Summary of Terminal Evaluation

<table>
<tr><td colspan="4">I. Outline of the Project</td></tr>
<tr><td colspan="2">Country：
Thailand</td><td colspan="2">Project title：
Innovation on Production and Automotive Utilization of Biofuels from Non-Food Biomass</td></tr>
<tr><td colspan="2">Issue/Sector：
Energy and Mining</td><td colspan="2">Cooperation scheme：
Science and Technology Research Partnership for Sustainable Development</td></tr>
<tr><td colspan="2">Division in charge:
Industrial Development and Public Policy Department</td><td colspan="2">Total cost：
about 480 million Yen</td></tr>
<tr><td rowspan="2">Period of Cooperation</td><td rowspan="2">Cooperation period:
(R/D): 16 May 2010 to 31 March 2015
(Extension): 16 May 2010 to 31 March 2016</td><td colspan="2">Partner Country’s Implementing Organization：
• National Science and Technology Development Agency (NSTDA),
• Thailand Institute of Science and Technological Research (TISTR),
• King Mongkut’s University of Technology North Bangkok (KMUTNB)</td></tr>
<tr><td colspan="2">Supporting Organization in Japan：
• National Institute of Advanced Industrial Science and Technology (AIST),
• Waseda University (WU)</td></tr>
<tr><td colspan="4">1. Background of the Project
Research on alternative energy has a long history in the Kingdom of Thailand. Development of bioethanol and biodiesel have been addressed as parts of the Royal Projects since around 1970 and energy generated from food biomass such as oil palm and sugarcane are currently the mainstream. On the other hand, it is preferable to avoid utilizing food biomass for generating fuels; thus, examination on this method is required. Due to this background, there have been growing needs for clarification of development mechanism of non-food biofuels and standardization of tests on these biofuels in Thailand. Although Jatropha oils and surplus agriculture residues are listed as potential feedstock for production of non-food biofuels, Jatropha contain toxic materials such as phorbol ester, so their detoxification is needed for utilization as biofuels. Development of fundamental technologies for upgrading biofuels as automotive utilization is essential and technical problems are required to be overcome.

Considering these situations, the Government of the Kingdom of Thailand requested support of the Government of Japan under the form of scientific technical cooperation (SATREPS) with aiming at innovating technologies of biofuels production from non-food biomass. In response to this request, detailed planning survey was conducted in September 2009 and the record of discussion (R/D) on</td></tr>
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technical cooperation project “Innovation on Production and Automotive Utilization of Biofuels from Non-Food Biomass” with the period from May 2010 to March 2015 was signed in February 2010. The Project was extended one year up to March 2016 in consideration of the influence caused by the heavy flood in 2011. Therefore, the Project period is six years, which has another additional one year on the original schedule.

2. Project Overview

(1) Overall Goal

The Improved technologies for biofuels from non-food biomass by the Project are disseminated in Thailand.

(2) Project Purpose

Fundamental technologies to produce biofuels from non-food biomass for automotive utilization are developed.

(3) Outputs

(For Research Achievement 1) Establishment of technologies to produce high quality and safe BDF from Jatropha oil

【Task 1】

1. Detoxification conversion technology for production of non-toxic BDF is developed.
2. Standardized production technology of high-quality BDF in a pilot-scale is developed.
3. Catalyst utilization technology for upgrading Jatropha BDF is developed.
4. CO_2 reduction effect of high quality BDF from Jatropha oil is clarified by the Life Cycle Assessment (LCA).

【Task 4】

5. Automobile fuel compatibility of high quality BDF produced by the Project is proven.

(For Research Achievement 2) Establishment of production technology of bio-oil and high quality automobile fuel from Jatropha residue

【Task 2】

6. Production technology of bio-oil from Jatropha residues by thermal/ catalytic conversion is developed.
7. Separation and stabilization technologies of bio-oil are developed.

【Task 3】

8. Deoxygenation and catalytic hydrotreating technologies for upgrading of bio-oils to the quality of petroleum gasoline and diesel oil are developed.
9. Co-processing technology of deoxygenated bio-oils and conventional petroleum, which can be utilized at a conventional petroleum refinery, is developed.
10. CO_2 reduction effect for using Jatropha derived oils as transportation fuels is clarified by the Life

Cycle Assessment (LCA).

【Task 4】

11. Automobile fuel compatibility of bio-oils from Jatropha residues, including bio-oils upgraded with conventional petroleum, is proven.

