

Country Name	Project for Sustainable Development of Rural Area by Effective Utilization of Bio-wastes with Highly Efficient Fuel Cell Technology
Socialist Republic of Viet Nam	

I. Project Outline

Background	<p>At the time of the Ex-Ante Evaluation, while Viet Nam's economy was growing at an annual rate of about 6-7%, energy consumption was growing faster than that, at more than 10% per year. Therefore, Viet Nam was expected to shift from a net energy exporter to an importer by 2015, making securing electricity and primary energy supplies necessary. Moreover, negative aspects of this economic growth included regional disparities between urban and rural areas and the spread of environmental pollution and destruction. In the Mekong Delta region, where shrimp and other aquaculture industries were flourishing, the production of marine products was greatly affected by the cost of electricity required to operate aquaculture pond facilities and the unstable power supply, which caused the pumps, turbines, and other equipment in aquaculture ponds to shut down, leading to a decline in water quality. Thus, this project was implemented to efficiently utilize unused energy in rural areas, to secure a stable energy supply in the country, and to improve the local environment by developing fuel cell power generation technology using biomass-derived fuels.</p>										
Objectives of the Project	<p>Through establishing a laboratory for solid oxide fuel cells (SOFC), developing SOFC system running on biogas, producing biogas stably in quantity and quality from local biomass resources, demonstrating a model of energy circulation system composed of shrimp culture, sludge collection, biogas production, vegetable cultivation, water quality management, and power generation, and developing a road map for SOFC technology dissemination, the project aims at developing fuel cell technology running on local bio-energies with higher electrical efficiency and demonstrating an environmentally friendly energy circulation system, thereby contributing to the utilization of such system for the realization of a low-carbon society and the improvement of living standard of local people.</p> <ol style="list-style-type: none"> Expected Overall Goal: Utilization of stable energy system which uses bio-wastes as energy resources is promoted, contributing to the realization of low-carbon society, the improvement of living standard of local people and sustainable development. Project Purpose: Fuel cell technology running on local bio-energies such as bio-wastes with higher electrical efficiency is developed and an environmentally-friendly energy-circulation system using bio-wastes such as sludge in shrimp ponds as energy resources is demonstrated. 										
Activities of the Project	<ol style="list-style-type: none"> Project Site: Ho Chi Minh City Main Activities: (1) Establish a SOFC laboratory; (2) Design and develop a balance of plant (BOP) for biogas-fuelled SOFC and SOFC module considering thermal management, and develop prototype SOFC system; (3) Conduct chemical analysis of local biomass resources such as sludge in shrimp pond and agricultural residues and lab-scale methane fermentation experiment using local biomass resources, and perform a demonstration of biogas production in shrimp pond; (4) Prepare the demonstration site, improve water quality and aeration efficiency utilizing engineering techniques, conduct vegetable cultivation utilizing methane fermentation residues, modify gas engine generator for biogas operation, install electric distribution equipment, and monitor the reduced amount of greenhouse gas emissions and amounts of sludge and residues used for energy resources; and (5) Conduct PR activities of the energy circulation utilizing SOFC, hold annual expert panel organized by practical persons, researchers, and NGOs, and develop a road map for dissemination etc. Inputs (to carry out above activities) <table style="width: 100%; border: none;"> <thead> <tr> <th style="text-align: left;">Japanese Side</th> <th style="text-align: left;">Vietnamese Side</th> </tr> </thead> <tbody> <tr> <td>1) Experts: 1 person (long term) and 30 persons (short term)</td> <td>1) Staff Allocated: 33 persons</td> </tr> <tr> <td>2) Trainees Received: 28 persons</td> <td>2) Office space for Japanese researchers and operation expenses</td> </tr> <tr> <td>3) Equipment: SOFC system, scanning electron microscope/energy dispersive x-ray spectroscopy, water filtration system, aeration system, carbonization facility, methane fermentation facility, lab-scale methane fermentation reactors, CNS analyzer, and biological microscope etc.</td> <td></td> </tr> </tbody> </table> 			Japanese Side	Vietnamese Side	1) Experts: 1 person (long term) and 30 persons (short term)	1) Staff Allocated: 33 persons	2) Trainees Received: 28 persons	2) Office space for Japanese researchers and operation expenses	3) Equipment: SOFC system, scanning electron microscope/energy dispersive x-ray spectroscopy, water filtration system, aeration system, carbonization facility, methane fermentation facility, lab-scale methane fermentation reactors, CNS analyzer, and biological microscope etc.	
Japanese Side	Vietnamese Side										
1) Experts: 1 person (long term) and 30 persons (short term)	1) Staff Allocated: 33 persons										
2) Trainees Received: 28 persons	2) Office space for Japanese researchers and operation expenses										
3) Equipment: SOFC system, scanning electron microscope/energy dispersive x-ray spectroscopy, water filtration system, aeration system, carbonization facility, methane fermentation facility, lab-scale methane fermentation reactors, CNS analyzer, and biological microscope etc.											
Project Period	(ex-ante) April 2015 – March 2020 (60 months) (actual) April 2015 – March 2020 (60 months)	Project Cost (Japanese side only)	(ex-ante) 326 million yen, (actual) 362 million yen								
Implementing Agency	Institute for Nanotechnology (INT) of Vietnam National University Ho Chi Minh City (VNUHCM), Ho Chi Minh City University of Technology (HCMUT), Can Tho University (CTU), and Hoang Vu Co. (Demonstration site of the project)										
Cooperation Agency in Japan	Kyushu University, Shizuoka University, Meiwa Co., Ltd., Daicem Membrane-Systems LTD., Magnex Co., Ltd., and Nakayama Iron Works. LTD.										

