Kingdom of Cambodia

FY2018 Ex-Post Evaluation of Japanese Grant Aid Project

"The Project for Construction and Rehabilitation of Small Hydro Power Plants in Rattanakiri Province"

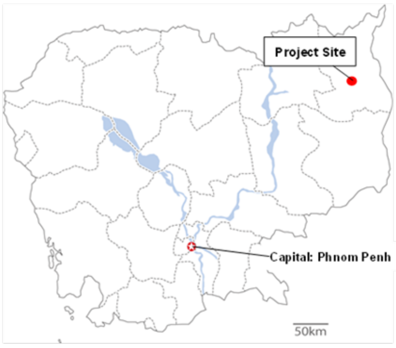
External Evaluator: Masumi Shimamura, Mitsubishi UFJ Research and Consulting Co., Ltd.

0. Summary

This project constructed a small hydropower plant and renewed facilities of an existing small hydropower plant in Rattanakiri Province, which is located at the northeast of Cambodia, with the aim of providing stable power supply in the rural area of the country and diversifying energy sources. The expansion of power supply and promotion of rural electrification through development of hydropower plants of this project, which is clean energy, is consistent with Cambodia's development policy and development needs as well as Japan's assistance policy. Therefore, the relevance of the project is high. In terms of project implementation, the project cost was as planned, and project period was within the plan. Therefore, efficiency of the project is high. Regarding the project effects, as for quantitative effects, maximum output has achieved the target. Although operating rate, gross annual energy output, and reduction of CO_2 emission have not achieved the targets due to the decrease in water volume, improvement of their actual figures is expected in the future looking from the trend of rainfall data. As for qualitative effects, it was confirmed from the interviews with local residents and commercial-scale power users that stable power supply and rural electrification had been realized from the project. Therefore, it can be regarded that the project has largely achieved its objectives. In terms of impacts, the number of factories and major public facilities are increasing in Rattanakiri Province, and interviews with local residents and commercial-scale power users suggest that the project is contributing to the improvement of economic and social development. Furthermore, the project contributes to the expansion of power sources utilizing domestic water resources and the improvement of self-sufficiency rate in power supply. The project also contributes to the reduction of CO_2 emission, considering that further imports of power derived from thermal power generation would have been necessary if this project had not been implemented. Therefore, the project has largely generated its planned effects; thus, its effectiveness and impacts are high. No negative impacts on natural environment and resettlement have been reported. This project utilizes the superior products and technologies of the small and medium-sized enterprise in Japan. As for operation and maintenance, institutional / organizational, technical, financial aspects as well as maintenance situation are in good condition, and the executing agency has been operating the power plants smoothly. Therefore, sustainability of the project effects is high.

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

1. Project Description



Project Location

O'Chum No.2 Power Plant
(Turbine and Generator)

1.1. Background

In Cambodia, maximum power and the amount of electricity generated had been increasing by more than 20% on average annually since 2003 until 2008[1]. On the other hand, the ratio of imported electricity to the amount of electricity supplied had reached 61.5%, and more than 90% of domestic power generation was dependent on small-scale diesel generation. Consequently, electricity tariff level in Cambodia was higher than the neighboring countries.[2] In addition, while electrification rate in the urban area was 87% (2008), that in the rural area was only 13%.[3] Rattanakiri Province, which is located at the northeast of the country near the Vietnamese border, has a population of 160 thousand, and its main industry is agriculture. The population growth rate was high at 4% or more per year but electrification rate was low at 16% (2011).[4] On the other hand, since the area is mountainous, potential for small hydropower development was high. The Province's power supply was covered by a small hydropower plant in O' Chum District near the provincial capital Ban Lung as well as imports from Vietnam. Although there was a height difference that could be utilized for a small-scale hydropower, the power plant site had not been fully used, and output of the existing power plant was declining due to troubles caused by aging of facilities after 20 years or more of operation. The project aims to provide stable power supply in the project area and to promote rural electrification by constructing a small hydropower plant and renewing facilities of the existing small hydropower plant in Rattanakiri Province.

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[1] Information from the materials provided by JICA.
[2] Ibid.
[3] Ibid.
[4] Ibid.

1.2 Project Outline

The objective of this project is to provide stable power supply in the rural area and to diversify energy sources by constructing a small hydropower plant and renewing facilities of the existing small hydropower plant in Rattanakiri Province, which is located at the northeast of Cambodia, thereby contributing to the improvement of economic and social development as well as reduction of greenhouse gas emission in the country.

Grant Limit / Actual Grant Amount	1,487 million yen / 1,486 million yen
Exchange of Notes Date / Grant Agreement Date Revised Exchange of Notes Date / Revised Grant Agreement Date	March 2013 / March 2013 March 2015 / April 2015
Executing Agency	Electricite du Cambodge (EDC)
Project Completion	November 2015
Target Area	O' Chum Village, Rattanakiri Province
Main Contractors	Nishizawa Limited / Konoike Construction Co., Ltd. (JV)
Main Consultants	Electric Power Development Co., Ltd. / Chuden Engineering Consultants Co., Ltd / The Chugoku Electric Power Company, Incorporated (JV)
Procurement Agency	-
Preparatory Survey	July 2012 – March 2013
Related Projects	-

2. Outline of the Evaluation Study

2.1 External Evaluator

Masumi Shimamura, Mitsubishi UFJ Research and Consulting Co., Ltd.

2.2 Duration of Evaluation Study

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

Duration of the Study: August 2018 – September 2019

Duration of the Field Study: October 28 – November 16, 2018

3. Results of the Evaluation (Overall Rating: A[5])

3.1 Relevance (Rating: ③[6])

3.1.1 Consistency with the Development Plan of Cambodia

At the time of planning, Cambodian government's *the National Strategic Development Plan (2009-2013)* emphasized the importance of securing power supply capacity, lowering electricity tariff, strengthening power related institutions and promoting their capacity development. In addition, *The Strategy and Plan for Development of Rural Electrification* prepared in 2011 has set targets that Cambodia would achieve 100% village electrification rate including battery lighting by 2020 and 70% household electrification rate through grid connection by 2030. This project aims at providing stable power supply and improving living environment of residents in Rattanakiri Province located near the border with Vietnam, and it can be said that the project was consistent with the development policy at the time of planning.

At the time of the ex-post evaluation, Cambodian government's *the Rectangular Strategy Phase III (2013-2018)* and *the National Strategic Development Plan (2014-2018)*, which embodied *the Strategy*, set out "Infrastructure Development: Power Development" as one of priority issues, and emphasized the increase of power supply, the realization of power access (enhancement of village electrification rate), and the electricity connection between regions (power grid connection). In addition, *the Rectangular Strategy Phase IV (2019-2023)* announced in September 2018 also points out the importance of reducing electricity tariff, increasing power supply and improving reliability of power supply. Furthermore, *the Energy Sector Development Plan (2005-2024)* and *the Strategy and Plan for Development of Rural Electrification*[7] indicate the importance of rural electrification, and the government of Cambodia maintains its targets to achieve 100% village electrification rate by 2020 and 70% household electrification rate by 2030. The implementation of the project is also consistent with the development policy of Cambodia at the time of ex-post evaluation.

3.1.2 Consistency with the Development Needs of Cambodia

At the time of planning, Rattanakiri Province had a high growth rate of population of 4% or more annually, however, electrification rate was low at 16%. The Province's power supply was covered by the existing O'Chum No. 2 power plant as well as imports from Vietnam. However, although there was a height difference that could be utilized for a small-scale hydropower, the power plant site has not been fully used, and output of the

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

[6] ③: High, ②: Fair, ①: Low

[7] *The Strategy and Plan for Development of Rural Electrification* prepared in 2011 which clearly sets forth its targets for 2030 is still valid at the time of ex-post evaluation.

existing power plant was declining due to troubles caused by aging of facilities after 20 years or more of operation.

