Production Efficiency Analysis of Biodiesel fuel Production Plants in Japan

Mari OGATA, *Graduate School of Economics, Kyushu University, Fukuoka, Japan*

1. INTRODUCTION

【What is Biodiesel Fuel ? 】

Biodiesel fuel (BDF) is a fuel for diesel engines made from vegetable oil. In Japan, it is produced from waste cooking oil collected from businesses and households.

BDF is a non-carbon-increasing (carbon-neutral) fuel that can contribute to the reduction of CO_2 emissions.

In Japan, a new "Basic Plan for the Promotion of Biomass Utilization" was approved by the Cabinet in 2016, and it is expected that BDF will be used as an energy source.

【What's the issue?】

Due to the high production cost of BDF, many factories have been forced to abandon their business due to unprofitability.

In order to solve this problem, it is important for BDF production plants to be efficient, reduce production costs, and increase profits.

【Aim statement】

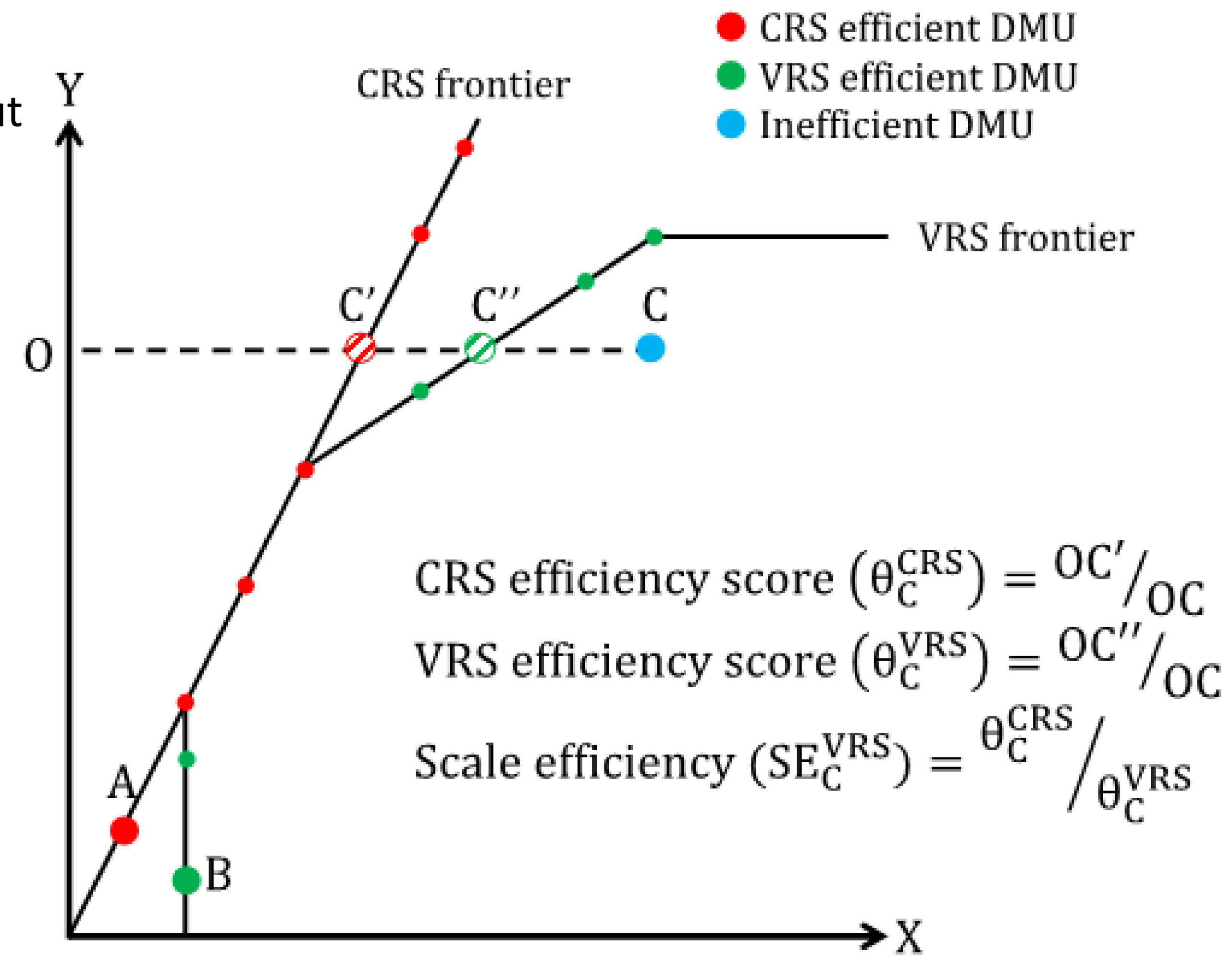
In this study, we evaluated the production efficiency of 39 BDF production plants in Japan and estimated cost reduction potential.

