

MOEJ/GEC JCM Project Planning Study (PS) 2014
Summary of the Final Report

**“Energy Saving at Phnom Penh Water Supply Authority (Cambodia)
 by Improving Efficiency of Water Treatment Plants”**

(Implementing Entity: METAWATER Co., Ltd.)

1. Overview of the Proposed JCM Project

Study partners	Matsuo Consultants Co., Ltd: Joint implementer in charge of review of mechanical technologies and evaluation of environmental integrity Deloitte Touche Tohmatsu LLC: Subcontractor in charge of preparation of the MRV methodology form for greenhouse gas (GHG) reduction Phnom Penh Water Supply Authority: Project implementing body, counterpart and local survey cooperator		
Project site	Phnom Penh Municipality, the Kingdom of Cambodia (Cambodia)		
Category of project	Energy Saving		
Description of project	The Phum Prek Water Treatment Plant (WTP) and the Chamkar Mon WTP of the Phnom Penh Water Supply Authority (PPWSA), Cambodia’s largest water supplier, were constructed in the 1990s. Pump facilities are aging and the specifications of the pumps and the plants’ power receiving and transforming remain as they were at the time the facilities were built. The efficiency of their equipment is low compared with equipment available in Japan. Electricity charges in the Phnom Penh Municipality are as high as US\$0.18/kWh, which is equivalent to those in Japan. There is great demand for a reducing these charges. This project is intended to improve efficiency at these water treatment plants and reduce greenhouse gas emissions by introducing energy-saving equipment from Japan.		
Expected project implementer	Japan	METAWATER Co., Ltd	
Expected project implementer	Host country	PPWSA	
Initial investment	US\$ 1,243,700	Date of groundbreaking	March, 2016 (scheduled)
Annual maintenance cost	US\$ 5,300	Construction period	14 months
Willingness to investment	Under deliberation	Date of project commencement	April, 2017 (scheduled)
Financial plan of project	PPWSA is the first enterprise listed in the Cambodian Securities Exchange. The company’s operating revenue increased from US\$ 7.7 million in 2001 to about US\$ 28.5 million in 2011. Faced with aging facilities, PPWSA has established a renewal plan and has raised funds to replace and upgrade equipment. The economic feasibility and profitability of this study has been indicated, and the initial investment cost can be covered by the capital that has been raised. Equipment maintenance costs are handled as normal operating expenses.		

<p>GHG emission reductions</p>	<p>485 tCO₂/year*</p> <p>① Energy saving achieved by introducing inverter-control system to pumps. : 440 tCO₂/year*²</p> <p>② Reduction of electricity transmission loss between water treatment plants and water intake plants. : 40 tCO₂/ year</p> <p>③ Energy Saving by introducing high efficiency electric transformers. : 5 tCO₂/ year</p> <p>* Rounded half off to the nearest whole number.</p>
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2. Study Contents

(1) Project development and implementation

1) Project planning

Project Implementation System

The international consortium will have METAWATER act as administrative agent and be responsible for delivery of energy-saving equipment and management of electrical engineering. Local contractors will be among the members of the consortium. Candidates to be considered will be local contractors with proven records of high-quality work in construction and mechanical and electrical work. The target implementation system will include Matsuo Consultants Co., Ltd who will provide technology used in the management of pumps and motors, and Deloitte Touche Tohmatsu LLC will assist capacity building of the PPWSA, the project implementing body, in such areas as implementation of MRV. This is the first time a Joint Crediting Mechanism will be applied in a project involving a water utility that is expected to utilize Japanese water-supply technology and know-how. It should be noted here that, currently most water services, including management and maintenance, in Japan are provided by public utility corporations, and private enterprises have not accumulated a great deal of experience in managing water supply businesses. In this context, the Water and Sewer Bureau of Kitakyushu City, which has substantially contributed to the development of Cambodia's water supply enterprises, will participate and provide assistance with the utilization of Japanese water supply technology.

Construction and Operation Schedules

Among the water treatment plants managed by the PPWSA, the Phum Prek Water Treatment Plant (WTP) supplies water mainly to the center of Phnom Penh Municipality. To cope with increasing water demand the plant is promoting a plan to upgrade its distribution pumps, using pumps that will be larger in scale. The PPWSA has already purchased a 520kW and a 272kW pump, to replace a 320kW and a 180kW pump. The motors to be purchased allow introduction of an inverter-control system. This study identified introduction of the inverter-control system as a target for the project because using this system is considered to be a very effective way to reduce GHG emissions.

For the Chamkar MonWTP, a plan is under way to have it specialize in water supply to newly constructed commercial facilities and newly developed areas. Day-and-night water demand is expected to fluctuate greatly when this plan is implemented, and the introduction of an inverter-control system is considered to be an efficient option to deal with this. This study assumes that an inverter-control system will be used for one pump.

Electricity transmission on lines from WTPs is how power is received at both the Phum Prek Water Intake Plant (WIP) and the Chamkar MonWIP. The PPWSA has expressed concern over not only transmission loss, but also disconnection risk. Actually, a disconnection accident occurred in the past in the line from the Phum Prek WTP to the WIP. This study indicates that changing the way electricity is received to direct reception has advantage in that it will reduce transmission loss and greatly reduce the risk of disconnection. Accordingly, this change has been made a target of this project.

The transformer used to transform 3.3kV at the Phum Prek WTP to 380-220V is supplying power to low-voltage power utilities. This transformer has been used since plant operation began in 1995 and is increasingly showing signs of aging. The study indicates that upgrading the transformer to a high-efficiency unit will enable significant improvement of energy efficiency. Accordingly, this change has been made a target of this project. The upgrades and improvements described above require partial or total electric power outage. The PPWSA estimates that a maximum of 2 hours of outage in the nighttime is acceptable, and the work will be done within this time period to minimize adverse effects on plant operations.