At the time of ex-post evaluation, securing stable power supply in rural areas continues to be highly necessary for the economic and social development. Specifically, maximum power demand, power supply at peak demand, and power consumption during the period from 2012 to 2018 all show high growth rates of around 20% a year on average throughout Cambodia. Growth rates are even higher in northeast Cambodia and in Rattanakiri Province, where the project is located – the average annual growth rates are more than 30% in northeast Cambodia, and around 30% in Rattanakiri Province. Village electrification rate in 2018 is 86.85% nationwide, whereas those in northeast Cambodia and in Rattanakiri Province are still 52.27% and 55.97%, respectively – improvement of electrification rate still remains an issue to be tackled with. (Table 1)

From the above, the project is in line with the development needs of Cambodia at the time of planning and the ex-post evaluation.

Table 1: Maximum Power Demand, Power Supply at Peak Demand, Power Consumption and Village Electrification Rate for Cambodia Nationwide, Northeast Cambodia and Rattanakiri Province

	2012	2013	2014	2015	2016	2017	2018
Cambodia Nationwide							
Maximum Power Demand (MW)	486.3	626.0	784.4	951.3	1,068.0	1,269.4	1,518.2
Power Supply at Peak Demand (MW)	825.0	1,088.0	1,359.0	1,986.0	2,115.0	2,322.0	2,650.0
Power Consumption (GWh)	3,527.4	4,051.6	4,861.4	6,015.4	7,033.1	8,072.8	9,307.0
Village Electrification Rate (%)	49.65	51.07	60.32	66.55	74.74	81.58	86.85
Northeast Cambodia (Mondul Kiri, Rattanakiri and Stung Treng Provinces)							
Maximum Power Demand (MW)	6	9	12	20	22	28	32
Power Supply at Peak Demand (MW)	6	9	12	20	22	28	32
Power Consumption (GWh)	28	36	46	53	73	110	N.A.
Village Electrification Rate (%)	13.10	18.56	19.00	23.14	29.50	45.77	52.27
Rattanakiri Province							
Maximum Power Demand (MW)	3.69	4.17	5.40	5.89	7.20	12.57	14.01
Power Supply at Peak Demand (MW)	3.69	4.17	5.40	5.89	7.20	12.57	14.01
Power Consumption (GWh)	17.2	22.73	27.91	33.36	37.42	47.40	45.48
Village Electrification Rate (%)	8.75	15.42	16.25	20.83	30.86	52.26	55.97

Source: Results from questionnaire survey of Electricity Authority of Cambodia (EAC).

3.1.3 Consistency with Japan’s ODA Policy

At the time of project planning, Japanese government’s *Country Assistance Strategy for Cambodia (2012)* and *Project Development Plan (the same year)* placed “strengthening the economic foundation” as a priority area, and cooperation in power sector development was regarded as one among others. Furthermore, Japanese government put up a policy to support the utilization of superior technologies of Japan in the field of new energy and the realization of green growth in Japan Revitalization Strategy.

The project aims to contribute to the stable power supply in rural areas, the improvement of economic and social development in Cambodia, and the reduction of greenhouse gas emission. In addition, design policies, etc. were considered on the premise of utilizing superior products and technologies of small and medium size enterprises in Japan. Thus, the project is consistent with the above strategies.

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

3.2 Efficiency (Rating: ③)

3.2.1 Project Outputs

The project constructed O’Chum No.1 power plant (265kW) and renewed facilities of O’Chum No.2 power plant (480kW×2) with the aim of providing stable power supply in the project area. Table 2 compares the planned and actual outputs of major outputs.

Table 2: Comparison of Planned and Actual Outputs

Items	Plan	Actual (Difference)
O’Chum No.1 Power Plant (new construction)		
Intake	Concrete structure, height 7.15m, width 2.20m	As planned
Penstock	Diameter 1.0 – 1.5m, length 457m	As planned
Turbine and Generator	Cross-flow turbine 295kW 3 phase AC induction generator 350kVA	As planned
Installed Capacity	265kW	As planned
Power House	One-story building with floor area of 64 m^2	Floor area expanded to 92 m^2 (Because the dimensions of various facilities were larger than originally designed)

Administrative Road Repair	Length 624m, width 4.0m (3.0m travelled width + 0.5m shoulder × 2), low-cost pavement	O’Chum No.1 dam seepage countermeasure work and installation of new administrative road based on the seepage countermeasure work
O’Chum No.2 Power Plant (equipment renewal)		
Turbine and Generator	Horizontal shaft Francis turbine 507 kW × 2units 3 phase AC brushless synchronous generator 600kVA × 2units	As planned
Installed Capacity	480 kW × 2units (Total 960kW)	As planned
Administrative Road Repair	Length 383m, width 5.0m (4.0m travelled width + 0.5m shoulder × 2), low-cost pavement	Already repaired by the executing agency (EDC) before construction
Transmission / Distribution Line (new construction)[8]		
22 kV Medium-Voltage Distribution Line	Length 730m	As planned
Consulting Services		
Items		Actual (Difference)
Design and Construction Management		With design and construction management work related to dam seepage countermeasure work
Assistance in Tendering		As planned
Construction (Procurement) Management		With additional construction (procurement) management work regarding dam seepage countermeasure work
Capacity Building Program (Soft Component) for Operation and Maintenance of Power Plant Operation Staff		With technology transfer regarding measurement of water level and seepage volume of O’Chum No.1 dam and maintenance surrounding the reservoir

Source: Results from questionnaire survey of executing agency (EDC)

[8] Although not mentioned in the ex-ante evaluation report, this was included in the implementation plan.

As a major change (increase of scope) from the original plan, additional work was implemented on seepage countermeasure for the existing O'Chum No.1 dam. It became clear that a large amount of water seepage was occurring from the O'Chum No.1 dam in August 2014 after commencement of main construction work. Thus, an emergency measure was carried out which made it possible to collect water in a stable manner, by putting back drainage with filter material after placing drainage in the foundation excavation section of administrative road where water seepage from the dam was occurring. However, from the viewpoint of securing safety of the dam (prevention of dam seepage failure), the need for permanent response was recognized and measures were undertaken. As regards increase of project scope, a revised Grant Agreement was concluded in April 2015, and the additional work (water seepage countermeasure work) was started from the same month. Specifically, installation of new administrative road for the O'Chum No.1 power plant, and survey, design and construction management work on water seepage countermeasure were additionally carried out. In addition, regarding capacity building program (soft component) for operation and maintenance for power plant operation staff, technology transfer concerning measurement of water level and seepage volume of O'Chum No.1 dam as well as maintenance surrounding the reservoir was added. According to the executing agency Electricite du Cambodge (hereinafter referred to as "EDC") and the project consultant, it was difficult to grasp the risk of water seepage at the time of planning because the area around the dam was covered with plants and trees during the survey and examination at the time of detailed design of the project., In addition, since it was a rainy season, the ground was wet by rainwater, which made it difficult to grasp the details of water seepage. According to EDC, as regards to water seepage, no particular problem occurred during project implementation, and the additional construction has kept the seepage amount below the warning level since the start of operation of the power plant, and thus dam safety has been ensured and efficient management of dam has been realized.

As another major output change, the floor area of newly constructed O'Chum No.1 power plant building was expanded from the originally planned 64m^2 to 92 m^2. This was because, as a result of the contractor's optimum design for this project, the dimensions of various facilities such as power generation equipment have become larger than the originally designed.