Finally, we propose measures to improve the production efficiency of inefficient plants.

2. METHODOLOGY and DATA

【Data envelopment analysis (DEA)】

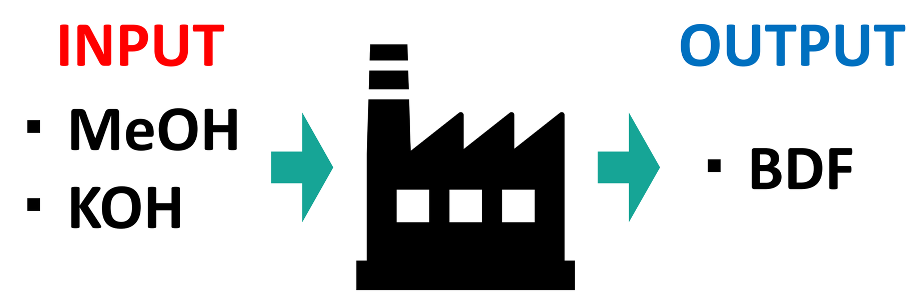
- Graph on the right shows the amount of input (horizontal axis) and output (vertical axis).
- The dots in this graph represent decision-making units (DMUs: BDF factories in this study).
- Assuming constant harvest, red points like A are efficient, and assuming variable harvest, green points like B are efficient and
- DMUs with inefficient production are represented by blue dots like C.
- Inefficient DMUs can be estimated as the percentage deviation from the efficiency frontier.
- Scale Efficiency (SE) can be estimated by dividing the CRS efficiency score by the VRS efficiency score.



CRS efficiency score $(\theta_C^{CRS}) = OC'/OC$

VRS efficiency score $(\theta_C^{VRS}) = OC''/OC$

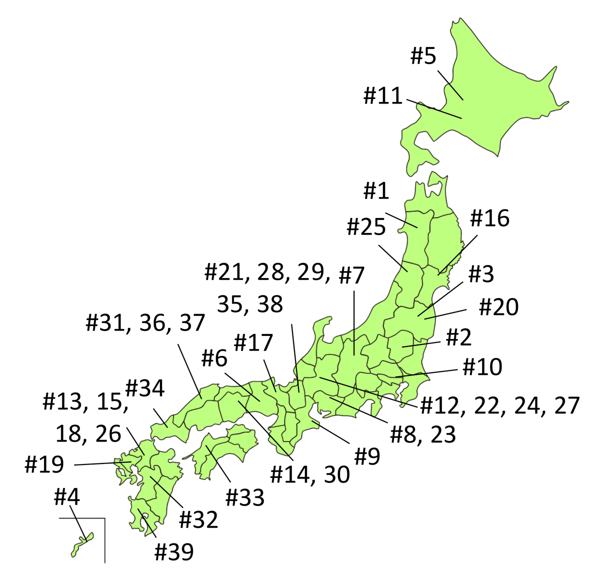
Scale efficiency $(SE_C^{VRS}) = \theta_C^{CRS}/\theta_C^{VRS}$



【Data】

In this study, we evaluate the efficiency of 39 plants using data on the annual input of methanol and potassium hydroxide and the output of BDF.