Management System and Achievements of the Project Implementing Body

The PPWSA was established in 1954. Its shares were listed on the Cambodian Securities Exchange in April 2012. As of 2014, the PPWSA was capitalized at about US\$21 million, and it had 727 employees. Operating profit has steadily grown, increasing from about US\$2.2 million in 2001 to about US\$9.1 million in 2011, and about US\$12.8 million in 2013.

The PPWSA's board of Directors consists of a total of 7 directors, 1 from the Ministry of Industry and Handicraft (MIH), 1 from the Ministry of Economy and Finance (MEF), 1 from the Phnom Penh Municipality

Council, 1 outside director, one public investor, and 2 from the PPWSA. The Board sets the annual budget and makes investment decisions. It has quarterly meetings, and special meetings are held on an as-needed basis. Included among the executives working under the Board of Directors are 1 Director General and 6 Deputy Director Generals.

Evaluation of Business Profitability

(1) Assumptions used in evaluation of business profitability

1) Project implementation system

It is assumed that the PPWSA has completed facilities as a part of its own water-supply facilities and will continue operations. The possibility of separating this project from the PPWSA's business and establishing an SPC is low. The source of funds for facility maintenance (including investment costs) not covered by the JCM financial program will be determined on the basis of the PPWSA budget. The evaluation assumes that a portion of the earned surplus in the operating budget can be used as a source of investment funds.

2) Project period

The PPWSA is a going business, but the achievements of the project must be evaluated within a certain period of time. The standard lifecycle of energy-saving equipment is around 20 years, during which investment must be recovered, and profit appropriate to the invested capital must be secured.

3) Currency used in evaluation

All of amounts is evaluated on a US\$ basis.

4) Effect of reducing electricity charges

The advantages of reducing electricity charges are evaluated on the basis of the current mean purchase price of US\$0.18/kWh. The comparison is discussed using the reduction of electric power consumption in the proposed JCM reference.

5) Price fluctuation

All of costs including maintenance expenses are based on US dollars because the inflation rate in Cambodia is low and stable for a developing country. The annual average inflation rate for the past 15 years (1998 – 2013) is 4.2%. It remains stable at a maximum of 8%, with the exception of an abnormal 25% in 2008. This can be averaged at 2.8% annually, excluding 2008.

6) Discount Rate

An annual discount rate of 3% is used in the present worth evaluation and was employed during discussions with the PPWSA.

(2) Applicable evaluation indices:

The business profitability evaluation indices to be used to ensure multilateral evaluation are “pay-back period,” “net present worth” and “internal rate of return.”

1) Pay-Back Period method

The pay-back period is an index playing an important role in investment decision-making. In this evaluation, the PPWSA considers 6 years is used as a rough standard offering certainty of investment recovery.

2) Net Present Worth (NPW) method

This is based on Discounted Cash Flow (DCF), which means the setting of the discount rate and the project lifecycle must be rational. In this study, a general standard service life of 20 years is used, while a 10-year plan for early confirmation of the results and a 30-year plan based on the concept of using the quality material for long period were also considered. In the discussion, a plan with a 3% discount rate is used

because there is no specific standard value.

3) Internal rate of return (IRR) method

As in the case of the NPW method, 20-year is used. Investment decisions are made on the basis of comparison with capital cost. Since capital cost is based on the capital policy of the individual enterprise in question, final decisions depend on the PPWSA. The PPWSA's return on net assets, which is approximately 6%, is presented as a reference. When Japanese private enterprises engage in a PPP project overseas, they set forth higher profitability, which includes accounting for business risk. This project involves a public enterprise that essentially does not seek profitability, which indicates that a return on net assets of 6% or less should be sufficient.

(3) Evaluation results

Table 1 shows the results of the evaluation of the contents of the proposals (options) for the Phum Prek WTP and Chamkar Mon WTP (PP WTP and CM WTP in this table). The discount rate is set at 40% of the total initial investment cost. Among the individual options, specifically, the proposed introduction of an inverter-control system for PP WTP (Option 1) and the proposed reduction of transmission loss for CM WTP (Option 5) are evaluated as offering sufficient return effects on investment because the Pay-Back period is around 6 years that is a target value of the PPWSA, the NPW in a project lifecycle of 20 years exceeds the investment amount (with a DCF return 2 times or more greater than the investment), and the IRR for 20 years exceeds 10%. The evaluation also indicates that other options could not independently achieve such a return on investment. When all options are employed, however, the return is evaluated to be sufficient with the Pay-Back period within 6 years, the NPW larger than the initial investment value, and the IRR with nearly 18%, so that efforts is being made to encourage the PPWSA to employ all of options.

