Indonesia

FY2021 Ex-Post Evaluation Report of Technical Cooperation Project

"Pilot Study for Carbon Sequestration and Monitoring in Gundih Area, Central Java Province, Indonesia"

External Evaluator: Keishi Miyazaki, OPMAC Corporation

0. Summary

The purpose of this project was to promote Carbon Dioxide Capture and Storage (CCS) programs in the Gundih gas field in Central Java, Indonesia, by conducting research on CO_2 storage evaluation technology, and CO_2 sequestration and monitoring technology, which is necessary for CCS technology application. This project was highly relevant to Indonesia's development plan and development needs, as well as to Japan's ODA policy. Therefore, its relevance is high. Three of the five outputs were achieved or nearly achieved and two were partially achieved. Since the overall goal has been achieved and six initiatives for social implementation have been implemented or were being implemented at the time of the ex-post evaluation, it is judged that the overall goal has been achieved. The project has contributed to improvement of the research capacity of the implementing agencies in Indonesia, and there were no problems in the utilization and maintenance of the equipment. No negative impact on the natural environment, land acquisition, or resettlement was observed. Therefore, the effectiveness and impact of the project is high, as the project has been effective as planned. Both the project cost and project period were within the plan, and the efficiency of the project is high. No major problems have been observed in the policy background and the institutional/organizational, technical, financial aspects. Therefore, the sustainability of the project effects is high.

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

1. Project Description

Project Location

A well planned for CO_2 injection in the Gundih gas field

1.1 Background

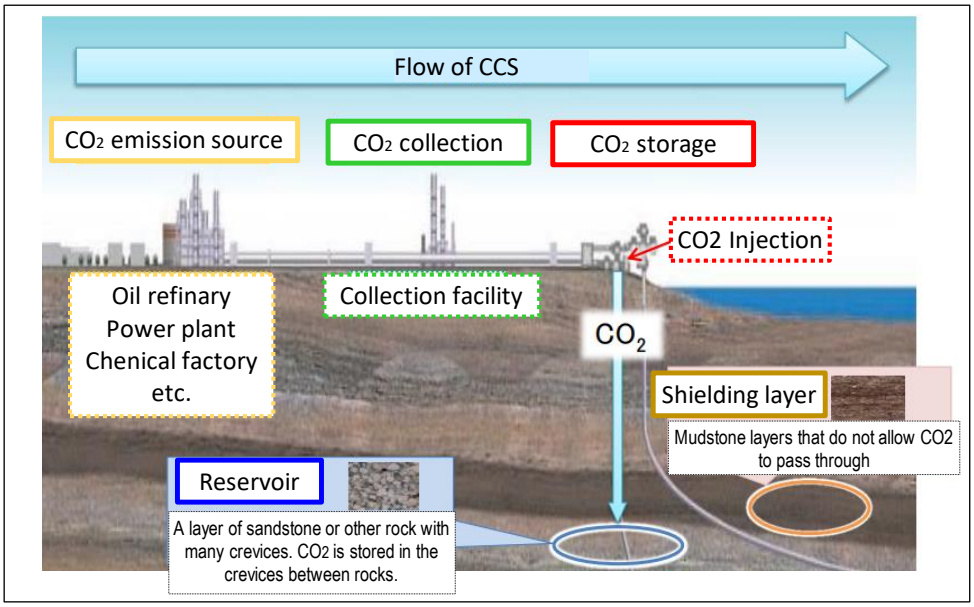
Indonesia was the world's third largest greenhouse gas emitter after China and the United States when CO_2 emissions from peatlands were included (3,143 million CO_2 equivalent tons, according to a report by Wetlands International), and there were concerns about the increase in greenhouse gas emissions associated with increased energy demand due to economic growth. In light of this, the second Yudhoyono administration, inaugurated in October 2009, positioned climate change measures as a key policy issue, setting a voluntary target of reducing greenhouse gas emissions by 26% compared to business as usual (BAU) by 2020, and establishing the *"Indonesia Climate Change Sectorial Roadmap"* (March 2010), a sectoral roadmap for adaptation and mitigation measures over a 20-year period from 2010 to 2029. The roadmap pointed out the possibility of CCS as one of the measures to reduce greenhouse gas emissions from coal-fired thermal power plants. However, research and studies on CCS had only just begun in Indonesia. In Japan, on the other hand, research and technological development related to CCS had been conducted since around 2000, and a certain level of technological development had been achieved through demonstration studies, particularly with regard to the development of technology for monitoring geologically sequestrated CO_2 behavior. Against this background, the Indonesian government requested that Japan conduct joint research for the development of CCS technology in Indonesia.

1.2 Project Outline

Overall Goal		Carbon Capture and Storage (CCS) programs in Indonesia are promoted for accelerating oil and gas development and production with zero CO_2 emission.
Project Purpose		Standard Operating Procedure (SOP) for CO_2 storage evaluation technology, CO_2 sequestration and monitoring technology, which is necessary for CCS technology application, is proposed for promoting CCS programs in onshore gas fields in Indonesia.
Outputs	Output 1	Detailed action plan of the project including implementation structure is completed for CO_2 sequestration and monitoring in the Gundih gas field.
	Output 2	Characterization/evaluation of CO_2 sequestration sites(s) and CO_2 storage are completed to proceed the activities under Outputs 3 and surface facility simulations.
	Output 3	Feasibility study including surface facility design and cost evaluation is completed for CO_2 sequestration and monitoring in the Gundih gas field.
	Output 4	Geophysical and geochemical technologies which can be

		applied for CO_2 sequestration and monitoring are evaluated in the actual storage to determine integrated technologies for storage evaluation and CO_2 monitoring.
	Output 5	SOP is prepared based on the analysis and the evaluation of the Gundih gas field CO_2 sequestration and monitoring.
Total cost (Japanese Side)		370 million yen
Period of Cooperation		September 2012-September 2017
Target Area		Bandung and Gundih gas field, Central Java Province
Implementing Agency		Bandung Institute of Technology (Institute Teknologi Bandung: ITB)
Other Relevant Agencies/ Organizations		Pertamina
Consultant/ Organization in Japan		Kyoto University, Waseda University, Kyushu University, Fukada Geological Institute
Related Projects		None

The main focus of the joint research in this project was the development and application of methods for selecting optimal CO_2 reservoirs based on geological and geophysical knowledge and monitoring the behavior of the geologically sequestrated CO2. At the same time, research on related CO_2 separation, capture, and injection methods, regulations, risk analysis, and social acceptability were also included. The CO_2 separation and recovery method was applied to a portion of the CO_2 released into the atmosphere as an associated gas during natural gas production at the Gundih gas field in Central Java, owned by the state-owned oil company Pertamina. The CO_2 was to be further liquefied and transported to a well owned by Pertamina, approximately 40 km from the gas field, for injection over a period of two years. Ultimately, the project aimed to develop and disseminate the SOP as a technical guide for geologically sequestrated CO_2 projects based on the results of the above study. On the other hand, it was planned that the drilling of the CO_2 injection well would be handled separately by the Indonesian side, since it was assumed that the cost may be as much as 1.5 billion yen which would be difficult for the project to handle.



Source: Ministry of Economy, Trade and Industry (METI).