(For human resources development/technology transfer, practical application of BDF production technologies)

【Task 5】

12. Researchers involved with biofuels production and utilization are nurtured.

13. Preparations for practical application of BDF production technologies are done.

(4) Inputs

Japanese side：Total cost about 270 million Yen

1) Experts　18 short term expert (28 MM), long term expert as Project Coordinator (2 in total)　2) Persons who participated in trainings in Japan　36 persons

3) Equipment

Pilot Plant for high quality biodiesel fuel production, Standard apparatus for catalytic reaction test, Real-time PM analyzer, Liquid chromatograph, etc.

Thai Side：

1) Counterparts: 95 counterparts

2) Facilities (Project office at NSTDA, TISTR, KMUTNB) and equipment for analysis

3) Local cost for daily local activities and automobile running test, conversion cost of pilot plant at TISTR, and maintenance cost for the laboratory at KMUTNB, etc.

II. Evaluation Team

Members of Evaluation Team

No.	Name	Position	Organization
1	Mr. Kaoru Suzuki	Team Leader	Senior Advisor to the Director General (Energy), Industrial Development and Public Policy Department, JICA
2	Mr. Yamato Kawamata	Planning and Coordination	Assistant Director, Team 1, Energy and Mining Group, Industrial Development and Public Policy Department, JICA
3	Mr. Jun Totsukawa	Evaluation Analysis	Director, Sano Planning Co., Ltd
4	Mr. Masayuki Sato	Observer	Principal Associate Research Supervisor, Department of International Affairs (SATREPS Group), JST

Period of Evaluation	31/January/2016-13/February/2016	Type of Evaluation： Terminal Evaluation

III. Results of Evaluation

3-1 Accomplishment of the Project (note: The word of H-FAME in this paper has the same meaning as high quality BDF)

3-1-1 Achievement of the Outputs

(For Research Achievement 1) Establishment of technologies to produce high quality and safe BDF from Jatropha oil

【Task 1】Production of high quality BDF from Jatropha oil

1. Detoxification conversion technology for production of non-toxic BDF is developed.

Achieved: The phorbol ester was reduced below its detection limit, which satisfies the safety level.

2. Standardized production technology of high-quality BDF in a pilot-scale is developed.

Achieved: A high quality BDF production plant with detoxification and oxidation stabilization units was already installed at TISTR.

3. Catalyst utilization technology for upgrading Jatropha BDF is developed.

Achieved: The Project's output, H-FAME, satisfies the quality requirement of EAS-ERIA Biodiesel Fuel Standards, EEBS:2008 as well as the Bio-Diesel Guidelines of the World Wide Fuel Charter.

4. CO_2 reduction effect of high quality BDF from Jatropha oil is clarified by the Life Cycle Assessment (LCA).

Achieved: In the process of FAME production, the emission amount of CO_2 was calculated as approximately 0.42 $kgCO_{2\ eq}$/kg FAME, and the one during the transition process to H-FAME was approximately 0.18 $kgCO_{2,eq}$/kg H-FAME.

【Task 4】Evaluation of automobile fuel compatibilities of high quality BDF

5. Automobile fuel compatibility of high quality BDF produced by the Project is proven.

Achieved: Engine bench test and automobile running test of mixed oil confirmed the compatibility with the automobile fuel. Material compatibility evaluation results showed that H-FAME has the same quality of existing BDF in terms of material corrosion and elastomer swelling.

(For Research Achievement 2) Establishment of production technology of bio-oil and high quality automobile fuel from Jatropha residue

【Task 2】Production and upgrading of bio-oil from Jatropha residues

6. Production technology of bio-oil from Jatropha residues by thermal/ catalytic conversion is developed.

Achieved: By use of Ultra Stable Y zeolite and Beta zeolite, the residual oxygen in the Jatropha bio-oil reduced below 5wt%.

A prototyped circulating fluidized bed pyrolyzer was developed and installed at TISTR. It started operation at the end of 2014 and treats Jatropha residue between 300kg and 500 kg per day.

7. Separation and stabilization technologies of bio-oil are developed.

Achieved: The Project successfully developed technologies for bio-oil separation and stabilization. A prototyped water extraction separator that enables to separate bio-oil into water-soluble fractions and water-insoluble ones was also developed and installed at NSTDA.

【Task 3】Upgrading Bio-oils and Life Cycle Assessment

8. Deoxygenation and catalytic hydrotreating technologies for upgrading of bio-oils to the quality of petroleum gasoline and diesel oil are developed.

Achieved: By use of sulfide $NiMo/Al_2O_3$, the oxygen content of bio-oil from Jatropha residue was reduced from 23wt% to between 9 and 12wt%.