Table 1. Business profitability evaluation result

	Initial investment (US\$)	Electricity saving (MWh/year)	After JCM financial program		
			Pay-back period (Year)	NPW for 20 years (US\$)	IRR for 20 years (%/year)
Option 1 (PP WTP) Inverter	560,200	667	2.9	1,374,195	34.1%
Option 2 (PP WTP) Transmission loss	327,900	40	27.3	-89,622	-2.8%
Option 3 (PP WTP) High eff. Transformer	109,300	18	20.2	-17,377	-0.1%
Total(PP WTP)	997,400	725	4.8	1,267,195	20.4%
Option 4 (CM WTP) Inverter	164,400	37	15.2	-2,085	2.8%
Option 5 (CM WTP) Transmission loss	81,900	38	7.2	52,622	12.6%
Total(CM WTP)	246,300	75	11.1	50,537	6.4%
Total	1,243,700	800	5.4	1,317,732	17.9%

Financial Plan for the initial investment/maintenance and MRV

The PPWSA has established a plan and raised funds for upgrades and improvements to cope with ageing equipment. When economic feasibility and profitability of this study are identified, these funds can be used to contribute to the initial investment. After indicating the initial investment for this project, a hearing was conducted with PPWSA officials to obtain their opinions. They said that an initial investment from the PPWSA's own funds

would be considered provided that a JCM financial program is offered to a maximum extent while the scale of the initial investment for the project is maintained. The PPWSA has high expectations of the project not only because of the opportunity it provides to reduce electricity charges, but also because of its potential business profitability and GHG reduction. In order to realize the project, discussions are under way concerning PPWSA budgetary measures, explanation of this project to the Board of Directors, and procurement methods. The PPWSA officials also said that, in this scale of the project maintenance expenses, the equipment maintenance expenses and MRV may be accommodated within the normal budget for operating costs.

Risk Analysis

(1) External environmental factors

General external environmental factors are the PESTEL (Politics, Economy, Society, Technology, Environment, Law) elements. Although their impacts are limited, in this project, the risk of economy, technology, and law is considered as follows:

- ① Among economic risk factors, the one affecting the feasibility of business most is the changes in the value of the country's currency. Cambodia, the target country of this project, has its own currency, the riel, but the Cambodian market is operated on a US\$ base. The currency risk of this project that is subject to business evaluation on a US\$ base is limited to the cost of equipment supplied from Japan.
- ② The technology risk factor is a risk that the project facilities may have to be upgraded with the new technology before completion. In other words, further technology upgrades in the future may make the project facilities outdated halfway through the project cycle. The target Pay-Back period is set at around 6 years so that the investment recovery can at least be completed even if further upgrades are needed halfway into the project.
- ③ Legal risk includes the possibility that the application of Japanese superior environmental technologies targeted by JCM might be contracted to a third-country enterprise as a result of compliance with the procurement requirements of the public enterprise. To cope with this type of risk, discussions will be held with the PPWSA and other Cambodian agencies concerning ordering methods. One is a method of ordering while increasing the necessity of utilizing Japanese products. For this purpose, a cost-related disadvantage can be minimized by means of the effect of weak yen, and the JCM financial program and a performance requirement for procurement can also be set as a tendering requirement. Another method would involve ordering according to a comprehensive evaluation method being established in Japan.

(2) Internal environmental factors

Decision making for investment in the project requires the PPWSA to take certain budgetary steps beforehand. The budgetary year of the PPWSA is the calendar year (January to December). Many adjustments will have to be made to achieve implementation in 2015. Some confusion may result from adjusting the schedule in Cambodia and the JCM procedural schedule in Japan, and this could possibly hinder concluding a contract. This issue may be overcome by taking steps to prevent misunderstanding through closer ties between our study team and the relevant organizations such as Japanese Government, the PPWSA, and other Cambodian agencies.

Other Items related to Business Feasibility

(1) Tax system

① Taxability and operating conditions of permanent establishment (PE)

Except for some ministerial ordinances containing descriptions related to PE, no ministerial ordinance deals with PE in detail. Confirmation could not be made regarding taxes on enterprises equivalent to PE or whether or not PE taxation has occurred in the course of practical operation.

② Tax incentives / Impeditive tax system

Currently, we do not see anything equivalent to a special tax incentive or impeditive tax system. Cambodia has increased its minimum wage and faces requests for various preferential tax measures from foreign enterprises. But no specific measures have been identified yet.

③ Customs / VAT

A hearing was held with the General Department of Customs and Excise (GDCE), but no significant reply could be obtained due to a lack of experience in importing of products utilizing the Joint Crediting Mechanism. Generally, tax benefits can be received by applying for such benefits with an approval letter on tax benefits from the PPWSA to the GDCE.

2) Permits and Licenses for project development and implementation

The urban water supply business in Cambodia is under the jurisdiction of the MIH. The PPWSA engages in the water supply business in the Phnom Penh Municipality under a license from the MIH. No new license has to be acquired. This project is to upgrade part of aged equipment by installing new equipment that will provide higher efficiency. Initially it was thought that an environmental assessment would be needed to obtain a permit and license, but the hearing with the PPWSA confirmed that this was not necessary. Actually, once the project investment details have become clear, normal procedures will be followed after discussions with the MIH Water Supply Department.

3) Advantage of Japanese technology

a) Superiority of Japanese technology

Distribution pumps

Distribution pumps used at water supply facilities works must be manufactured according to use conditions and are required to be superior in performance and to have toughness and durability to endure long-time use. The WTPs in the host country have pumps made in Japan, Europe, the US, China, and Korea. In the case of the Phum Prek WTP and the Chamkar Mon WTP, the target WTPs in the project, most of operating pumps are made by Kubota (a few by Ebara). Operation with these pumps has been successful for more than 10 years. It is believed that their efficiency and durability are favorably evaluated on the basis of these operating results. According to hearings with end users, there are cases in which pumps made in Europe and the US break down in a little more than ten years, and that those made in China break down within a few years. When they are evaluated in terms of lifecycle costs and when consideration is given to their useful life span, although their initial purchase price may be higher, selection of the long-life pumps made in Japan can be considered to offer greater benefit.

