,798.19GWh/year), 1,594.6GWh/year (roughly 20%), was supplied by this project. Apart from this thermal plant, there are a Hrazdan CCPP No.5[8] and a Hrazdan TPP[9]. The latter is more than 40 years old, and will cease operation in 2017 due to deterioration. The government of Armenia is therefore planning to develop new power sources at the time of this ex-post evaluation, and as a way of strengthening and stabilizing the country's power facilities, CCPP construction is under consideration at a site adjacent to this project.

Based on the above, securing a stable electricity supply remains a priority for Armenia at the time of this ex-post evaluation, and this project continues to be important. Therefore, this project is consistent with the development needs of the country at the time of both the appraisal and the ex-post evaluation.

3.1.3 Relevance to Japan's ODA Policy

Based on the ODA Charter approved by the Cabinet in 1992 and the "Medium-Term Policy on Official Development Assistance" formulated in the same year, JICA developed the "Strategy for Overseas Economic Cooperation Operations", laying out the overall direction of ODA loans and priority regions and sectors. In this strategy the following were identified as priority sectors: (1) strengthening of the economic structure for sustainable growth and the removal of impediments to this growth (appropriate macroeconomic management, strengthening of the economic infrastructure, improved economic infrastructure); (2) poverty alleviation and mitigation of regional disparities; (3) environmental conservation including disaster prevention and disaster management; and (4) human resources development and institution building.

[6] This will be explained further in Section 3.4.1.1 Alleviation of Future Power Shortage under Impacts. The main power sources of Armenia are nuclear, thermal and hydro power. Total installed capacity by source is: nuclear power approximately 400MW (one place); thermal power 1,500MW (three places); and hydro power 1,880MW (11 places) at the time of the ex-post evaluation.
[7] Net power generation is the total gross power generation produced minus the electricity consumed within the plant.
[8] The approximate capacity is 285MW, and net generation is 638GWh/year (2015). It began operation in 2012.
[9] The capacity is roughly 810MW and net generation is approximately 547GWh/year (2015). It began operation in 1969.

This project supports Armenia in its aim to stabilize power supply and promote economic growth by developing power infrastructures. Since it is in line with priority above, it can be said that this project was consistent with Japan's ODA policy.

In light of the above, this project has been highly relevant to the development policies and development needs of Armenia, as well as to Japan's ODA policy. Therefore, its relevance is high.

3.2 Efficiency (Rating: ③)

3.2.1 Project Outputs

This project constructed a CCPP with a power generation capacity of 205MW level of electricity and heat supply capacity of 103 Gcal/h on a vacant plot of land adjacent to the existing Yerevan Thermal Power Plant in southern Yerevan[10]. Table 1 shows the planned and actual outputs of this project. The project outputs were achieved as per the initial plan.

Table 1: Planned and Actual Outputs of the Project

Plan at the Time of Appraisal (2005)	Actual at the Time of Ex-Post Evaluation (2016)
1) Construction of a combined cycle co-generation power plant (gas turbine power generation facility, steam turbine generation facility, heat recovery steam generator (HRSG), associated facilities and spare parts)	1) – 4) were implemented as planned.
2) Renovation of the existing related facilities (cooling, circulation water pump and pipes, chemical shop, outdoor switching station, heat pipes, pipes for water for industry and extinguishing fires)	
3) Related civil engineering and construction works (including leveling of the project site)	
4) Consulting services (detailed design, preparing documents for pre-qualification, bidding and contracting, assisting procurement, construction supervision, quality evaluation, assisting operation and maintenance, supporting environmental monitoring, technology transfers and human resource development for the facility operation and maintenance)	

Source: Documents provided by JICA, answers to the questionnaire and site inspections (actual at the time of the ex-post evaluation)

[10] It was confirmed through interviews with YTPP and site inspections that the existing power generation facility and the heat facility (two units) at Yerevan Thermal Power Plant ceased operation in 2010 and 2013, after the completion of this project.

Photo 1: Inside the Yerevan CCPP

Photo 2: Central Control Room

3.2.2 Project Inputs

3.2.2.1 Project Cost

The project cost was planned to be 21,224 million yen at the time of the appraisal (of which Japanese ODA Loan was 15,918 million yen). In principle, efficiency is evaluated by comparing the actual expenditure with the initial plan. However, since the loan agreement for this project was amended in May 2008 (with the provision of an additional loan)[11] as a result of the extreme inflation of prices affected by world markets, and cause of the cost increase was not related to prolonged procurement process as the procurement was generally smooth. Therefore the actual cost was compared with the revised project cost after the time of loan agreement amendment. The planned project cost after the revision was 38,444 million yen (of which Japanese ODA Loan was 26,409 million yen).