Regarding the above changes in outputs, according to EDC and the project consultant, the additional work and the accompanied additional scope were appropriate changes because it was necessary to take measures from the viewpoint of securing safety of the dam, and the floor area expansion of the power plant building had to take place to accommodate larger facilities. As regards additional work for seepage control, a revised Grant Agreement was concluded based on the request from the Cambodian side, after considering the appropriateness and necessity sufficiently, and the expansion of the floor area of the O'Chum No.1 power plant building was a change for the smooth and safe operation of the power plant equipment. Thus, they are considered to be appropriate changes.

As a result of the interview with EDC and the project consultant, all the tasks to be undertaken by the Cambodian government on matters necessary for the project implementation, such as securing necessary land for construction work and obtaining permission and approval required for construction, have been duly completed without any problems.

Water Intake Tower of O'Chum No.1 Dam

O'Chum No.1 Power Plant
(Power Plant Building and Penstock)

O'Chum No.1 Power Plant
(Water Seepage Countermeasure Work)

O'Chum No.1 Power Plant
(Turbine and Generator)

O'Chum No.2 Power Plant (Building)

O'Chum No.2 Power Plant (Penstock)

3.2.2 Project Inputs

In analyzing the inputs (project cost and project period), based on the relevance and appropriateness of scope increase mentioned above, project cost and project period assumed for the implementation of additional construction were added to the plan and compared with the actual results. In other words, project cost and project period at the time of conclusion of a revised Grant Agreement were considered as the plan and compared with the actual results.

3.2.2.1 Project Cost

While the total project cost was initially planned to be 1,488 million yen, the actual cost was 1,487 million yen as planned (100% of the planned amount). Of which, the government of Cambodia disbursed 1 million yen as planned.

Besides, the grant limit in the Grant Agreement before revision was 1,206 million yen, and the limit after revision became 1,487 million yen. It was confirmed with EDC and the project consultant that the difference, 281 million yen, was the increased cost related to water seepage control work and the accompanied additional scope. It can be judged that the additional work and the accompanying additional scope were appropriate and commensurate with the inputs.

3.2.2.2 Project Period

While the overall project period was planned as 33 months (plan at the time of a revised Grant Agreement), the actual period was 32 months, which is one month shorter than planned (97% of the initial plan). According to EDC and the project consultant, implementation of additional seepage control work was facilitated especially during the dry season (April to May), which made it possible to complete the construction one month earlier than planned.

Table 3 summarizes the comparison of planned and actual project period.

Table 3: Comparison of Planned and Actual Project Period

Plan	Actual
April 2013 – December 2015 (33 months)	April 2013 – November 2015 (32 months)
Breakdown: Detailed Design and Assistance in Tendering	
April 2013 – September 2013 (6 months)	April 2013 – September 2013 (6 months)
Breakdown: Construction	
October 2013 – December 2015 (27 months)	October 2013 – November 2015 (26 months) Of which, dam seepage countermeasure construction period: April 2015 – November 2015 (8 months)

Source: Ex-ante evaluation report and information provided by JICA

Note 1) The definition of project completion is at the time of completion of additional water seepage countermeasure work. Project period does not include warranty period for both plan and actual.

The project cost was as planned, and project period was within the plan. Therefore, efficiency of the project is high.

3.3 Effectiveness and Impacts[9] (Rating: ③)

3.3.1 Effectiveness

3.3.1.1 Quantitative Effects

At the time of planning, maximum output, operating rate, gross annual energy output, and reduction of CO_2 emission were set as quantitative effects of the project. Table 4 summarizes baseline, target and actual figures between 2015 and 2018 for each indicator. As the project completion is November 2015, the target year to be compared is 2018, 3 years after completion.

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

Table 4: Quantitative Effects of the Project

Indicators	Baseline	Target	Actual			
	2012	2018 3 Years After Completion	2015 Completion Year	2016 1 Year After Completion	2017 2 Years After Completion	2018 3 Years After Completion
[Effect Indicator] Maximum Output (kW) (1) O'Chum No.1 Power Plant (2) O'Chum No.2 Power Plant	— 820	265 960	265 960	265 960	265 960	265 960
[Operation Indicator] Operating Rate (%) Note 1) (1) O'Chum No.1 Power Plant (2) O'Chum No.2 Power Plant	— 31	34 45	8.11 26.83	9.17 22.24	22.53 38.69	24.66 37.07
[Effect Indicator] Gross Annual Energy Output (MWh/year) Note 2) (1) O'Chum No.1 Power Plant (2) O'Chum No.2 Power Plant	— 2,620 Note 3)	771 3,747	188.43 2,256.56	212.95 1,887.74	523.07 3,254.39	563.50 3,068.80
[Environment Related Indicator] Reduction of CO_2 emission (t/year) Note 4) (1) O'Chum No.1 Power Plant (2) O'Chum No.2 Power Plant	— 1,071.5	315.3 1,532.5	77.07 922.93	87.10 765.13	213.94 1,331.05	230.47 1,255.14
[Reference Information] Number of villages connected to the grid in the project area and getting power supply from the project	6	—	N.A.	N.A.	N.A.	21
[Reference Information] Number of households connected to distribution lines in the project area and getting power supply from the project	230	—	N.A.	N.A.	N.A.	1,360

Source: Information provided by JICA and results from questionnaire survey of EDC Rattanakiri Office

Note 1) Operating rate (%) = annual power generation / (rated power output × number of hours in a year) × 100

Note 2) Gross annual energy output (MWh/year) = annual power generation (gross generated power)

Note 3) An annual average output of the existing O'Chum No.2 Power Plant of the past 6 years

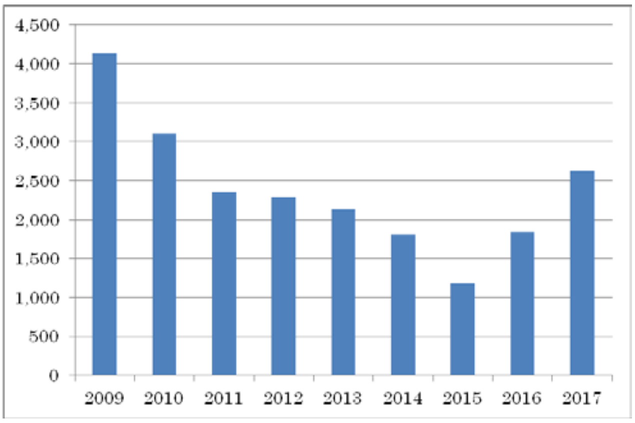
Note 4) Volume of CO_2 emission reduced: actual output from O'Chum No.1 and No.2 power plants (increased volume) × emission coefficient of Vietnam (generating end) 409 kg CO_2/MWh

Note 5) Baseline figures of reference information (in 2012) are the number of villages and the number of households that received power supply from the existing O'Chum No.2 power plant

Maximum outputs have achieved the targets every year after the start of operation. Operating rates have not achieved the targets. Looking at the actual figures in 2018, O’Chum No.1 power plant has achieved 73% of the target, and O’Chum No.2 power plant 82% of the target. Gross annual energy outputs are almost linked to the operating rates,[10] and the actual figures in 2018 are 73% of the target for O’Chum No.1 power plant and 82% of the target for O’Chum No.2 power plant. In the same token for CO_2 emission reduction effect,[11] the actual figures in 2018 are 73% of the target for O’Chum No.1 power plant and 82% of the target for O’Chum No.2 power plant.

The main reasons for unachieved targets for operating rate (as well as gross annual energy output and CO_2 emission reduction effect, which are both linked to operating rates) are as follows.