Table 1　Flow of CCS (Image)

1.3 Outline of the Terminal Evaluation

1.3.1 Achievement Status of Project Purpose at the Terminal Evaluation

The project purpose was partially expected to be met.

Due to gas leakage found in the borehole where CO_2 injection was planned, monitoring of CO_2 behavior could not be conducted in the reservoir, and the CO_2 behavior could not be evaluated before the project was completed. Therefore, although preparation took place of a "Standard Operating Procedure (SOP) for Safe and Effective CO_2 Sequestration Technology in On-shore Areas," which summarized the results of the joint research, it was partially incomplete in terms of content. On the other hand, through the cooperation of Japanese and Indonesian researchers, advanced technology and methods were utilized to conduct baseline surveys, such as Time-Domain Electromagnetic (TDEM) and high-resolution seismic surveys, before CO_2 injection, and through the joint research, technology for CO_2 sequestration and monitoring in Indonesia were developed.

1.3.2 Achievement Status of Overall Goal at the Terminal Evaluation (Including Other Impacts)

The terminal evaluation did not make a determination on the level of achievement of the overall goal.

1.3.3 Recommendations from the Terminal Evaluation

The following items are recommendations from the terminal evaluation.

(1) Continuous coordination with main stakeholders in Indonesia, JICA, and the

Asian Development Bank (ADB)

(2) Public relations of CCS

(3) Utilization of equipment

(4) Establishment of a legal framework to encourage CCS

(5) Analysis of the contribution of CCS to the achievement of Nationally Determined Contributions (NDCs) of greenhouse gases

2. Outline of the Evaluation Study

2.1 External Evaluator

Keishi Miyazaki, OPMAC Corporation

2.2 Duration of Evaluation Study

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

Duration of the Study: July 2021 – January 2023

2.3 Constraints during the Evaluation Study

Due to the widespread of COVID-19, the planned field survey was cancelled and replaced by a remote survey with an Indonesian field survey assistant. Therefore, in addition to the questionnaire, online interviews were conducted in response to this situation.

This project is a Science and Technology Research Partnership for Sustainable Development (SATREPS[1]), and ex-post evaluation of SATREPS projects are usually conducted as an internal evaluation. JICA's Evaluation Department decided to conduct this project as an external ex-post evaluation, judging that valuable lessons could be learned from the evaluation survey process, such as interviews with domestic stakeholders. However, due to the timing of the introduction of the new evaluation criteria, this ex-post evaluation was conducted based on the old evaluation criteria (5 evaluation items).

3. Results of the Evaluation (Overall Rating: A[2])

3.1 Relevance (Rating: ③[3])

3.1.1 Consistency with the Development Plan of Indonesia

[1] SATREPS are implemented by the Japan Science and Technology Agency (JST), the Japan Agency for Medical Research and Development (AMED) and JICA, with support from the Ministry of Foreign Affairs and the Ministry of Education, Culture, Sports, Science and Technology, to promote science and technology cooperation and science and technology diplomacy with developing countries through collaboration with Japan's excellent science and technology and ODA. The aim of SATREPS is to acquire new knowledge and technology and create innovations that will lead to solutions to global issues such as the environment, carbon neutrality, bioresources, disaster prevention and infectious diseases, as well as to improve the independent research and development capacity of developing countries and build a sustainable system of activities that will contribute to solving these issues.

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

[3] ③: High, ②: Fair, ①: Low

The second Yudhoyono administration, which took office in October 2009, set the goal of reducing greenhouse gas emissions by 26% by 2020 (41% with international support) compared to business as usual (BAU). *The National Medium-Term Development Plan (RPJM)* (2010-2014) identified "Environment and Disaster Management" as one of its priority areas. In order to continue to incorporate climate change issues in the RPJM, the Indonesian government made climate change measures a key policy issue for the administration, including the formulation of a sectoral roadmap for adaptation and mitigation measures over a 20-year period from 2010 to 2029, *the Climate Change Roadmap for the Republic of Indonesia* (March 2010). The roadmap identified climate change as an important policy issue for the Indonesian government. Increasing greenhouse gas emissions from coal-fired thermal power plants, on which the country depends for energy, were noted as a particular challenge, and CCS was considered as a potential mitigation measure.

At the time of the ex-post evaluation, *the National Medium Term Development Plan (RPJMN)* (2020-2024) identified increasing resilience to disasters and the addressing of climate change as priorities, with low-carbonization included as part of this. Specifically, items are categorized into (1) improving environmental quality, (2) improving resilience to disasters and climate change, and (3) low-carbon approaches, with numerical targets set for each. For (3) low-carbon approaches, the goal is to reduce greenhouse gas emissions by 27.3% by 2024 compared to BAU. Prior to the 26th Conference of the Parties (COP26) to the United Nations Framework Convention on Climate Change (UNFCCC) held in October-November 2021, Indonesia had announced *the Indonesia Long-Term Strategy for Low Carbon and Climate Resilience* in July of the same year, and stated that it would achieve carbon neutrality by 2060.

Based on the above, it can be seen that addressing climate change, including greenhouse gas reduction, was a priority in Indonesia's national development plan at the time of planning and ex-post evaluation, and therefore the project is consistent with the development plan of Indonesia.

3.1.2 Consistency with the Development Needs of Indonesia

At the time of the ex-ante evaluation, the Indonesian government had established the Directorate General of New Renewable Energy and Energy Conservation within the Ministry of Energy and Mineral Resources (MEMR) in February 2011 to promote new energy and energy conservation. The Directorate General announced *Vision 25/25*, which aimed to achieve a 25% share of new and renewable energy in primary energy by 2025, together with *the Clean Energy Initiative* to promote it. This initiative was a comprehensive guide to reducing CO_2 emissions from fossil fuel combustion, and CCS technology

development was to be promoted as one of the post-combustion measures for fossil fuels. On the other hand, research and studies on CCS had just begun in the country. ITB, one of the leading universities in Indonesia and the implementing agency of this project, had accumulated much knowledge in geology, geophysics, geochemistry, and other related fields but had limited experience in CCS research and surveys. Therefore, it was necessary for ITB, a leader in engineering technology in the country, to accumulate technical knowledge on CCS. Meanwhile, the Gundih gas field in Central Java, owned by the state-owned oil company Pertamina, which was the subject of this project's demonstration study, produced 20% CO_2 as an associated gas during natural gas production, and approximately 800 tons of CO_2 was emitted into the atmosphere daily.

At the time of the ex-post evaluation, the Government of Indonesia had set the goal of increasing crude oil production to 1 million barrels per day by 2030 and natural gas production to 12 BSCFD (1 billion standard cubic feet per day) by optimizing existing oil field production, discovering new reserves through exploration, and implementing enhanced oil recovery (EOR) and enhanced gas recovery (EGR) methods. CCS and Carbon Capture, Usage and Storage (CCUS) technology are essential for this. Therefore, the Government of Indonesia is in the process of formulating regulations to promote CCS/CCUS as a ministerial regulation of MEMR, which also refers to the SOP for the CO_2 sequestration technology developed in this project. The regulations focus on the use of CCS/CCUS[4] in the oil and gas sector through EOR, EGR, and enhanced coalbed methane recovery technology (ECBM), and the necessary framework from technical, legal, economic, and business perspectives has been discussed. In January 2022, *a Memorandum of Cooperation on the "Realization of Energy Transitions"* was signed between Japan's Ministry of Economy, Trade and Industry (METI) and MEMR. The MOU lists areas of cooperation as the development and deployment of technology that contribute to realistic energy transitions, such as hydrogen, fuel ammonia, carbon recycling, and CCS/CCUS, as well as support for efforts in multilateral forums to promote technical cooperation in these areas.