The actual cost was 33,720 million yen as compared with the revised planned cost (38,444 million yen), approximately 88% of the plan. (It was lower than the plan mainly due to fluctuations in exchange rates[12]). The reasons for the additional loan provision are explained below.

Due to the trend of increasing demand for construction worldwide and an influx of capital into the market, price of steel materials increased globally on and after the project launched (2005). In addition to the price increase in steel materials, demand for power generation mainly in emerging nations increased, and demand for construction of thermal power generation plants increased since demand for higher quality gas turbines (the main part of a cogeneration thermal power plant)

[11] The conditions of the additional loan were the same as those applied at the time of the exchange of notes in March 2005: an interest rate of 0.75%, repayment period of 40 years (of which the grace period is 10 years) and general untied terms.

[12] During the project implementation, Japanese yen appreciated against the US dollar and the Armenian dram (AMD).

markedly increased, and the construction and installation price increased by 160% and the price (US dollar-based) of the whole plant construction of this project including gas turbines and other related facilities increased by 200%, as compared with 2004 (before the start of the project[13]). Under such circumstances, the contract amount as in September 2007 for the plant construction was significantly higher than the initial expectation[14]; this contract amount was not particularly high and quite appropriate considering the market price at that time. However, it was difficult for the government of Armenia to come up with the funds to cover the differences in cost within such a short period of time[15]. As the imbalance between domestic power supply and demand was becoming urgent, the Armenian government requested an additional loan from the Japanese government with a view to preventing further price inflation, in view of the time constraints. As such situations were difficult to predict or avoid, it is judged that the decision to extend the additional loan was appropriate.

3.2.2.2 Project Period

At the time of the appraisal, the project period was planned to be six years and seven months (79 months), from March 2005 to September 2011. However, after the amendment of the loan agreement (the extension of the additional loan), the project period was changed to seven years and three months (87 months) from March 2005 to May 2012. As a consequence, this ex-post evaluation compares the actual period with the updated plan. The actual project period was seven years and two years (86 months) from March 2005 to April 2012, which is approximately 99% of the plan.

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

Financial Internal Rates of Return (FIRR)

FIRR was recalculated using the same conditions as at the time of the appraisal: taking electricity revenue as a profit and the construction cost and maintenance expenses of this project as costs, and assuming a project life of 30 years. The result was 16.08%, which is higher than 13.4% calculated at the time of the appraisal. This is because income from electricity sales was higher than expected at the time of the appraisal[16], increasing the profits.

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[13] The source is documents provided by JICA.

[14] The contract amount was 24,538 million yen, which was significantly higher than 14,361 million yen, the initial budget for the main construction (the planned amount).

[15] There was also self-supporting effort by the government of Armenia, such as supplementing for increased costs related to the spare parts of gas turbines, with their own budgets. (The source is documents provided by JICA.)

[16] At the time of the appraisal: 15.69AMD/kWh, at the time of the ex-post evaluation: 27.82AMD/kWh, which is an increase in the electricity wholesale price by about 177%.

In light of the above, both the project costs and project period were within the plan. Therefore, the efficiency of the project is high.

3.3 Effectiveness[17] (Rating: ②)

3.3.1 Quantitative Effects (Operation and Effect Indicators)

This project constructed a CCPP with a power generation capacity of 205MW level and heat supply capacity of 103Gcal/h, with a view to increasing the capacity of the power supply. Table 2 shows the targets and actual figures indicating the quantitative effects of this project[18].

[17] Sub-rating for Effectiveness is to be put with the consideration of impact.
[18] The target was for the year of project completion. Although the project completion was 2012, actual data was not available for that year. This ex-post evaluation therefore compares it with the actual figure, one year after the project completion (2013).

