Internal Ex-Post Evaluation for Technical Cooperation Project (SATREPS[1])

Conducted by Thai Office: August, 2021

Country Name	**Innovation on Production and Automotive Utilization of Biofuels from Non-Food Biomass in Thailand**
Kingdom of Thailand	

I. Project Outline

Background	In Thailand, development of bioethanol and biodiesel derived from food biomass including palms have been conducted since 1970's. However, the needs for clarification of biofuel development mechanisms from non-food biomass and standardization of the test for them were increasing as it was desirable to avoid food shortage problem caused by conversion of food to fuel. Although Jatropha was selected as one of promising alternatives for raw materials to produce non-food biomass, Jatropha contained toxic substance. Therefore, it was necessary to eliminate the toxic substance in order to utilize it for biofuel. Also, it was essential to establish basic technologies for quality improvement in order to practically apply the biofuel derived from Jatropha.		
Project Objectives	Through 1) establishment of production technologies for safe and high quality biodiesel fuel (BDF) derived from Jatropha oil, 2) establishment of refining technologies for bio oil from Jatropha residues and production technologies for high quality BDF, 3) human resource development of researchers, 4) practical application of the BDF production technologies, the project aimed at development of basic technologies for production of automotive fuel using Jatropha of non-food biomass, thereby contributing to dissemination of the improved production technologies for BDF from non-food biomass in Thailand. 1. Expected Overall Goal: Fundamental technologies to produce biofuels from non-food biomass for automotive utilization are developed. 2. Project Purpose: Fundamental technologies to produce biofuels from non-food biomass for automotive utilization are developed.		
Project Activities	1. Project Site: Bangkok 2. Main Activities: 1) Activities for production of high quality BDF from distilled Jatropha oil, 2) Activities for production of biooil from Jatropha residues, 3) Activities for upgrading of biooil and lifecycle assessment, 4) Activities for compatibility assessment of biofuel from Jatropha residues, 5) Activities for human resource development, technical transfer and practical application of BDF production technologies. 3. Inputs (to carry out above activities): Japanese Side 1) Experts: 28 persons 2) Trainees received: 36 persons 3) Equipment: Test device for high quality BDF production, Realtime PM analyzer, High performance liquid chromatography, the prototype extraction and separation apparatus, and so on. 4) Local operation costs: cost for procurement of materials (Jatropha oil and residues, materials and equipment for research activities and others), transportation and travel expenses, communication and transport costs, cost for seminars, trainings and meetings, cost for dissemination activities (costs for printing and events), cost for project assistants and translators, and so on. Thai Side 1) Staff allocated: 95 persons 2) Facilities and land: Project office in each implementing agency, materials and equipment for laboratories, expansion of laboratory, securing the installation site for the pilot plant, and so on. 3) Local operation costs: cost for vehicle running test (1st test), cost for modification of the pilot plant, cost for consumables of the laboratories, utility cost for the project office, and so on.		
Project Period	May 2010 – March 2016 (Extension Period: March 2015 – March 2016)	Project Cost	Ex-ante: 387 million yen, Actual: 346 million yen
Implementing Agencies	National Science and Technology Development Agency(NSTDA），Thailand Institute of Scientific and Technological Research (TISTR），King Mongkut's University of Technology North Bangkok (KMUTNB）		
Cooperation Agency in Japan	National Institute of Advanced Industrial Science and Technology (AIST), Waseda University		

II. Result of the Evaluation

1 Relevance
<Consistency with the Development Policy of Thailand at the Time of Ex-Ante Evaluation > The Project was consistent with Thailand's policies such as the "National Strategy for Climate Change" (2008-2012) and the "15-Year Alternative Energy Development Plan" (2008-2022) aiming at promotion of alternative energies. <Consistency with the Development Needs of Thailand at the Time of Ex-Ante Evaluation>

[1] SATREPS: Science and Technology Research Partnership for Sustainable Development

The Project was consistent with Thailand's development needs for avoiding food problem caused by conversion of food to energy, clarification of mechanism of non-food biofuel development and standardization of the tests in the county aspiring promotion of biodiesel utilization.

<Consistency with Japan's ODA Policy at the Time of Ex-Ante Evaluation>

The Project was consistent with "Economic Cooperation Plan for Thailand" (May 2006) focusing "support for environment management system" as a part of "countermeasures against issues associated with maturing society" which was one of the priority areas

<Evaluation Result>

In light of the above, the relevance of the project is high.

