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Developing New BDF (Bio Diesel Fuel) Program towards Zero Emission

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Abstract

The negative impact of pollutants in any form to the environment, makes it imperative for mankind to develop systems that shall attain zero emission. Recognizing this and to be able to contribute in attaining that goal, we at Mie University, are now developing a BDF program towards zero emission in our newly established Iga Integrated Research Institute, Mie, Japan. This paper introduces to you the existing and proposed projects as well as our activities in the institute.

The Japanese government in 2006 designed and revised "The fundamental policy for biomass utilization" to enhance more effective utilization of biomass to recover energy from the wastes. Major unutilized wastes include among others, livestock excreta, sawmill dusts, logging residues, food residues and sewage. These wastes especially, livestock excreta, sawmill dusts and logging residues abound in rural areas where progress is slow because of underpopulation due to immigration. The Japanese government hopes to be able to address this concern by generating jobs through the establishment of "Biomass Town Project" under the Ministry of Agriculture, Forestry and Fishery (MAFF). The planned project targets the reutilization of more than 90% of wastes and the effective utilization of more than 40% of biomass from lumber and forest residues. To support this target, the government had already mobilized more than 300 municipalities all over Japan.

However, specific properties of biomass such as bulkiness and low energy per unit density cause some difficulties in their collection and handling. These entail high costs in transporting biomass to other places from generation areas. Utilization of biomass in areas where it was produced will develop and activate the locality through employment generation. It will also relieve other areas from receiving wastes generated elsewhere under the precept, "local production for local consumption." This is a good reason to get some public support to construct sustainable society.

Located northwest of Mie Prefecture, Iga City's major industry is agriculture, such as, stockbreeding and forestry. Under the "Biomass Town Projects", Iga City in 2008 proposed to undertake "Rape-seed oil project" (Iga Nanohana project) to the National government in order to attract young people to repopulate the area and reinvigorate the aging population.

One of essential features of this project is the creation of renewable energy from used vegetable oil and the rape-seed oil as biodiesel fuel (BDF) for agricultural machineries. And unlike the biodisel fuel (BDF) from EU which was synthesized from vegetable oils (sun flower, rape seed), the BDF in Japan is synthesized from kitchen waste oils. This explains the high production of BDF (several thousands liters per cycle) in EU compared to very low production in Japan (average of 100 liters per cycle). The exception is Kyoto City-Hall, a model on the use of BDF from recycled vegetable oils, which produces from 50～200L/cycle.

The BDF processors in Japan are called as "Community scaled BDF-Processor" which are usually enterprising cities, towns and villages or a small business without know-how and technical skills in BDF production. To help Iga City hall make BDF effectively, Mie University and Mie Prefectural Environmental Institute participated in this project starting from the planning stage. This report outlined the Iga-nanohana project and current status of BDF production from the BDF-Processor in local area.

Currently, we are investigating BDF production from used oil but our future plans include exploration of other BDF sources such as phytoplankton, Jathropa and other potential materials for biofuel production. Taking care of the terrestrial environment through zero emission programs is a step that can be taken to control or even prevent the negative impact of land-based activities to the coastal environment.

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The Japanese government have recently designed and revised "The fundamental policy for biomass utilization" in 2006 to enhance more effective utilization of biomass for recovering energy from the waste. Major unutilized waste included livestock excreta, sawmill remainder, logging residue, food residue and sewage waste. Especially these waste such as livestock excreta, sawmill remainder and logging residue, distributed in rural areas where make progress underpopulation. Japanese government counteracts low population for these areas from the view point of Biomass utilization.

However, specific properties of biomass such as bulky and low energy density cause some difficulties of their collection and handling. This does not allow biomass transportation with low cost but "local production for local consumption." Therefore, biomass utilization in the generated area will develop and activate rural area by creating additional employment. This is a good reason to get some public support to construct sustainable society. Depending on this concept, Ministry of Agriculture, Forestry and Fishery (MAFF) planned "Biomass Town Projects", containing reutilization of waste more than 90% and effective utilization of unutilized biomass such as lumber and forest residues more than 40% and asked to municipalities to set up the projects more than 300 in all over Japan.

Iga-city, located northwest at Mie Prefecture, major industry of this city is agriculture, such as, stockbreeding and forestry. Iga-city proposed "Biomass Town Projects" as "Rape-seed oil project"(Iga Nanohana project) to National government at 2008, to activate a depopulated and an aged area. One of essential features of this project is creation of renewable energy production by waste vegetable oil and the rape-seed oil to supply fuel as biodiesel fuel (BDF) to agricultural machine.

