Arab Republic of Egypt

FY2017 Ex-Post Evaluation of Japanese ODA Loan

"Kuraymat Integrated Solar Combined Cycle Power Plant Project (I) (II)"

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

0. Summary

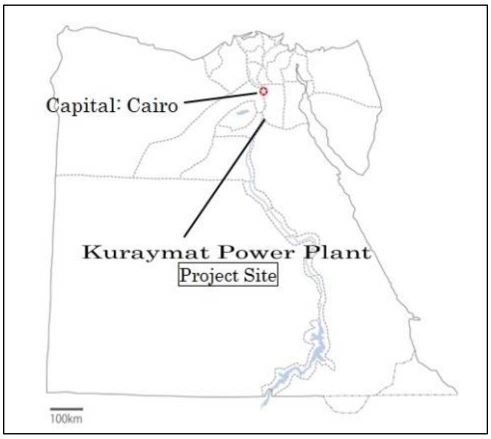
This project involved the construction of a solar thermal and gas integrated power plant in Kuraymat[1], located approximately 100km south of Cairo, in order to produce electricity to be supplied to Egypt's existing power grid and to contribute to the economic development and environmental improvements of Egypt by mitigating environmental impacts through the introduction of the auxiliary energy of solar thermal power generation. The Government of Egypt indicated in the *National Five-Year Development Plan* (2002/2003-2006/2007) and the *Egypt Strategic Framework for Economic and Social Development plan Until year 2022* that it will promote renewable energy such as combined cycle power generation as well as solar thermal and wind power generation. Therefore, the project's relevance is high given the development needs from growing electricity demand and consistency with Japan's ODA policy. In terms of efficiency, project outputs were implemented almost as planned, but project costs significantly exceeded the initial plan due to the impacts of worldwide steel price rise and the rising cost of plant facilities, including gas turbines. The project period required more time than initially anticipated for selection procedures and negotiations for the contractor of the main construction component of the project. Therefore, the efficiency of the project is low. The project faced malfunctions/breakdowns of the gas turbine, etc., two years after the start of commercial operations and the shutdown period before and after this incident was prolonged. Additionally, partial malfunctions also occurred in the gas turbine and steam turbine even after the repair work completed in July 2016, resulting in several instances of shutdowns due to mechanical failures. Therefore, the quantitative effect indicators of this project did not achieve the target values. In terms of impacts realized from this project, the actual figures of the relevant indicators are considered to be limited. Thus, the effectiveness and impacts are determined to be fair. There are no major problems in the institutional, technical and financial aspects of Kuraymat Power Plant, which is responsible for the operation and maintenance of this project. No major problems in particular have occurred in the operation and maintenance of other

[1] Kuraymat is located approximately 100km south of Egypt's capital of Cairo. Kuraymat was selected because of the following reasons: (1) the area is a desert with few residences and no obstacles in terms of facility construction (the project site is on government-owned land); (2) cooling water is required for use in the power plant and the Nile River is located in close proximity, making it easy to source water, (3) the transmission grid is located close by; and (4) a natural gas pipeline for supplying the gas combined cycle facility is located nearby.

facilities and equipment. Consequently, the sustainability of the project's effect is high.

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

2. Project Description



Project Location

Power Plants Developed by this Project

1.1 Background

Prior to the start of this project, Egypt faced the urgent task of developing planned power generation facilities in line with demand in order to achieve a stable supply of electricity. Egypt relies almost entirely on natural gas and heavy oil for the fuel needed for power generation, and oil field development for natural gas made progress. Meanwhile, the Government of Egypt has explored the use of new and renewable energy, such as wind and solar thermal power, with an emphasis on effects of load reduction in the future. As a result, the country moved ahead with promoting energy conservation and the use of new and renewable energy in order to secure electricity supply. In such circumstances, the development of integrated facilities that include high efficiency gas combined cycle power generation and solar thermal facilities for mitigating environmental impacts aimed to secure the electricity supply needed for economic growth and achieve environmental conservation. This matched the needs of the Government of Egypt.

1.2 Project Outline

The objective of this project is to construct an integrated solar combined cycle power plant in Kuraymat, about 100km south of Cairo City, to produce electricity to be supplied to domestic existing transmission grid, by using solar heat as an supplemental energy for power generation, and reduce the environmental burden, thereby contributing to economic development and environmental improvement of Egypt.

Loan Approved Amount/ Disbursed Amount	Phase I: 10,665 million yen / 10,664 million yen Phase II: 9,440 million yen / 9,421 million yen
Exchange of Notes Date/ Loan Agreement Signing Date	Phase I: December, 2005 / January 2006 Phase II: December, 2008 / December 2008
Terms and Conditions	Phase I: Condition for procurement & installation of facilities: Interest Rate: 0.75% Repayment Period: 40 years (Grace Period: 10years) Conditions for Procurement: General Untied Consulting Service: Interest Rate: 0.75% Repayment Period: 40 years (Grace Period: 10 years) Conditions for Procurement: General Untied Phase II: Condition for procurement & installation of facilities: Interest Rate: 0.65% Repayment Period: 40 years (Grace Period: 10years) Conditions for Procurement: General Untied Consulting Service: Interest Rate: 0.01% Repayment Period: 40 years (Grace Period: 10 years) Conditions for Procurement: General Untied
Borrower /Executing Agency	New and Renewable Energy Authority (hereafter referred to as "NREA") / NREA (Guaranteed by The Government of Arab Republic of Egypt)
Project Completion	June, 2011
Main Contractors (Over 1 billion yen)	Mitsui & Co., Ltd. (Japan) / Iberdrola Ingeniería y Construcción (Spain) (JV), Arab Engineering and Distribution Company (Egypt)
Main Consultants (Over 100 million yen)	Fichtner Solar GMBH (Germany)
Related Studies (Feasibility Studies, etc.)	F/S (Own fund by Egyptian government (Ministry of Electricity and Energy), June 2000)
Related Projects	【Cooperation by other aid organizations】 ・Grant aid grant by Global Environment Facility[2] (hereafter referred to as "GEF") (support for parts of solar thermal power generation such as solar collectors) (May 2004)

[2] At the joint World Bank-IMF development committee meeting held in September 1989, France and Germany proposed a fund for preserving and improving the environment. The first meeting involving participating countries was held in May 1991 based on the resolution passed by the World Bank's Board of Governors. The GEF officially started thereafter in 1994. Meetings and ordinary meetings have been held regularly.

2. Outline of the Evaluation Study

2.1 External Evaluator

Kenichi Inazawa, Octavia Japan Co., Ltd.

2.2 Duration of Evaluation Study

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

Duration of the Study: November 2017 - December 2018

Duration of the Field Study: March 11-27, 2018 and July 20-28, 2018

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

3.1 Relevance (Rating:③[4])

3.1.1 Consistency with the Development Plan of Egypt

At the time of appraisal, the Government of Egypt had established the *National Five-Year Development Plan* (2002/2003-2006/2007[5]), which cites the need to maximize the use of resources, transition thermal power plants to combined cycle versions from the standpoint of generation efficiency, and promotion of solar thermal and wind power projects to increase the use of new and renewable energy. In other words, this project, which develops a power plant with energy derived from gas combined cycle power generation and solar thermal power, was consistent with Egypt's development policy.