Table 2: Baselines, Targets and Actual Figures Indicating Quantitative Effects

Indicator	Target	Actual		
	2011 At the time of project completion	2013 One year after project completion	2014 Two years after project completion	2015 Three years after project completion
【Operational Indicators】				
1) Maximum Output	205MW*	220MW	220MW	220MW
2) Maximum heat output per hour	103Gcal/h	0	0	0
3) Capacity factor (power generation)	70.0%	85.0% or higher	80.6%	88.8%
4) Capacity factor (heat supply)	50.0%	0	0	0
5) Availability factor	86.7%	90.0% or higher	82.9%	91.2%
6) Auxiliary power ratio	2.8%	3.1%	3.1%	3.1%
7) Gross thermal efficiency (power generation + heat supply)	68.0%	49.0% or higher**	49.3%**	49.3%**
8) Forced outage hours by cause	Human error: 0 hour/year Machine failure: 0 hour/year Periodic inspection: 1,160 hours/year	Human error: 0 hour/year Machine failure: 0 hour/year Periodic inspection: 240 hours/year	Human error: 0 hour/year Machine failure: 0 hour/year Periodic inspection: 1,089 hours/year	Human error: 0 hour/year Machine failure: 0 hour/year Periodic inspection: 240 hours/year
9) Forced outage frequency by cause	Human error: 0 times/year Machine failure: 0 times/year Periodic inspection: Once/year	Human error: 0 times/year Machine failure: 0 times/year Periodic inspection: Once/year	Human error: 0 times/year Machine failure: 0 times/year Periodic inspection: Once/year	Human error: 0 times/year Machine failure: 0 times/year Periodic inspection: Once/year
【Effective Indicators】				
1) Net generation	1,222GWh/year	1,764GWh/ year	1,398GWh/ year	1,594GWh/ year
2) Heat supply	451,100Gcal/ year	0	0	0

Source: Documents provided by JICA (targets at the time of the appraisal), answers to the questionnaire and YTPP's responses (at the time of the ex-post evaluation)

Note*: Average of 220MW during winter when power demand is high, and 190MW during summer when the demand is low.

Note**: Data is only for power generation.

Regarding the indicators shown in Table 2, the status at the time of the ex-post evaluation was confirmed using the questionnaire and interviews with YTPP. The status of the operational indicators is as follows:

1) The targeted maximum output (205MW) was calculated by taking an average of 220MW for the winter when power demand is high and 190MW for the summer when the demand is low. By implementing this plant, maximum output was made sure of 220MW, as per initial expectation.

2) The maximum heat output per hour[19] is "zero", since the heat is not being supplied from the start of operation of this project (April 2010) to the time of ex-post evaluation. The main reason is that the operation of the Nairit Chemical Plant unexpectedly stopped in early 2010 due to financial problems, and there was no longer a demand for heat. Though YTPP expected that more than 90% of the heat would be supplied solely to the Nairit Chemical Plant before the start of this project, YTPP is not in a position to supply heat because of the factory's shutdown

3) The capacity factor (power generation)[20] is higher than initially expected.

4) The capacity factor (heat supply) is "zero", as heat has not been supplied for the reasons stated above[21].

5) The availability factor[22] is generally as initially expected. It is slightly low in 2014 since a major periodic maintenance (C Periodic Inspection)[23], which is held every four years, described later in this report, was conducted that year.

6) The auxiliary power ratio[24] indicates the status of performance maintained by the generation plant. The ratio is generally as per the initial expectation.

7) The gross thermal efficiency[25] indicates the status of performance maintained and energy saving levels. Due to the absence of heat supply, the actual figure is slightly lower than the target; however, the gross thermal efficiency for the power generation alone was generally as per the initial expectation[26].

[19] "Heat" supplied by this plant is high, on average 295°C. At the time of the appraisal, it was expected that heat would be supplied through the pipeline from this plant for the purpose of manufacturing chemical products.
[20] This is calculated by dividing power generated in a year by (rated output x number of hours in a year) x 100.
[21] According to YTPP, they can begin supplying heat immediately if there is a demand for heat.
[22] (Hours of operation in a year divided by the number of hours in a year) x100.
[23] YTPP classifies the major maintenance inspection held once in four years as C Periodic Inspection.
[24] (Power consumed inside the plant in a year divided by the net generation) x 100.
[25] (Yearly net generation x 860) divided by (yearly fuel consumption x combustion calorific value) x 100.
[26] According to YTPP, if there is a demand for heat supply, the gross thermal efficiency (power generation plus heat supply) would account for more than 70%.