Inverters

Japan is actively engaged in developing inverter technology. A major manufacturer succeeded in commercialization of a transistor inverter, the world first, in 1974. Currently, this manufacturer has developed such innovative technologies as zero-speed high torque even without encoder. The manufacturer is leading the world in the field of efficiency and energy saving with high-voltage inverters developed by integrating a series of multiplex high-voltage inverters with low-voltage inverters. This technology has achieved power conversion efficiency as high as 97% and a power factor of 0.95 (at rated load) over a wide rotation range. This inverter is provided with an interface for user support during maintenance and adjustment, which leads to access to high technology for maintenance. When compared with inverters made by Chinese enterprises, the inverters made by Japanese manufacturers are generally superior in durability. Evaluation based on a balance between the performance and price will show the advantages of selecting Japanese inverters.

Transformers

As a part of global warming prevention policies in Japan, the country's Law on the Rational Use of Energy (Energy Saving Law) has made it compulsory to achieve a standard value through a "top-runner method" to improve the transformer efficiency. This standard value is attained by using what is called the "top-runner

transformer.”

In March 2012, a “Second Criteria for Determination” was issued. This was followed by a review of the target standard value and a revision of JIS in 2014. This led to the start of a changeover to the “Top-Runner Transformer 2014” that achieved the “Second Criteria for Determination” in April 2014. Japan’s top-runner reference value is ranked top among leading countries in this field. The introduction of Japanese products contributes to GHG reduction so that its selection brings significant benefits.

b) Current market conditions, competitive products, etc. in host country

Pumps

The study was conducted on the pumps used at 4 WTPs operated by the PPWSA. It was discovered that most of the pumps were made by Kubota (Japan). Some of the others were made by Ebara Corporation (Japan) and Peme Gourdin (Algeria). A hearing with the local suppliers confirmed that pumps made by Tsurumi Manufacturing (Japan) and Grundfos (Denmark) are used in WTPs other than the PPWSA’s described above. Statistical data on market share, etc. could not be confirmed.

Inverters

Inverters are designed to control the speed of pumps to achieve energy saving by reducing pressure loss. They are advantageous because water service tower equipment becomes unnecessary when inverters are used. Most inverters for large pumps in WTPs are made by manufacturers other than pump manufacturers. Among the WTPs operated by the PPWSA, the Niroth and Chroy Changwar WTPs have introduced inverter-control systems. Systems at both WTPs were built with ODA assistance from the Japanese and French Governments, and the inverters were produced by ABB (Switzerland). Almost none of the other Cambodian WTPs have made the switch to inverter-control systems with their pumps.

In the future, demand for inverter-controlled pumps is expected to increase for water supply in the buildings with the recent construction boom in the Phnom Penh Municipality.

Transformers

The transformers installed at 3 WTPs operated by the PPWSA were studied. It was learned that the highest number of transformers were made by ABB (Switzerland), followed by those made by Takaoka Electric Mfg (Japan), Thibidi (Vietnam), Alstom (France), and Minel-Trafo Mladenovac (Yugoslavia). In a hearing conducted with the suppliers, it was learned that transformers made by Tira Thai and Precise (both Thailand) and Thibidi were introduced in most cases because they are inexpensive. It was not confirmed whether or not there is any statistical data on market shares of transformer manufacturers.

In Cambodia, introducing extra-high voltage transformers connected to the grid requires the approval of EDC (Electricité du Cambodge). The EDC’s transformer procurement specification designates transformers made by ABB, Schneider Electric (France), GE (US), and Thibidi. A hearing with EDC confirmed that ABB-made transformer has been introduced most among the EDC-approved transformers.

4) MRV structure

The study on MRV structure was performed for the project target WTPs operated by the PPWSA: the Phum Prek WTP and the Chamkar Mon WTP. At present, the person in charge of monitoring is undertaking measurement and recording of electric power consumption, current values, distribution pump flow rates and transformers, which are necessary to calculate GHG emission reductions. Both the measurements and the calculation results are checked and approved by both the monitoring manager and JCM Project General

Manager (see figure below). When this project is implemented, a part of monitoring items necessary for calculation of GHG emission reduction and the calculation of GHG emission reduction will be added to the existing monitoring work. It was confirmed that the existing structure may be applied as it is for implementation of the project.

The CO₂ emission factor of a grid is necessary for the calculation of GHG emission reductions. The factor released by the Ministry of Environment (MOE) of Cambodia for the Phnom Penh area is used. The latest version, which was released in 2010, is scheduled to be updated in early 2015. The factor is updated every 3 or 4 years, and the person in charge of monitoring must collect the latest data as required.

As for the present state of recording and storage of collected data, the person in charge on site writes it by hand and stores it in a paper-based control table. Some of the data is entered in a PC for electronization. This is confirmed by superiors. There are problems with, this procedure, however. For example, the data in the control table is written in the Khmer language and could not be checked by the study team, who does not understand the Khmer. Essential portions will be translated into English when the project is implemented.

The MRV structure is shown in Figure 1 below.