At the time of ex-post evaluation, the Government of Egypt (Egypt Economic Development Conference) established the *Five-Year Macroeconomic Framework/Strategy* (2014/2015-2018/2019). It cites the need to eliminate electricity shortages by increasing installed capacity, improving electricity services, including revising electricity tariff, and promoting the deregulation of the electricity market and encouraging new entry of private companies. In addition, in June 2012 the Government established the *Egypt Strategic Framework for Economic and Social Development plan Until year 2022*, which provides aspirations and strategy for national development following the Egyptian Revolution (2011). As part of the country's natural resource management strategy, the plan cites the diversification of energy resources and expansion of renewable energy use. Specifically, the plan considers the following approach as one of its electricity policy measures over the next several decades; shifting to electricity supply

3 A: Highly satisfactory, B: Satisfactory, C: Partially satisfactory, D: Unsatisfactory
4 ③: High, ②: Fair, ①: Low
5 Since the fiscal year of Egypt begins every year from July, it will be such description.

sources mainly from renewable energy such as solar thermal and wind power and combined cycle power generation that uses natural gas producible in Egypt as an alternative to oil for which it relies on imports.

Based on the above, throughout the time of the appraisal and the time of ex-post evaluation, the Government of Egypt is focusing on the promotion of combined cycle power generation that uses natural gas and renewable energy such as solar thermal power and wind power. Consequently, at the time of both the appraisal and ex-post evaluation, the consistency of this project is acknowledged through the national development plan and sector plan.

3.1.2 Consistency with the Development Needs of Egypt

Prior to the start of this project in 2002, the power supply-demand balance was very tight, resulting in frequent power outages during peak summer demand. Table 1 indicates electricity supply-demand conditions at the time. Securing power generation facilities was an urgent task in order to secure the stable power supply. With the Government of Egypt promoting the energy conservation and use of new and renewable energy while maintaining electricity supply, the development of integrated facilities that include high efficiency gas combined cycle power generation and solar thermal facilities for mitigating environmental impacts aimed to secure the electricity supply needed for economic growth and achieve environmental conservation. In other words, strong development needs were confirmed.

At the time of ex-post evaluation, the tight conditions involving installed capacity and electricity demand during peak times are improved, but as Table 2 indicates electricity demand is on an uptick. Taking into account this situation, the Government of Egypt is working to increase the installed capacity in areas across the country. In 2012, the Government established a new plan spanning 7 years, under which it is moving ahead with increasing installed capacity (total of 13,200MW)[6]. Under this plan, NREA is working on the development of power plants powered by renewable energy throughout the country. Up to the time of the ex-post evaluation, a wind power project[7] has been implemented in Zafarana along the Red Sea and a solar thermal power project led by private-sector investment with the goal of increasing[8] installed capacity was carried out in Aswan in the south. NREA has participated/cooperated in the form of project cooperation.

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[6] As one example, at the time of ex-post evaluation, projects were being implemented for the introduction or reinforcement of combined cycle power generation facilities in Damanhur, El-Seiuf, Mahmoudia, and Benha.
[7] Installed capacity is 1,500 MW in total.
[8] Installed capacity is 200 MW in total.

Table 1: Electricity Supply-Demand Balance Before Start of This Project (1999/00 - 2002/03)

	1999/00	2000/01	2001/02	2002/03
Generation facility capacity (MW)	11,988	12,376	13,485	14,789
Power demand at peak time (MW)	11,736	12,376	13,326	14,401
Supply reserve ratio (%) **Note*	2.1	0	1.2	2.7

Source: JICA documents
Note: Reserve ratio ={(generation facility capacity - power demand at peak) / generation facility capacity} × 100

Table 2: Electricity Supply-Demand Balance in the Last Few Years (2011/12 - 2014/15)

	2011/12	2012/13	2013/14	2014/15
Generation facility capacity[9] (MW)	29,075	30,800	32,015	35,220
Power demand at peak time (MW)	25,705	27,000	26,140	28,015
Supply reserve ratio (%) **Note*	10.9	12.3	18.4	20.4

Source: Egyptian Electricity Holding Company (EEHC)
Note: Reserve ratio ={(generation facility capacity - power demand at peak) / generation facility capacity} × 100

Based on the above, at the time of ex-post evaluation securing electricity through increased generating capacity is an important task for Egypt, and power generation facilities are being developed throughout the country. Consequently, the consistency of this project with development needs is acknowledged both at the time of appraisal and at the time of ex-post evaluation.

3.1.3 Consistency with Japan’s ODA Policy

The *Country Assistance Program for Egypt* established by Japan’s Ministry of Foreign Affairs in June 2000 cited (1) development of economic and social infrastructure, and industrial promotion; (2) poverty reduction measures; (3) enhanced human resource development and education; (4) environmental conservation and improvement in living environment; and (5) promotion of trilateral cooperation (South-South cooperation). Additionally, the *Medium-Term Strategy for Overseas Economic Cooperation Operations* prepared by JICA in 2005 positioned “a foundation for sustained growth” as a key field and advocated for assistance in order to promote sustainable growth through economic and social infrastructure development, including electricity essential to private-sector activities. Moreover, the policy called for proactive support of the limitation or reduction of greenhouse gases through renewable energy and energy conservation to combat environmental issues as part of another key field cited as “support for global issues and

[9] At the time of ex-post evaluation, Egypt's power generation mix consists of 90% for thermal power generation, 8% for hydroelectric power generation, 2% for wind power and solar power generation. (Source: 2014/2015 annual report of The Ministry of Electricity and Renewable Energy of Egypt). Renewable energy accounts for about 700MW (35,220MW x 2%) of Egypt’s total installed capacity in 2014/2015 per Table 2. As discussed in 3.2.1 Efficiency and Outputs, the maximum output of the gas turbine and steam turbine of this project (Kuraymat Power Plant) is 130MW (combined total). In other words, this represents about 0.37% of the 35,220MW (2014/2015) per Table 2.

peace building.” Furthermore, the *Country Assistance Strategy for Egypt* prepared by JICA in 2005 considered socioeconomic infrastructure development and efforts to combat environmental issues as key fields, taking into account Egypt was facing issues related to sustainable economic growth and environmental conservation.

This project supports the development of Egypt’s economic and social infrastructure and contributes to environmental conservation through development of economic infrastructure, and it is acknowledged as consistent with Japan’s ODA policy.

This project has been highly relevant to the Egypt’s development plan and development needs, as well as Japan’s ODA policy. Therefore its relevance is high.

3.2 Efficiency (Rating: ①)

3.2.1 Project Outputs

This project involved the construction of a solar thermal and gas integrated power plant in Kuraymat, located approximately 100km south of Cairo. Table 3 presents the project’s output plan and actual results. In addition, Figure 1 presents the correlation between combined cycle and solar thermal power generation systems.