II. Result of the Evaluation

<Special Perspectives Considered in the Ex-Post Evaluation>

¹ SATREPS: Science and Technology Research Partnership for Sustainable Development

- [Target Year for the Overall Goal] In accordance with the road map prepared under the project, the target year for the Overall Goal to be achieved is 2024, and this ex-post evaluation will evaluate the prospects for its achievement by 2024.
- [Continuation status of Indicator 2 and Indicator 4 of the Project Purpose] The status of the continuation of these indicators after the project completion were difficult to confirm, so that the status of these were regarded as “N.A.”.

1 Relevance/Coherence
<p>[Relevance]</p> <p><Consistency with the Development Policy of Viet Nam at the Time of Ex-Ante Evaluation></p> <p>The project was consistent with the development policy of Viet Nam at the time of ex-ante evaluation. In the “Seventh National Electricity Master Plan” formulated in 2011, the Government of Viet Nam aimed to promote the development of renewable energies, especially biomass power generation, to increase to 500 MW by 2020 and 2,000 MW by 2030. In addition, the “National Target Program to Respond to Climate Change” was formulated in December 2008 as a decision of the Prime Minister, and various policy formulations for climate change countermeasures were being promoted across ministries and agencies.</p> <p><Consistency with the Development Needs of Viet Nam at the Time of Ex-Ante Evaluation></p> <p>The project was consistent with the development needs of Viet Nam at the time of ex-ante evaluation. Shrimp ponds in the Mekong Delta region were often connected by waterways, and when shrimp disease occurred in one pond, it was often transmitted to other ponds. Therefore, a stable electricity supply to operate pumps for water agitation and water quality control were very important factors for shrimp farming. Moreover, due to the effects of sludge, the use life of aquaculture ponds was estimated to be about ten years. Therefore, there was a great need for sustainable aquaculture industry development through the management and effective use of sludge.</p> <p><Appropriateness of Project Design/Approach></p> <p>The project design/approach was appropriate. No problem attributed to the project design/approach was confirmed.</p> <p><Evaluation Result></p> <p>In light of the above, the relevance of the project is ③².</p>
<p>[Coherence]</p> <p><Consistency with Japan’s ODA Policy at the Time of Ex-Ante Evaluation></p> <p>The project was consistent with Japan’s ODA policy to Viet Nam at the time of ex-ante evaluation. The “Country Assistance Policy for the Socialist Republic of Viet Nam” (2012) states that Japan supports Viet Nam to supply energy stably and promote saving energy to meet the demands for economic infrastructure, which are increasing along with economic growth. It also states that to deal with the negative aspects of the growth, Japan supports the country in addressing threats such as disasters and climate change.</p> <p><Collaboration/Coordination with JICA’s other interventions></p> <p>Although the collaboration/coordination between the project and JICA’s other interventions was not planned at the time of ex-ante evaluation, it was implemented, and the positive effect was confirmed at the time of ex-post evaluation. Two young researchers from the Institute for Nanotechnology (INT) of Vietnam National University Ho Chi Minh City (VNUHCM) attended JICA scholarship programs, including “Hydrogen Energy Program” and “Scholarship Program” under AUN/SEED-Net Project during the project implementation. Through these programs, the young researchers enhanced their research capacities and contributed to the research activities under the project.</p> <p><Cooperation with other institutions/ Coordination with international framework></p> <p>Although the cooperation/coordination with other institutions was not planned at the time of ex-ante evaluation, it was implemented, and the positive effect was confirmed at the time of ex-post evaluation. There was the university-industry cooperation with Magnex Co., Ltd. under the project, and as a result, the SOFC system running on biogas was successfully developed.</p> <p><Evaluation Result></p> <p>In light of the above, the coherence of the project is ③.</p>