As described above, at the time of both planning and ex-post evaluation, there was a high need for research and technology development related to CCS in Indonesia, and this project is consistent with the development needs of Indonesia.

3.1.3 Consistency with Japan's ODA Policy

Japan's Country Assistance Program for the Republic of Indonesia at the time of the ex-

[4] For example, by injecting CO_2 into old oil and gas fields, the CO_2 is stored underground while the remaining crude oil and natural gas in the oil and gas fields is pushed out under pressure, thereby reducing CO_2 emissions and increasing oil and natural gas production.

ante evaluation included "Assistance to improve the capacity of the Asian region and the international community to respond to challenges" as one of the priority areas. Through this, Japan was to assist in "addressing global-scale issues such as environmental conservation and climate change." In addition, in the Ministry of Foreign Affairs' "*Rolling Plan for Indonesia"* (August 2010), the climate change countermeasures program was positioned as a "special issue." At the UN Climate Change Summit in September 2009, Japan announced financial and technical support for reducing CO_2 emissions in developing countries with CO_2 emission reduction targets of 25% below 1990 levels and 33.3% below 2005 levels by 2020. Efforts to reduce CO_2 emissions have been a national issue for both Japan and Indonesia.

Thus, it can be said that at the time of planning, the project and Japan's ODA policy were highly consistent.

Based on the above, this project was highly relevant to Indonesia's development plan and development needs, as well as Japan's ODA policy. Therefore, its relevance is high.

3.2 Effectiveness and Impacts[5] (Rating: ③)

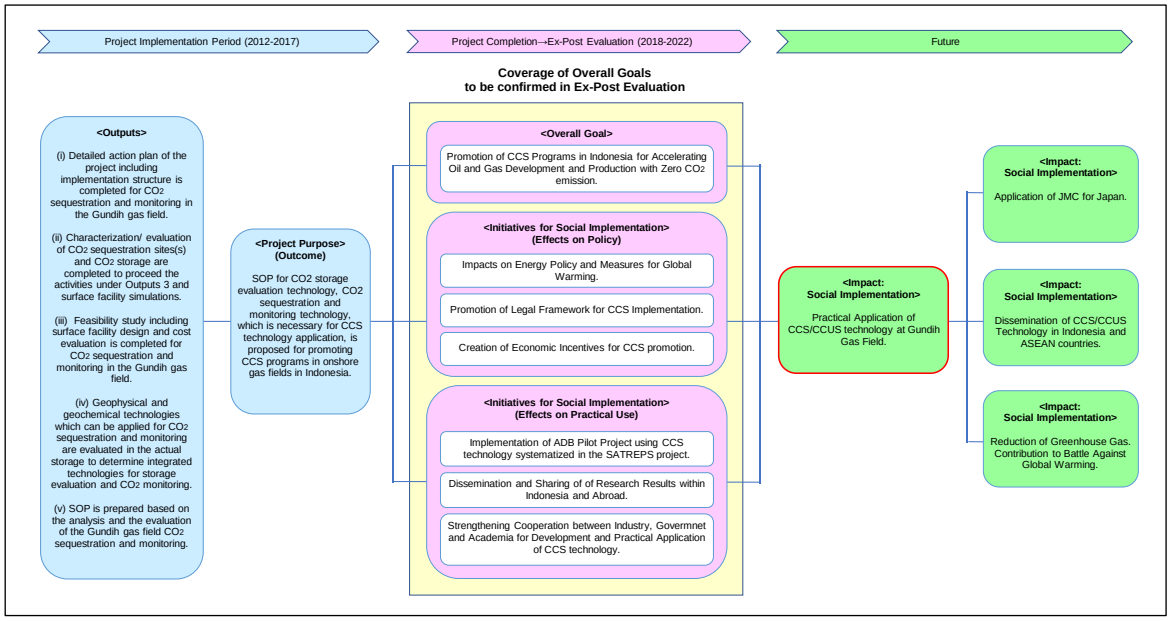
This project is a technical cooperation project conducted within the framework of SATREPS, and its ultimate goal is to promote the social implementation of science and technology that responds to the issues and needs of the partner country, rather than merely providing support for basic and applied research. The social implementation aimed at by this project is considered to be the "Practical application of CCS technology at the Gundih gas field," which will be followed by the "Utilization of Joint Crediting Mechanism (JCM) to achieve Japan's greenhouse gas reduction target," "Dissemination of CCS technology within Indonesia and ASEAN countries," and "Reduction of greenhouse gas emissions." It is necessary that several stages and processes are passed through from the execution of SATREPS to the realization of social implementation. Therefore, in this ex-post evaluation, "Initiatives for Social Implementation" that should be achieved within three to four years after the project completion were identified and defined as the coverage of overall goals to be confirmed. The coverage of overall goals includes the original overall goal of the project, "To promote CCS programs in Indonesia for accelerating oil and gas development and production with zero CO_2 emission."

"Initiatives for Social Implementation" were grouped under "Effects on Policy": (1) Impact on energy policy and measures for global warming in Indonesia, (2) Promotion of a legal framework for CCS implementation, (3) Creation of economic incentives for CCS promotion, and "Effects on Practical Use": (4) Implementation of ADB pilot projects using

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

the CCS technology systematized in the SATREPS project, (5) Dissemination and sharing of research results within Indonesia and abroad, and (6) Strengthening of cooperation between industry, government, and academia for the development and practical application of CCS technology.

The analytical framework used in this ex-post evaluation and the coverage of overall goals to be identified in this ex-post evaluation are shown in Figure 2.



Source: Created by the Evaluator

Figure 2 Evaluation Framework and Coverage of Overall Goals

3.2.1 Effectiveness

3.2.1.1 Project Output

(1) Output 1

Output 1, "Detailed action plan of the project including the implementation structure is completed for CO_2 sequestration and monitoring in the Gundih gas field" was achieved. At the start of the joint research, technical teams were formed for each technical topic and an annual operation plan was established. In addition, a detailed action plan for CO_2 sequestration and monitoring in the Gundih gas field was discussed and prepared.

(2) Output 2

Output 2, "Characterization/evaluation of CO_2 sequestration site(s) and CO_2 storage are completed to proceed the activities under output 3 and surface facility simulations" was achieved. Using the data on geological conditions, borehole and seismic exploration provided by Pertamina and geological data from field surveys, a database of geology and geophysics, and the physical property data for the Gundih gas field were compiled, and a

geological and reservoir model for CCS of the Gundih gas field was constructed in 2013. Simulation studies on CO_2 behavior were conducted on the geological and reservoir models with varying different parameters, and it was concluded that the reservoir would be safe from CO_2 leakage for a long period of time. In addition, a feasibility study, including surface facility design and cost evaluation, simulated the corrosion rate of the borehole during the CO_2 injection period, and the results were incorporated into the detailed design of the surface facilities.