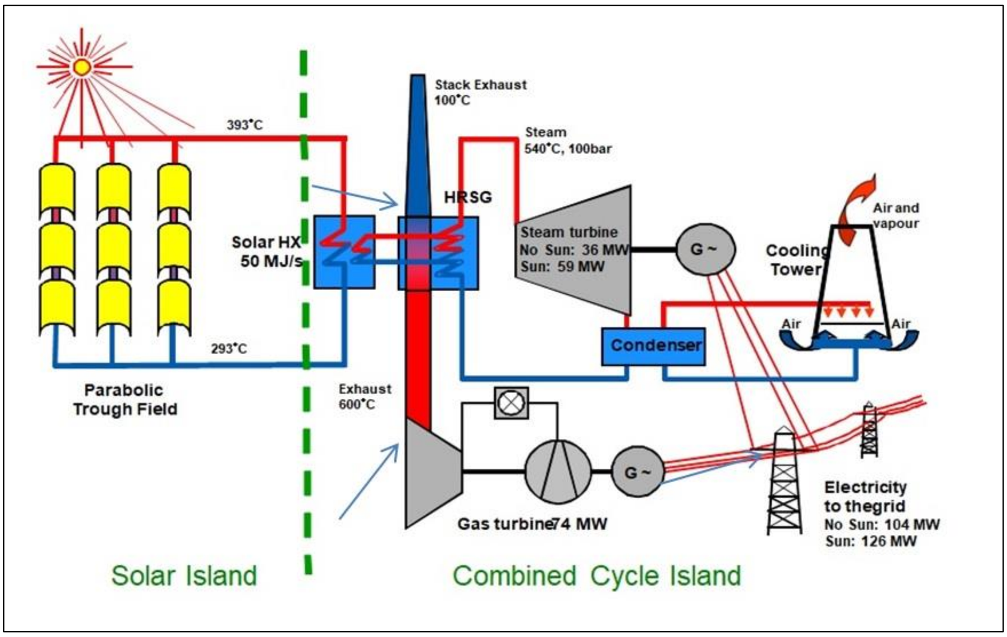
Table 3: Planned and Actual Outputs of this Project

Planned at the time of appraisal (Phase I: 2006, Phase II: 2008)	Actual at the time of ex-post evaluation (2018)
1) Civil works and procurement of equipment, etc.	
(1) Solar thermal and gas integrated power plant - Gas turbine (80MW x 1) - Steam turbine (70MW x 1) (of this, 40MW by gas turbine heat recovery and 30MW by solar thermal recovery) - Generator (Gas turbine: 80MW, Steam turbine: 70MW - Heat recovery steam generator （HRSG） (1 unit) - Main transformer - Control & instrumentation equipment	(1) Solar thermal and gas integrated power plant - Gas turbine (74MW x 1) - Steam turbine (56MW x 1) (of this, 36MW by gas turbine heat recovery and 20MW by solar thermal recovery) - Generator (Gas turbine: 74MW, Steam turbine: 56MW - Heat recovery steam generator （HRSG） (1 unit) - Main transformer - Control & instrumentation equipment

- 22kV/66kV outdoor switchgear - Cooling water equipment - Solar thermal power generation facilities (not covered by ODA loan; assistance by Global Environment Facility (GEF))	- 22kV/66kV outdoor switchgear - Cooling water equipment - Solar thermal power generation facilities (assistance by GEF; output of 20MW)
2) Consulting services	
(1) Construction supervision (2) Assistance for operation and maintenance	As planned.

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

Regarding the project's outputs, it was implemented basically as planned as confirmed by the questionnaire, the visit and interviews with NREA during the field survey. While the output of gas/steam turbines and generators is lower somewhat than the initial plan, this is because it was revealed through a detailed design after the start of the project that gas turbine performance yields output less than the initial assumption because the daytime temperature around the Kuraymat power plant is high, causing generating efficiency to decline.



Source: Drafted based on NREA's documents

Figure 1: Combined Cycle of This Project and Solar Thermal Power Generation System

3.2.2 Project Inputs

3.2.2.1 Project Cost

Table 4 shows the planned and actual project costs. The total project cost was planned to be 21,383 million yen[10] (of this 10,665 million yen was covered by ODA loan), and the actual total project cost was 34,453 million yen (of this 20,085 million yen was covered by ODA loan), which exceeded the plan significantly (approximately 161% of the plan). The main reasons for this are as follows. Since the start of this project, the price of steel worldwide had increased, followed by the cost of plant facilities including gas turbines. Trends in the price of steel pipes, wire, and bar products according to the CRU Steel Price Index[11], which shows the rise of steel prices, indicate that prices rose approximately 40% from the time of the project's appraisal (February 2005) to conclusion of the contract with the construction contractor after completing bidding procedures (September 2007). In addition, Free on Board (FOB) for the gas turbine including the cost to transport freight to the vessel in port exporting the item from the factory increased to 1.75[12] in mid-2007 after the project started, compared to the price of the gas turbine in 2005 prior to the start of the project considered as 1. Moreover, the reason why the actual project cost for the construction of the integrated power plan (solar thermal) exceeded the plan is also attributed to the soaring cost of materials and labor. These can be viewed as unavoidable circumstances. In addition, the increased amount of consulting services was mainly due to the delay of project period.

Table 4: Original Plan and Actual Costs of This Project

	Original Plan (2006)			Actual Costs at Completion		
	Foreign Currency Million Yen	Local Currency LE	Total Million Yen	Foreign Currency Million Yen	Local Currency LE	Total Million Yen
1) Integrated power plant construction (Gas)	9,895	87	11,429	17,430	282	21,945
2) Integrated power plant construction (Solar heat)	3,952	80	5,369	7,369	187.329	10,368

10 The initial plan (Project Phase I) called for the total cost of the project to be 21,383 million yen, but an additional ODA loan (Project Phase II) was provided thereafter in December 2008, making the total cost of the project 46,131 million yen (foreign currency: 28,335 million yen, domestic currency: 17,796 million yen; 20,105 million yen covered by ODA loan). The ex-post evaluation of this project compares with the planned amount in the initial plan (Project Phase I).

11 This is a reference index created by CRU, a think tank headquartered in London, UK, that compiles overall trends into a single index, taking into account steel prices in Asia, Europe, North America and other countries.

12 The sources for the above are documents provided by JICA and interviews with NREA.

3) Consulting services	465	6	567	1,329	8.314	1,462
4) Interest during construction	305	0	305	390	-	390
5) Administration cost	0	48	847	-	-	-
6) Land acquisition cost	-	-	-	-	-	-
7) Tax	0	162	2,864	-	18	288
Total	14,618	382	21,383	26,518	495.643	34,453

Source: JICA documents, NREA documents, Answers on questionnaire
Note: The abbreviation LE in the table stands for the Egyptian Pound. The foreign exchange rate at the time of appraisal was 1 USD to 6.22 LE and 1 LE to 17.7 yen. In contrast, the foreign exchange rate computed at the time of ex-post evaluation (average rate during the project period) is 1 USD to 5.92 LE and 1 LE to 16.01 yen.

3.2.2.2 Project Period

Table 5 shows the project's planned and actual period. At the time of appraisal, the project period was planned for the 4 year 3 month period (51 months) from April 2005 to June 2009. However, the actual project period was the 6 year 3 month period (75 months) from April 2005 to June 2011, exceeding the plan (approximately 147% of the plan)[13]. The main reason for this is because more time than anticipated was required for the selection procedures for the contractor of the construction works as well as negotiations and confirmation. The background to this is the impact of rising steel prices and plant facility costs including the gas turbine noted in 3.2.2.1 Project Cost.