(1) Because hydropower uses water resources, operating rate is greatly affected by the amount of rainfall of that year. After the start of operation of power plants, rainfall during the rainy season has decreased (especially in 2015, the rainfall volume was extremely low due to the El Niño phenomenon). According to EDC and the project consultant, the target figures set at the time of planning were prepared based on the condition of rainfall before the creation of the preparatory survey report (2012), and the rainfall volume at that time was more than that of the recent years. Figure 1 shows the rainfall data[12] of Ban Lung City (the capital city of Rattanakiri Province) which is adjacent to O’Chum District, where the power plants are located.



Source: Prepared based on the information provided by the executing agency.

Figure 1: Rainfall Data of Ban Lung City (unit: mm)

(2) In the last few years, opening of pepper, rubber and cashew nut plantations has been rapidly increasing in the catchment area (water collection area) around the reservoir of

[10] As the notes in Table 4 show the definition of indicators, both operating rate and gross annual energy output have a variable of annual power generation, and they both are positively correlated. In other words, since the rated power output of each power plant and the number of hours in a year are constant, an increase in operating rate leads to an increase in annual power generation (that is, an increase in gross annual energy output).

[11] As shown in the note in Table 4, volume of CO_2 emission reduction is derived by multiplying a certain coefficient to the generated power (increased volume) of each power plant, thus if the volume of power generation increases, volume of reduced CO_2 emission will also increase.

[12] Rainfall data of Ban Lung City was also used at the time of the ex-post evaluation for the comparison with the time of planning since it is mentioned in the preparatory report (p.33) that “Power generation plan of O’Chum No.1 power plant was prepared using the inflow volume to O’Chum No.1 dam, which was estimated from the rainfall data in Ban Lung City. This was because there was no data on water level, inflow volume and outflow volume of O’Chum No.1 dam” at the time of project planning.

O’Chum No.1 dam. Because a large amount of water is consumed at the farms, the amount of water in the reservoir is decreasing.

From the above, it can be considered that the targets set at the time of planning were somewhat high when looking back on trend of rainfall from the start of power plant operation to the ex-post evaluation. In fact, referring to average figures of operating rates of hydropower plants in each country,[13] published by the US Energy Information Administration, figures are as follows in Asia: 40% in Japan, 37% in China, 34% in India, and 25% in Korea. Although a simple comparison with this project is not relevant, when viewed as a reference figures, the target figure of 45% for O’Chum No.2 power plant seems somewhat high.

Reservoir of O’Chum No.1 Dam
(The other side is a pepper plantation.)

It can be judged that the effects of the project have been achieved to some extent taking into consideration of the following: both power plants have been operating smoothly since the start of their operation, and maximum outputs have achieved the target every year; with regard to other indicators, it is expected that the actual figures will improve along with the recovery of rainfall, when looking at the trend of rainfall data; and also, from interviews with beneficiaries (local residents and commercial-scale power users) (as stated below), stable power supply and promotion of rural electrification have been realized by the development of hydropower plants in this project.

The reason why the actual figure of O’Chum No.2 power plant’s operating rate in 2018 is lower than that in 2017 is because of accumulation of sediments in the O’Chum No.2 dam reservoir, which has decreased the volume of water. Regarding this, EDC Rattanakiri Office, which is in charge of operation and maintenance the project, is planning to remove sediments by 2020, and there are concrete prospects for the recovery of reservoir water volume and the increase in operating rate.

3.3.1.2 Qualitative Effects (Other Effects)

As qualitative effects of the project, it was expected that stable power supply, promotion of rural electrification and diversification of energy sources would be realized.

[13] U.S. Energy Information Administration “ Electric generator capacity factors in various countries and regions, 2008-2012 averatge” https://www.eia.gov/todayinenergy/detail.php?id=22832 (Accessed on April 23, 2019)

With regard to stable power supply and promotion of rural electrification, when looking at the trend around 2015 in Table 1 above at the time when both power plants started to supply power, maximum power demand, power supply at peak demand, power consumption, and village electrification rate in Rattanakiri Province, where the project is located, all show upward trend. Therefore, it can be considered that the project is contributing to the increase of power supply as well as promotion of rural electrification. Also, according to the interviews with local residents and commercial-scale power users[14] (all are beneficiaries of the project who live or do business in Ban Lung City or O'Chum District) carried out during project site survey, almost all the respondents pointed out that the project has contributed to the increase of the power supply in the power supply area,[15] and to the promotion of stable power supply and rural electrification. According to the interviews, before the project, the power supply area received power from the existing O'Chum No.2 power plant as well as imports from Vietnam. There were some unelectrified areas in O'Chum District (such as areas where minority Krung tribe people live) that were not connected to distribution lines. In such places, local residents used battery electricity for living, and since the completion of the project, power has been supplied from the distribution lines to the areas which had not been electrified. In addition, in the areas that had already been connected to the distribution lines in Ban Lung City and O'Chum District, planned power outages and sudden power outages occurred before the project, and it took time to recover.[16] Thus, power supply was not stable before the project. While power outage is not completely eliminated after the project, it has been confirmed that significant improvement took place compared with the situation before the project. Therefore, the project is considered to contribute to stable power supply and promotion of rural electrification.

As for diversification of energy sources, looking at the generation energy composition in northeast Cambodia and Rattanakiri Province (Table 5), the share of hydropower is increasing in the northeast and Rattanakiri Province in 2015, when both power plants

[14] Breakdown of interviewees is as follows: 9 men (7 in 30's, 1 in 50's, and 1 in 60's) and 8 women (1 in 10's, 1 in 20's, 2 in 40's, 2 in 50's and 2 in 60's), with a total of 17 people. Local residents live in the power supply area of the power plants. Their occupations are: owners of restaurants and stalls, shop owners (selling general merchandise and groceries, etc.), resident housekeeper, cassava farmers, cashew nut farmers, housewives etc. Commercial-scale power users are as follows: owners or managers of supermarkets and coffee shops, branch of a bank, restaurants, private university, gas stations and coffee shops, located in the power supply area of the power plants.

[15] Power generated by this project is also supplied to Ban Lung City, O'Chum District, Bar Kaev District and Ou Ya Dav District. After the project, all 15 villages in the surrounding area that were not connected to the grid were connected and electrified. As a result, 1,130 households are newly connected to distribution lines and receiving power supply from the project. (Note: There are 6 villages in Ban Lung City, and O'Chum District, Bar Kaev District and Ou Ya Dav District are also comprised of several villages.)

[16] Situation varied depending on the location due to the difference of electric wiring condition and power lead-in. In areas where power outages were severe, outages occurred once or twice a month, lasting a half day to one day per outage.

started operation. Since then, the share of hydropower has fluctuated due to the increase in electricity demand, but for Rattanakiri Province, power sources in 2016 and 2017 were only hydropower and imports from Vietnam. Thus, it can be said that the project is contributing to the reduction of imports (further imports would have been necessary if the project had not been implemented). From this, it can be said that the project contributes to the expansion of power sources utilizing domestic water resources and the improvement of self-sufficiency rate in power supply.

Power interchange from Stung Treng Province in 2018 is due to the completion and start of operation of the hydropower Lower Sesan 2 power plant,[17] which was built in Stung Treng Province, adjacent to Rattanakiri Province. Also, according to EDC, power interchange to the Rattanakiri Province will continue in the future. Cambodian government aims to improve self-sufficiency rate in power supply and secure energy security by increasing power generation and supplying power within the country that had previously relied on imports from neighboring countries.