<p>[Evaluation Result of Relevance/Coherence]</p> <p>In the light above, the relevance/coherence of the project is ③.</p>
2 Effectiveness/Impact
<p><Status of Achievement of the Project Purpose at the Time of Project Completion></p> <p>At the time of project completion, the Project Purpose was mostly achieved as planned. The project successfully developed a highly efficient fuel cell (the SOFC system) running on local bioenergy (Indicator 1). The amount of electrical power generated by the biogas production plant introduced by the project reached 1kW (Indicator 2). Benefits and electricity supply capacities of the energy circulation system using biomass wastes, which were verified in the project, were recognized both domestically and internationally through workshops, seminars, research papers and so on (Indicator 3). Research results of the project were also published or in the process of being published as more than ten research papers in international journals (Indicator 4).</p> <p><Continuation Status of Project Effects at the Time of Ex-Post Evaluation></p> <p>By the time of the ex-post evaluation, the project effects have continued. Most of the major research facilities and equipment procured under the project (except for a CNS analyzer, which needs repair) and all the key research outputs produced by the project, such as the SOFC system, membrane filtration system, and methane fermentation and carbonization facilities, have been utilized by implementing agencies for continued research and training. Based on these research outputs, several new projects have also been implemented. Although the road map for SOFC technology dissemination has not been updated or elaborated after the project completion due to the widespread COVID-19 pandemic, INT has continued the research and dissemination based on the existing road map. While Magnex Co., Ltd. has not upgraded the SOFC system to be introduced to their business market due to the COVID-19³, the performance of the SOFC system has been enhanced and catalytic materials to be used in the system have continuously been developed by researchers who were involved in the</p>

² ④ : very high, ③ : high, ② : moderately low, ① : low

³ The SOFC system’s stacks were developed and copyrighted by Magnex Co., Ltd. The role of the implementing agencies under the project was to develop catalytic materials to be used in the system.

project.

<Status of Achievement for the Expected Overall Goal at the Time of Ex-Post Evaluation>

At the time of ex-post evaluation, the Overall Goal has been partially achieved. According to the road map for SOFC technology dissemination developed under the project, at least one case of the SOFC system is to be installed and introduced to the community in the Mekong Delta region by 2024, except for the one installed in the demo-site during the project implementation. The Yuko-Keiso Co., Ltd. has cooperated with Tuan Hien Aquaculture Company in Tien Giang Province to implement a new project for social implementation of zero-emission shrimp farming with SOFC and Internet of Things (IoT) from 2022 to 2025, which is funded by New Energy and Industrial Technology Development Organization (NEDO) of Japan. Two SOFC systems are going to be installed for research purposes in the Tien Giang Province by March 2024 under the project.