While, the biodiesel fuel (BDF) was synthesized from vegetable oils such as seed of sun flower or that of rape seed from EU, it was synthesized from kitchen waste oils from Japan. Reflecting these conditions, the production scale of BDF was several thousands liter per cycle in EU. However, except Kyoto City-Hall case, production scale of BDF is very small (50 ～ 200 L/cycle). These BDF processors in Japan were called as "Community scaled BDF-Processor". An enterprising body of the BDF-processor is cities, towns and villages or a small business without know-how and technical skills for BDF production. To help Iga-city hall to make BDF effectively, Mie University and Mie prefectural Environmental Institute participated in this project starting with the planning stage. This report outlined of Iga-nanohana project and current status of BDF production from the BDF-Processor in local area.

Materials and Methods

Chemical qualities of BDF

We visited BDF-facilities in our area, and carried out oral questionnaire such as (1) installation year, (2) production volume (L), (3) operation frequency, (4) purification process of BDF, (5) waste water treatment, and (6) treatment of waste glycerin. And synthesized BDF, byproducted waste glycerin and wastewater were collected from 13 facilities (n=13) to analyze chemical qualities. The compositions of BDF were analyzed by GC-FID, and purity of glycerin also was determined by HPLC in normal phase with differential refractometer. The Qualities of waster water were analyzed along JIS-K0102, such as pH, suspended solid (SS), BOD, COD, and n-hexane extracts (oil and grease).

Outline of Iga-City

Iga city located at northwest of Mie prefecture. Major area of Iga was included in Iga-basin. Therefore temperature difference between hot and cold season was quite large intervals. Percentage of primary industry was 5.8% in industrial nomenclature. Agriculture is key industry. However, this agriculture society is rapidly aging with lack of heritor. From the view point of land inventory, forestry covered over 61.8% in this basin, while farmland was 14.3% (Table 1). Therefore, city government enforces a policy dividing administrative district into 3-categories (farm, forestry and resident). On the other hand, since high way from Osaka and Nagoya runs through Iga, recently tourists headed this area in the search of "Greenary and Forestry". Moreover, world wide well known Matsuo Basho (Haikai) was originally from this city. For these reasons, Iga-city potentially has the ability to pull in more customers.

Overview of "Iga-Nanohana" Project

Reflecting above mentioned situation of agriculture and nature, Iga City hall established "the Biomass Town Project" named Iga Nanohana (in Japanese) Project aiming at activation of an agriculture area and reservation of new employment (Fig. 1). The important features of the project are construction and implementation of recycling system based on agriculture. That is, the farmer grows rape using land lying idle and vegetables without agrochemicals. The farmer also makes rape-

Table 1 Brief overview of Iga (2005)

Area (Km2)	558					
Population	100,623					
Households	34,575					
Land inventory						
	Farmland	Forestry	Aqueduct	Road	Residentia	Others
ha	8010	34522	1185	2471	2821	6808
%	14.3	61.8	2.1	4.4	5.1	12.2
	Farm households					
	6720					
industrial nomenclature						
	Primary (%	Secondary	Tertiary			
	5.8	40.6	53.6			

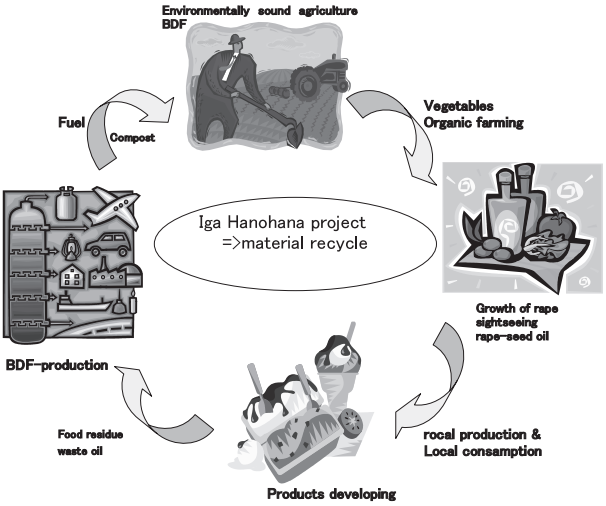

Fig. 1. Outline of Iga-Nanohana Project (Biomass Town).