For the "evaluation of CO_2 sequestration site(s) and CO_2 storage[6]," we reinterpreted the existing reflectometry geophysical data, conducted on-site borehole surveys and geological surveys, created a geological model, built a numerical reservoir model using that model, and conducted an injection simulation to precisely evaluate the injection site and characteristics of the reservoir. Also, the possibility of the reactivation of nearby faults was evaluated by focusing on changes in pore pressure in the reservoir due to injection. This was technology newly developed by this project.

(3) Output 3

Output 3, "Feasibility study including surface facility design and cost evaluation will be conducted for CO_2 sequestration and monitoring in the Gundih gas field" was mostly achieved. The feasibility study report on the surface facility design and directions for CO_2 sequestration and monitoring in the Gundih gas field was compiled, refined, and submitted to the relevant organizations in March 2015. The construction of the surface facility, the preparation of injection wells, and CO_2 capture, transport, and injection were not included in the scope of this project, but ADB showed interest and offered to fund the research, and therefore this feasibility study was conducted with financial support from ADB. A risk analysis study of the project was also conducted with funding from Norway.

(4) Output 4

Output 4, "Geophysical and geochemical technologies which can be applied to CO_2 sequestration and monitoring are evaluated in the actual storage to determine integrated technologies for CO_2 storage evaluation and monitoring," was partially achieved. The reason for the partial achievement was that although the evaluation of the CO_2 storage evaluation and monitoring method was completed up to the acquisition of data before CO_2 injection, the possibility of gas leakage in the existing borehole was pointed out (Jepon-1) where CO_2 injection was planned, making CO_2 injection difficult, and as a result, it was

[6] Storage evaluation is the determination of the geological, mechanical, and hydraulic properties of the strata into which CO_2 is injected from the surface, using geological, physical, and chemical tests and analytical methods. This allows an evaluation of the extent (amount and duration) to which CO_2 can be sequestered.

impossible to achieve an evaluation of the underground behavior of CO_2 by project completion. Meanwhile, with regard to CO_2 behavior monitoring and evaluation technology, the time-domain electromagnetic survey method, a reflectance geophysical survey using vibroseis seismic source, and a surface deformation measurement method using interferometric SAR (InSAR) were technology that were applied for the first time in Indonesia through this project.

(5) Output 5

Output 5, "SOP will be prepared based on the analysis and the evaluation of the Gundih gas field CO_2 sequestration and monitoring" was partially achieved. In addition to the research results of Outputs 1 to 4, the draft SOP for CO_2 sequestration and the monitoring of onshore gas fields was prepared by incorporating the results of a literature survey on CCS conducted around the world, a CCS demonstration experiment at Iwanohara in Nagaoka City conducted by the Research Institute of Innovative Technology for the Earth (RITE), and a large-scale CCS demonstration experiment in Tomakomai City conducted by METI of Japan. However, as mentioned above, since it was still impossible to perform CO_2 injection at the Gundih gas field at the time of project completion, the draft SOP was not finalized because it did not reflect the results of analysis and the evaluation of the monitoring of underground CO_2 behavior after CO_2 injection.

In addition to the activities described in Output 1 through 5 above, this project has been selected as a FY2015 "Program for Dissemination and Promotion of Global Warming Countermeasure Technology" by the New Energy and Industrial Technology Development Organization (NEDO). With the support of this NEDO program, a feasibility study for a Joint Crediting Mechanism (JCM), a bilateral trading of carbon credits that promoted by Japan, was conducted using this project as a case study.

3.2.1.2 Achievement of Project Purpose

The project purpose of "SOP for CO_2 storage evaluation technology, CO_2 sequestration and monitory technology, which is necessary for CCS technology application, is proposed for promoting CCS programs in onshore gas fields in Indonesia" is judged to have been partially achieved. The level of achievement for each indicator is shown in Table 1.

Table 1 Achievement of Project Purpose

Purpose	Indicator	Actual
[Project Purpose] SOP for CO_2 storage evaluation technology, CO_2 sequestration and monitory technology, which is necessary for	Indicator 1: A proposal of an SOP for safe and effective CO_2 sequestration technology in onshore is disseminated to 20	Partially Achieved • Although the SOP created through this project was shared with Indonesian government agencies, universities, local governments, companies, etc., monitoring of CO_2 behavior in the reservoir was not implemented as CO_2 injection could not be conducted

Purpose	Indicator	Actual
CCS technology application, is proposed for promoting CCS programs in onshore gas fields in Indonesia	organizations.	before project completion. Therefore, it was difficult to distribute the completed version of the manual because the monitoring results were not reflected in it.
	Indicator 2: Technologies for CO_2 sequestration and monitoring are developed with Indonesia researchers and engineers through collaborative work.	Achieved • Through collaborative work between Japanese and Indonesian researchers, a base line survey utilizing advanced methods and technology such as TDEM and high resolution seismic technology was completed before CO_2 injection, and monitoring technology for CO_2 movement has been developed.

Source: Provided by JICA

Indicator 1, "A proposal of a SOP for safe and effective CO_2 sequestration technology in onshore is disseminated to 20 organizations," was partially achieved, and Indicator 2, "Technologies for CO_2 sequestration and monitoring are developed with Indonesian researchers and engineers through the collaborative work" was fully achieved. Although the SOP developed in this project was distributed to each organization, the monitoring results of CO_2 movement in the reservoir were not reflected because CO_2 injection could not be conducted before project completion, and therefore the distributed SOPs were not a final version. Meanwhile, however, through the joint research of this project, technology and methods for the monitoring of CO_2 behavior using TDEM and high-resolution seismic surveys were developed.

Due to issues such as Pertamina's legal liability for CO_2 injection, this project was made a national project under the direct control of MEMR. After project completion, it was expected that the existing borehole (Jepon-1), which was identified as a possible gas leak, would be rehabilitated with continued ADB support, and CO_2 injection and CO_2 behavior would be monitored as an ADB pilot project.

Based on the above, the project achieved at a limited level its project purpose.

3.2.2 Impacts

3.2.2.1 Achievement of Overall Goal

As mentioned above, the project's overall goal was "to utilize and promote CCS programs in Indonesia for accelerating oil and gas development and production with zero CO_2 emissions." In addition to this, "Initiatives for Social Implementation" to be achieved within three to four years after project completion were included in the coverage of the overall goals to be confirmed in the ex-post evaluation and the degree of achievement of these goals was determined. Table 2 shows the results of the overall goals.