<Other Impacts at the Time of Ex-Post Evaluation>

Since the project utilized available bio-waste for power generation, it contributed to the promotion of the energy circulation society. Moreover, the researchers' abilities to define problems, deploy research ideas, set objectives and priorities, and conduct sound scientific research have been improved through the project. The scientific literacy of the related governmental organizations, such as Department of Agriculture and Rural Development (DARD) and the Department of Science and Technology (DST) in Ben Tre Province, has also been improved through attending project meetings and workshops.

<Evaluation Result>

In light of the above, the effectiveness/impact of the project is ③.

Achievement of Project Purpose and Overall Goal

Aim	Indicators	Results	Source
(Project Purpose) Fuel cell technology running on local bio-energies such as bio-wastes with higher electrical efficiency is developed and an environmentally-friendly energy-circulation system using bio-wastes such as sludge in shrimp ponds as energy resources is demonstrated.	Indicator 1: Development of highly efficient fuel cell running on local bio-energy	Status of the Achievement (Status of the Continuation): achieved as planned (continued and further developed) (Project Completion) The project succeeded in developing a highly efficient fuel cell running on local bioenergy. The SOFC system developed by the project generates electricity using coconut pomace, rice straw, and bagasse together with concentrated sludge feeding to a digester, and this achieved the power generation efficiency of 62.5% Lower Heating Value (LHV) at a stack temperature of 710 Celsius and fuel utilization of 74.0% in July 2019. This was triple in efficiency and lower emissions of CO ₂ compared with conventional heat engine systems. (Ex-Post Evaluation) All the key research outputs produced by the project have been utilized by implementing agencies mainly for research and training purposes. The performance of the SOFC system has been enhanced, and catalytic materials to be used in the system have also been developed by researchers involved in the project and a JICA scholarship student from INT. Based on the research outputs produced by the project, the following projects have been implemented. (1) INT implemented the project titled the “Study on treatment of sludge in shrimp culture to produce porous carbon used as fertilizer and generate electricity” (2021-2022) to sustain research activities conducted under the SATREPS project. (2) Can Tho University (CTU) implemented the project titled “Assessment of biogas generating capacity of industrial shrimp pond sludge combined with available plant biomass resources in Tien Giang Province” (2020-2021) in cooperation with Yuko Vietnam Co., Ltd. (3) A new project for social implementation of zero-emission shrimp farming with SOFC and IoT is implemented by Yuko-Keiso Co., Ltd. in Tien Giang Province from 2022 to 2025 in cooperation with Tuan Hien Aquaculture Company. Several Japanese researchers who participated in the SATREPS project also contribute to this project.	Project Completion Report, questionnaire survey and interview with VNUHCM (INT), CTU, HCMUT, Magnex Co., Ltd., and a Japanese researcher participated in the project
	Indicator 2: Amount of electrical power obtained from regional bio-waste with sludge of shrimp pond reaches more than 1kW in demonstration site.	Status of the Achievement: Achieved as planned The generation capacity of the biogas production plant introduced by the project is 2 kW biogas at maximum based on the designed capacity of the fermentation system. Considering the energy efficiency of the SOFC, about 50%, the electrical power actually generated would be 1 kW. ⁴ (Ex-Post Evaluation) N.A.	Project Completion Report
	Indicator 3: Economic, social, environmental and financial benefits of	Status of the Achievement (Status of the Continuation): mostly achieved as planned (continued) (Project Completion) Through workshops and seminars, the participants, such as local government,	Project Completion Report, questionnaire

⁴ While this sentence is taken from the Project Completion Report, according to the description in Indicator 1 above, the SOFC system achieved a power generation efficiency of 62.5% in July 2019, which suggests that the system had achieved more than 1 kW of electricity by the time of the project completion.