2 Effectiveness/Impact

<Status of Achievement of the Project Purpose at the time of Project Completion>

The Project Purpose was achieved at the time of project completion. The technology to produce 1 ton of Hydrogenated Fatty Acid Methyl (H-FAME) per day was established and the quality of the "EAS-ERIA Standards" was ensured by oxidation stability of the H-FAME with 15.1 hours (Indicator 1). Also, upgrading biooil through hydrorefining process enabled to produce upgraded fuel which met the petroleum product quality (surfer <6.3ppm and oxygen <0.1wt%).

<Continuation Status of Project Effects at the time of Ex-post Evaluation>

The project effects have continued since project completion. The H-FAME related technologies, the key research outputs by the SATREPS project, have been succeed by the national project and the various kinds of verification test for utilization of the research outcomes. Based on the results of the tests, the specification standard for Biodiesel 10% blended fuel (B10) was determined and the commercial use was decided. Related to the national project, in October 2017, Idemitsu Kosan Co., Ltd., a Japanese company, concluded an agreement on technical cooperation for a project of Biodiesel high blended fuel with the National Metal and Materials Technology Center (MTEC) under NSTDA and Global Green Chemical Plc., a Thai major biodiesel fuel production company, and has provided technical supports for the project.

Also, the research activities related to H-FAME has been continued. For the period from 2016 to 2019, the national project for commercial scale technology development and actual vehicle running test was implemented by the implementing agencies of NSTDA and TISTR using 6.8 million Thai baht (THB) funded by the Energy Conservation Promotion Fund under the Ministry of Energy. In addition, MTEC took an initiative for implementation of the Asia Pacific Economic Cooperation (APEC) project (EWG 20 2016A), "Guidelines toward High Biodiesel Blended Diesel (e.g. B20) Specification in the APEC Region". As a part of consideration of BDF standard for biodiesel 20% blended fuel (B20), assessment of H-FAME was conducted and its dissemination was considered.

The research facilities and equipment constructed or installed by the SATREPS project have been continuously used for the related research. The pilot plant for production of H-FAME in TISTR has been used by the national project and the many visitors from the country and the overseas have visited the site. On the other hand, the prototype extraction and separation apparatus installed in NSTDA was not utilized at the time of ex-post evaluation because large scale biooil production by the biomass thermal decomposition method was not promoted by the government of Thailand.

<Status of Achievement for Expected Overall Goal at the time of Ex-post Evaluation>

The Expected Overall Goal was achieved at the time of ex-post evaluation. The SATREPS project aimed at "dissemination of production technologies for upgraded BDF using non-food biomass to Thai researchers and engineering companies" (Indicator 1) and had promoted development of BDF using non-food biomass including Jatropha which did not adversely affect food security when the project started. However, the government of Thailand had greater interest to expand utilization of biofuel derived from palm because of the viewpoints such as to support palm farms confronting the recent stagnant demand for palms. As a result, the Thai government policy guided to promote utilization of the H-FAME technologies for BDF production mainly using surplus of food biomass (palm) from edible consumption. As mentioned above, the H-FAME technologies developed by the SATREPS project has been further promoted by the national project for the upgrading technology of BDF from palm of food material which had been considered during the implementation of the SATREPS project. In December 2018, MTEC/NSTDA announced that the national project carried out technical transfer of the H-FAME technologies as commercial scale production technology development to the two major fuel production companies, Global Green Chemical Plc., and Bangchak Biofuel Co., Ltd. They succeeded continuous operation of H-FAME production for several tons per day under the technical support by Idemitsu Kosan Co. ltd. Also, as for actual vehicle running test, B10 was used for the test and running performance assessment was done.

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

There are some positive impacts of the Project confirmed at the time of the ex-post evaluation. For commercialization of the H-FAME technologies, a Japanese company was interested in the technologies and planned commercialization of the production in Indonesia. However, the commercialization plan was suspended since the overseas business of the company was downsizing due to the worldwide pandemic of COVID-19. Besides that, for the period from 2016 to 2018, the Third Country Training Program for the ASEAN countries, aiming at dissemination of the H-FAME technologies, was delivered by NSTDA, TISTIR and KMTNB under the assistance by JICA. Also, the Third Country Training Program for the ASEAN countries aiming at dissemination of renewable energies is planned in 2021, in which H-FAME technologies will be covered. Currently, the H-FAME technologies has internationally recognized as upgrading technologies for BDF, and universities and research institutes have been conducting wide variety of researches related to the H-FAME technologies. Although a Lao researchers' group attempted to obtain a fund for research on BDF production using another non-food material, Pongamia, which was considered in the SATREPS project, they have not successfully obtained the fund so far.