9. Co-processing technology of deoxygenated bio-oils and conventional petroleum, which can be utilized at a conventional petroleum refinery, is developed.

Achieved: The Project developed co-processing technology of deoxygenated bio-oil and conventional petroleum. The quality of fuel satisfies the indicator's requirements as follows: the figure of sulfur, between 6.3 and 16 ppm, and oxygen content, below 0.1wt%.

10. CO_2 reduction effect for using Jatropha derived oils as transportation fuels is clarified by the Life Cycle Assessment (LCA).

Achieved: CO_2 emission in the process of Jatropha residues pyrolysis to bio-oil and its upgrading was clarified.

【Task 4】Evaluation of automobile fuel compatibilities of biofuels from Jatropha residues

11. Automobile fuel compatibility of bio-oils from Jatropha residues, including bio-oils upgraded with conventional petroleum, is proven.

Partly not achieved: Automobile fuel compatibility of biofuels was confirmed by the evaluations on material compatibility, but not yet by engine combustion performance. Engine combustion performance evaluation has not been conducted yet mainly because of insufficiency of biofuels volume for implementation of the engine bench test.

【Task 5】Human resources development/technology transfer, practical application of BDF production technologies

12. Researchers involved with biofuels production and utilization are nurtured.

Achieved: In the course of the Project implementation, the Project related personnel elaborated many of research papers and presentations.

13. Preparations for practical application of BDF production technologies are done.

Achieved: Through implementation of the Project along with discussion between Thai and Japanese sides, the followings are identified as necessary issues to tackle: 1) Stable procurement of raw material, 2) Quality of H-FAME, and 3) Business feasibility. In this line, the Project has already started

preparation of making proposals for the next phase.

3-1-2 Achievement of the Project Purpose

Project Purpose: Fundamental technologies to produce biofuels from non-food biomass for automotive utilization are developed.

The Project has been achieved as of the Terminal evaluation.

The Project produced H-FAME from Jatropha, which satisfies the 'EAS-ERIA Bio-Diesel Fuel Standards'. The H-FAME produced by the Project showed 15.1 hours oxidation stability while the EAS-ERIA standard's minimum requirement is 10 hours. (Indicator 1)

The quality of biofuels from Jatropha residues by the Project also satisfies the quality standards of petroleum gasoline and diesel oil through its upgrading process. (Indicator 2)

3-2 Summary of Evaluation

* Five categories are evaluated by five ranks: high, relatively high, moderate, relatively lower, and low.

3-2-1 Relevance: High

The Project is in accordance with the priority of development policies of Thai government and with Japan's Assistance policy.

The Eleventh National Economic and Social Development Plan 2012-2016 stresses the importance on research and development to increase the productivity and utilization of bio-energy. In addition, the Alternative Energy Development Plan 2012-2021 as well as the revised one in 2015 declared further promotion of bio-energy use along with research and development.

The Project's contents meet with such policies' direction and technical needs of the counterpart organizations including research institutes and university. In this line, the relevance of the Project is evaluated high.

3-2-2 Effectiveness: High

The Project purpose, which is to produce biofuels from non-food biomass for automotive utilization, has been satisfactorily achieved as of the Terminal evaluation. By use of Jatropha, the Project developed the technologies to produce H-FAME, which is the upgraded product of FAME, through hydrotreating process. The technologies to upgrade bio-oil from Jatropha residue were also successfully developed.

3-2-3 Efficiency: High

Manpower inputs from both Japanese and Thai side and material inputs contributed to achievement of outputs. Facility/material inputs as pilot plant for H-FAME and bio-oil production also gave a great impact on the Project's achievement. Flexible budget allocation by Thai side also enhanced efficiency of the Project activities such as automobile running test.

3-2-4 Impact: High

Impacts on policy, organizational and technical aspects are observed. One of the remarkable outputs by the Project, H-FAME, is reflected as one of prospective biodiesels in the revised Alternative Energy Development Plan (AEDP) 2015-2036. As to the organizational aspect, the Project promoted tighter relationship among stakeholders in line with research institutes, university, Ministry of Energy, and private companies. Also, the Project activities contributed to enhancing the technical knowledge of young researchers, and increased the number of academic reports/papers. Moreover, as the technical aspect, the H-FAME technology can be applied to both no-biomass and biomass materials.

3-2-5 Sustainability: Relatively High

1) Policy aspect

Thai government's Alternative Energy Development Plan towards the year of 2036, which shows the strong will of the government to enhance research and development of H-FAME and its utilization to the target year. It is evaluated that the sustainability of policy aspect is basically high. However, the global market of the oil price can be a risk factor to influence on the future of the policy intension.