The data is taken from the "Biomass Utilization Technology Information Database" available on the website of the Japan Center for Regional Environmental Resources.



3. RESULT and DISCUSSION

【Result 1. Efficiency score】

The results of the efficiency score of the CRS model showed that there were three efficient plants with an efficiency score of 1 (Nos. 9, 17, and 28) and 36 inefficient plants with an efficiency score of less than 1. In other words, 92% of the BDF plants in Japan were found to be producing inefficiently.

The four plants (Nos. 23, 27, 29, and 30) that were inefficient in terms of CRS score but efficient in terms of VRS score have no problems in terms of technology but need to improve their production scale. In contrast, the 32 plants that were inefficient in both CRS and VRS scores need to improve both their production technology and production scale. Since the VRS and SE scores represent the ratio of improvement in technology and scale, these plants need to improve their efficiency with reference to the VRS score and SE ratio.

Table 1. Efficiency score and scale efficiency for BDF plants

No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
CRS	0.77	0.71	0.98	0.76	0.79	0.92	0.78	0.86	1.00	0.79	0.71	0.84	0.71	0.66	0.70	0.81	1.00	0.78	0.82	0.91
VRS	0.85	0.94	0.98	0.77	0.80	0.93	0.94	0.91	1.00	0.80	0.77	0.89	0.80	0.71	0.77	0.84	1.00	0.80	0.83	0.91
SE	0.90	0.75	1.00	0.98	0.99	1.00	0.82	0.94	1.00	1.00	0.91	0.94	0.89	0.93	0.92	0.97	1.00	0.98	0.99	1.00

No.	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
CRS	0.73	0.84	0.86	0.84	0.89	0.74	0.79	1.00	0.97	0.59	0.89	0.86	0.75	0.80	0.61	0.77	0.90	0.65	0.84
VRS	0.78	0.86	1.00	0.87	0.89	0.80	1.00	1.00	1.00	1.00	0.90	0.90	0.76	0.84	0.62	0.79	0.91	0.67	0.88
SE	0.94	0.98	0.86	0.97	1.00	0.93	0.79	1.00	0.97	0.59	0.99	0.96	0.98	0.95	0.98	0.97	0.99	0.98	0.96

【Result 2. Cost reduction potential by inefficient plants】

This graph shows the cost reduction potential per liter of BDF produced at 36 inefficient plants.

The cost reduction potential can be estimated by multiplying the quantity-based reduction effect by the unit price of the input factors (methanol 55 yen/L, potassium hydroxide 360 yen/kg).As a result of the estimation, the cost reduction effect was 3.4 yen/L on average.

According to the results of a survey on biodiesel fuel initiatives for 2020, the overall production cost of BDF is about 119.1 yen, so if the results of this study are reflected, the cost can be reduced to 114.7 yen.