8) and 9) The forced outage hours and frequency (by cause) are generally as initially expected. Due to the regular periodic inspections in 2013 and 2015 (A and B Periodic Inspections, which will be described below), the operation stopped for 240 hours (ten days in total) each time. In 2014, there was an outage of 1,089 hours due to the major periodic inspection held every four years (C Periodic Inspection). The C Periodic Inspection required a long time, because the main units such as gas turbines are dismantled and checked. Under the A and B Periodic Inspections held in 2013 and 2015, the functions of the main and control equipment are checked and repaired as needed, together with related facilities. As per the initial expectation, there has been no case of human error or machine failure since the completion of this project.

With regard to the effect indicators:
1) The net generation has exceeded the initial expectation. The actual figure for 2014 is lower than other years because of the major periodic inspection (C Periodic Inspection), which reduced the operation hours of power generation unit.
2) There is no actual figure for the heat supply because no heat is being supplied from the start of this project to the time of the ex-post evaluation, as explained above.

Photo 3: Gas Turbine Generation Facility

Photo 4: Heat Supplying Pipe

3.3.2 Qualitative Effects (Other Effects)

Reduction of Environmental Impact

At the time of the appraisal, it was expected that the construction of the latest and environmentally friendly model of CCPP would minimize the environmental burden on areas such as the capital, Yerevan. As a result of construction of the latest CCPP, the old existing power plant ceased operation. Since sulfer content is removed from natural gas during

processing, CCPP which uses natural gas has less impact on environment with no emissions of sulfur oxides, dust and soot. Comparing latest model of CCPP with the conventional thermal plant, the CCPP of this project has more advantage considering adopted measures of low NOx type burner and implemented proper burning management[27]. Therefore, it is thought that this project has contributed to reduce negative impacts on the environment around the city.

[27] For example, the amount of NOx emission on the latest CCPP is below the half, comparing with that of the conventional thermal plant.

3.4 Impacts

3.4.1 Intended Impacts

3.4.1.1 Alleviation of Future Power Shortage

At the time of the appraisal, it was expected that this project would address the issue of insufficient reserve capacity and predicted future power shortages. Table 3 shows the changes in net generation, imports and exports of power and domestic power consumption of Armenia between the start of this project and the time of the ex-post evaluation.

Table 3: Changes in Net Generation*, Imports and Exports of Power and Domestic Power Consumption**

(Units: GWh/year)

	2005	2006	2007	2008	2009	2010
1) Net Generation	5,943	5,602	5,572	5,779	5,341	6,183
2) Power Imports	320	352	409	338	266	246
3) Power Exports	1,045	608	313	360	366	1,061
4) Domestic Power Consumption	5,032	5,117	5,443	5,543	5,090	5,219
	2011	2012	2013	2014	2015	
1) Net Generation	7,105	7,667	7,381	7,389	7,433	
2) Power Imports	189	79	137	191	160	
3) Power Exports	1,383	1,578	1,226	1,236	1,339	
4) Domestic Power Consumption	5,637	5,924	6,077	6,142	6,050	

Source: The Ministry of Energy and Natural Resources
Note*: Net generation is the total gross power generation minus the electricity consumed within the plant.
Note**: The sum of net generation and the balance of power imports and exports does not match the domestic power consumption due to the loss in transmission which occurs before electricity is actually consumed.

1) Net generation has generally increased over the past 10 years. As previously shown in Table 2, net generation by this project was 1,594GWh in 2015, accounting for about 20% of the total net generation for the entire country which is 7,433GWh/year shown in Table 3. Without this project, it is likely that the demand for 4) domestic power consumption would not have been met; this project can therefore be said to have had a high level of contribution towards stabilizing power supply. Regarding 2) power imports, although Armenia temporarily relies on neighboring countries for electricity using the international transmission line temporarily, this has followed a decreasing trend. This is because domestic power generation and net generation have been increasing every year, and the country is moving towards realizing a stable power supply throughout the year. On the other hand, 3) power exports have been following an increasing trend in general, since Armenia has been increasing its power exports every year in

return for its imports of natural gas from Russia (via Georgia) and Iran (barter trade[28]). For reference purposes, Armenia's natural gas imports are shown in Table 4, and these have been following an increasing trend. The government of Armenia has taken a decision to significantly increase natural gas imports from Iran after 2019[29]. It is therefore expected that power exports to Iran will also increase in the near future. Therefore, it is presumed that the role of this project will be even more important, given that it accounts for roughly 20% of the country's net power generation.