Table 2　Achievement of Overall Goal Assumed in the Ex-post Evaluation

Overall Goals	Actual
[Overall Goal] Promotion of CCS programs in Indonesia for accelerating oil and gas development and production with zero CO_2 emissions	Indicator: At least 5 CCS programs will be planned in Indonesia based on the SOPs proposed by this project.
	Achievement • The SOP proposed by this project provided technical guidance on matters related to CCS implementation from a broad perspective. This SOP was being used as a reference for the CCS/CCUS regulations that were being formulated at the time of the ex-post evaluation. • At the time of the ex-post evaluation, MEMR received applications from domestic and foreign companies for research and study projects for CCS/CCUS commercialization in Indonesia, 9 projects were approved, and research and preparatory works are underway. In five of these nine projects, ITB is conducting studies and research jointly with Indonesian and foreign companies, including Japanese companies, and SOP is being used as the basic information necessary for these studies and research projects.
[Effects on Policy] (1) Impact on energy policy and measures for global warming in Indonesia	• Based on the policy that CCS/CCUS could be one solution for energy transition in Indonesia, "Presidential Decree No. 98/2021 on the Instrument for the Economic Value of Carbon for Achieve Nationally Determined Contribution (NDC) Targets and Control of Carbon Emission in Development" was issued in 2021. This presidential decree provided an important legal basis for the government's efforts to reduce greenhouse gas emissions and achieve Indonesia's NDC. • The presidential decree mentions that the reduction of carbon emissions can be implemented by introducing engineering technology such as CCS/CCUS.
[Effects on Policy] (2) Promotion of a legal framework for CCS implementation	• In May 2017, the National Center of Excellence for CCS/CCUS was established at ITB under the leadership of MEMR, and the Center was ordered to draft new regulations to support CCS/CCUS in Indonesia. At the time of the ex-post evaluation, the Center was in the process of developing the new regulations with the aim of enacting them by the end of 2022. • The regulations are expected to address the rights of contractors to implement CCS or CCUS in their work areas; project approval and implementation mechanisms; economic incentives; measurements, reporting, and verification (MRV) requirements (for greenhouse gas emissions); health, safety, environmental, and social monitoring; decommissioning and transfer responsibilities after project completion. • The SOP proposed in the project includes technology for evaluating deep geological formations and monitoring underground CO_2 distribution and behavior. These technology and methods will be incorporated and utilized in the regulations.
[Effects on Policy] (3) Creation of economic incentives for CCS promotion	• The CCS/CCUS regulations mentioned above also consider a framework of economic incentives, including how to monetize carbon credits and distribute the proceeds, with a focus on the oil and gas companies that are the operators of CCS/CCUS projects.
[Effects on Practical Use] (4) Implementation of ADB pilot projects using the CCS technology systematized in the SATREPS project	• After completion of this project, the project became eligible for support from the ADB's Global Warming Prevention Program. With ADB support, a proposal and evaluation of a method for rehabilitating an existing borehole (Jepon-1) that was identified as a potential gas leak, and an updated feasibility study, which included the design of surface facilities, social acceptability and legal considerations, were conducted. As a result, it became clear that in order to implement the CCS pilot project, it would be necessary to drill a new injection well rather than rehabilitate and utilize the existing well. There was also a difference of opinion among the parties concerned regarding the handling of the hydrogen sulfide (whether hydrogen sulfide should be injected underground together with CO_2) generated in the process of separating and recovering CO_2 from associated gas. Ultimately, it was concluded that it would be difficult to drill new boreholes considering the scale of the ADB project budget (approximately 1.2 billion yen), and the ADB pilot project was canceled in the fall of 2019. • Subsequently, the Government of Indonesia, the Indonesian implementing agency, and the Japanese cooperating agencies requested that the Japanese government cooperate with the continuation of the CCS pilot project. As a

Overall Goals	Actual
	result, a review of the feasibility study conducted by ADB (FY2020) took place, a study to resolve issues (FY2021) was carried out under METI's scheme "Study on the Infrastructure Development Project for Acquisition of JCM Credits," and the basic design for the CCS pilot project (Pre-FEED) was completed. • Based on the above, it is planned that a CCS pilot project will be conducted in the Gundih gas field from FY2022 onward, utilizing NEDO's scheme "Program to Facilitate Private-Sector-Led Promotion of Low Carbon Technology Oversea" (NEDO-JMC). The project period for this pilot project is 5 years, with a budget of approximately 6-7 billion yen, and the schedule is as follows: detailed design of the pilot facilities (FEED) from 2022 to 2023; engineering, procurement, and construction (EPC) from 2023 to 2025; CO_2 injection and monitoring to start by 2026. • Many of the results from this project, such as the CO_2 behavior monitoring method, the injection method, and the basic design of the surface facilities, will serve as the basis for this pilot project.
[Effects on Practical Use] (5) Dissemination and sharing of research results within Indonesia and abroad	• The research results of this project are actively disseminated and shared by ITB and MEMR through presentations at international conferences, international symposiums, webinars, through academic papers, etc., both in Indonesia and abroad. • The ITB is also a member of the International Energy Agency Greenhouse Gas R&D Program (IEAGHG)[7] and, together with national representatives, mostly from developed countries, has proposed strategies for implementing CCS/CCUS, especially in developing countries. The two-week CCS/CCUS course organized by ITB and IEAGHG in 2020 was attended by 250 participants, with many ITB faculty members and Japanese researchers working on this project as instructors.
[Effects on Practical Use] (6) Strengthening of cooperation between industry, government, and academia for the development and practical application of CCS technology	• The National Center of Excellence for CCS/CCUS established at ITB is positioned as the research center for CCS/CCUS in Indonesia and also functions as a coordination window between industry and MEMR for CCS/CCUS projects in the country. It plays an important role in developing and promoting CCS/CCUS technology through collaboration between industry, government, and academia. • In addition to the National Center of Excellence for CCS/CCUS, the Center for Carbon Dioxide and Flared Gas Utilization was established at ITB in March 2020 to conduct research and consulting works as commercial activities related to CCS/CCUS. Through this new organization, ITB has more opportunities to directly engage in CCS/CCUS projects in collaboration with private companies.

Source: Questionnaire responses and interview results from the Indonesian implementing agencies and Japanese cooperating agencies.

The overall goal "to utilize and promote CCS programs in Indonesia for accelerating oil and gas development and production with zero CO_2 emissions" had been achieved at the time of the ex-post evaluation. The SOP proposed by the project was being used as a reference for the regulations on CCS/CCUS being developed at the time of the ex-post evaluation. In addition, at the time of the ex-post evaluation, of the nine projects approved by MEMR for the commercialization of CCS/CCUS, ITB was conducting joint research and studies with Indonesian and foreign companies, including Japanese companies, for

[7] IEAGHG was established in 1991 based on an agreement concluded under the International Energy Agency (IEA) to evaluate and promote greenhouse gas reduction technology, disseminate information on evaluation studies, and promote international cooperation. Currently, among the technology for reducing greenhouse gases, CCS is the main target of activities. Nineteen countries, including Japan and Indonesia, the European Commission (EU), the Organization of Petroleum Exporting Countries (OPEC), and 22 companies are participating. One of IEAGHG's main activities is the operation of the CCS expert network, the organization of workshops and large international conferences.

five projects, and the SOP was being used as basic information necessary for these studies and research.

Regarding "(1) Impact on energy policy and measures for global warming in Indonesia," in relation to this project, "Presidential Decree No. 98/2021 on the Instrument for the Economic Value of Carbon for Achieve NDC Targets and Control of Carbon Emission in Development" was issued in 2021, indicating the need to introduce engineering technology such as CCS/CCUS to reduce carbon emissions.