Table 5: Generation Energy Composition in Northeast Cambodia and Rattanakiri Province

	2012	2013	2014	2015	2016	2017	2018
Northeast Cambodia (Mondul Kiri, Rattanakiri and Stung Treng Provinces)							
Hydro	6.54%	4.61%	3.32%	18.31%	4.13%	4.06%	24%
Diesel	21.70%	7.99%	1.16%	0.46%	0.16%	1.20%	0.005%
Biomass	-	0.50%	-	-	-	-	2.2%
Imports (from Vietnam)	71.76%	86.90%	95.52%	56.55%	51.67%	48.75%	25.4%
Imports (from Laos)	-	-	-	24.67%	44.04%	45.99%	39%
Rattanakiri Province							
Hydro	20.98%	15.30%	1.91%	7.33%	5.57%	7.38%	5.31%
Diesel	-	-	0.22%	0.59%	-	-	-
Power from Stung Treng Province (through 35kV National Grid)	-	-	-	-	-	-	47.60%
Imports (from Vietnam)	79.02%	84.70%	97.87%	92.07%	94.43%	92.62%	47.09%

Source: Results from questionnaire survey of EAC and EDC.

Note 1) Due to rounding errors, some totals will not become 100%.

[17] Total construction cost of the hydropower Lower Sesan 2 power plant is about USD 816 million. A joint venture in which China's Hydrolancang International Energy holds 51% of shares, Cambodia's diversified conglomerate, the Royal Group holds 39% of shares, and Vietnam Electricity (EVN) holds 10% of shares received an order by BOT method for 45 years (including 40 years of operation). (BOT method (Build, Operate and Transfer Scheme) is a method in which private companies raise their own funds, construct facilities, operate and manage for a certain period, and transfer the ownership after the period ends.) It first started generating power of about 50 MW in October 2017, and all 8 plants will be operated in 2018 to be 400 MW. It will be the largest power plant in Cambodia. The generated power is to be sold to EDC at 6.95 cents/kwh.
(Source) https://www.morningstar.co.jp/msnews/news?rncNo=1811860 (Accessed on April 9, 2019)

3.3.2 Impacts

3.3.2.1 Intended Impacts

In this project, (1) enhancement of economic and social development and (2) reduction of greenhouse gas emission were expected as impacts. The appearance of these impacts is described below.

(1) Enhancement of Economic and Social Development

Table 6 shows transition of the number of factories, hotels and guesthouses, hospitals, and schools (elementary, junior high and high schools) in Rattanakiri Province, as well as the distance of public roads where street lights are installed.

Table 6: Transition of the Number of Factories, Hotels, Population and Major Public Facilities in Rattanakiri Province

	2015	2016	2017	2018
Factories	29	32	61	63
Hotels/Guesthouses	49	49	49	50
Population	183,092	188,981	194,773	201,547
Hospitals	81	82	82	82
Primary Schools	195	203	218	218
Junior High Schools	17	19	25	25
Senior High Schools	5	5	5	5
Distance of public roads with street lights (km)	9	10	13	15

Source: Prepared based on the information provided by EDC Rattanakiri Office.

As regards the number of factories in Rattanakiri Province, with the increase of plantations, the number of crop processing plants is increasing year by year, and it can be considered that the improvement of power situation by the project has contributed to the infrastructure development for establishing factories. As for public facilities, population of Rattanakiri Province is increasing, and the number of hospitals and schools as well as the distance of public roads with street lights are also increasing as shown in Table 6. Thus, it is thought that the state of local people’s life is improving.

In addition, as a result of interviews with local residents and commercial-scale power users[18] conducted at the time of project site survey, almost all the respondents confirmed that the project contributes to the improvement of economic and social development. Local residents responded that they feel the economy has been activated due to the

[18] The interviewees are the same 17 people listed in footnote 14.

increasing number of shops and restaurants in Ban Lung City in the last couple of years. Many of them also pointed out that household appliances (refrigerator, rice cooker, washing machine, TV, water supply pump) have increased at each home, and that they can do housework even at night as power is supplied for 24 hours (there is no need to rush to finish housework while it is light), and that they can now watch TV at night. In addition, they also pointed out security and safety effects, such as the change of atmosphere because Ban Lung City has become brighter even at night thanks to the building lights and outside lights. They also mentioned that now they can drive motorbikes safely at night.

Commercial-scale power users responded as follows: realization of stable power supply has become one of the factors for business expansion such as opening a new coffee shop (an owner of supermarket and coffee shop, and an owner of gas plant and coffee shop), and stable power supply has helped to expand operations and install additional equipment such as ATMs (bank managers). At the university, the number of air conditioners and computers has increased, and the number of classes at night (17:30 to 20:30) has also increased from three to four, and faculties and students feel safe at night since streets have become brighter (clerk at a private university).

With regard to electricity tariff, as shown in Table 7, until 2018, Rattanakiri Province had not changed tariff setting of 670 riel/kWh for all industrial, commercial and residential customers. However, based on the policy of Cambodian government, since 2018, electricity tariff in the Province was unified to that of Cambodia nationwide, except for Ban Lung City. As part of the government's rural electrification promotion policy, in Rattanakiri Province, electricity tariff has been kept lower than that in urban areas, except for residential customers in the vicinity of Phnom Penh (≤50 kWh/month) so far. It is expected that the electricity tariff in Ban Lung City will be kept low after 2018.

Table 7: Trend of EDC Electricity Tariff

	2015	2016	2017	2018
Rattanakiri Province (Industrial, commercial and residential customers) (riels/kWh)	670	670	670	670
Vicinity of Phnom Penh				
Industrial and commercial customers who are connected to MV at 22kV (USD/kWh)	0.177	0.172	0.167	0.165
Residential customers (>200kWh/month) (riels/kWh)	820	780	770	750
Residential customers (>50kWh/month) (riels/kWh)	720	720	720	720
Residential customers (≤50kWh/month) (riels/kWh)	610	610	610	610

Source: Prepared based on the information provided by EAC and EDC Rattanakiri Office.

Note 1) Unit is USD/kWh for industrial and commercial customers in the vicinity of Phnom Penh, and riel/kWh for others. (2015-2017: 1 USD = 4,000 riel, 2018: 1 USD = 4,100 riel)

Note 2) Tariff in Rattanakiri Province in 2018 is the one in Ban Lung City. Based on the policy of Cambodian government, since 2018, electricity tariff in Rattanakiri Province was unified to that of Cambodia nationwide, except for Ban Lung City.

(2) Reduction of Greenhouse Gas Emission

Regarding CO_2 emission reduction effect, as mentioned above (Quantitative Effects under Effectiveness), the actual figure in 2018 for O'Chum No.1 power plant is 230 tons, which is 73% of the target, and the actual figure for O'Chum No.2 power plant in the same year is 1,255 tons, which is 82% of the target. The amount of power generated by hydropower from the project becomes an alternative to the amount of power imported from Vietnam. Considering that further import of power derived from thermal power generation, etc. would have been necessary if this project had not been implemented, hydropower of this project, which is clean energy, has contributed to the reduction of CO_2 emission.

3.3.2.2 Other Positive and Negative Impacts

(1) Impacts on the Natural Environment

This project does not fall under a large-scale project in hydropower and dam/reservoir sectors stipulated in the *JICA Guidelines for Confirmation of Environmental and Social Considerations* (promulgated in April 2010), and undesirable effects on environment were judged not to be serious. In addition, the project does not fall in the area of sensitive characteristics and sensitive areas. Therefore, the project was classified as Category B. Preparation of Environmental Impact Assessment and Initial Environmental Impact Assessment report is not required under Cambodian domestic law for this project.