Table 4: Origin and Volume of Armenia's Natural Gas Imports

(Units: million m³/year)

Origin of Imports	2011	2012	2013	2014
Russia*	1,609	1,967	1,956	2,062
Iran	460	488	405	389
Total	2,069	2,455	2,361	2,451

Source: The Public Service Regulatory Commission (PSRC)

Note*: This is imported via a neighboring country, Georgia, because Armenia does not share a border with Russia. It is imported from Russia using an international gas pipeline.

3.4.1.2 Contribution to Sustainable Growth of the Economy

Table 5 shows the Gross Domestic Product (GDP) between the start of this project and the present. It has been gradually increasing, except for 2008-2009 when it was affected by the global financial crisis. It is thought that this project has contributed to stabilizing Armenia's power supply and achieving energy security by increasing the power supply through increased natural gas imports, while playing a role in supporting the nation's economy.

The Public Services Regulatory Commission (hereafter referred to as "PSRC"), an economic and industrial body which regulates electricity tariffs in Armenia, commented in an interview: "Had this project not been implemented, the electricity tariff could have been higher than the current level[30]. It shows that CCPP enables relatively low-cost power generation, and that it is contributing to an improvement in people's livelihoods and economic revitalization. In addition,

[28] In principle, Armenia exports approximately 3kWh of electricity in exchange for 1 m³ import of natural gas.

[29] At the time of the ex-post evaluation, imports of natural gas from Iran were about 390 million m³/year or less. However, a decision has been taken to markedly increase it to about 1,160 million m³/year in 2019 (Source: YTPP interviews)

[30] As reference information, a decision was made about surge of electricity tariff in June 2015 and demonstration by citizen of Yerevan immediately occurred against the surge. The tariff increased up to 48.78AMD/kWh after August 2015, from the previous 41.82AMD/kWh. However, it was confirmed through interviews that, had the electricity generation with low costs like this project not realized, the tariff would have exceeded the level more than 48.78AMD/kWh. In other words, it is thought that there is possibility of anxiety against the tariff, which would become bigger among the citizens.

Iran has a large population and economic base[31] with overflowing demand for power, and electricity exports are expected to grow further in the future." With this comment, it is thought that the contribution of this project to the country's economy and social stability is not small.

Table 5: Gross Domestic Product (GDP) of Armenia

(Units: 1 billion USD)

2005	2006	2007	2008	2009
4.90	6.38	9.21	11.66	8.65
2010	2011	2012	2013	2014
9.26	10.14	9.96	10.43	10.88

Source: The World Bank.

3.4.2 Other Impacts

3.4.2.1 Impacts on the Natural Environment

At the time of the appraisal, it was expected that this project would require a two-phase Environmental Impact Assessment (EIA). The first phase was approval by the Ministry of Environmental Protection, which was obtained in September 2003. The second phase was approval by the same ministry in September 2008, before the start of the main construction. It was confirmed through the interviews with YTPP and the EIA documentation that there were no particular problems or delay concerning the approval process.

In addition, it was confirmed through the questionnaire, interviews with YTPP and site inspections that there were no air pollution, water pollution, noise, vibration or negative impacts on the eco-system[32].

Environmental monitoring is the responsibility of the production technology division of YTPP. In case of a problem, immediate action will be taken to address the matter. However, as there have not been any negative environmental impacts or problems since the completion of this project, no measures have been taken as a result of their monitoring.

3.4.2.2 Land Acquisition and Resettlement

Land had already been secured for the construction (about 20ha) before the start of this project. It had been a vacant plot owned by Yerevan city authorities, which was transferred to YTPP with facilitation from the Armenian government. As it was an empty plot, no resettlement

[31] The population is 78.5 million (Source: State of World Population 2014). GDP was 402.7 billion USD (source: IMF estimate, 2014)

[32] There are no residential areas or commercial facilities around this project, and there has been no case of air pollution, noise, vibration or negative impacts on health.

was required. It was confirmed through interviews with YTPP that no financial compensation was needed and that this proceeded smoothly.

3.4.2.3 Other Positive or Negative Impacts

Table 6 shows the per-kWh electricity wholesale prices and electricity tariffs of this project and other thermal plants at the time of the ex-post evaluation.