	the electricity supply capacity of energy-circulation system using bio-waste such as sludge in shrimp ponds verified in the project, are recognized in both domestic and international.	aquaculture farmers, and local communities, recognized the benefits and the electricity supply capacities of the energy circulation system using biomass wastes in the Mekong Delta region. Moreover, the benefits of introducing the systems developed through the project were internationally presented through research papers and verbal presentations at international symposiums and meetings. (However, financial benefits were to be continuously explored since the system established by the project was only the prototype and still very costly.) (Ex-Post Evaluation) While the widespread COVID-19 pandemic severely limited the activities for disseminating the SOFC technology, INT has continued research and disseminated the SOFC technology to a possible extent based on the existing road map.	survey and interview with VNUHCM (INT)
	Indicator 4: Research results in the project are published in internationally appreciated journals.	Status of the Achievement: achieved as planned As of February 2020, a total of 13 research papers were published or in the process of being published in international journals, among which ten papers were co-authored with INT, and one was with CTU. (Ex-Post Evaluation) N.A.	Project Completion Report
(Expected Overall Goal) Utilization of stable energy system which uses bio-wastes as energy resources is promoted, contributing to the realization of low-carbon society, the improvement of living standard of local people and sustainable development.	Indicator 1: Number of installations of the energy circulation system developed in the project in Mekong Delta reaches 3.	Status of the Achievement: partially achieved (Ex-Post Evaluation) Two energy circulation systems are going to be installed for research purposes in Tien Giang Province by March 2024 under the new project (the project for social implementation of zero-emission shrimp farming with SOFC and IoT).	Questionnaire survey and interview with VNUHCM (INT)

3 Efficiency

The project cost slightly exceeded the plan (the ratio against the plan: 111%), and the project period was as planned (the ratio against the plan: 100%). The actual cost exceeded the planned cost because of purchasing additional equipment for research purposes and the higher actual cost of some equipment. Particularly, the actual cost of the SOFC system was much higher than the planned cost because additional technology improvements were required to run the SOFC with biogas stably and safely in a remote area.

	Project Cost (Japanese side only, yen)	Project Period (months)
Plan (ex-ante)	326 million yen	60 months
Actual	362 million yen	60 months
Ratio (%)	111%	100%

Outputs were produced as planned.

In the light above, the efficiency of the project is ③.

4 Sustainability

<Policy Aspect>

National policies such as the “National Green Growth Strategy for 2021-2030 period, with a vision to 2050”⁵ and the “National Strategy for Climate Change until 2050”⁶ (issued in 2022) and an international policy framework such as the 27th session of the Conference of the Parties (COP27) to the United Nations Framework Convention on Climate Change held in SharmEl-Sheikh in 2022 support promotion of green growth, carbon-neutral economy, and the reduction of greenhouse gas emissions, which in turn supports the promotion and dissemination of the SOFC system that has a high potential to contribute to an environmentally friendly energy circulation system.

<Institutional/Organizational Aspect>

INT and a research team of a Japanese researcher who participated in this project have continued research to develop catalytic materials for the SOFC system after the project completion, utilizing a fund provided by the Japanese government. This research collaboration is likely to be sustained, as two researchers from INT have received JICA’s scholarship for a Ph.D. course in Japan under the supervision of the Japanese researcher, and he has also recently visited Viet Nam to discuss with INT for formulating a new research project. INT has also discussed with DARD and DST of Ben Tre Province on conducting research activities related to the project’s research outcomes. In addition, CTU has cooperated with Daicen Membrane-Systems LTD. to introduce products of the company, including a membrane filtration system, to aquacultural companies in Tien Giang Province. Most of the equipment and facilities installed by the project have been properly operated and maintained by INT, CTU, and HCMUT. The equipment installed in the demonstration site is also properly maintained by staff hired by INT. INT plans to move the equipment in the demonstration site to the Center for High-Tech Agriculture in Binh Dai, under DARD of Ben Tre Province, in the future.