Table 5: Original Plan and Actual Periods of This Project

	Original Plan (At the time of appraisal: 2006)	Actual
Whole Project	April 2005 - June 2009 (51 months)	April 2005 - June 2011 (75 months)
1) Selection of consultant	April 2005 - August 2006	April 2005 - September 2006
2) Bidding procedure for construction works	September 2005 - August 2006	December 2005 - September 2007
3) Construction works	September 2006 - June 2009	January 2008 - December 2010
4) Warranty period	July 2009 - June 2011	August 2011 - August 2013
5) Consulting services	August 2006 - September 2010	October 2006 - June 2013

Source: JICA documents, Answers on questionnaire

[13] This project was considered completed at the start of commercial operations on June 29, 2011. Consulting services continued until June 2013, but for the purpose of this evaluation actual period of the consulting services will not be counted as the actual project period. Furthermore, in December 2008 an additional ODA loan (Project Phase II) was granted, with the planned project period in Phase II spanning from May 2005 to August 2012. However, this evaluation will compare the planned period at the time of the initial plan (Project Phase I) with the actual project period.

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

Financial Internal Rate of Return (FIRR)

At the time of appraisal, a financial analysis was conducted based on the electricity sales income of the Kuraymat Power Plant as the benefit, the investment cost (project cost) and cost of operation and maintenance as the costs, and a project life of 25 years. As a result, the Financial Internal Rate of Return (FIRR) was calculated to be 1.1%. At the time of ex-post evaluation, an attempt was made to re-calculate the results using the same calculation method, but because the generator output was insufficient for the most recent three-year period, which meant the expected benefit (electricity sales income) was not satisfactory, and this coupled with the drop in the value of the Egyptian Pound[14] since 2016 caused the total benefit to fall below the total costs, resulting in a negative internal rate of return[15].

Economic Internal Rate of Return (EIRR)

At the time of appraisal, a financial analysis was conducted based on revenue from increased electricity supply, CO_2 reduction, and the gain associated with exports from the reduced use of fuel in Egypt as the benefits, the investment cost (project cost) and cost of operation and maintenance as the costs, and a project life of 25 years. As a result, the Economic Internal Rate of Return (EIRR) was calculated to be 18.3%. At the time of ex-post evaluation, CO_2 reduction was removed from benefits because Egypt has no emissions trading scheme, and an attempt was made to re-calculate the results using the same calculation method with the two benefits of revenue from increased electricity supply and the gain associated with exports from the reduced use of fuel in Egypt. For the same reasons as FIRR, the internal rate of return was calculated to be negative[16].

The project cost significantly exceeded the initial plan due to the impacts of worldwide steel price rise and the rising cost of plant facilities, including gas turbines. Additionally, the project period exceeded the initial plan because it required more time than initially anticipated for the selection procedures and negotiations for the contractor of the main construction work of the project. Based on the above, the project cost greatly exceeded the plan and the project period

[14] The Egyptian Pound depreciated approximately 60% against the yen from 2015 to 2017, and the downward trend is still evident even at the time of ex-post evaluation.
[15] Furthermore, when the signing year of the ODA loan agreement is used as the start point of the project life, the FIRR is negative both at the time of appraisal and at the time of ex-post evaluation.
[16] When the signing year of the ODA loan agreement is used as the start of project life, the EIRR at the time of appraisal is 17.8% but negative at the time of ex-post evaluation.

exceeded the plan. Therefore, efficiency of the project is low.

3.3 Effectiveness and Impacts[17] (Rating: ②)

3.3.1 Effectiveness

3.3.1.1 Quantitative Effects (Operation and Effect Indicators)

Table 6 shows the project's operation and effect indicators. The target value is the value established at the time of appraisal (2006), while the actual figure is the value after the start of operations of the power generation facilities.

Table 6: Operation and Effect Indicators (Target and Actual) of this Project

Indicator	Target	Actual			
	2012 Two years after the project completion	June 2011 - August 2013 (27 months) After 1 to 2 years of completion	September 2013 - June 2016 (34 months) After 2 to 5 years of completion	July 2016 - May 2017 (11 months) After 5 to 6 years of completion	June - December 2017 (7 months) After 6 to 7 years of completion
【Operation Indicators】					
1) Maximum Output (MW)	140 MW	N / A (Although there was a time of operation, there were many suspensions, so calculation is not appropriate.)	N / A (Operation completely stopped)	118	114
2) Plant Load Factor (%)	70%			54.0 (Average for 11 months)	47.5 (Average for 7 months)
3) Plant Availability (%)	91%			82.67 (Average for 11 months)	58.4 (Average for 7 months)
4) Gross Thermal Efficiency (%)	50%			35.04 (Average for 11 months)	41.09 (Average for 7 months)
5) Outrage Hours by Human Errors (hours)	0 hour/year			0 hour (11 months)	0 hour (7 months)
6) Outrage Hours by Machines Errors (hours)	0 hour/year	8,838 hours (total for 27 months)		1,812 hours (Total for 11 months)	1,772 hours (Total for 7 months)
7) Planning Outrage Hours by Periodical Inspection (hours)	720 hours/year	N/A		660 hours (Total for 11 months)	420 hours (Total for 7 months)
【Effect Indicators】					
8) Annual Amount of Net Generated Output (GWh/year)	816 GWh/year	Same as above	Same as above	496 GWh (Total for 11 months)	268 GWh (Total for 7 months)
9) Reduction of CO_2	160,740t			115,992 t	56,865 t

[17] Sub-rating for Effectiveness is to be put with consideration of Impacts.

Emission (tCO_2/year)	CO_2/year *Note			CO_2 / year (Amount of solar heat reduction is 23,772 tCO_2 / year)	CO_2 / year (Amount of solar heat reduction is 19, 116 tCO_2 / year)

Source: JICA documents, Answers on questionnaire, Interviews with NREA
Note: This value was calculated based on the annual CO_2 emissions from the standard thermal power plant in Egypt (heavy oil and gas mixing fired) in case such a power plant generated the same amount of electricity as this project. The reduction amount from solar heat is 19,800t CO_2/year of the total.

The gas turbine developed for this project broke down, causing the shutdown of the power plant during the period from September 2013 to June 2016. The cause of this breakdown was a defect in the rotating part[18] inside the turbine called the rotor. NREA transported this turbine out of the country, where repairs were carried out until June 2016[19]. Also, the gas turbine malfunctioned continuously between the start of commercial operations from June 2011 (time of completion) to September 2013. While the plant operated at times, it was offline for most of this time. Therefore, it is determined that the project had not achieved its target value two years after completion. However, repairs completed and the power plant restarted operations from July 2016. Considering this background information, this evaluation study will take into account the situation after July 2016. The following is a review on the actual figures for each indicator:

1) Maximum Output

The actual figures from July 2016 to May 2017 (five to six years after completion) were slightly lower than the target value. The main reason cited is the breakdown of two maintenance vehicles (Photo 1) that clean the solar heat collectors caused by problems with the motor and hydraulic instrumentation and these vehicles were not in operation due to a shortage of spare parts which caused dust and soot to accumulate on the collectors, resulting in lower output. Other causes are that two vehicles were not operational due to the same reason from June to December 2017 (six to seven years after completion) as well as plant shut down due to periodic maintenance[20] for the gas turbine from October 2017.