As for other impact, many female researchers participated in the SATREPS project and they had great achievements related to the H-FAME technologies in Thailand. It should be notable that the SATREPS project contributed to their excellent works.

No negative impact by the SATREPS project was confirmed at the time of ex-post evaluation.

<Evaluation Result>

Therefore, both the effectiveness and impact of the project is high.

Achievement of Project Purpose

Aim	Indicators	Results

(Project Purpose) Fundamental technologies to produce biofuels from non-food biomass for automotive utilization are developed.	Indicator 1: It is possible to produce Biodiesel Fuel (BDF) which meets the 'EAS-ERIA' Biodiesel Fuel Standards (10.0 hours oxidization stability which is higher than the UE standard EN 14214 of 6.0 hours) on a one (1) ton per day basis.	Achievement Status: Achieved (Continued) (Project Completion) ● The SATREPS project established technologies to produce H-FAME, high quality BDF, with 1 ton per day. (Ex-Post Evaluation) ● The research activities related to the H-FAME technologies have been continued.
	Indicator 2: The quality of biofuels from Jatropha residues produced and upgraded by the Project satisfies the quality standards of petroleum gasoline and diesel oil (sulfur contents < 10ppm, oxygen < 0.1wt%) at laboratory level.	Achievement Status: Achieved (Achieved) (Project Completion) ● Upgraded biooil processed by hydrorefining enabled to produce upgraded fuel which meets the quality of petroleum product (sulfur < 6.3 ppm, Oxygen <0.1wt%) (Ex-Post Evaluation) ● Refer to the Indicator 1.
(Overall Goal) Fundamental technologies to produce biofuels from non-food biomass for automotive utilization are developed.	Indicator By 2019, the improved technologies for biofuels from non-food biomass by the project are disseminated to researchers and engineering firms in Thailand through the Thai research institutions engaged in the project, including seminars, training courses, technical services and so on.	Achievement Status: Achieved. ● Research activities on the H-FAME technologies have been conducted since 2017 by the national project for upgrading biofuel from palm and efforts on commercialization has been promoted. In addition, the technical transfer to the major fuel production companies in Thailand was done for development of commercial scale production technologies. As a result, they succeeded a continuous operation for production with several tons per day in 2018. ● Although the H-FAME technologies were developed for production of biofuel from non-food biomass including Jatropha, the ones have been utilized for production of biofuel from palm (food biomass).

Source : Terminal Evaluation Report, JST Terminal Report, Questionnaire and Interview Surveys with MTEC, TISTIR and KMUTNB. Interview with the research group leader of the Japanese side.

3 Efficiency

Both the project cost and the project period exceeded the plan (ratio against the plan:114 %, 108%, respectively). The project cost exceeded due to an increase in cost for repairing the equipment damaged by the flood. The project outputs were produced as planned, except for the evaluation of automobile fuel compatibilities of biofuels from Jatropha residues which could not be implemented due to lack of bio-oil. The project period was extended for one year because the research facilities and equipment including the H-FAME production plant were damaged by the large scale flood in Bangkok and the vicinity areas in 2011 and their reconstructions took long time. In addition, the Japanese researchers were forced to evacuate for seven months by the evacuation order by the Ministry of Foreign Affairs of Japan

Therefore, the efficiency of the project is fair.

4 Sustainability

<Policy Aspects>

The Department of Alternative Energy and Efficiency of the Ministry of Energy clearly mentioned the further development of the H-FAME developed by the SATREPS project for commercialization as an action for attaining the goal to increase the blended portion of BDF (more than 7% BDF blended) in the "Alternative Energy Development Plan (AEDP 2015)". It was announced that B10 is designated as the standard BDF since October 2020. Therefore, it is expected that utilization of the H-FAME will be promoted as one of technical option to increase the BDF blended proportion. "AEDP" was revised to "AEDP 2018" and was approved by the Cabinet in October 2020. In the revised AEDP, while the target level of the goal was brought down to the realistic level, the expansion of BDF utilization has been continuously focused as one of goal and "test of H-FAME utilization by general diesel automobile" as an action to be promoted in order to attain the goal.