seed oil from the rape. These crops were sold at project center periodically. The consumer purchases these crops. After that, generated waste oil was collected by Iga-city with suitable manner and is returned to a farmer as BDF by conversion facility for farm machines and implements. At the same time, generated food residue from individual houses and night soil (including animal excreta) converted in compost by same conversion facility. These materials support farm house. This recycling system is called as "Nanohana Project" in Japan. The Nanohana Project becomes also one of important constituent factor in Biomass Town Project. As we mentioned before, major raw material of BDF in Japan, was waste vegetable oil. Therefore, production volume of BDF was restricted by collected volume of waste oil at targeted area. Since the volume of waste oil collected not only domestics but also industry ranged from 10000 to 20000 L/yr in population size from 10000 to 100000, it was not enough to synthesize BDF for all farmers in Iga area. In this project, Iga-city hall prepared 100ha as growing area for rape to crop rape seed. This growing area was the widest one in Japan. Moreover, after oil pressing from rape seed, a lot of oilcake was byproducted from oil milling. The oilcake also became good compost for vegetable growing in farm and gardening for residents. This route also is recycling system based on agriculture.

Results and Discussion

Current status of "Community scaled BDF-Processor"

More than 15-BDF processors were installed in Mie prefecture. Details of typical processors were listed in Table 2. As the production volume of BDF range from 50 to 200 L/cycle, the scale of BDF-production was relatively small in our area. From this Table 2, most of installation sites make choice of wet-type (synthesized raw BDF was neutralized by H_2SO_4 or HCl, then salted out by NaCl, and rinsed by tap water and dewatered at 98℃) to improve the purity of BDF. This generated rinsing water containing with high concentration of BDF became waste water from BDF-processor and consist of one of serious problems in this process (Table 3). Low quality (Table 4) glycerin was by producted not only wet-type but also dry-type (use raw BDF as fuel without purification). In order to treat this liquid waste, business owner pay 40 ～ 60 yen/L to waste processor. The treatment of waste water and bypoducted glycerin were essential problems of installation of BDF-processor. Another problem of BDF is utilization as fuel. Japanese government enforces the utilization of 5%BDF mixed with diesel fuel (B5), but every places where we visited use BDF as B100%.

Chemical quality of BDF

There is an official standard for BDF-quality (B5) in our country because government enforces B5 utilization as fuel. However as we pointed out above, most of companies and local governments use BDF as B100%. Taking into consider-

Table 2 Current operational condition of BDF-processors

	Company		Local government			
	Todaya-Hotel	Daikyo.Ltd	Miyama	Fujiwara	Nagasima	Futami
Population(2003)			9963	7253	10617	9008
Number of households			4074	2170	4399	2999
Number of deposit-site			15	65	80	11
Recovery frequency			1／month	2／week	1/week	2/month
Start	2002	2006	2003	2001	2002	2002
Capacity(L/day)	50	100	100	50	100	entrust production
Operating day(day/month)	16	every day	6	15	4-8	—
BDF-production(L/Y)	10000	24000	12000	24000	9000	
Waste glycerin	¥50/L	¥50/L	¥50/L	¥50/L	¥50/L	¥50/L
BDF-processor	Dry	Wet	Wet	Wet	Wet	—
Waste water	no	exist	exist	exist	exist	-
B100% or B5*	B100%	B100%	B100%	B100%	B100%	B100%

Table 3 analysis of waste water from BDF-processor

	pH	EC	COD	BOD	SS	oil & griese
waste water #1			60000	2640		144900
waste water #2	7.35	1164	8250	315		313
waste water #3	7.3	452	2840	100	510	304
waste water #4	6.58	82	25000	52	316	110
waste water #5	6.87	145	1700	232	255	510
waste water #6			6250	1840	7700	4250

EC;uS/cm
COD-oil& griese:mg/L

Table 4 Composition of byproducted glycerin

	pH	Glycerin(mg/g)	K(mg/g)
waste glycerin #1	10.3	350	41.8
waste glycerin #2	10.3	400	62.1
waste glycerin #3	10.3	358	45.9
waste glycerin #4	10.4	358	46.0

ation no official standard, Kyoto-city hall, where local government established effective introduction of BDF (B20) as fuel for public bus routes for the first time, and proposed tentative standard (named Neat standard) for B100%. We analyzed and compared chemical properties collected BDF with this tentative standard except color of BDF. The color of collected BDF was from dark to light yellow without turbidity. The density (22 ℃) of BDF fall within from 0.86 to 0.90 (g/ml) except only one sample. According to the Neat standard, content of fatty acid methyl ester (FAME %) is over 96.5%, the content of FAME collected BDF fall within from 72-100% by HPLC analysis, on the contrary, the content of residual triglyceride fall within 0.03 to 3%, respectively. Since higher concentration of triglyceride in BDF caused significantly engine damage, to improve esterification efficiency is next task of processing. Major components of FAME are methyl ester of oleic acid and linolic acid reflecting composition of vegetable oils in Japan (Fig.2). The other parameters which need quality control of BDF will be analyzed further investigation.