[18] Comprised of multiple ring-shaped components on top of one another.
[19] The reason for the breakdown has not been clearly determined, and even at the time of ex-post evaluation, NREA continues to discuss compensation and the cause with the construction contractor through the project's consultant. The repair cost was borne by NREA.
[20] Performed every two years. It continued until February 2018.

2) Plant Load Factor, 3) Plant Availability

The actual figures from July 2016 to May 2017 (five to six years after completion) did not reach the target value. As a reason for this, NREA cited frequent shutdowns caused by malfunctions resulting from high lubricant oil temperature, high exhaust dispersion, and excessive heat in the LP drum in the steam turbine, in addition, rising of the exhaust heat temperature, very low air intake volume in the vent turbine compartment, and the excessive burden on the DLN compartment fan in the gas turbine. In terms of the actual value from June to December 2017 (six to seven years after project completion), the speed of the gas turbine did not pick up and the exhaust temperature was high, which resulted in limited incineration time. In addition, periodic maintenance was performed on the gas turbine starting in October 2017, leading to a shutdown of operations, which caused the actual figures to fall short of the target values[21]. Afterward, at the time of ex-post evaluation (as of July 2018) the gas turbine and steam turbine are operating normally.

4) Gross Thermal Efficiency

The actual figures for the periods from July 2016 to May 2015 (five to six years after completion) and from June to December 2017 (six to seven years after completion) did not reach the target value due to declined thermal efficiency caused by a water leak in the heat exchanger tube sheet. At the time of ex-post evaluation (as of July 2018), the heat exchanger was repaired and it is operating normally.

5) Outrage Hours by Human Errors, 6) Outrage Hours by Machines Errors, 7) Planning Outrage Hours by Periodical Inspection

Although no outages occurred due to human errors, there were outages due to mechanical problems. The reason for this is as explained in 2) Plant Load Factor and 3) Plant Availability above. According to NREA, the gas turbine and steam turbine experienced malfunctions from the start of operations, and it claims there were defects in the equipment, but at the time of ex-post evaluation the cause has yet to be determined and discussions with the construction contractor

[21] Considering the malfunctions of the gas turbine, NREA concluded a maintenance support agreement with a foreign company in order to steadily carry out maintenance and inspection, purchase spare parts, and introduce the latest technologies, etc. (NREA concluded a long-term maintenance support agreement for eight years with a foreign company. Operation is carried out following the program prepared by the company and NREA. A system is in place where an immediate response can be taken in case of malfunction or accident. Gas turbine operations are managed online by the company's management control division, and it is continuously monitored. If an incident were to occur, this company provides instructions or advice by telephone or email). As for the steam turbine, according to NREA, a foreign company will be selected after a competitive bid in 2018 and a long-term support contract following similar standards is expected to be concluded.

continue. 7) Planning Outage Hours by Periodical Inspection have gone according to initial expectations.

8) Annual Amount of Net Generated Output

The actual figures for the period from July 2016 to May 2017 (five to six years after completion) declined due to inoperability of maintenance vehicles for cleaning and a drop in maximum output, as discussed above. Furthermore, the period from June to December 2017 (six to seven years after completion) was less than one year and periodic maintenance was performed on the gas turbine starting in October the same year, resulting in a decline in the generated output.

9）Reduction of CO_2 Emission

The introduction and operation of a solar thermal and gas integrated solar combined cycle power plant by this project was also expected to contribute to a reduction in CO_2 emission. The actual figures are below the target values. This is attributed to a drop in generated output caused by a shutdown due to the malfunction of the steam turbine and gas turbine as discussed above from July 2016 to May 2017 (five to six years after completion). Additionally, the period from June to December 2017 (six to seven years after completion) was a short period of only seven months and power generation declined due to the periodic maintenance performed on the gas turbine starting in October the same year.

Photo 1: Specialized Cleaning Vehicle for Solar Heat Collectors

Photo 2: Solar Heat Collectors

3.3.1.2 Qualitative Effects (Other Effects)

This project was expected to mitigate environmental impacts by generating electricity using solar thermal energy as an auxiliary energy source for power generation. However, no particularly useful comments were obtained from NREA senior management and field staff with regard to this project's effect on mitigation of environmental burden and Egyptian society. This can be attributed to the fact that particularly notable and detailed effects have not been realized (effects related to environmental impact mitigation) since the installed capacity of the solar thermal power generation system is small and the gas turbine was shutdown for a little less than three years between September 2013 and June 2016, meaning that electricity was not produced nor supplied to the transmission grid using solar thermal power generation.

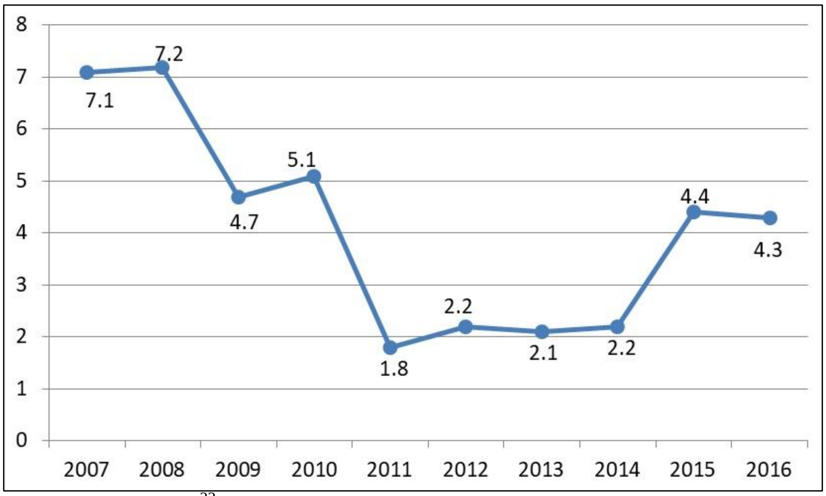
3.3.2 Impacts

3.3.2.1 Intended Impacts

1) Contribution to Economic Development of Egypt and Improvement of People's Livelihood

Figure 2 shows the trends for Egypt's GDP growth rate, Figure 3 presents the number of electrical service subscribers, and Figure 4 shows amount of electricity sales (electricity consumption).