<Technical Aspect>

Researchers of INT, CTU, and HCMUT have sustained their research capacities and skills through attending intensive lectures, related seminars, training sessions at the demonstration site, and discussions at Kyushu University in Japan, drafting research papers, and participating in research activities funded by a local budget. As mentioned above, two researchers from INT have received JICA’s scholarship for a Ph.D. course in Japan, and they have contributed to the performance enhancement of the SOFC system under the

⁵ Decision No.1658/QD-TTg

⁶ Decision No.896/QD-TTg

supervision of the Japanese researcher. The prospect for future improvement of their research capacities is relatively high, as INT and the Japanese researcher who participated in this project plan to continuously cooperate in the future through a new project. Researchers at INT, CTU, and HCMUT have also sustained their skills to properly operate and maintain (O&M) the equipment and facilities installed by the project through O&M manuals and continuous discussions with Japanese researchers. Governmental authorities such as the Ministry of Agriculture and Rural Development, the Ministry of Science and Technology, DARD, and DST also have sufficient scientific literacy, as they have specialized research units under these organizations, and these authorities focus on sustainable development in the Mekong Delta.

<Financial Aspect>

INT secured USD 65,000 (approximately VND 1,565 million) from VNUHCM to continue research activities and operate and maintain the equipment and facilities installed in INT and the demonstration site for the period of 2021-2022. CTU received financial support from Yuko Vietnam Co., Ltd. from December 2020 to February 2021 with a total budget of VND 119 million for the continued research activities. DARD and DST of Ben Tre Province have also secured a state budget to support research activities related to biomass utilization and water quality control. INT has recently applied to a project funded by DST of Ben Tre Province to further develop and apply the environmentally friendly energy circulation system developed under the project more widely in Ben Tre and other provinces in the Mekong Delta. INT, CTU, and HCMUT have continuously endeavored to secure financial resources for continued research and O&M of the equipment and facilities.

<Environmental and Social Aspect>

No issue on environmental and social aspects has been observed, and it has not been necessary to take any countermeasures.

<Evaluation Result>

In light of the above, no problem has been observed in terms of the policy, institutional/organizational, technical, financial, environmental, and social aspects. Therefore, the sustainability of the project effects is ④.

5 Summary of the Evaluation

The project achieved developing fuel cell technology running on local bio-energies and demonstrating an environmentally friendly energy circulation system (Project Purpose) as planned, and partially achieved promoting the utilization of such a stable energy system (Overall Goal) in view of the expected level of utilization. After the project completion, most of the major research facilities and equipment procured under the project and all the key research outputs produced by the project have been utilized for continued research and training. As for sustainability, implementing agencies have continued research collaboration with Japanese researchers who participated in the project, sustained their research capacities and skills, and secured financial resources for continued research and O&M of the equipment and facilities.

Considering all of the above points, this project is evaluated to be highly satisfactory.

III. Non-score Items

Additionality and Creative Values:

Through the development of a model of an environmentally friendly energy circulation system, including the SOFC system running on biogas and membrane filtration system in collaboration with Japanese research institutions, which are innovative initiatives to secure stable energy supply and improve the local environment, research capacities of Vietnamese researchers have been greatly enhanced.

IV. Recommendations & Lessons Learned

Recommendations for Implementing Agency:

The SOFC system running on biogas, which was developed under the project, is still complex and costly for farmers in Viet Nam to adopt in their farming. Thus, the research team of implementing agencies should continue efforts to simplify the system and reduce adoption costs to increase the financial benefits of the system.

Lessons Learned for JICA:

While the actual project period was as planned, procedures and regulations on importing equipment used for international cooperation projects, particularly regulations on tax exemption, are complicated in Viet Nam, and it took a long time to import the equipment during the project implementation. Thus, when implementing a project involving the import of equipment, project stakeholders should check the regulations and procedures required for importing equipment before starting the project, and start preparation for an import procedure at an early stage.



SOFC system and distribution control panel installed at Demo-site, Ben Tre province



Scanning electron microscope and energy dispersive x-ray spectroscopy installed at INT, Ho Chi Minh City