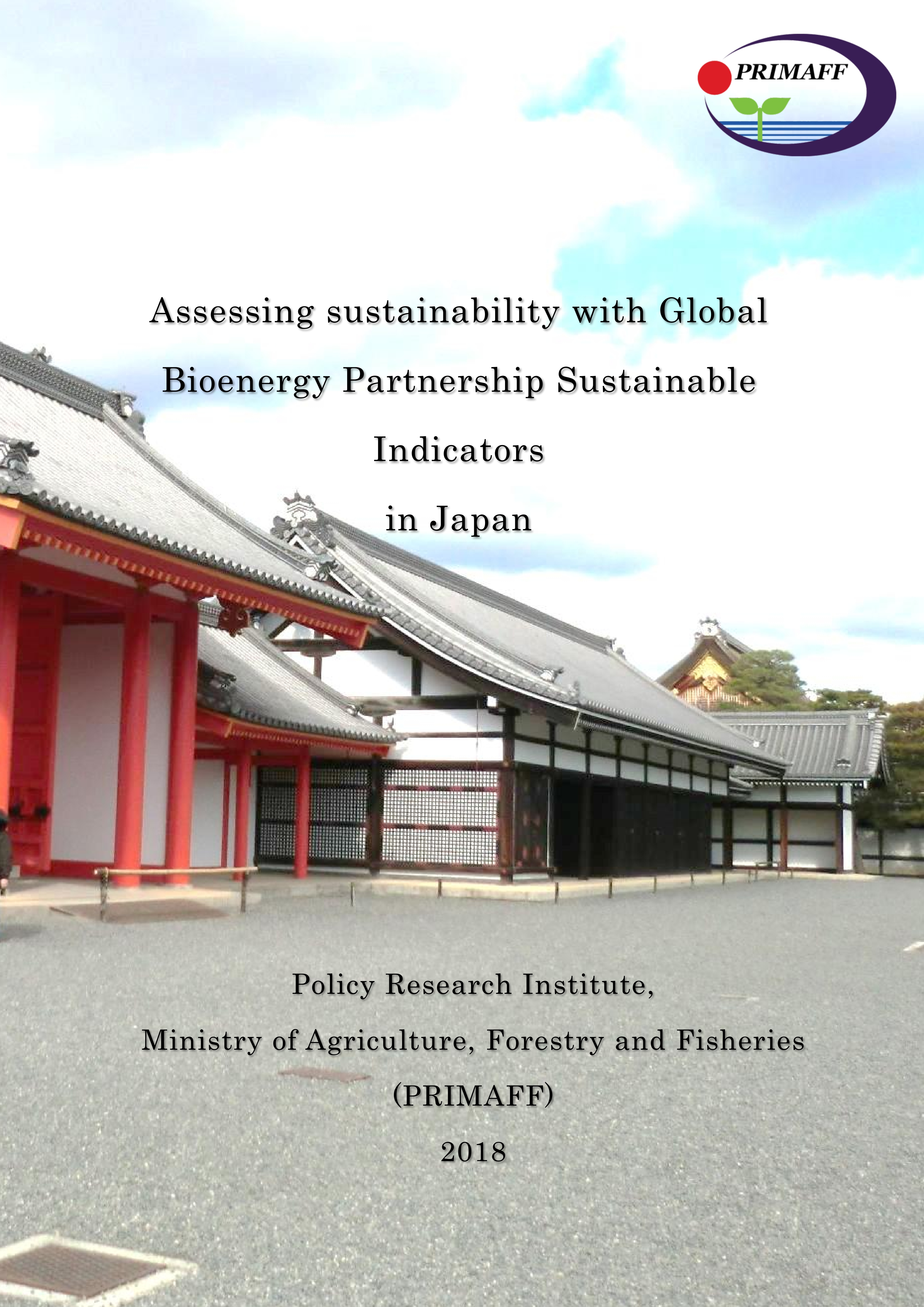

Assessing sustainability with Global Bioenergy Partnership Sustainable Indicators in Japan

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(PRIMAFF)

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Cover photo: Kyoto Imperial Palace

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Abbreviations

BDF	Biodiesel fuel
CNG	Compressed natural gas
GBEP	Global Bioenergy Partnership
GHG	Greenhouse gas
GSIs	GBEP Sustainability Indicators
HI	Herfindahl index
ILO	International Labour Organization
JPY	Japanese Yen
LCA	Lifecycle assessment
NO_X	Nitrogen oxide
PAJ	Petroleum Association of Japan
PRIMAFF	Policy Research Institute, Ministry of Agriculture, Forestry and Fisheries
SO_2	Sulfur dioxide
TARWR	Total actual renewable water resources
TAWW	Total actual water withdrawal
WCO	Waste cooking oil

Preface

In November 2011, a regular meeting of the Global Bioenergy Partnership (GBEP) was held in Tokyo and GBEP sustainability indicators (GSIs) for bioenergy were approved. Based on discussions, Japanese delegates presented the results of a pilot application of GSIs using a case study on biodiesel fuel (BDF) processing and utilization from waste cooking oil in Kyoto. This pilot application was conducted by the Policy Research Institute, Ministry of Agriculture, Forestry and Fisheries (PRIMAFF) at the request of the headquarters of the Ministry. The study constitutes the first application of GSIs globally. Details of the results of the pilot study were published in Japanese in a PRIMAFF project report (Hayashi, 2014). However, information for international stakeholders was available only in a presentation file from the GBEP Tokyo meeting uploaded to the GBEP website (Hayashi, 2011), and therefore, no detailed information was available in English. Although more than 6 years have passed since the implementation of the study, the study remains important and informative because the GBEP continues to promote GSIs.