<Institutional/Organizational Aspects>

NSTDA and TISTR have sustained the organizational setting for the research activities related to H-FAME and other research institutions including universities have been continuously conducting the research activities. By the "Feasibility Study on Social Implementation of Bioenergy in East Asia" under the "e-ASIA Joint Research Program" (e-ASIA JRP), Japan and the ASEAN countries (Thailand, Vietnam, Indonesia, Myanmar and Lao PDR) aligned at the regional level and conducted economic assessment and lifecycle assessment (LCA) and so on as well as considered technical strategies for utilization of the H-FAME technologies in the society[2]. Also, the public-private network by the national project was established and has been sustained afterwards.

For the facilities and equipment installed by the SATREPS project, as mentioned above, the organizational setting for proper management was established by each research institution participated in the SATREPS project, and those research institutions have carried out regular maintenance and operation management.

<Technical Aspects>

The researchers involved in the SATREPS project have continued the research activities related to the H-FAME technologies through participations in the national project, the APEC project and so on, and they have continuously made efforts to keep or improve their research capacity. The research outputs by the SATREPS project were compiled in the project report. Moreover, they have been presented at many international conferences and published as academic papers. Also, MTEC invited Dr. Yoshimura, the team leader of the Japanese researchers, as a "Visiting Senior Researcher", by their own budget and had his guidance for their research activities. That enabled to

[2] https://www.jst.go.jp/pr/info/info1245/index_e.html

establish a system for enhancing their research capacity.

As for the government actions for utilization of the H-FAME technologies in the society, the implementation of the national project brought about the government authorities' deeper understanding on the H-FAME technologies in the background with the increasing interests in expansion of utilization of biofuel from palm from the viewpoints such as to support for the palm farms. Those facts indicate that the scientific literacy of the government authorities have been sustained or even improved. Furthermore, the relevant research institutions have contributed to dissemination and awareness raising on the research outputs of the SATREPS project since the H-FAME technologies were addressed in the workshops and symposiums organized or co-organized by them.

In terms of maintenance of the research facilities and equipment installed by the SATREPS project, the pilot plant for H-FAME production at TISTR has been continuously used after the project completion and the relevant researchers have sustained their skills and knowledge for operation and maintenance of the plant. The prototype extraction and separation apparatus at NSTDA was not in use at the time of ex-post evaluation as mentioned above. The relevant documents including manuals have been properly kept.

<Financial Aspects>

As mentioned above, the research budget has been secured by the national project for practical use of the H-FAME technologies. In addition, the budget for the utilization of the research outcomes has been ensured by the e-ASIA Joint Research Program of JST.

<Evaluation Result>

In the light of the above, there has been no problem from any aspects. Therefore, the sustainability of the effects through the Project is high.

5 Summary of the Evaluation

The project has achieved the Project Purpose and the Overall Goal through the development of the H-FAME technologies for upgrading BDF and the actions for commercialization of the technologies. The research activities related to the H-FAME technologies have been continued and disseminated to the ASEAN countries other than Thailand. As for efficiency, the project cost and the project period exceeded the plan. Considering all of the above points, this project is evaluated to be highly satisfactory.

III. Recommendations & Lessons Learnt

Recommendations for Implementing Agencies

[For the Ministry of Energy]

- Clarification of bioenergy as liquid transport fuel, formulation of the roadmap for establishment of the decarbonized society in mid and long run and continuation of efforts to ensure sustainable support

  While the energy transformation has been accelerated for the establishment of the decarbonized society, the reports by the international authorities, including the International Energy Agency (IEA) highlighted that biomass energy had extremely important role as a measure for realization of the decarbonized society, in particular, in Southeast Asian region. On the other hand, the stagnant oil price leads limited economic viability of BDF and large price volatility of palm which is one of raw materials for biofuel can be a risk for commercialization of BDF. Furthermore, progress of the competitive technologies, such as electric vehicles, affects economic viability of BDF. Therefore, it is recommended to formulate roadmap for higher blended proportion of BDF than B20 for the establishment of the decarbonized society and clarification of the bioenergy as liquid transport fuel as well as promotion of steady technological development in mid and long-run in order to sustain actions which are not affected by the prices of oil and biomass in short and mid-term. At the same time, it is desirable to continue efforts to obtain assistance from the countries and others for short-term.