【Unit：%】

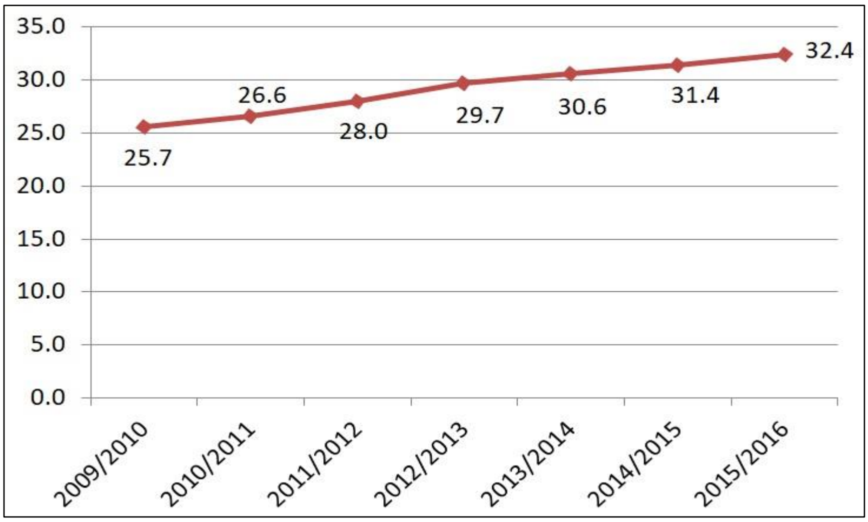


Source: World Bank[22]

Figure 2: GDP Growth Rate Nationwide

[22] Reference source: https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG?end (Accessed on March 30, 2018)

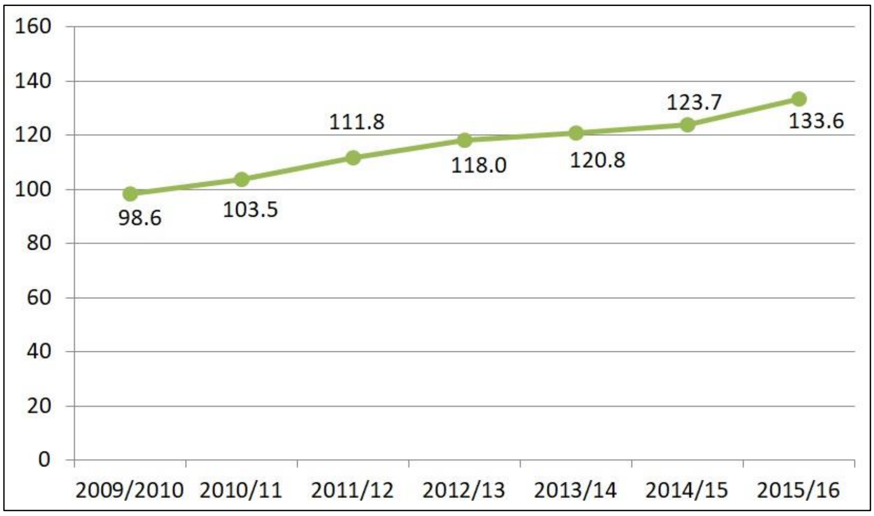
【Unit: million people】



Source: Egyptian Electricity Holding Company (EEHC)

Figure 3: Number of Electrical Service Subscribers Nationwide

【Unit: GWh】



Source: Egyptian Electricity Holding Company (EEHC)

Figure 4: Amount of Electricity Sales (electricity consumption)

As Figure 2 indicates, the country's GDP growth rate has declined and stagnated since 2011, which is believed to be attributed to the political unrest, sluggish economy, and poor public safety seen in the country following the Egyptian Revolution. Since 2015, steady economic growth has been continuing, but the current growth rate is not as high as the rate just immediately after the start of the project. Meanwhile, as Figure 3 and Figure 4 indicate, the number of electrical service subscribers and electricity sales (electricity consumption) are on an uptick. Interviews[23] with senior management of NREA and Egyptian Electricity Holding Company (EEHC) yielded the following comments, "The Egyptian Central Government has been prioritizing investment in the electricity sector since several years ago and is focused on increasing installed capacity, in particular. Therefore, new power plants are being built or existing ones improved across the country", "Several years ago, there were many instances of running into electricity supply shortages. There were concerns that the power will go out or could be cut off only by using air conditioning during the day in summer time. However, the situation is now improving and we no longer have to worry about this" and "There were planned outages in the past, but none at the time of ex-post evaluation. I think this shows that progress is being made with establishing a stable electricity supply. Stability of electricity supply is a top priority. It is a driving force behind people's improved living standards, increased productivity at companies and vitality." Considering these comments, the country's domestic situation has stabilized gradually after the Egyptian Revolution (2011) and demand for electricity appears to be increasing. Therefore, it can be said that this project has played a role in contributing to economic activity and improvement of people's lives through the stable supply of electricity. However, as discussed in 3.1.2 Consistency with Development Needs of Egypt, attention needs to be paid to the fact that the power generation capacity of this project is extremely small compared to Egypt's total power generation capacity of 35,220MW, and that the gas turbine was shutdown for approximately three years after project completion.

2) Contribution to Promoting Development and Utilization of New and Renewable Energy Technologies

In this survey, the following comments were obtained from the same interviews with NREA and EEHC senior management with regard to the development and promotion of the use of new and renewable energy technologies. "Prudent consideration is needed for the introduction of renewable energy power generation facilities because the upfront investment cost (construction cost) piles up. However, operation and maintenance costs are relatively inexpensive, so there is a high possibility that introduction of this technology will pick up speed given the cost effectiveness", and "The determining factor of which renewable energy to use, wind or solar thermal energy, depends on the specific point in time and market needs. For example, wind power received less attention about ten years ago, but the power generation cost of the power generation facility has declined and now it is considered a promising option. We are following

[23] In this survey, key informant interviews with NREA executives (4) and EEHC executives (2) were conducted.

these trends. Additionally, we will continue to implement solar thermal power projects, too, mainly in southern regions.” In addition, according to NREA, there have been many visits from people both inside and outside of Egypt during project implementation and after completion. These visits have involved students, academics and diet members, etc., who have deepened their understanding of the project. In other words, visits have deepened understanding about renewable energy, including solar thermal energy, which could serve as a launching pad for advancing the development of power generation facilities throughout Egypt for the future. As mentioned previously, although the impact of this project is surmised to be limited, the technical knowledge and experience concerning this project’s solar thermal power generation and gas combined cycle power generation systems could be a leading example that can be utilized for other solar thermal power generation projects in the future.

Photo 3: Steam Turbine Room

Photo 4: Cooling Tower

3.3.2.2 Other Positive and Negative Impacts

1) Impact on the Natural Environment

This project is categorized as B according to environmental guidelines following an environmental appraisal carried out in accordance with the *JBIC Guidelines for Confirmation of Environmental and Social Considerations* (April 2002). The environmental impact assessment (EIA) for this project was approved by the Ministry of Environment of Egypt in November 2004.

The NREA headquarters has a department in charge of environmental and social considerations in relation mainly to environmental appraisals for new projects and waste disposal planning and implementation. With regard to Kuraymat Power Plant, there is no requirement for monitoring in accordance with environmental standards and environment related data is not measured. Nevertheless, power plant staff patrol the project site and strive to address any problem they may detect in a quick manner. If a negative impact on the natural environment is confirmed, there is a system in place whereby the power plant will notify the NREA headquarters, which will immediately report to the Ministry of Electricity and Renewable Energy of Egypt and receive instructions. Based on interviews with the NREA headquarters and power plant staff along with a field visit, it was confirmed that no negative impact on the environment (air pollution, water quality, noise and vibrations, or negative impact on the ecosystem) has occurred during the project implementation and after project completion. The area around the power plant is a desert region, with no homes or commercial facilities. Therefore, there have been no impacts, noise and vibrations, or adverse health effects, etc., caused by air pollutants.