2) Organizational and technical aspect

All the organizations who participated in the Project have solid and sustainable organizational structure and technical expertise, serious concerns on their sustainability are not observed.

3) Financial aspect

As of the Terminal evaluation period, the Project has already prepared several proposal options in order to continue the studies with larger scale plants of H-FAME production. The options of the budget sources are fund from Japan and another from Thai private companies'. Both options have a certain level of possibilities to successfully receive the budget, though, it is not assured yet.

3-3 Contribution factors

- Effective use of assets on personal relation and infrastructure between Japan and Thailand

Japan and Thailand has kept long and good relationship for long time not only by the JICA project but also collaborative research works. The Project was able to proceed on the basis of such historical assets not only on laboratory infrastructure but also personal relationship. It helped both sides to work in harmonized manner all the time.

- Recognition of management strata personnel of counterpart organizations

The management strata personnel's high recognition led to securement of the budget for not only the daily works at the Project activities but also relatively large amount of budget such as automobile running test by NSTDA.

- Cooperation by a private company

The Project received cooperation from a private company on automobile running test. Its cooperation

contributed to achievement of the Project purpose.

- Frequent communication among the Project personnel

The Project paid attention on frequent and close communication not only within the researchers but also with government officials including Ministry of Energy. Such elaborated communication environment led to reflection of the Project's outputs on policy document of the Thai energy sector.

- Active implementation of public relations

Public relations were also actively and effectively conducted in the Project to disseminate the Project's outputs to relevant stakeholders through exhibition at science expo, distribution of brochures, making PR video, etc.

3-4 Inhibition factors

- Heavy flood in the year of 2011

Heavy flood in 2011 caused the damage of the pilot plant for H-FAME production, and also put off installation timing of another pilot plant for bio-oil production at TISTR. The postponement of installation of bio-oil production plant accordingly caused the delay in bio-oil production. Vice versa, the one-year extension arrangement produced positive effects. The most representative example is reflection of the Project's output, H-FAME, on the newly revised Alternative Energy Development Plan in 2015.

3-5 Conclusion

A series of the Project activities and its purpose were consistent with the Thai governmental policy and the needs of the government as well as the counterpart organizations including NSTDA, TISTR and KMUTNB.

The Project achieved successfully the purpose as originally expected. The highlighted output as H-FAME technology was reflected in the newly revised Alternative Energy Development Plan to 2036 since the Ministry of Energy recognized the potential through a variety of events in particular of the automobile running test. It should be noted as a great impact produced by the Project.

All the Project related organizations together have already prepared the next phase actions, demonstration project. Sustainability towards the social application stage is almost ensured along with this preparation effort. The remaining issue is to finalize the budget source for implementation of the demonstration project.

3-6 Recommendations

(1) Implementation of demonstration project

It is recommended that demonstration project on H-FAME with larger scale plant be implemented as the next stage towards social application stage. It is necessary to start discussion regarding which organization to take what roles in the demonstration project including the secretariat role for coordination of the stakeholders.

(2) Keeping and/or developing communication network

It is recommended to sustain the communication network that the Project established, and to develop further with supply side players such as Ministry of Agriculture, and user side players as oil makers and automobile makers.

(3) Continuous studies of bio-oil, and biofuel from non-food biomass

It is recommended to continue the study of bio-oil, and biofuel from non-food biomass including Jatropha from the viewpoint of business and reliable supply chain for the future.

(4) Dissemination of the research outputs to ASEAN countries and others

It is recommended for Thailand to disseminate H-FAME technology to ASEAN countries as a technical leader of H-FAME in the region through Asian and Pacific Centre for Transfer of Technology, International Renewable Energy Agency, etc.

3-7 Lessons learned

- Effectiveness of communication platform

The Steering Committee effectively functioned to enhance communication among the counterpart organizations and the government officials including Ministry of Energy. With an eye to policy reflection, key ministries should be invited in communication events even if they are not official counterparts.

- Effectiveness of earlier contacts with private companies

The Project has been paying attention on the importance of collaboration with private companies. Therefore, the Project had started making contacts even before the Project's research produced tangible outputs. Such earlier contacts accordingly formulated mutual consensus, and resulted in receiving cooperation from a private company. The lesson in here is to make earlier contacts with private companies towards not only for enhancement of the Project activities but also for the future actions to social application stage.

3-8 Follow up

Nil