According to EDC, environmental monitoring (water quality, noise, vibration, soil, waste) during the project implementation and after the start of operation has been carried out by visual observation, etc. No negative impacts on natural environment have been reported and no complaints have been pointed out from local residents. In addition, as measures against water pollution that may occur during construction, contractors have appropriately taken mitigation measures such as preventing inflow of excavated soil into river, and thus no particular problem has been pointed out. From the interviews with EDC and local residents, as well as from the results of site survey at the time of ex-post evaluation, no major problem with respect to natural environment has been identified.

(2) Resettlement and Land Acquisition

Land acquisition did not take place because all construction work of the project was carried out within the premises of EDC. With regard to resettlement, two households had illegally built huts for cashew nuts farming within the EDC premises. Appropriate compensation (compensation by reacquisition price) was made by EDC in accordance with Cambodian domestic law as well as JICA Guidelines for Confirmation of Environmental and Social Considerations, and the households left the place without problems.

The two households who left were relatives and ethnic minorities (Krung tribe). Interview with one household was carried out during site visit. As a result, no particular problem was pointed out regarding consultation process with EDC and procedures for compensation. There was no objection from the family about the amount of compensation as well. The head of the household was employed by EDC Rattanakiri Office after completion of the project, generating a new source of income for the family.

From the above, it is considered that there was no particular problem with resettlement.

(3) Other Impacts

Generators and related equipment of the project were manufactured by a small and medium-sized enterprise in Japan. According to EDC, they are excellent products with a modern operation system, easy to operate, and have been running smoothly without any problems since the start of power supply. In fact, generators and related equipment installed by "The Project for the Rural Electrification on Micro-Hydropower in Remote Province of Mondul Kiri," which was implemented with Grant Aid in the past were also manufactured by the same company. It is confirmed that both projects utilize superior products and technologies of a small and medium-sized enterprise in Japan, and the introduction of the latest operation system has enabled the executing agency to operate and maintain the equipment easily. (During the field survey, with a cooperation of EDC Mondul Kiri Office, site visit to that hydropower plant was conducted.)

This project has largely achieved its objectives. Therefore, effectiveness and impacts of the project are high.

3.4 Sustainability (Rating: ③)

3.4.1 Institutional/Organizational Aspect of Operation and Maintenance

The operation and maintenance of the power plants after project completion is undertaken by EDC Rattanakiri Office under the supervision of EDC Head Office (Generation Department). At the time of the ex-post evaluation, the Office had 109 staff, and headed by the Chief of the Office, personnel are assigned to each Division such as Technical, Accounting and Business, and Administration. Technical Division consists of Generation Division in charge of operation and maintenance of power plants, and Transmission and Distribution Division in charge of operation and maintenance of transmission and distribution network. EDC Rattanakiri Office and EDC Head Office are constantly in communication and close collaboration system is in place. In addition, as regards securing budget for operation and maintenance as well as recruitment and placement of staff, EDC Rattanakiri Office makes application to EDC Head Office and then budget allocation and personnel recruitment/placement are carried out after approval from the Head Office (approval from Board of Directors as regards to budget). Furthermore, for procurement of spare parts, EDC Rattanakiri Office makes application to EDC Head Office, and bid procedures are carried out at EDC Head Office.

Figure 2 shows the structure and personnel of Generation Division of O'Chum No. 1 and No. 2 power plants of EDC Rattanakiri Office. Two staff always work at each power plant, and operation and maintenance are carried out with a four-shift system for six hours each (total of 17 staff are deployed). Under this system, periodic measurement of water inflow, reservoir water level and seepage volume are also conducted. Furthermore, inspections of reservoir, areas around the reservoir, intakes, waterways, power plant buildings, etc. have been carried out regularly (monthly and yearly) without any problems and are reported to

EDC Head Office. Considering the scale of the facilities, it can be considered that the number of staff is secured.

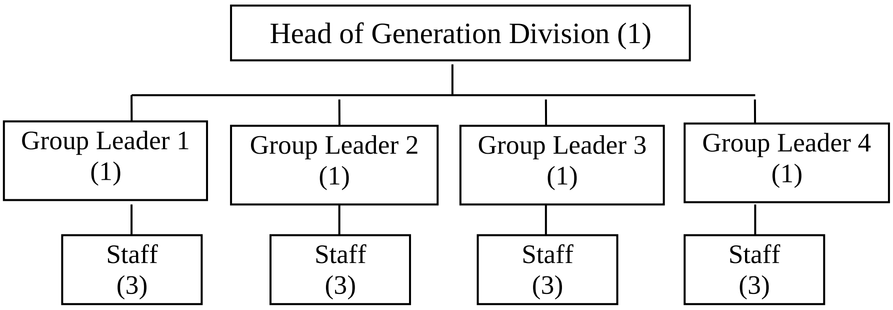


Figure 2: Structure and Personnel of Generation Division of EDC Rattanakiri Office
Source: Prepared based on the information provided by EDC Rattanakiri Office.

Transmission and Distribution Division had 24 staff before project completion (2013), but the number of staff has been increased to 36 at the time of the ex-post evaluation, and the Division is also in charge of maintenance of distribution facilities newly developed by the project. Although there is no dedicated staff in charge of the distribution facilities of the project, appropriate action is taken according to the situation and thus there is no problem.

At the time of planning, O'Chum No.1 power plant was assumed to be remotely controlled from O'Chum No.2 power plant without placing operators, however, at the time of the ex-post evaluation, O'Chum No.1 power plant was manned. According to EDC Rattanakiri Office, remote control of O'Chum No.1 power plant from O'Chum No.2 power plant is institutionally and technically possible, however, since internet connection is unstable, and in the case of unmanned operation, there is a risk such as theft or artificial damage from outsider. Thus, EDC Rattanakiri Office decided to always place two staff to operate and maintain O'Chum No.1 power plant. Based on the situation, this judgement is deemed appropriate.

Therefore, no particular problem has been identified regarding institutional/organizational aspect of operation and maintenance.

3.4.2 Technical Aspect of Operation and Maintenance

All the staff in charge of operation and maintenance have bachelor's degree in engineering (electrical/mechanical, etc.) or are graduates of technical schools, etc. Those who have accumulated sufficient skills and experiences in the operation and maintenance of power generation facilities are deployed. According to interviews with EDC Rattanakiri Office, technical staff have been working for 3 to 15 years.

Training and technical transfer related to operation and maintenance were carried out by the consultant under the capacity building program (soft component) of the project (total of about 2 months from mid to late October 2014, and from early January to early February 2015). In addition, the manufacturer of generator and equipment gave guidance on maintenance of machine (total of about 1.5 months from early to mid November 2014, and from early February to early March 2015). Contents of training and guidance have been shared and utilized in EDC Rattanakiri Office, including newly hired staff. At each power plant, operation and maintenance as well as periodic inspections are conducted in accordance with the manual and maintenance/inspection guideline prepared under the capacity building program (soft component). Manual and maintenance/inspection guideline are prepared in English and Khmer, shared with staff of Generation Division, and used for their daily work.

At EDC, human resource development and management system has been established, and every year one to two staff members of Generation Division attend maintenance training for hydropower plants in Phnom Penh. In the field, on the job training is also conducted to staff, including those newly hired.

Furthermore, staff members of Generation Division measure and record water inflow, reservoir water level, seepage volume, etc. periodically. The record is stored together with power generation record, inspection record, and failure record, which will be utilized for consideration of future large-scale repair.

Considering institutional aspect of EDC Rattanakiri Office and the current good state of operation and maintenance, no particular problem has been identified regarding the technical aspects of operation and maintenance.