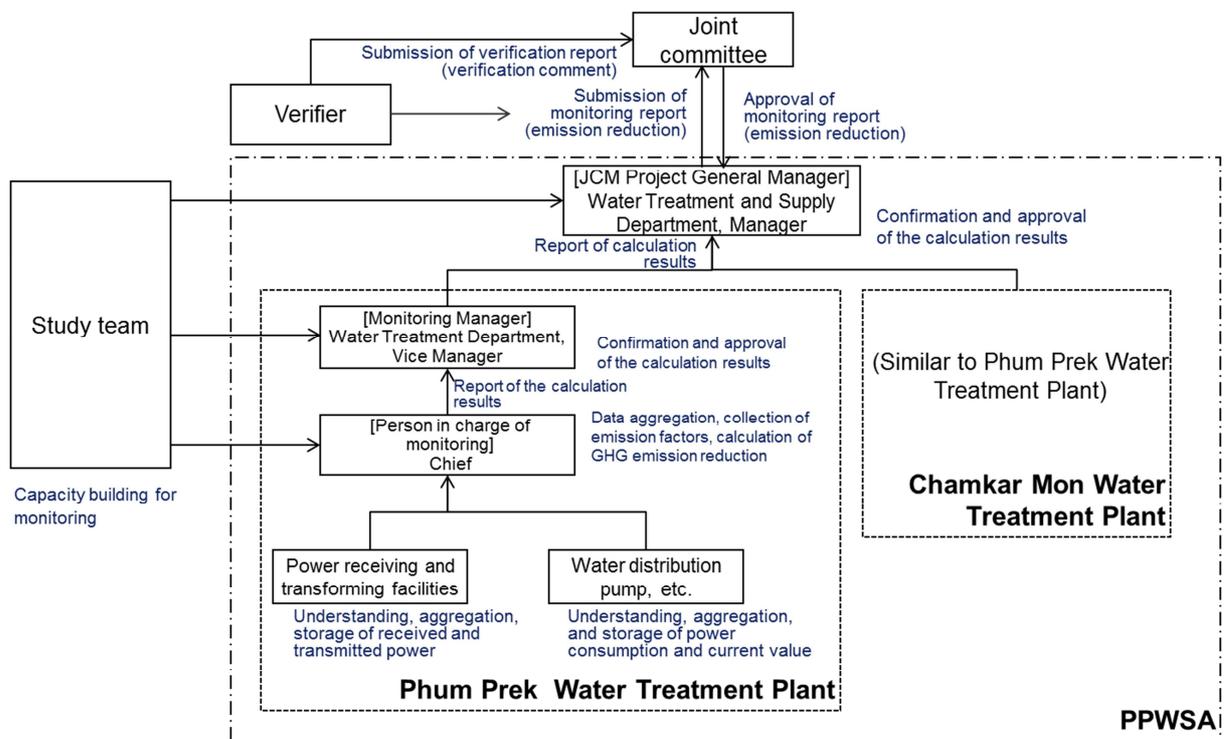


Figure 1. The MRV Implementation System

5) Environmental integrity and Sustainable development in host country

This project, whose implementing body is the PPWSA, is intended to save electricity by improving efficiency in the operation of water supply equipment at the Phum Prek WTP and the Chamkar Mon WTP in the Phnom Penh Municipality of Cambodia. This will result in reductions of GHG emissions. The targeted water-supply equipment is mainly the electricity receiving equipment and pumps. Most of them, particularly those planned and built in the 1990s, are aging. Upgrading the equipment will result in improvement of the performance.

Principal environment-related laws and regulations of Cambodia include the Law on Environmental Protection and Natural Resources Management promulgated in 1996. Other more specific laws include the Sub-Decree on Management of Solid Waste (1999), Sub-Decree on the Water Pollution Control (1999), and

Sub-Decree on the Control of Air Pollution and Noise Disturbance (2000). For evaluation of environmental impact, the Sub-Decree on the Implementation of the Environmental Impact Assessment Process was enforced in 1999, which specifies the type, contents, and scale of projects requiring an environmental impact evaluation. As it pertains to the water supply business, this ordinance covers water-supply development projects for 10,000 persons or more per day.

This project is intended to achieve energy saving and GHG emission reduction through upgrading and improvement of the equipment in the current PPWSA water supply business. It is not a project requiring a study of the environmental impact. Therefore, there is no need to obtain a license or permission for an environmental impact evaluation in the course of project implementation. A local hearing confirmed that implementation of a new environmental-impact study was not necessary.

This project will demonstrate positive benefits in terms of the environment, such as GHG emission reduction. The measures to secure favorable environmental effects and to avoid adverse effects during implementation of this project are as follows:

Securing favorable effects

This project will contribute to the promotion of Cambodia’s basic policies on water supply and health announced by the Government in 2003: “To ensure that all citizens are able to receive safe water, to have sanitary facilities, and to enjoy a safe and healthy living environment well adapted to the natural environment.” Energy saving will also contribute to reducing city water production costs, which in turn will help improve civil life by supplying city water at a lower cost.

Avoiding adverse effects

This project will involve upgrading equipment at WIPs and WTPs. Since the major part of the work will be done on the sites of the WIPs and WTPs, negative effects accompanying the work, such as noise and vibration, will be restricted to the plant areas. It is also possible to minimize waste generation in the form of old pieces of equipment being replaced by taking such measures as storing and utilizing them through refurbishing as reserve equipment. When their disposal becomes necessary, they should be disposed of as industrial waste under control of the Department of Public Works and Transport (DPWT).

6) Toward project realization (planned schedule and possible obstacles to be overcome)

(2) JCM methodology development

In this study, the JCM methodology was reviewed in terms of 3 energy-saving approaches as outlined below.

A	Energy Saving by Introducing Inverter-control Systems to Pumps	Controlling motor speeds by adding inverters
B	Reduction of Electricity Transmission Loss between WTPs and WIPs	Changing power reception system at WIPs to direct reception from the grid
C	Energy Saving by Introducing High-Efficiency Electric Transformers	Upgrading transformers to high-efficiency type

1) Eligibility criteria

A. Energy saving by introducing inverter-control systems to pumps

It is assumed that the methodology related to energy-saving through introducing inverter-control systems to pumps, as developed in this study, is applied to the project that meet all of criteria below.

Criterion 1	A project which introduces an inverter-control system to pumps without an inverter-control system.
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Criterion 2	The capacity of project pump motors is more than 100 kW.
Criterion 3	The rated electricity conversion efficiency is more than 97% and rated power factor is more than 95% of a high-voltage inverter.
Criterion 4	Periodical check is planned to perform more than 2 times annually.