With regard to "(2) Promotion of legal framework for CCS implementation," the National Center of Excellence for CCS/CCUS established within ITB in 2017 is leading the process of developing regulations on CCS/CCUS (Ministry of Energy and Mineral Resources' Regulation) with the aim of enactment by the end of 2022. This is expected to address: the rights of contractors in the implementation of CCS or CCUS in their work areas; project approval and implementation mechanisms; economic incentives; measurements, reporting, and verification (MRV) requirements (for greenhouse gas emissions); health, safety, environmental, and social monitoring; decommissioning and transfer responsibility after project completion. The SOP proposed in this project will be incorporated into the regulations.

Regarding "(3) Creation of economic incentives for CCS promotion," in the regulations on CCS/CCUS, a framework of economic incentives is also discussed, including how to monetize carbon credits and distribute the proceeds, with a focus on oil and gas companies as operators of CCS/CCUS projects.

With regard to "(4) Implementation of ADB pilot projects using the CCS technology systematized in the SATREPS project," after the completion of this project, it was expected that this project would be eligible for ongoing ADB support for global warming countermeasures, and it was anticipated that ADB funding would be provided to rehabilitate the existing borehole (Jepon-1) that had been identified as a potential gas leak. This was to be followed by CO_2 injection and monitoring of CO_2 movement as a pilot project. However, due to the investigation, the drilling of a new borehole was required to implement the CCS pilot project. This was difficult to handle with the size of the anticipated ADB project budget, and thus the ADB pilot project was ultimately canceled in the fall of 2019. Subsequently, a review of the feasibility study conducted by ADB (FY2020) and a study to resolve issues (FY2021) were conducted under Japan's METI scheme "Study on the Infrastructure Development Project for Acquisition of JCM Credits," and the basic design for the CCS pilot project (Pre-FEED) was completed. The above studies were conducted by a consortium of Japanese plant engineering companies, electric power companies, engineering consultants, and ITB and Pertamina, which entered into a joint research agreement with the consortium. Based on the above, it is planned that a CCS

pilot project will be conducted in the Gundih gas field from FY2022 onwards, under the same implementation structure, utilizing NEDO's "Program to Facilitate Private-Sector-Led Promotion of Low Carbon Technology Overseas" (NEDO-JMC) scheme. The plan envisions the detailed design (FEED) of surface facilities (CO_2 capture facilities, CO_2 transport facilities, CO_2 injection facilities, etc.) from 2022 to 2023, followed by engineering, procurement, and construction (EPC) from 2023 to 2025, and CO_2 injection and monitoring to start by 2026.

Regarding "(5) Dissemination and sharing of research results within Indonesia and abroad," the research results of this project have been disseminated and shared within and outside of Indonesia by ITB and MEMR through presentations at international conferences, international symposia and webinars, and academic papers.

With regard to "(6) Strengthening of cooperation between industry, government, and academia for the development and practical application of CCS technology," industry-government-academia collaboration is underway to develop and promote CCS/CCUS technology, centering on the National Center for Excellence for CCS/CCUS which was established at ITB as a research center for CCS/CCUS in Indonesia. ITB has also established the Center for Carbon Dioxide and Flared Gas Utilization, and ITB itself is increasingly engaged in research and consulting work related to CCS/CCUS in cooperation with private companies.

From the above, it is clear that the overall goal of the project has been achieved, and the six initiatives for social implementation have been implemented or are being implemented. Therefore, the project has achieved overall goal.

3.2.2.2 Continuation of Project Effects

(1) Utilization and Continuation of Research Results

As explained in "3.2.2.1 Achievement of Overall Goal," after project completion, an updated feasibility study, which included the design of surface facilities, supported by ADB (FY2018-2019) and a basic design survey for the CCS pilot project by utilizing Japan's METI scheme (FY2020-2021) were conducted. The above studies are based on the research results of this project.

Meanwhile, although the SOP proposed in this project was not a complete version because it did not reflect the monitoring results of CO_2 movement in the reservoir, the proposed SOP will be integrated into the regulations on CCS/CCUS that are being developed. The ITB will not update the SOP in the future, as formulation of regulations is the top priority.

(2) Capacity Building of Researchers

Prior to the implementation of this project, research and study on CCS had just started in Indonesia, and ITB's research and study experience in the field of CCS was limited. Since then, through joint research with Japanese researchers through the project and training opportunities in Japan, ITB's research capabilities in the field of CCS have improved dramatically. The National Center for Excellence for CCS/CCUS, which was established at ITB as a result of the project, has ITB faculty members who were engaged in the project as core members, and human resource development related to CCS/CCUS in Indonesia is underway. In addition, ITB is expanding its research area from the CCS research undertaken in this project to research and demonstration of CCUS which effectively utilizes captured and stored carbon dioxide.

(3) Equipment Utilization and Maintenance Status

The project provided various types of research and survey equipment, including an earthquake survey system, a micro-earthquake monitoring system, receiver exchange units, electromagnetic method survey equipment, gravity monitoring meters, weather station survey equipment, GPS equipment, etc. This equipment continued to be used for educational and research purposes at ITB after project completion, and maintenance is generally satisfactory.

Pertamina Central Processing Plant at the Gundi gas field

New borehole for demonstration testing (Kedungtuban borehole)

Proposed site for surface facilities

Natural gas production plant

Pertamina staff

3.2.2.3 Other Positive and Negative Impacts

(1) Impacts on the Natural Environment

At the Pertamina Central Processing Plant (CPP) in the Gundih gas field, environmental monitoring activities as part of Labor, Health, Safety, and Environmental Protection (HSE) measures were conducted every three months during the implementation of this project, and emissions and waste were analyzed by a third party. According to the interview with the project officials, the CO_2 released into the atmosphere as an associated gas during natural gas production from the Gundih gas field contains a high percentage of hydrogen sulfide, and therefore the Central Production Facility uses desulfurization

equipment to remove the hydrogen sulfide. According to Pertamina, no negative impact on the natural environment associated with the project had been confirmed.

(2) Resettlement and Land Acquisition

Since the project site is located within the Pertamina CPP Gundih, no land acquisition or relocation of residents occurred as a result of implementation of the project. In the future, the drilling of a new demonstration borehole 4 km away from the CPP and the construction of a pipeline to transport CO_2 from the CPP to the borehole is to be implemented as part of the pilot project. However, the pipeline will be constructed along a right of way (ROW) already acquired by Pertamina, and therefore no new land acquisition or resettlement will occur.

The project purpose was partially achieved through the implementation of this project. The overall goal was achieved, and six initiatives for social implementation have been implemented or are being implemented. At the time of the ex-post evaluation, the research results were being utilized and the project effects were continuing. The project has contributed to the improvement of the research capacity of the researchers at the Indonesian implementing institution, and there were no problems in the utilization and maintenance of the equipment. No negative impact on the natural environment, land acquisition, or resettlement was observed.

In light of the above, the implementation of this project has produced the effects as planned. Therefore, effectiveness and impact of the project are high.

3.3 Efficiency (Rating: ③)

3.3.1 Inputs

A comparison of planned and actual results by inputs is shown in Table 3.