Table 6: Advantages of This Project Compared to Other Thermal Plants in Armenia

Thermal Plan	At the Time of the Ex-Post Evaluation	
	Electricity Wholesale Price	Electricity Tariff
①This Project *The operation began in 2010.	27.825AMD/kWh	48.78AMD/kWh
②Hrazdan CCPP No.5 **The operation began in 2012.	35.00AMD/kWh	
③Hrazdan TPP **The operation began in 1969.	44.445AMD/kWh	

Source: YTPP
Remark: One Armenian dram (AMD) = 0.247 Japanese yen (exchange rate as in late January 2016)

The electricity wholesale price is the unit price at which each plant sells electricity to the electricity networks of Armenia (hereafter referred to as “ENA”), while the electricity tariff is applicable to end consumers (normal households). Difference caused by subtracting each plant’s electricity wholesale price from the electricity tariff gives ENA’s revenue. The plant operation performance is generally high for ①This project and ②Hrazdan CCPP No.5. Both plants are operating power generation facilities with high thermal efficiency; however, according to YTPP, this project is generating power for a lower cost, because the technical standards for operation and maintenance are high. By contrast, ③Hrazdan TPP began operation more than 40 years ago, and it has disadvantages in terms of its deterioration and operation due to its high maintenance cost and wholesale price. In view of this situation, it is presumed that this project is profitable for ENA and that it is contributing to stabilizing power distribution in this country.

With regard to the operation and effect indicators (quantitative effect indicators), maximum output, capacity factor (power generation), availability factor, auxiliary power ratio, forced outage hours and frequency by cause as well as net generation either met or exceeded the initial expectations. However, maximum heat output per hour, plant capacity factor (heat supply portion), gross thermal efficiency (power generation + heat supply portion) and heat supply did not reach the initial targets, mainly due to the shutdown of Nairit Chemical Plant. While net

generation, electricity exports and domestic power consumption have been generally increasing over the past ten years, and it is thought that this project's contribution has not been small. In light of the above, this project has to some extent achieved its objectives. Therefore, the effectiveness and impact of the project are fair.

3.5 Sustainability (Rating: ③)

3.5.1 Institutional Aspects of Operation and Maintenance

The executing agency at the time of the ex-post evaluation is YTPP. YTPP is an organization fully owned by the government of Armenia and supervised by the Ministry of Energy and Natural Resources. In addition to supervising projects conducted by YTPP, the ministry appoints the president and organizes board meetings.

YTPP has about 450 employees in total. The department responsible for this project operates and maintains the facilities, working directly for the president. There are four divisions in this department (Operation Division, Automatic Control Supervision Division, Central Repair Division, and Water and Sewage Treatment System Division). At the time of the ex-post evaluation, the department has 67 employees in total. It was confirmed through field inspections and interviews with YTPP's executive staff that the number of employees is sufficient, and that each division is suitably staffed with appropriate personnel.

In light of the above, it is judged that no problems are observed in the institutional aspect of the operation and maintenance.

3.5.2 Technical Aspects of Operation and Maintenance

At YTPP, staff training was conducted as necessary during the implementation of this project. Four people attended the "Gas Turbine / Thermal Power Generation Technology Training" organized by JICA in 2011. In addition, four people attended the "Water Cooling Tower / Thermal Power Generation Facilities Training" in the same year, and two attended the "Training in Analysis and Management of Chemical Systems for Thermal Power Generation" in 2012, organized by an European training institute. Furthermore, after the completion of the project, two people attended the "Training in Consultant Selection, Recruitment and Preparation of International Financial Reports" organized by the International Training Center (ITC) of the International Labour Organization (ILO) in 2014, and two people took the World Bank's "Training in Financial Management and Disbursement Procedure" in 2015.

Many experienced staff are engaged in this project. It was confirmed through the field inspections that well-experienced staff are assigned to appropriate positions. Almost all staff members are university graduates or more highly educated. Competitive entrance exams are conducted and thorough on-the-job training, are also provided for newly recruited staff. Based on the above, operation and maintenance technical standards are assessed as being secured[33].

It was confirmed through the site inspections that operation and maintenance manuals are distributed to each department and are being used appropriately.

In light of the above, it is judged that the technical standards of operation and maintenance are sufficient and that there are no problems.

3.5.3 Financial Aspects of Operation and Maintenance

Table 7 shows the operation and maintenance costs of this project.