Reason for Criterion 1:

This criterion was set by taking into account the following situation. Substantial energy-saving is expected from introducing the inverter-control systems to pumps without the system, thereby controlling the motor speed depending on the supply flow. On the other hand, if pumps already have an inverter-control system, replacing such system with a new one can achieve limited energy savings.

Reason for Criterion 2:

Pump performance characteristics vary depending on the capacity of the pump and its motor (pump's source of motive power). Generally, efficiency increases with equipment size. The numerical value was set by selecting the project pump on the basis of a study on the pump capacity at the 4 WTPs operated by the PPWSA.

Reason for Criterion 3:

Japan is in a leading position in technological development of inverters. This numerical value was set for the purpose of enhancing the GHG emission reduction effect by introducing higher-efficiency Japan-made equipment. Currently, there is no standard to prescribe how to calculate the efficiency and power factor.

Reason for Criterion 4:

Regular inspections are essential to sustain GHG emission reduction effects through the introduction of inverter-control systems to pumps. This numerical value was set after confirming the frequency of regular inspections with the inverter manufacturer.

B. Reduction of electricity transmission loss between WTPs and WIPs

It is assumed that the methodology related to reducing electricity transmission loss between WTPs and WIPs, as developed in this study, is applied to the project that meets all of the criteria outlined below.

Criterion 1	A project which changes the electricity receiving system which transmits electricity from water treatment plants to water intake plants via private transmission cables to individual electricity receiving system.
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Reason for Criterion 1:

This methodology is applicable to WIPs that receive electricity from WTPs via an independent transmission system provided between these plants. This type of transmission system has been employed because, in case of power failure, it is necessary to transmit to WIP the electricity generated by a captive power generator provided in the WTP. However, in recent years, the frequency of operating the captive power generator (mainly a diesel generator) has decreased because the frequency of power failure has decreased due to stabilization of the grid and a steep rise in fuel costs. In other words, the necessity of the existing transmission system is decreasing.

This project is designed to reduce GHG emissions by reducing transmission loss by changing the power

reception method to direct reception from the grid. Therefore, the criterion of this methodology was described as “a project which changes the electricity receiving system to individual electricity receiving system.”

C. Energy saving by introducing high-efficiency transformers

It is assumed that the methodology related to the introduction of high-efficiency transformers, as developed in this study, is applied to the project. It meets all of the criteria indicated below.

Criterion 1	Capacity of project transformers is between 500kVA and 1,000kVA.
Criterion 2	The rated efficiency of project transformers is at least 98.5%.

Reason for Criterion 1:

Generally, transformer efficiency is higher when the equipment is larger. The transformers covered by this project were selected and the numerical values were set with reference to the transformers the PPWSA has for its WTPs.

Reason for Criterion 2:

A study was made of the transformers at 3 WTPs operated by the PPWSA and the transformer efficiency of manufacturers as recommended by the electric power company, EDC, of Cambodia. A relationship was established between transformer capacity and efficiency. Then, the reference efficiency was determined within the range of transformer capacity to be upgraded in this project. The transformers to be connected to the Cambodia grid must be those made by manufacturers recommended by EDC, and they must comply with the specifications designated by EDC.

After studying the Japan-made transformers planned to be introduced in this project, numerical values superior to the reference efficiency was set. Thanks to the transformer top-runner system, the efficiency of Japan-made transformers is at the world’s highest level. This numerical value was set to further increase GHG emission reductions through the introduction of transformers made by Japanese companies. The methodology to calculate the efficiency is prescribed in JIS C 4306.

2) Calculation of GHG emissions (including reference and project emissions)

A. Energy saving by introducing inverter-control system to pumps

In this methodology, the difference between the reference and project emissions is assumed to be the GHG emission reduction achieved by implementing this project. It is calculated as follows:

$ER_p = RE_p - PE_p$ <p>ER_p: Emission reduction [tCO₂/p] RE_p: Reference emissions during a given period p [tCO₂/p] PE_p: Project emissions during a given period p [tCO₂/p]</p>

In Cambodia, inverter-control systems have been introduced to only a few pumps in the WTPs operated by the PPWSA. Since these pumps were installed with Japanese and French ODA, the BAU scenario in Cambodia in which pumps without the inverter control system is appropriate.

The reference emission is calculated as the product of the electricity consumption of project pump

multiplied by the proportion of electricity consumption of the reference pump relative to that of project pump and the emission factor of electricity consumed by the pump.

To calculate the reference emission, the reference pump was set as one whose electricity consumption is more conservative than the case of using the pump without an inverter-control system in the BAU scenario. Specifically, the pumps of 4 PPWSA WTPs were studied and the $P_{REF,LF,p}$ of the following equation comes on the conservative side relative to BAU. The PPWSA is an agency with the most efficient WTPs in Cambodia, so that they are considered adequate as the reference target.

$$RE_p = \{EC_{PJ,p} * (P_{REF,LF,p} / P_{PJ,LF,p})\} * EF_{grid}$$

RE_p : Reference emissions during a given period p [tCO₂/p]

$EC_{PJ,p}$: Amount of electricity consumed by project pumps during a given period p [MWh/p]

LF : Operation load factor (flow rate) of project pumps [-]

$P_{REF,LF,p}$: Electricity consumption ratio of reference pumps at LF [-]

$P_{PJ,LF,p}$: Electricity consumption ratio of project pumps at LF [-]

EF_{grid} : CO₂ emission factor of a grid [tCO₂/MWh]