Table 3 Planned and Actual Inputs

Inputs	Plan	Actual (At Project Completion)
(1) Experts	• Long-term: 1 person (Coordination) • Short-term: 20 persons, approx. 80 man-months (Geology, Geological physics, Oil exploitation, etc.)	• Lon-term: 1 person • Short-term: 26 persons, total 27.4 man-months (Geology, Geological physics, Oil exploitation, etc.)
(2) Trainees received	N.A.	86 persons
(3) Equipment	Various measurement devices, computers and software for data analysis, etc. necessary for CO_2 monitoring work	Earthquake survey system, micro-earthquake monitoring system, receiver exchange units, electromagnetic method survey equipment, gravity monitoring meters, weather station survey equipment, GPS equipment, etc.
(4) Operational costs	N.A.	Approx. 51.6 million yen
Japanese Side Total Project Cost	401 million yen	357 million yen

Inputs	Plan	Actual (At Project Completion)
Indonesia Side Total Project Cost	N.A. (Personnel costs of the counterpart, etc.)	N.A. (Personnel costs of the counterpart staff, project office, travelling costs, costs for procurement of equipment (Gravimeters, ultrasonic velocity test equipment, multi-electrode geothermal systems, etc.)

Source: Documents provided by JICA.

3.3.1.1 Elements of Inputs

The number of experts (researchers) dispatched from Japan was 27 (1 long-term expert and 26 short-term experts). The number of trainees from Indonesia was 86. Joint research on CCS and monitoring in the Gundih gas field was successfully conducted within the project period, new technology and methods were developed, such as "CO_2 sequestration sites and storage evaluation" and "CO_2 behavior monitoring and evaluation," and the SOP was prepared. The equipment provided is generally well utilized and maintained. The project was implemented based on partnership, with the Indonesian side providing 29 counterparts from ITB and 4 from Pertamina to engage in the project, and the Indonesian side covering the counterpart personnel costs, project office, travel expenses, and equipment purchase costs.

3.3.1.2 Project Cost

The project cost on the Japan side was 357 million yen versus the planned 401 million yen, which was within the plan (89% of the plan).

3.3.1.3 Project Period

The project period was as planned (100%), with an actual of 60 months (September 2012 to September 2017) versus the planned 60 months (April 2012 to March 2017).

Both the project cost and project period were within the plan. Therefore, efficiency of the project is high.

3.4 Sustainability (Rating: ③)

3.4.1 Policy and Political Commitment for the Sustainability of Project Effects

The Indonesian government has set specific reduction targets for greenhouse gas emissions in its Nationally Determined Contribution (NDC) and Long-Term Low Emission Development Strategy, and CCS is positioned as one of the effective means to achieve these targets. For this reason, the Indonesian government is actively working to promote CCS/CCUS. This project was placed under the direct control of MEMR in 2017 and is positioned as a national project. In addition, regulations on CCS/CCUS, which are

necessary for promoting CCS/CCUS in Indonesia, are being developed.

Thus, the policy and political commitment necessary to sustain effectiveness has been secured.

3.4.2 Institutional/Organizational Aspects for the Sustainability of Project Effects

[MEMR]

MEMR is responsible for the overall resources and energy sector, which consists of four Directorates (Directorate General for New, Renewable Energy and Energy Conservation, Directorate General for Oil and Gas, Directorate General for Minerals and Coal, and Directorate General for Electricity) and three Agencies (Human Resource Development Agency of Energy and Mineral Resources, Research and Development Agency of Energy and Mineral Resources, and Geological Agency). Of these, the Oil and Natural Gas Engineering and Environment Bureau (10 staff) under the Directorate General of Oil and Gas is responsible for developing the regulations (ministerial regulations) on CCS/CCUS that are being developed. The Ministry has been cooperating with Japan's METI and has been building cooperative relationships in the energy sector for many years. In January 2022, a Memorandum of Cooperation on the realization of energy transition was signed with METI, and the two countries will continue to cooperate in developing and promoting CCS/CCUS technology.

[ITB]

ITB was established in 1959 in West Java Province as the first engineering university in Indonesia with 12 faculties and departments, 128 research programs, 111 research groups, 25 centers, 7 research centers, and 7 centers of excellence[8]. After project completion, research, development, the demonstration of CCS/CCUS technology in ITB have mainly been carried out through the National Center for Excellence for CCS/CCUS, established in 2017, and the Center for Carbon Dioxide and Flared Gas Utilization, established in 2020. The former is positioned as the center for research and development of CCS/CCUS in Indonesia, and the latter as the body for research and consulting services related to CCS/CCUS in collaboration with private companies. Both centers have about 45 staff members (who concurrently work in both organizations[9]), and many ITB faculty members involved in this project play essential roles in both centers as center directors and in other key roles.

As mentioned above, ITB and Pertamina have concluded a joint research agreement with

[8] A research center established at a university that centralizes excellent human resources and state-of-the-art facilities.

[9] Staff members work at either center depending on the nature of their work. Work at the National Center for Excellence for CCS/CCUS is on a volunteer (unpaid) basis.

the Japanese consortium. They are jointly conducting the basic design for the CCS pilot project (Pre-FEED) in FY2020-2021 under the METI scheme. The CCS pilot project in the Gundih gas field utilizing the NEDO scheme planned for FY2022 and onward will continue to be carried out under the same structure.

Since project completion, ITB has continued research and educational exchanges with Japanese partner institutions such as Kyoto University, Waseda University, Kyushu University, and the Fukada Geological Institute, and researchers in both countries frequently exchange information with each other. Japanese partner institutions also accept doctoral students and post-doctoral researchers from ITB. The team leaders of the Japanese researchers in this project continue to support ITB's research activities as overseas advisors to the National Center for Excellence for CCS/CCUS.

[Pertamina]

Pertamina is the largest state-owned oil and natural gas company, which was initially established in 1957 as the Oil and Gas Corporation. The shares in Pertamina are owned by the Indonesian government. The company is engaged in the exploitation, refining, domestic sales, and export of oil and natural gas in Indonesia. Pertamina has six sub-holding companies[10] under its holding company. Among them is the oil and gas exploration and production sub-holding company PT Pertamina Hulu Energi (PHE), which has 59 domestic and international subsidiaries, 8 joint ventures, and 2 subsidiaries. One of the subsidiary companies of PHE is Pertamina EP Cepu (PEPC), Zone 11, and this company owns the Gundih gas field.

In CPP Gundih, 10 employees (5 production staff, 3 mechanics, and 2 electrical equipment staff) have been assigned, and the maintenance and management of the facility is outsourced to contractors. As mentioned above, ITB and Pertamina have concluded a joint research agreement with the Japanese consortium and will continue to work on the CCS pilot project in the Gundih gas field.

Therefore, the institutional/organizational aspects necessary to sustain effectiveness are secured.

3.4.3 Technical Aspects for the Sustainability of Project Effects

[MEMR]

At the time of the ex-post evaluation, MEMR prepared draft regulations for CCS/CCUS through the National Center for Excellence for CCS/CCUS. These regulations are to be

[10] Pursuant to the Decrees of the Minister of SOE No. SK-198/MBU/06/2020 dated June 12, 2020, each subsidiary owned by the Pertamina Group was allocated to seven sectors and reorganized into "sub-holdings" and "corporations."

enacted and put into effect by the end of 2022, after consultation with stakeholders in each country and coordination among relevant ministries and agencies. The Ministry is also in charge of reviewing, approving, and monitoring CCS/CCUS projects in Indonesia, and is monitoring nine research projects for the commercialization of CCS/CCUS that had been approved at the time of ex-post evaluation.