Table 7: Operation and Maintenance Costs of this Project

(Units: thousand AMD)

2012	2013	2014	2015
10,600,000	9,900,000	19,900,000	10,800,000

Source: YTPP

Except for 2014, the costs have been at a similar level each year. The 2014 cost was higher than that in other years because of the major maintenance mentioned above (C Periodic Inspection), which is held every four years, and which required 10 billion AMD (about 2.4 billion yen). According to YTPP, “Sufficient budgets are allocated to operation and maintenance every year. The necessary funds for the C Periodic Inspection are also disbursed without any problems. There is no operation and maintenance problem caused by shortage of funds. Since there has not been any case of breakage or failure associated with this project, almost the same level of funding is provided every year.” Based on these comments, it is thought that there are no particular problems with the financial aspects of operation and maintenance.

For reference, Table 8 gives YTPP’s income statements for the last three years, and Table 9 gives YTPP’s balance sheet for the last three years.

[33] All operation and maintenance staff take examinations every two years in which their working knowledge is regularly checked. There is a system whereby if a person fails this exam, another exam will be given three months later, and the person will be dismissed if s/he fails again.

(Reference) Table 8: YTPP's Income Statements

(Units: thousand AMD)

Item	2012	2013	2014
① Operating income (revenue from selling electricity, etc.)	54,852,441	55,343,815	64,409,966
② Operating expenses	(56,705,089)	(60,101,520)	(65,440,741)
③ =①+②	(1,852,648)	(4,757,705)	(1,030,775)
④ Selling and general administrative expenses	(521,942)	(490,066)	(827,114)
⑤Total Balance (③+④)	(2,374,590)	(5,247,771)	(1,857,889)
⑥Other income	99,816	16,483	359,421
⑦Other expenses	(620,977)	(786,254)	(1,329,210)
⑧=⑤+⑥+⑦	(2,895,751)	(6,017,542)	(2,827,678)
⑨Financial expenses	(997,671)	(1,027,427)	(1,535,994)
⑩Non-operating income (interest and currency exchange profit, etc.)	2,218,746	23,596,441	4,372,302
⑪Pre-tax profit (⑧+⑨+⑩)	(1,674,676)	16,551,472	8,630

Source: YTPP

Note: The figures in brackets are negative numbers.

(Reference) Table 9: YTPP's Balance Sheet

(Units: thousand AMD)

Item	2012	2013	2014
① Fixed assets	151,880,246	155,619,283	160,717,026
② Current assets	14,501,809	19,208,932	26,569,903
③ Total Assets (①+②)	166,382,055	174,828,215	187,286,929
④ Fixed liabilities	137,999,274	120,433,583	126,699,809
⑤ Current liabilities	16,246,460	23,364,365	34,134,065
⑥ Shareholders' equity	12,136,321	31,030,267	26,453,055
⑦ Total Liabilities and equity (④+⑤+⑥)	166,382,055	174,828,215	187,286,929

Source: YTPP

From Table 8 it can be seen that the operational costs have been slightly higher than the operational income; however, the difference is not significant. After 2013, pre-tax profit became positive. One factor is that the non-operating income (interest and currency exchange revenue, etc.) was large that year. The pre-tax profit was positive in 2014; however, it was similarly affected by the non-operating income. In any case, there has not been a situation in which securing the operation and maintenance costs shown in Table 7 were of concern. With regard to Table 9, it can be seen that shareholders' equity increased in 2013 and 2014 compared with 2012. In addition, according to YTPP, as natural gas imports from Iran increase in the future, power generated in Armenia will steadily increase, which will increase the availability factor

and thus YTPP's profits are also expected to increase. It is therefore predicted that the financial situation will improve further in the near future, following this ex-post evaluation.

Based on the above, it is judged that there are no major concerns with the financial aspects of operation and maintenance of this project.

3.5.4 Current Status of Operation and Maintenance

The operational status of the gas turbine power generation facility, steam turbine power generation facility, HRSG and associated facilities is good. Since the completion of the project, there have been no cases of breakage or failure.

YTPP formulates a maintenance plan every year and carries out operation and maintenance tasks based on this plan. The tasks are categorized into periodic works and daily maintenance works. The periodic maintenance works are carried out every year, and a major piece of maintenance work (C Periodic Inspection) is also conducted once in every four years, for which a huge budget (about 2.4 billion yen) is required. For daily maintenance, maintenance works for the power facilities are conducted by different teams (every half a year, every three months, every month, every week or every day). In addition, spare parts are procured and secured in an appropriate manner. There is no problem with the procurement system, nor are there any delays in delivery.