The project emission is calculated as the product of the electricity consumption of project pump multiplied by the emission factor electricity consumed by the pump.

$$PE_p = EC_{PJ,p} * EF_{grid}$$

PE_p : Project emissions during a given period p [tCO₂/p]

$EC_{PJ,p}$: Amount of electricity consumed by project pumps during a given period p [MWh/p]

B. Reduction of electricity transmission loss between WTPs and WIPs

In this methodology, the difference between reference and project emissions is assumed to be the GHG emission reduction achieved by implementing this project. It is calculated as follows:

$$ER_p = RE_p - PE_p$$

ER_p : Emission reduction [tCO₂/p]

RE_p : Reference emissions during a given period p [tCO₂/p]

PE_p : Project emissions during a given period p [tCO₂/p]

A hearing with the responsible persons at WTPs in Cambodia and confirmation of the drawings showed that there was no case of reducing transmission loss by changing to an individual electricity reception method as dealt with in this methodology. Accordingly, the adequate scenario to be used as the BAU scenario in Cambodia is to continue the use of the existing transmission system with an independent line to WIPs.

The reference emission is calculated as the product of the power loss at the transformer and transmission line, which are part of equipment put out of use because of change of the existing reference electricity receiving system to the project system of an individual receiving type, multiplied by the grid emission

factor. Note that this methodology sets, as a reference, systems unique to the Phum Prek WTP and the Chamkar Mon WTP.

[PP WTP]

$$RE_p = (EL_{REF,1,p} + EL_{REF,2,p}) * EF_{grid}$$

[CC WTP]

$$RE_p = (EL_{REF,3,p} + EL_{REF,4,p} + EL_{REF,5,p}) * EF_{grid}$$

RE_p : Reference emissions during a given period p [tCO₂/p]

$EL_{REF,1,p}$, $EL_{REF,2,p}$, $EL_{REF,3,p}$, $EL_{REF,4,p}$, $EL_{REF,5,p}$:

Amount of electricity transmission loss of parts of reference electricity receiving system during a given period p [MWh/p]

EF_{grid} : CO₂ emission factor of a grid [tCO₂/MWh]

In this methodology, the project emission is set to zero so that the GHG emission reduction due to project implementation is calculated from the transmission loss at a part of the reference electricity receiving system that is put out of use after the project.

$$PE_p = EL_{PJ,p} * EF_{grid}$$

PE_p : Project emissions during a given period p [tCO₂/p]

$EL_{PJ,p}$: 0 MWh/p

EF_{grid} : CO₂ emission factor of a grid [tCO₂/MWh]

C. Energy saving by introducing high-efficiency transformers

In this methodology, the difference between reference and project emissions is assumed to be the GHG emission reduction achieved by implementing this project. It is calculated as follows:

$$ER_p = RE_p - PE_p$$

ER_p : Emission reduction [tCO₂/p]

RE_p : Reference emissions during a given period p [tCO₂/p]

PE_p : Project emissions during a given period p [tCO₂/p]

As the transformers are not replaced very often in Cambodia as in the case of Japan, the adequate BAU scenario to be employed is one in which the existing transformer continues to be used during the equipment upgrade process. A transformer which has one of the largest market shares is introduced in the case of a new introduction project. The reference emission is kept conservative by assuming the introduction of a transformer with efficiency higher than BAU. The reference emission is calculated as follows:

$$RE_p = \{ET_{PJ,2,p} * (1/\eta_{REF} - 1)\} * EF_{grid}$$

RE_p : Reference emissions during a given period p [tCO₂/p]

$ET_{PJ,2,p}$: Amount of transformed electricity at the secondary side of project transformers

during a given period p [MWh/p]

η_{REF} : Electricity transformation efficiency of reference transformers [-]

EF_{grid} : CO₂ emission factor of a grid [tCO₂/MWh]

The project emission is calculated as the product of the transformation loss with the introduced project transformer multiplied by the emission factor of electricity to be transformed. The transformation loss of project transformer is calculated as a difference of electric energy between primary and secondary sides.

$$PE_p = (ET_{PJ,1,p} - ET_{PJ,2,p}) * EF_{grid}$$

PE_p : Project emissions during a given period p [tCO₂/p]

$ET_{PJ,1,p}$: Amount of transformed electricity at the primary side of project transformers during a given period p [MWh/p]

$ET_{PJ,2,p}$: Amount of transformed electricity at the secondary side of project transformers during a given period p [MWh/p]

3) Data and parameters fixed *ex ante*

A. Energy saving by introducing inverter-control system to pumps

In this methodology, either preset or default values are used for the following:

1. Performance curve of reference pump
2. Performance curve of project pump
3. Rated electricity consumption of project pumps per hour
4. CO₂ emission factor of a grid

1. After reviewing the test data of six types of pumps introduced at 4 PPWSA WTPs the performance curve of the reference pump was set in such a manner as to ensure that GHG emission is kept on the conservative side.

2. Manufacturers' test data will be used for the performance of project pump.

3. Manufacturers' designated value will be used for the rated electricity consumption of project pumps per hour.

4. For the grid emission factor, the factor at the Phnom Penh grid is made public by the Climate Change Department, the MOE, and renewed every few years. (At the time this report was submitted, the 2010 edition was the latest one.) The numerical value of this factor is determined by calculating the weighted average of the output (made public by EDC in its annual report for each type of power structure (heavy oil, gas oil, hydraulic power, woody biomass, coal, import) of the grid located in Cambodia) and the electricity emission factor by fuel in OECD countries as made public by the International Energy Agency (IEA).