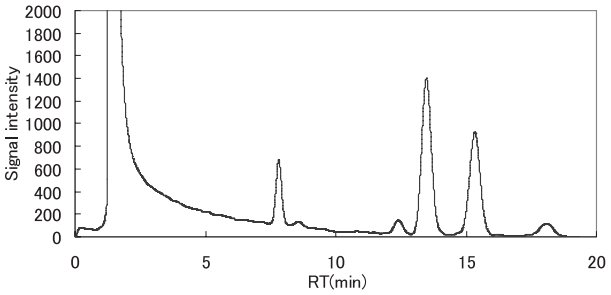

Fig. 2. Major components of BDF.

Estimation of BDF production volume from "Nanohana Poject"

In the initial stage of the project, an ability of BDF-conversion facility from waste oil is only 100 L/cycle. However, this production volume is not enough to operate all agriculture machines in targeted area. Moreover, when BDF-processor substantially operated every day, feed volume of waste oil in the area does not draw level with conversion rate from survey of questionnaires. Therefore Iga-local government taking Nanohana Project a stage farther, 100ha farm land for the rape

growing was prepared in this project at second stage. From this farm land, we can crop 200,000 (max case) kg/yr rape seed. The estimated obtained BDF volume is 60,000 L/yr and the volume of estimated oil cakes is 140,000 kg/yr respectively. In this secondary stage, major source of BDF manufacture changes waste vegetable oil into rape seed oil (Fig. 3). From this calculation, byproducted glycerin was 9600 kg/yr. Development of low cost and effective development and utilization of glycerin became prime task in this project. Noting relatively high concentration of residual K as catalyzer, an utilization as compost was investigated by biodgradation of glycerin. $1m^3$ of wooden chip and $1m^3$ of food residues (as microbial source) was mixed by power shovel. 1% of byproducted glycerin was successively loaded to this mixture. Fermentation of glycerin by microbial consortium was carried out in the out side without special treatment. Glycerin concentration in the mixture became detection limit (<50ppm) within 1-month (Fig. 4), but the case of 10% loading of glycerin to the mixture, the concentration of residual glycerin was about 1% with same period. These results suggested us biodegradation of glycerin for compost with low cost.

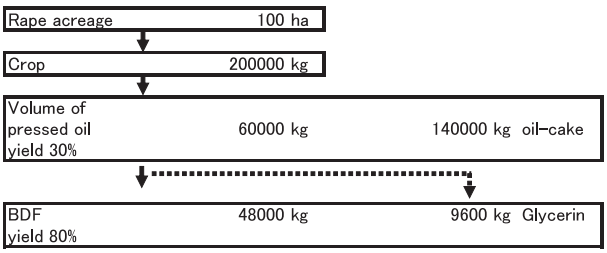

Fig. 3. Estimated amounts of BDF, oil-cake and glycerin of Nanohana-project.

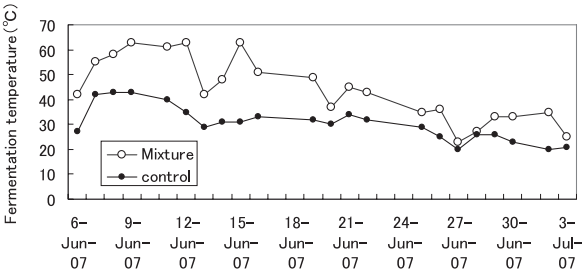

Fig. 4. Variation of fermentation temperature of glycerin decomposition.

Conclusion

BDF can be used as an alternative fuel to fossil one. However, the cost of the byproducted glycerin and wastewater treatment are weak points which are fastened to a running cost became large. Therefore creation of the added value exceeding these negative costs is considered to be a further subject. The "Nanohana Project" proposed in this report is considered to be one of the countermeasures of weak points.