In light of the above, no major problems have been observed in the institutional, technical or financial aspects of the operation and maintenance system. Therefore, the sustainability of the effects of the project is high.

4. Conclusion, Lessons Learned and Recommendations

4.1 Conclusion

This project constructed CCPP in a suburb of the capital Yerevan, with a view to enhancing the power supply capacity. This project is consistent with power sector development policies in Armenia, such as the "Integrated Financial Rehabilitation Plan for Public Utilities" (2003-2007) and the "Main Direction for Developing the Energy Sector in the Period up to 2036" (2015). Before the start of the project, the Yerevan Thermal Power Plant, which had been operational since early 1960s, was aging, and there was a need to construct new power facilities in order to stabilize the power supply. At the time of the ex-post evaluation, the Armenian government

plans to develop and attract investments for new power sources; and thus this project is consistent with the development needs of the country. Additionally, given that this project is also harmonized with the assistance policy of Japan, the relevance of this project is high. The actual project costs fell within the planned budget, as did the project period; the efficiency is also therefore high. With regard to the project effectiveness, the maximum output, capacity factor (power generation), availability factor, auxiliary power ratio, forced outage hours and frequency by cause, as well as net generation, either met or exceeded the initial expectations, on the whole. On the other hand, the maximum heat output per hour, plant capacity factor (heat supply portion), gross thermal efficiency and heat supply did not reach the initial targets, mainly due to the shutdown of the Nairit Chemical Plant. Therefore, the effectiveness and impact are fair. Since no particular problems are observed in the institutional, technical and financial aspects of operation and maintenance, the sustainability of the effects of this project is high.

In light of the above, this project is evaluated to be highly satisfactory.

4.2 Recommendations

4.2.1 Recommendations to the Executing Agency

It is recommended that the Armenian side (the Ministry of Energy and Natural Resources) discuss actions to be taken in the future regarding the demand for heat supply. At the time of this ex-post evaluation, there is some discussion regarding the resumption of operation of Nairit Chemical Plant. It is recommended that the Ministry of Energy and Natural Resources continue its discussion of the realization of heat supply from this project for Nairit Chemical Plant at its resumption of operation and explore other possibilities of the effective utilization of waste heat in the future.

4.2.2 Recommendations to JICA

None

4.3 Lessons Learned

Contribution to Smooth Project Implementation through Training Opportunities and OJT

YTPP has promoted and maintained the project smoothly, throughout the overall implementation, and operation and maintenance following the completion, and no problems are foreseen for future maintenance. In addition to offering ample training opportunities and OJT, YTPP has a system in which employees are periodically tested in order to maintain and improve

their maintenance abilities, (and) thus the organization is always staffed with capable personnel. These are the factors that have led the project to success. For the formulation of future similar projects, it is important that JICA and the executing agencies study issues related to capacity development of staffs, and formulate systems that will allow the project to train and retain the human resources necessary to sustain the project's effects, such as offering training opportunities to staff and introducing periodic examinations as needed.

Comparison of the Original and Actual Scope of the Project

Item	Plan	Actual
1. Project Outputs	1) Construction of a combined cycle co-generation power plant (gas turbine power generation facility, steam turbine generation facility, waste-heat recovery boiler, associated facilities and spare parts) 2) Reconditioning of the existing related facilities (cooling, circulation water pump and pipes, chemical shop, outdoor switching station, heat pipes, pipes for water for industry and extinguishing fires) 3) Related civil engineering and construction works (including leveling of the project site) 4) Consulting service (detailed design, preparing documents for qualification, bidding and contracting, assisting procurement, construction supervision, quality evaluation, assisting operation and maintenance, supporting environmental monitoring, technology transfers and human resource development for the facility operation and maintenance)	1) – 4) were implemented as planned.
2. Project Period	March, 2005 – May, 2012 (87 months)	March, 2005 – April, 2012 (86 months)
3. Project Cost		
Amount Paid in Foreign Currency	28,725 million yen	27,318 million yen
Amount Paid in Local currency	9,719 million yen	6,402 million yen (Approx. 24,910 million dram)
Total	38,444 million yen	33,720 million yen
Japanese ODA Loan Portion	26,409 million yen	26,399 million yen
Exchange Rate	1 USD=108 JPY 1AMD=0.326JPY (As in February 2008)	1 USD=98.46JPY 1AMD=0.257JPY (Average during the project's implementation (2005-2013).

		Source: International Financial Statistics, IMF)