3.4.3 Financial Aspect of Operation and Maintenance

The necessary operation and maintenance costs are estimated by EDC Rattanakiri Office, and the budget request will be made to EDC Head Office (Generation Department) where it is scrutinized. Then, after the consultation and approval by the Board of Directors, the budget will be allocated to EDC Rattanakiri Office.

Table 8 shows budget (requested amount by EDC Rattanakiri Office), actual allocation and actual expenditure of operation and maintenance cost of the power plants. In some years, actual allocation and actual expenditure are higher than the request amount by EDC Rattanakiri Office, but all necessary amounts have been covered without problems by diverting expenses within EDC Rattanakiri Office or getting additional allocation from Head Office in the middle of the fiscal year. Therefore, there has not been a financially insufficient situation.

Table 8: Operation and Maintenance Cost of the Power Plants

(Unit: USD)

	2015	2016	2017	2018
Budget (Requested Amount)	188,623	306,313	292,187	323,077
Actual Allocation	200,527	232,048	276,825	267,490
Actual Expenditure	272,400	197,206	312,602	381,393

Source: Results from questionnaire survey of EDC.

Note 1) Operation and maintenance cost includes personnel expenses.

Note 2) Actual allocation in 2015 is more than the budget (requested amount) because necessary remaining expenses immediately after the completion of the project were increased as a result of the close review by EDC Head Office. Actual expenditure is higher than actual allocation because additional expenditures such as logging of trees and cleaning of catchment area around the reservoir occurred. The increased amount was diverted from other Divisions of EDC Rattanakiri Office.

Note 3) Actual expenditure in 2017 is more than actual allocation because additional expenditures such as logging of trees and cleaning of catchment area around the reservoir occurred. The increased amount was diverted from other Divisions of EDC Rattanakiri Office.

Note 4) Actual expenditure in 2018 is higher than actual allocation because EDC Head Office made additional order for spare parts and provided additional budget allocation. Bulk purchase made it possible to save cost in the long run.

Table 9 shows the revenue of the power plants. From a simple comparison with the actual operation and maintenance expenditures in Table 8 above, it can be seen that the electricity sales from the small hydropower of this project exceed the operation and maintenance costs of the project in any year.

Table 9: Revenue of the Power Plants

(Unit: USD)

	2015	2016	2017	2018
O'Chum No. 1 Power Plant	30,059	33,971	83,442	92,084
O'Chum No.2 Power Plant	359,975	298,428	519,153	501,487
Total	390,034	332,398	602,595	593,571

Source: Results from questionnaire survey of EDC.

Note 1) Partial inconsistency of figures exists due to rounding errors

As of September 2018, EDC Rattanakiri Office had 6,311 customers (number of contracts) and maintained a very high tariff collection rate of 99%. Behind this, there are efforts of the Office to improve collection rate. Specifically, following efforts can be highlighted: improving accuracy of monthly electricity usage measurement (meter reading), updating the customer data and financial data daily and managing them properly, extending business hours of the payment counter established in the first floor of EDC Rattanakiri Office (it used to open only in the morning (7:30 to 11:30), but from 2017 the counter also opens from 14:00 to 16:30), and taking prompt action to delinquent payers (warnings are issued to large customers in a timely manner, and for general households, electricity supply is suspended for non-payment over 14 days after the due date).

Financial data of EDC Rattanakiri Office and EDC (Head Office) are shown in Table 10 and 11, respectively.

Table 10: Financial Data of EDC Rattanakiri Office

(Unit: USD)

	2015	2016	2017
Electricity Sales (This Project)	390,034	332,398	602,595
Electricity Sales	4,326,783	4,945,127	6,368,170
Other Operating Revenue	106,274	140,869	177,477
Total Operating Revenue	4,823,091	5,418,395	7,148,243
Power Purchase Cost (from Vietnam)	3,066,422	3,376,452	4,517,758
Personnel	510,291	641,460	876,973
Maintenance	157,343	227,756	454,155
Depreciation	263,261	1,290,705	1,629,261
Import Duty	367,878	422,950	565,807
Other Operating Expenses	394,202	587,193	662,857
Total Operating Expenses	4,759,396	6,546,516	8,706,811
Operating Income	63,695	-1,128,121	-1,558,569
Non-operating Income	10,991	11,443	-3,706
Extraordinary Income	2,550	-10,257	-2,024
Income before Income Tax	77,236	-1,126,935	-1,564,299
Income Tax	49,028	53,890	69,764
Net Income	28,208	-1,180,826	-1,634,063

Source: Results from questionnaire survey of EDC.

Note 1) Partial inconsistency of figures exists due to rounding errors

Table 11: Financial Data of EDC (Head Office)

(Unit: USD)

	2015	2016	2017
Electricity Sales	3,763,629,241	4,186,986,746	4,621,417,322
Connection Service Fees	34,298,112	31,110,473	35,284,199
Other Income	15,722,090	17,836,957	23,115,531
Total Operating Revenue	3,813,649,443	4,235,934,176	4,679,817,052
Purchased Power	2,820,985,078	2,949,421,687	3,314,063,910
Fuel Costs	6,927,267	18,332,808	5,277,383
Salaries and Other Benefits	153,172,713	185,441,109	227,268,471
Depreciation	82,468,483	141,379,081	137,409,477
Amortization	195,512	233,077	379,207
Import Duty	29,065,630	28,005,342	25,500,387
Other Operating Expenses	214,287,293	272,541,286	327,671,791
Total Operating Expenses	3,307,101,976	3,595,354,390	4,037,570,626
Operating Profit	506,547,467	640,579,786	642,246,426
Net Finance Costs	39,682,849	46,293,765	76,392,568
Profit before Income Tax	466,864,618	594,286,021	565,853,858
Income Tax Expense	98,108,272	119,012,184	101,335,662
Net Profit	368,756,346	475,273,837	464,518,196

Source: EDC Annual Report

Note 1) Partial inconsistency of figures exists due to rounding error

Looking at the financial data of EDC Rattanakiri Office, while operating revenue is growing sharply (2016: 12% increase from the previous year, 2017: 32% increase from the previous year), operating expenses are growing at a faster pace than this (2016: 38% increase from the previous year, 2017: 32% increase from the previous year). This is because EDC, which has a public service obligation, has developed grid connections to unprofitable, unelectrified villages based on rural electrification promotion policy of Cambodian government. Thus, EDC Rattanakiri Office has expanded transmission and distribution network to remote areas without electricity in accordance with this policy. As a result, recurrent cost is increasing. Although there is a remarkable increase in electricity sales, as mentioned above, electricity tariff has been kept low compared to urban areas (see Table 7), and EDC Rattanakiri Office's deficit in net profit is expanding due to such policy background. However, since EDC Head Office has supported all these deficits and provided necessary budget allocation, there is no trouble with EDC Rattanakiri Office's work. In fact, in terms of EDC Head Office's financial data, operating revenue is growing steadily, and net profit is also in the black. In other words, there is no problem with financial status of EDC as a whole, and EDC Rattanakiri Office's finance is supported by the profit of EDC Head Office, and the operation and maintenance costs are covered without problems.

Payment Counter for Electricity Tariff
(1st Floor of EDC Rattanakiri Office)

From the above, operation and maintenance cost of the power plants has been appropriately financed and there seems to be no direct effect of EDC Rattanakiri Office's financial situation on this project.

3.4.4 Status of Operation and Maintenance

The power generation facilities constructed by the project has been maintained well and operated smoothly, without major problems or failures since the handover in March 2015 until the time of ex-post evaluation. At the site visit during field survey, operation status of both power plant facilities and situation of water seepage measures for which additional construction was carried out were checked, and it was confirmed that power plants have been operated and maintained without problems.