2) Resettlement and Land Acquisition

This project did not involve any land acquisitions or resettlement. The project site is located on state-owned land (land owned by the Government of Egypt) and was acquired prior to the start of the project. There were no people living in the area near the project site. As a result the project did not involve resettlement.

As for the project's operation and effect indicators (maximum output, plant load factor, plant availability, gross thermal efficiency, annual amount of net generated output, and amount of reduction of CO_2 emission), the gas turbine experienced a malfunction and breakdown two years after the start of commercial operations and there was a prolonged shutdown around this time, causing the project to fall short of the target values. Additionally, from July 2016 to December 2017, after repairs on the gas turbine were completed, the same turbine was shutdown due to a malfunction, which caused the actual figures of these indicators to be somewhat below the target values. However, there is no major problem with the operation status of the power generation facilities at the time of ex-post evaluation. In terms of the impacts from this project, the effectiveness is presumed to be limited considering the actual figures of these indicators. Therefore, effectiveness and impact of the project is fair.

3.4 Sustainability (Rating: ③)

3.4.1 Institutional Aspect of Operation and Maintenance

The executing agency of this project is NREA. NREA is an agency of the Ministry of Electricity and Renewable Energy that is responsible for power generation projects that use new or renewable energies or promote the R&D and spread of new and renewable energies such as wind power, solar thermal energy, and biomass, etc. Kuraymat Power Plant, a division of NREA, is placed in charge of the operation and maintenance of this project. The main operation and maintenance work of this power plant involves cleaning of the solar heat collectors, cleaning of the lubricated equipment, operation and maintenance of the gas turbine and steam turbine, and overhaul work, etc. Table 7 shows the power plant's workforce at the time of ex-post evaluation.

Table 7: Breakdown of Operation and Maintenance Staff at Kuraymat Power Plant (As of March 2018)

Type of occupation	Assumption after completion at the time of project appraisal (2006)	Number of staff at the time of ex-post evaluation
Number of engineers	Total of number of engineers, technicians and chemists: 122	29
Number of technicians		78
Number of chemists		17
Number of chauffeur		19
Number of security		27
Number of workers		10
Number of administrative affairs and public relations		3
	Total	183

Source: JICA documents, Answers from NREA

The number of Kuraymat Power Plant staff engaged in operation and maintenance work satisfies the initial assumption at the time of appraisal. As Table 7 indicates, at the time of appraisal, the required workforce (engineers, technicians, chemists only) for operation and maintenance of the project's facilities was estimated to be 122 persons. At the time of ex-post evaluation, this workforce stands at 124 persons (as of March 2018). According to the power plant's senior management, "We have secured the minimum necessary workforce, but it is desirable for us to increase our employees so that we can securely prevent unforeseen accidents or breakdowns involving facilities and/or equipment[24]. So far there are no major issues in terms of the institutional aspects of operation and maintenance because we are able to carry out this

[24] According to the power plant and NREA headquarters, "During the six month period prior to the time of the ex-post evaluation (March 2018), six engineers quit over wage and benefits issues, but replacements have not been hired. However, NREA plans to assign 8 to 12 engineers or specialists to Kuraymat Power Plant before the end of 2018. This action is intended to maintain the power plant's operation and maintenance's system." In addition, in June 2018, NREA made changes to the staff wage system with all staff receiving a uniform 7% raise in base pay. According to the power plant's senior management, "The revision to base pay was ground-breaking, and employee dissatisfaction will be eliminated as a result."

work with our present workforce and shift system.” EEHC has dispatched 12 engineers[25] to the power plant in order to assist with operation and maintenance work, and their knowledge and experience with regard to operation and maintenance is being shared with the power plant’s staffs.

Additionally, as noted in 3.3.1.1. Effectiveness and Quantitative Effects (Operation and Effect Indicators), due to the malfunctions of the gas turbine NREA concluded a long-term maintenance support agreement (eight years) with a foreign company in order to carry out maintenance inspections, purchase spare parts, and introduce the latest technologies, etc. Operation on this turbine is carried out following the program prepared by the company and NREA. A system is in place where an immediate response can be taken in case of malfunction or accident. Turbine operations are managed online by the company’s management control division, and continuous monitoring is carried out. As for the steam turbine, according to NREA a foreign company will be selected after a competitive bid in 2018 and a long-term support contract following similar standards is expected to be concluded.

Based on the above, no major problems with the operation and maintenance system at the time of ex-post evaluation are observed.

3.4.2 Technical Aspects of Operation and Maintenance

Most of the workers (mainly specialists/engineers) centered in Kuraymat Power Plant’s control room have an engineering background and graduated with a degree in electrical or mechanical engineering from a four-year university. There are quite a few young workers. At the time of the field survey, it was confirmed that there are many employees with a specialist background related to frontline operation and maintenance work (mainly technicians, engineers, chemists). In addition, according to the power plant, on-the-job training is provided as needed to new and current employees. In addition, as noted above, the power plant receives assistance from EEHC in the form of staff dispatch, which means knowledge and experience about operation and maintenance is being shared with the power plant’s workers.

There is a manual on the equipment and components of the power generation facilities and it is referred to during work as needed. In addition, records of operation and maintenance are prepared and kept.

[25] At the time of appraisal, it was assumed that engineers from EEHC would be dispatched as needed to the power plant in order to reinforce Kuraymat Power Plant’s operation and maintenance work. In 2010, after the start of the project, NREA and EEHC concluded an agreement and contract for the dispatch of staff (renewed every six months). The breakdown of these 12 engineers includes engineers/specialists (9) and chemical specialists (3) for the operation and maintenance of the gas turbine and steam turbine. These engineers are included in the workforce per Table 7.

Based on the above, there is no problem in the technical level of the Kuraymat Power Plant's operation and maintenance.

3.4.3 Financial Aspects of Operation and Maintenance

Table 8 shows the operation and maintenance budget (most recent three years) for facilities developed by this project. Every year, NREA prepares the budget, which is submitted to the Ministry of Finance through the Ministry of Electricity and Energy, the senior authority of the power plant. Funds are allocated after approval procedures are completed. The composition of the budget includes costs related to operation of major facilities such as the gas turbine (including periodic maintenance work performed once every two years), operating costs required for employee salary, etc., costs to purchase lubricant oil, costs to purchase supplies such as parts, and maintenance costs to maintain various equipment. The maintenance budget for 2015/2016 was low compared to other years. This was because the gas turbine was shutdown during this time. The maintenance budget for 2016/2017 and subsequent years increased as the gas turbine was returned to operation. For 2017/2018, the operating budget was higher than that of the previous year due to periodic maintenance work on the gas turbine (the maintenance budget was lower than the previous year because periodic maintenance work would be performed). NREA senior management mentioned "The operation and maintenance budget is allocated as needed. The budget is not short and there is no influence on the operation of the facilities. There are also funds available to purchase spare parts." Based on the above, it is determined that there is no financial problem in terms of operation and maintenance.