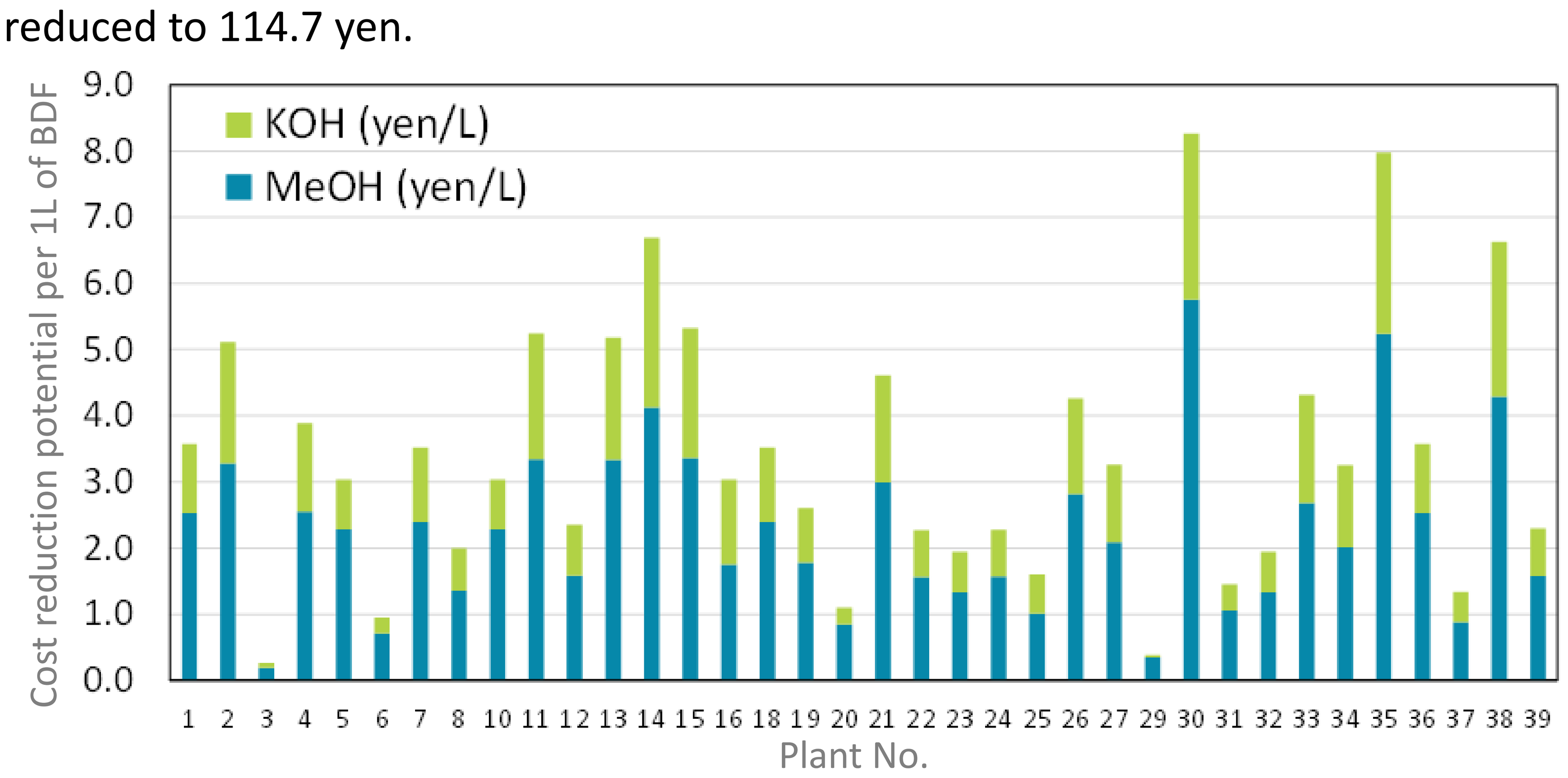


Figure1. Breakdown of cost reduction potential (yen) per 1 L of BDF production by inefficient plants.

【Result 3. Optimal production scale】

Figure 2 shows the relationship between BDF production volume and scale efficiency.

This figure shows that the smaller the BDF production volume is, the smaller the scale efficiency value is. On the other hand, some plants have a lower scale efficiency when the BDF production volume is too large.

The optimal production volume was estimated by drawing a quadratic approximation curve on this figure and calculating the values of the axes of the quadratic function.

According to the estimation results, the value of the axis of the quadratic function was $\log_{10}y=5.03$.In other words, the optimal production volume was found to be y=106,084L..