[ITB]

The majority of ITB faculty and researchers engaged in the work of the National Center for Excellence for CCS/CCUS and the Center for Carbon Dioxide and Flared Gas Utilization were involved in the implementation of this project and are capable of continuing the research results of this project. Some ITB faculty and researchers will be lecturers at ITB having received their PhD. degrees from Kyushu University in 2021. Through the work of both centers, ITB has expanded its research area from CCS research for carbon capture and storage to the research and demonstration of CCUS for effectively utilizing captured and stored carbon dioxide. During the implementation of this project, the use and maintenance of the equipment provided were transferred from the Japanese side to ITB. The equipment continues to be used, and the maintenance status is generally satisfactory.

[Pertamina]

Pertamina is the owner and operator of the Gundih gas field and is providing ongoing technical assistance for the implementation of the project and subsequent studies, including providing data on wells, underground and surface facilities in the Gundih area. In addition, Pertamina has signed a memorandum of cooperation with a Japanese plant and engineering company to promote decarbonization business and explore new projects in the areas of hydrogen, ammonia, CCUS, and biogas. Pertamina is also working with a Japanese oil production company to evaluate the feasibility of a CCUS project in the Sukowati oil field using bilateral credits. In addition to this project, Pertamina has signed a memorandum of understanding with a major partner in international oil for joint research on the application of CCS/CCUS technology in South Sumatra, East Kalimantan, and West Java and is actively involved in the research, development, and promotion of CCS/CCUS technology in Indonesia. Pertamina is also conducting research on the production of blue hydrogen[11] in the CCUS process, and is moving toward the conclusion of a joint research agreement between Pertamina Corporate University and Kyushu University.

[11] A method of decomposing fossil fuels such as natural gas and coal into hydrogen and carbon dioxide by Steam Methane Reforming or Autothermal Reforming, and the carbon dioxide is captured before it is released into the atmosphere.

Therefore, the technical aspect necessary to sustain effectiveness has been secured.

3.4.4 Financial Aspects for the Sustainability of Project Effects

The Department of Energy and Mineral Resources and ITB budgets (2017-2021) related to CCS/CCUS are shown in Table 4.

Table 4 CCS/CCUS related Budget

Item	2017	2018	2019	2020	2021
Ministry of Energy and Mineral Resources (Directorate General for Oil and Gas)	IDR 636,089,000	IDR 620,618,000	IDR 25,108,000	IDR 249,375,000	IDR 491,252,000
ITB (Center for Carbon Dioxide and Flared Gas Utilization)	USD 200,000	USD 150,000	USD 150,000	USD 350,000	USD 350,000
Pertamina	N.A.	N.A.	N.A.	N.A.	N.A.

Source: Response to questionnaires for Energy and Mineral Resources and ITB.
Note 1: In addition to the above, ITB has other revenue from consulting fees from collaborating private companies.
Note 2: No information was provided by Pertamina.

The project was positioned as a national project under the direct control of MEMR. After project completion, progress was made to the basic design for a CCS pilot project (Pre-FEED) with funds from ADB and the METI. From FY2022 onward, the implementation of pilot project using NEDO funds is planned. At the time of this ex-post evaluation, the Japanese consortium, METI, and NEDO were discussing the project's feasibility. If the project is adopted as a publicly solicited NEDO project, NEDO will provide a five-year budget to implement the pilot project. Meanwhile, after the jurisdiction of the CCS pilot project in the Gundih gas field is transferred from PT Pertamina Hulu Energi (PHE), a sub-holding company, to Pertamina EP Cepu (PEPC), Zone 11, which manages and owns the Pertamina Central Production Facility where the gas field is located, Pertamina is considering the possibility of providing the gas field operating costs.

Therefore, it can be concluded that there is no problem regarding the finances necessary to sustain effectiveness.

No major problems have been observed in the policy background and the institutional/organizational, technical, financial aspects. Therefore, the sustainability of the project effects is high.

4. Conclusion, Lessons Learned and Recommendations

4.1 Conclusion

The purpose of this project was to promote Carbon Dioxide Capture and Storage (CCS)

programs in the Gundih gas field in Central Java, Indonesia by conducting research on CO_2 storage evaluation technology, and CO_2 sequestration and monitoring technology, which is necessary for CCS technology application. This project was highly relevant to Indonesia's development plan and development needs, as well as to Japan's ODA policy. Therefore, its relevance is high. Three of the five outputs were achieved or nearly achieved and two were partially achieved. Since the overall goal has been achieved and six initiatives for social implementation have been implemented or were being implemented at the time of the ex-post evaluation, it is judged that the overall goal has been achieved. The project has contributed to the improvement of the research capacity of the implementing agencies in Indonesia, and there were no problems in the utilization and maintenance of the equipment. No negative impact on the natural environment, land acquisition, or resettlement was observed. Therefore, the effectiveness and impact of the project is high, as the project has been as effective as planned. Both the project cost and project period were within the plan, and the efficiency of the project is high. No major problems have been observed in the policy background and the institutional/organizational, technical, financial aspects. Therefore, the sustainability of the project effects is high.

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

4.2 Recommendations

4.2.1 Recommendations to the Implementing Agency

MEMR is expected to continue to demonstrate leadership, including coordination with relevant ministries and agencies, to ensure that the regulations on CCS/CCUS, which are currently being formulated, can be enacted and put into effect during 2021 as planned.

4.2.2 Recommendations to JICA

None

4.3 Lessons Learned

(1) Establishment of cooperative relationships with governments of relevant countries and international organizations interested in the research fields and subjects during the implementation of the project to enhance the sustainability of the research results after completion

Although it was not planned at the start of the project, ADB and the Norwegian government showed an interest in the research area of the project, and using the research funds provided by ADB, the project proceeded with studies on the social receptivity of the residents in the injection area, CO_2 capture technology in the Gundih gas field, the transport of CO_2, the surface facilities for injection, and the legal regulations for CCS implementation.

In addition, Norway provided the funding for a risk analysis study of the project. Furthermore, this project was selected by NEDO as a "Program for Dissemination and Promotion of Global Warming Countermeasure Technology" in FY2015, and using funds from this NEDO program, a feasibility study for a Joint Crediting Mechanism (JCM) was conducted for the CCS project in the Gundih gas field as a case study. Thus, collaboration with ADB, Norway, and NEDO was promoted during project implementation. Meanwhile, MEMR and Japan's METI have had a long-standing cooperative relationship in the energy sector, and many Japanese companies have also invested and secured interests in the Indonesian energy sector. In this way, the development and commercialization of CCS/CCUS technology in Indonesia have been expected to contribute to the dissemination of Japan's superior low-carbon technology and systems, and to global greenhouse gas reduction as well as to greatly benefit Japan and Japanese companies from the perspective of securing their future emission credits. In light of the above, ADB and METI decided to finance the research portion of the project even after project completion, and research for the CCS pilot project in the Gundih gas field has continued.

It is highly likely that the collaboration which took place during project implementation between the governments of the countries concerned and international organizations interested in the research fields and subjects of the project leads to the continuation of the research results after project completion.

(End.)