B. Reduction of transmission loss between WTP and WIP

In this methodology, either preset or default values are used for the following:

1. Transmission loss at the transformers and transmission lines provided in the reference electricity receiving system between WTPs and WIPs that are put out of use due to implementation of the

project

2. CO₂ emission factor of a grid

1. In regard to the transmission loss at the transformers and transmission lines put out of use due to implementation of the project, the Phum Prek WTP and the Chamkar Mon WTP covered by the project were checked to identify such transformer and transmission lines and the transmission loss determined for them was set as default. Specifically, the measured values at the Phum Prek WTP were used as a basis to determine the transmission loss at the Phum Prek WTP. Similarly, the measured values at the Phum Prek WTP were used to estimate the transmission loss at Chamkar Mon WTP. The transmission loss of transformers at the Chamker Mon WTP was estimated based on monitored data of the existing transformer at Phum Prek WTP.

2. The CO₂ emission factor of a grid is the same as in Methodology A.

C. Energy saving by introducing high-efficiency transformers

In this methodology, either preset or default values are used for the following:

1. Transformation efficiency of reference transformer

2. CO₂ emission factor of a grid

1. The transformation efficiency of the reference transformer was determined in such a manner that the GHG emission reduction could be kept on the conservative side of the BAU scenario. For this purpose, a study was made of the transformers introduced at 3 PPWSA WTPs and the transformer efficiency information provided by manufacturers recommended by EDC.

2. The CO₂ emission factor of a grid is the same as in Methodology A.

(3) Development of JCM Project Design Document (PDD)

1) Environmental impact assessment

The PPWSA is undertaking planned upgrading of equipment by maintenance so as to ensure a stable water supply.

This project can be categorized as a normal equipment upgrading project when viewed in terms of its scale. In the hearing with PPWSA responsible persons, it was confirmed that no environmental impact assessment had been performed in line with the work and that no guidance had been provided by the competent authorities.

It is concluded that this project does not require an environmental impact assessment because it is intended to save energy and reduce GHG emissions by upgrading and improving equipment in the PPWSA's water supply business.

Though the negative effects due to the work are restricted, planned management should be conducted with care and any generated wastes must be minimized, including reuse and recycling.

2) Local stakeholder consultation

The activities to be undertaken in this project are replacement of existing equipment or installation of new equipment within the sites of the PPWSA plants. There appears to be no legal regulations demanding explanation or exchange of opinions to/with the surrounding residents.

For this project, a committee meeting was held in October and December 2014, in which project members

provided an outline of the project and explanations on the progress and results of the study. The MOE, the MIH, and the PPWSA expressed their expectations of the GHG emission reduction project and raised questions on how Cambodia would benefit from it. They also asked for explanations of reference concepts related to the MRV methodology. An active exchange of opinions focusing on these issues took place. Some of the comments presented are shown below. It is evident that Cambodia has great expectations for GHG reduction.

Stakeholders	Relationship	Comments received
Ministry of Environment, Cambodia (MOE)	Government agencies with jurisdiction over environmental policies	We understand that successful completion of JCM projects could lead to lower electricity consumption and related costs, and reduced CO ₂ emissions. From the viewpoint of reducing CO ₂ , it is expected that the PPWSA will participate in this project.
Ministry of Industry and Handicraft, Cambodia (MIH)	Government agencies with jurisdiction over water supply projects	It is understood that this project offers return effect on investment and also GHG emission reduction effects. As GHG emission reduction is in line with the policy of Cambodia, we would like to support the realization of the project.
Phnom Penh Water Supply Authority (PPWSA)	Counterpart	The fact that this will lead to lower electricity charges and reduced GHG emissions is extremely important. We appreciate the efforts to reduce GHG emissions in Cambodia. The contents of the proposal are promising from the viewpoint of project profitability.

3) Monitoring plan

In this project, the monitoring items proposed for the WTPs are as follows:

A. Energy saving by introducing inverter-control systems for pumps

1. Amount of electricity consumed by project pumps or the electric current of those pumps.
(at the primary side of inverter)

B. Reduction of transmission loss between WTPs and WIPs

None

C. Energy savings achieved by introducing high-efficiency transformers

1. Amount of transformed electricity at the primary side of electric transformers.
(Measured at the nearest circuit breaker to the primary side)
2. Amount of transformed electricity at the secondary side of electric transformers.
(Measured at the nearest circuit breaker to the secondary side)

At present, in WTPs current values, discharge pressure, and discharge flow rates are measured every hour and entered manually in a log book. This is a daily check related to the pumps. On the other hand, measurement is made daily on the primary side of extra-high voltage transformers (power received from the grid). However, no measurement is made on the secondary side. Also, only some of the data thus obtained are converted to electronic form. Confirmation was made with the PPWSA that, during implementation of the project, additional measuring equipment related to monitoring items needed to calculate GHG emission reductions should be installed, and that, after development of the rules and procedures, all of the monitoring items should be converted to electronic form.

Once these monitoring items are prepared, GHG emission reductions can be calculated according to the approved methodology. A system allowing automatic calculation by entering monitoring items in a spreadsheet will be established after implementation of the project. Lectures on the GHG emission reduction calculation method were provided to the PPWSA in the course of a second and third field study.

4) Calibration of measuring instruments

A hearing with the PPWSA was held to determine whether or not calibration exists for the measuring equipment needed for all monitoring items. It was found out no calibration has been performed at all and its necessity has not been recognized. Besides, legal regulations stipulating calibration of measuring equipment could not be confirmed. EDC is said to undertake calibration of the equipment used to measure the power received on the primary-side of extra-high voltage transformers connected to the grid, which is in the possession of the EDC. It should be noted that the accuracy of EDC's measuring equipment complies with the IEC (International Electro-technical Commission) standards.