[For NSTDA and TISTR]

- Establishment of production and utilization technologies of H-FAME at the commercial level

  For the establishment of the production technologies of H-FAME at the commercial level, it is necessary to smoothly and efficiently obtain technical data which becomes basic data for design, and to conduct technological development for scaleup and cost down of production as well as optimization of production process. Also, it is desirable to consider demonstration plants by the business group which is expected to lead the utilization of the H-FAME technologies for the society and to carry out capacity building for establishment of production technologies. Moreover, in terms of utilization of the technologies, it is essential to establish technologies for distribution and storage of BDF in addition to assessments of compatibility with exhaust gas process after EURO 5, oxidation stability, impacts of characteristics other than impurities (High Solubility, Low calories, High Boiling Point, High capability in water absorption) on vehicle.
- Establishment of business model and implementation arrangement for commercialization of BDF

  One issue to be considered is that an implementation entity in a business model for BDF supply has not established yet. It is desirable to propose feasible business models, such as establishment of joint business entity with the existing FAME suppliers after reviewing their business strategies and to take necessary actions for implementation of government supports.
- Implementation of continuous activities for dissemination of non-food biofuels

  It might be difficult to materialize utilization of biofuel from non-food biomass in the society in short-term, which is the original goal for the SATREPS project. However, it is recommended to continue the research activities on it from the mid- and long-term view.

Lessons Learnt for JICA:

- H-FAME, upgraded BDF developed by the SATREPS project, is clearly mentioned as an effort for attaining the goal of alternative energy in the "Alternative Energy Development Plan" of the government of Thailand. In addition, after the completion of the SATREPS project, the national project started and the technological development for commercial scale production and the actual vehicle running test were implemented. It is essential for the promotion of actions to utilize the research outcomes to reflect the research outputs in the policies at the national level. In order to do that, the research targets are needed to be consistent with the policy goal and socioeconomic needs of the country. Therefore, it is preferable to identify situations of the target country at the time of project formulation and preparation and to promote the relevant technologies to the responsible ministries at the stage when the research outputs are in prospect.
- In the background of the SATREPS project, the Japanese research institutions and the Thai research institutions had been jointly engaged in the international research project and they established a good relationship of trust with vigorous communication before

starting the SATREPS project, which facilitated the smooth implementation of the research activities and brought about the research outputs as expected. Also, the cooperation of the SATREPS project with the Ministry of Energy of Thailand and the private companies (oil and automotive) of the both countries of Thailand and Japan at the early stage of its implementation and demonstration of the technologies under the cooperation were effective for the promotion of the technologies to the relevant ministries. In addition, the follow-up activities at the post project period have contributed to ensuring sustainability of the project effects and promoting the utilization of the research outcomes in the society. JICA continuously supported to establish an environment for the utilization of the research outcomes through a dispatch of the ex-leader of the Japanese researchers as a "Senior Volunteer", delivery of the third country training programs to disseminate the research outputs to the neighboring countries, and implementation of the follow-up project for effectiveness assessment of H-FAME as countermeasures to cope with PM 2.5. As clarification of the path to the utilization of the research outcomes in the society requires long term, it is effective to establish the joint research system before implementation of the SATREPS project. Also, it is essential to consider a strategy for the post project period and to build cooperation among the stakeholders based on scientific evidence during the implementation of the SATREPS project.

- In order to actively conduct public relation activities on H-FAME, the PR group organized by the SATREPS project implemented PR activities with various channels, including PR at the workshops on bioenergy in Thailand, leaflets on the SATREPS project including H-FAME, active information sharing of the H-FAME technologies to the ASEAN countries through the third county training programs supported by JICA, introduction of the H-FAME technologies to the management of oil companies, biodiesel companies and automotive companies in Thailand. Those PR activities are effective to build a social leaven to utilize the research outcomes. Therefore, it can be an effective idea to incorporate PR activities in the SATREPS project at the time of project design.
- In the SATREPS project, development of the H-FAME technologies was expected to be use for upgrading the low graded Jatropha FAME. However, the project design was revised to consider diversification of raw materials for biofuel based on the request of the Ministry of Energy of Thailand which had planned to use high concentrated FAME. It is considered as a good practice because of the wider scope of application of the basic technologies and the flexible and timely revision of the project plan.

Partial hydrogenation apparatus (TISTR)

FAME production plan (TISTR)