Table 8: Operation and Maintenance Budget for Facilities Developed by This Project

(Unit: Egyptian Pound)

	2015/2016	2016/2017	2017/2018
Operation Budget	93,920,780	86,647,107	236,885,357
Maintenance Budget	21,302	29,074,834	5,189,221

Source: NREA

3.4.4 Status of Operation and Maintenance

As stated in 3.4.1 Operation and Maintenance System, the main daily operation and maintenance work for the Kuraymat Power Plant consists of cleaning of the solar heat collectors and cleaning of lubricated equipment. Additionally, the gas turbine undergoes periodic maintenance including an overhaul once every two years and the steam turbine does the same every 12,000 hours of operation. This periodic maintenance was carried out on the gas turbine between October 2017 and February 2018, and it was shutdown during this period[26].

The solar heat collectors are cleaned every two days by two maintenance vehicles designed specifically for cleaning. At the time of ex-post evaluation, both were operating normally, but up to early 2018 one was undergoing repairs[27]. It is hard to procure vehicle parts locally in Egypt and repair work is difficult; therefore, normally vehicles are sent overseas (Europe) for repair work, which takes time. According to NREA, the project has experienced delays in the procurement and delivery of general parts for facilities and equipment[28]. However, at the time of ex-post evaluation, NREA indicated that the delivery and procurement situation are improving.

Based on the above, although conditions require time to procure, repair and secure parts for the project's facilities and equipment, it is determined there is no major problem with the operation and maintenance situation at the time of ex-post evaluation.

As a result, no major problems have been observed in the institutional, technical, financial aspects and current status of the operation and maintenance system. Therefore sustainability of the project effects is high.

4. Conclusion, Lessons Learned and Recommendations

4.1 Conclusion

This project involved the construction of a solar thermal and gas integrated power plant in Kuraymat, located approximately 100km south of Cairo, in order to produce electricity to be supplied to Egypt's existing power grid and to contribute to the economic development and environmental improvements of Egypt by mitigating environmental impacts through the introduction of the auxiliary energy of solar thermal power generation. The Government of Egypt indicated in the *National Five-Year Development Plan* (2002/2003-2006/2007) and the *Egypt Strategic Framework for Economic and Social Development plan Until year 2022* that it will promote renewable energy such as combined cycle power generation as well as solar thermal and wind power generation. Therefore, the project's relevance is high given the development needs from growing electricity demand and consistency with Japan's ODA policy.

[26] Plans call for this periodic maintenance to be performed on the steam turbine in 2019 (Similarly, it will be scheduled to stop operation for several months).
[27] NREA indicated its view that there were malfunctions in mechanical parts used on these vehicles from the beginning (hydraulic instrumentations for the motor). During the time these vehicles were not in operation, the solar heat collectors were cleaned using a fire fighting/water truck owned by NREA. In the near future, NREA plans to purchase additional vehicles to avoid any impediment to cleaning and maintenance work.
[28] However, according to Kuraymat Power Plant, it has already procured or sourced about 20 years worth of spare parts for the solar heat collectors.

In terms of efficiency, project outputs were implemented almost as planned, but project costs significantly exceeded the initial plan due to the impacts of worldwide steel price rise and the rising cost of plant facilities, including gas turbines. The project period required more time than initially anticipated for the selection procedures and negotiations for the contractor of the main construction component of the project. Therefore, the efficiency of the project is low. The project faced malfunctions/breakdowns of the gas turbine, etc., two years after the start of commercial operations and the shutdown period before and after this incident was prolonged. Additionally, partial malfunctions also occurred in the gas turbine and steam turbine even after the repair work was completed in July 2016, resulting in several instances of shutdowns due to mechanical failures. Therefore, the quantitative effect indicators of this project did not achieve the target values. In terms of impacts realized from this project, the actual figures of the relevant indicators are considered to be limited. Thus, the effectiveness and impacts are determined to be fair. There are no major problems in the institutional, technical and financial aspects of Kuraymat Power Plant, which is responsible for the operation and maintenance of this project. No major problems in particular have occurred in the operation and maintenance of other facilities and equipment. Consequently, the sustainability of the project's effect is high.

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

4.2 Recommendations

4.2.1 Recommendations to the Executing Agency

It is preferable that NREA examine measures so that spare parts procurement and repair work at the Kuraymat Power Plant can be addressed in a timely manner.

4.2.2 Recommendations to JICA

To enable steady procurement and sourcing of spare parts, it is desirable that JICA monitor Kuraymat Power Plant for the time being and make requests regarding areas of improvement as needed.

4.3 Lessons Learned

<u>Necessity of careful designing and supervision of construction work of power generation facilities</u>

The gas turbine procured for this project was shutdown for a prolonged period of time due to malfunction soon after the start of service and it was forced to shutdown later after the repairs due to a mechanical problem. Therefore, the executing agency must check to make sure that climate and environmental conditions at the project site are suitable for the gas turbine, which uses extremely fine mechanical parts, while thoroughly checking the technical and quality management capabilities of the construction contractor. If not suitable, it is important for the executing agency to take the appropriate actions or take steps to prevent malfunctions or accidents wherever possible through various considerations.

Comparison of the Original and Actual Scope of the Project

Item	Plan	Actual
1. Project Outputs	1) Civil work ① Solar thermal and gas integrated power plant - Gas turbine (80MW x 1) - Steam turbine (70MW x 1) (of this, 40MW by gas turbine heat recovery and 30MW by solar thermal recovery) - Generator (Gas turbine: 80MW, Steam turbine: 70MW - Heat recovery steam generator （HRSG） (1 unit) - Main transformer - Control & instrumentation equipment - 22kV/66kV outdoor switchgear - Cooling water equipment - Solar thermal power generation facilities (not covered by ODA loan; assistance by Global Environment Facility (GEF)) 2) Consulting services ① Construction supervision ② Assistance for operation and maintenance	1) Civil work ①Solar thermal and gas integrated power plant - Gas turbine (74MW x 1) - Steam turbine (56MW x 1) (of this, 36MW by gas turbine heat recovery and 20MW by solar thermal recovery) - Generator (Gas turbine: 74MW, Steam turbine: 56MW - Heat recovery steam generator （HRSG） (1 unit) - Main transformer - Control & instrumentation equipment - 22kV/66kV outdoor switchgear - Cooling water equipment - Solar thermal power generation facilities (assistance by GEF; output of 20MW) 2) Consulting services As planned.
2. Project Period	April 2005 to June 2009 (51 months)	April 2005 to June 2011 (75 months)
3. Project Cost		
Amount Paid in Foreign Currency	14,618million yen	26,518million yen
Amount Paid in Local Currency	6,765million yen	7,935million yen （495.643million Egyptian pound）
Total	21,383million yen	34,453million yen
ODA Loan Portion	10,665million yen	20,085million yen
Exchange Rate	1 Egyptian pound =17.7yen 1 USD=6.22Egyptian pound (As of February 2005)	1 Egyptian pound =16.01yen 1 USD=5.92 Egyptian pound （Average between 2006 and 2013, based on rates issued by the IMF’s International Financial Statistics Data)
4. Final Disbursement	Phase 1: August 2015 Phase 2: January 2016	