EDC Rattanakiri Office carries out daily patrols and inspections, and conducts regular maintenance (weekly, monthly, and yearly) based on maintenance and inspection guidelines, which will be utilized for the preparation of future large-scale repair. As mentioned above (Quantitative Effects under Effectiveness), sediments in the reservoir of O'Chum No.2 dam are to be removed by excavators by 2020, and there are prospects for recovery of water volume in the reservoir.

Spare parts are stored at EDC's warehouse and at O'Chum No.2 power plant, and inventory list is updated every year. For procurement of spare parts, EDC Rattanakiri Office makes application to EDC Head Office, and bid procedures will be carried out at EDC Head Office. According to EDC, spare parts that can be procured in Cambodia have so far been procured in a timely manner, as they can be obtained about 12 weeks after ordering.

Although there is no experience yet at the time of the ex-post evaluation, in the future, it will be necessary to order spare parts unique to the generator and related equipment from the

Japanese manufacturer (for example, a speed changer gear to keep the number of revolutions of water turbine constant). EDC Rattanakiri Office needs planned preparation because procurement is expected to take time and cost. As mentioned above, generators and related equipment installed for "The Project for the Rural Electrification on Micro-Hydropower in Remote Province of Mondul Kiri," which was implemented with Grant Aid in the past, were also manufactured by the same company as this project. When EDC Mondul Kiri Office ordered a speed changer gear from the company, an updated version of the product came in. There was no problem because it was usable as it was compatible with the existing product, however, with the advancement of technology, one needs to be careful that compatible spare parts may go out of production.

Therefore, no particular problem has been identified regarding the operation and maintenance status at the time of the ex-post evaluation, but planned procurement preparation is necessary in the future

No major problems have been observed in the institutional / organizational, 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 constructed a small hydropower plant and renewed facilities of an existing small hydropower plant in Rattanakiri Province, which is located at the northeast of Cambodia, with the aim of providing stable power supply in the rural area of the county and diversifying energy sources. The expansion of power supply and promotion of rural electrification through development of hydropower plants of this project, which is clean energy, is consistent with Cambodia's development policy and development needs as well as Japan's assistance policy. Therefore, the relevance of the project is high. In terms of project implementation, the project cost was as planned, and project period was within the plan. Therefore, efficiency of the project is high. Regarding the project effects, as for quantitative effects, maximum output has achieved the target. Although operating rate, gross annual energy output, and reduction of CO_2 emission have not achieved the targets due to the decrease in water volume, improvement of their actual figures is expected in the future looking from the trend of rainfall data. As for qualitative effects, it was confirmed from the interviews with local residents and commercial-scale power users that stable power supply and rural electrification had been realized from the project. Therefore, it can be regarded that the project has largely achieved its objectives. In terms of impacts, the number of factories and major public facilities are increasing in Rattanakiri Province, and interviews with local residents and commercial-scale power users suggest that the project is contributing to the improvement of economic and social development. Furthermore, the project contributes to the expansion of power sources utilizing domestic water resources and the improvement of self-sufficiency rate in power supply. The project also contributes to the reduction of CO_2 emission, considering that further imports of power derived from thermal power generation would have been necessary if this project had not been implemented. Therefore, the project has largely generated its planned effects; thus, its effectiveness and impacts are high. No negative impacts on natural environment and resettlement have been reported. This project utilizes the superior products and technologies of the small and medium-sized enterprise in Japan. As for operation and maintenance, institutional / organizational, technical, financial aspects as well as maintenance situation are in good condition, and the executing agency has been operating the power plants smoothly. Therefore, sustainability of the project effects 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

Importance of planned procurement of one-of-a-kind spare parts that need to be ordered to a Japanese company

In this project, it is necessary to order one-of-a-kind spare parts specific to generators and related equipment to the Japanese manufacturing company. As mentioned in the Lessons Learned below, since procurement is expected to take time and cost, EDC needs planned preparation including budget measures so that spare parts can be procured in a timely manner.

4.2.2 Recommendations to JICA

None.

4.3 Lessons Learned

Importance of eliminating risk factors to ensure sustainability of the project after completion when utilizing superior products and technologies of small and medium size enterprises in Japan

This project assumed the utilization of superior products and technologies of small and medium size enterprises in Japan in the field of hydropower. In fact, the project is equipped with products of the Japanese company with modern operation system, and the power plants have been running smoothly without problems since the start of operation to the time of ex-post evaluation. In the future, it will be necessary to order one-of-a-kind spare parts unique to the generator and related equipment from the Japanese manufacturer. The executing agency needs planned preparation including budget measures since procurement will take time and cost. Given that the spare parts are one-of-a-kind item, there is a danger that compatible spare parts may no longer be in production due to the advancement of technology. Thus, it is important to recognize that utilization of superior products and technologies of Japanese small and medium size enterprises encompasses such risks from the viewpoint of project sustainability. As such, it is important for JICA to confirm beforehand that compatible spare parts are to be secured in a timely manner during project life time at the time of project planning.

Therefore, the executing agency and JICA need to be well prepared for the risk anticipated after project completion to secure one-of-a-kind spare parts manufactured by Japanese small and medium size enterprises.

Importance of the executing agency's autonomous and continuous management efforts in promoting rural electrification (especially clean energy)

This project was implemented as part of Cambodian government's efforts to promote rural electrification. In accordance with the government's policy, EDC, the executing agency having public service obligation, has been promoting grid connection to non-electrified villages, which is unprofitable. As such, when looking at financial status of EDC Rattanakiri Office alone, deficits in net profit is expanding due to increase in recurrent costs. On the other hand, operating revenue of EDC Head Office is growing steadily, and net profit is also in the black. In addition, looking at EDC organization as a whole, financial soundness has been secured. In addition, EDC Rattanakiri Office maintains high collection rate of electricity tariff of 99% with its own efforts, and steady increase of operating revenue has taken place. Therefore, when undertaking unprofitable projects from policy point of view – promotion of rural electrification (especially clean energy) – it is important that the executing agency endeavors to improve financial soundness of the organization as a whole as well as its branch offices to proceed with autonomous management efforts.

Points to keep in mind about when estimating electric power generation of hydropower generation

Since there was no data on water level, inflow volume and outflow volume of O'Chum No.1 dam, power generation plan was prepared using the estimated amount of water inflow to the O'Chum No.1 dam referring to rainfall data in Ban Lung City at the time of project planning (a plan was prepared based on the assumption that the water volume calculated by subtracting the amount of natural evaporation, etc. from rainfall will flow into the dam). However, many targets set at the time of planning have not achieved as a result of significantly reduced rainfall due to

El Niño, etc. after project completion. As a result, targets of quantitative effects might have been a little too high. Originally, when planning a hydropower development, amount of water in the river and its tributary shall be measured at least for 10 years to predict power generation. In fact, for large-scale hydropower plant planning (for projects of several 10-billion-yen budget), grasping the water volume data holds the key to success or failure of the subsequent project – that is, it holds the key to setting targets in line with the plan. However, in case of small hydropower projects such as this project, water volume data often does not exist due to limitation of budget and manpower, etc. due to its small scale, and there is a possibility that same situation may occur. Therefore, when planning small hydropower development projects in the future, it is important to prepare generation plan (estimate power generation) with these points in mind. As a concrete measure, utilization of rainfall data published by JAXA (Japan Aerospace Exploration Agency) can be considered. The use of JAXA's Global Rainfall Watch[19] is expected to improve rainfall forecasting, so it will be useful for the feasibility study of hydropower projects in the future.

End

[19] JAXA's "Global Rainfall Watch" is published at the following URL: https://sharaku.eorc.jaxa.jp/GSMaP/index_j.htm