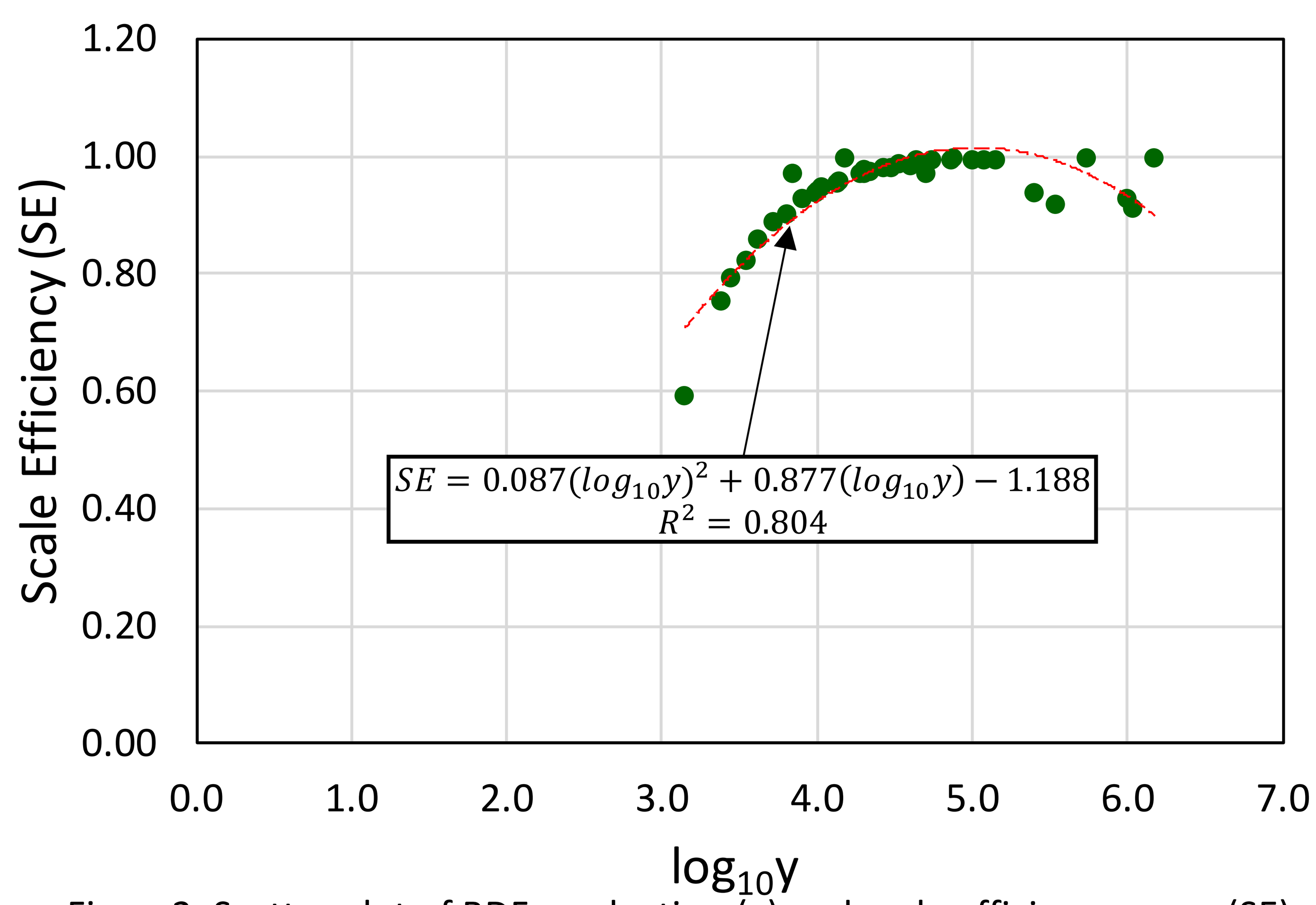


Figure2. Scatter plot of BDF production (y) and scale efficiency score (SE)

【Conclusion】

The results of the efficiency evaluation showed that most of the plants were producing inefficiently.

The cost reduction potential is about 3.4 yen per liter of BDF production on average, which could reduce the overall production cost to 114.7 yen.

However, in order to be competitive with the cost of 83.3 yen for diesel oil, at least another 31.4 yen worth of cost reduction is needed.

The result of the estimation of the optimal production scale was approximately 100,000 liters.

However, many plants are conducting production activities on a smaller scale than that.

Therefore, in order to expand the scale of production, there is a need for policies to collect more waste cooking oil from households and businesses.