This report presents the methods and results from the pilot application of GSIs to BDF processing and utilization in Kyoto, Japan, conducted in 2011. Section 1 presents the background of the study, Section 2 presents an overview of GSIs, and Section 3 introduces the study site. Section 4 describes methods for measuring GSIs, and Section 5 reports results from the application of GSIs. Finally, Section 6 discusses challenges and limitations of the application of GSIs, and Section 7 concludes the report.

The report is based on the measurement of GSIs conducted in 2011. Data and methods have not been updated since then, although errors in calculations have been corrected. Footnotes have been added to explain the peculiarities of the Japanese context to international readers. We applied methods discussed in the GBEP meeting held in Washington D.C. in May 2011, which are not available to the public. Note that these methods slightly differ from those published in the meeting report in November 2011.

We hope that this report provides useful information to international stakeholders who wish to apply GSIs in their own countries.

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1. Introduction

Initiatives to secure sustainable forms of bioenergy have been conducted globally in recent years. Bioenergy produced in Japan also requires a sustainability guarantee in accordance with globally accepted sustainability indicators. The Global Bioenergy Partnership (GBEP) Sustainability Indicators (GSIs) were globally agreed in 2011 upon discussion among various nations, including Japan, and international organizations. Japan may, therefore, be suggested to apply GSIs for assessing its own bioenergy sustainability.

However, because GSIs are designed for application in diverse nations and regions, including developing countries, GSIs are not necessarily adapted to Japan's bioenergy context. For instance, the GBEP indicator used for assessing diseases caused by indoor smoke may not be appropriate for Japan as solid biomass is not used for cooking in this country. In addition, GSIs are assessed with a range of statistics and data, and it is important to consider data availability in the country. Assessing data availability and applying GSIs to Japan's bioenergy sector will provide great insights for bioenergy sustainability assessment in the country. We also hope that our case study will foster international discussion on GSIs.

This study assesses bioenergy sustainability using a case study of biodiesel fuel (BDF) processing and utilization in Kyoto as the first application of GSIs in Japan. The study also aims to identify challenges in and solutions for the application of GSIs in the Japanese bioenergy context and highlight potential limitations of GSIs relevant to Japan as well as other countries.

Note that GSIs are designed to be applied at a national level and not at a plant level such as in the case study of Kyoto BDF. However, data at the national level have not yet been collated and synthesized in Japan; therefore, aggregation of plant-level assessments is required to conduct a national-level assessment. Considering these limitations in data availability, GSIs are applied at a plant level in Kyoto.

2. Overview of the GSIs[1]

In 2008, the GBEP established the Task Force on Sustainability to promote the sustainable production and use of bioenergy. One of the roles of the Task Force was to develop a science-based, technically sound, and highly relevant set of indicators to help policymakers and stakeholders meet national goals of sustainable development of bioenergy. The report prepared by the Task Force was published in November 2011.

Table 1 The set of 24 GSIs agreed upon in 2011 by the GBEP Task Force on Sustainability

Environmental	Social	Economic
1. Lifecycle greenhouse gas (GHG) emissions	9. Allocation and tenure of land for new bioenergy production	17. Productivity
2. Soil quality	10. Price and supply of a national food basket	18. Net energy balance
3. Harvest levels of wood resources	11. Change in income	19. Gross value added
4. Emissions of non-GHG air pollutants, including air toxics	12. Jobs in the bioenergy sector	20. Change in consumption of fossil fuels and traditional use of biomass
5. Water use and efficiency	13. Change in unpaid time spent by women and children collecting biomass	21. Training and requalification of the workforce
6. Water quality	14. Bioenergy used to expand access to modern energy services	22. Energy diversity
7. Biological diversity in the landscape	15. Change in mortality and burden of disease attributable to indoor smoke	23. Infrastructure and logistics for distribution of bioenergy
8. Land use and land-use change related to bioenergy feedstock production	16. Incidence of occupational injury, illness and fatalities	24. Capacity and flexibility of use of bioenergy

Source: GBEP (2011), Table on page 3 with author's modifications

The set of GSIs agreed upon by the Task Force consists of 24 indicators assessing the sustainability of bioenergy production and use (Table 1). The indicators are designed to report on environmental, social, and economic aspects of sustainable

[1] For details of GSIs, refer to GBEP (2011).

development. GSIs were developed to provide policymakers and stakeholders with a set of analytical tools to inform the development of national bioenergy policies and programs as well as monitor their impacts.

GSIs are unique in that they were created by the only multilateral initiative that has built consensus on the sustainable production and use of bioenergy among a wide range of national governments and international organizations. GSIs aim to guide analysis at the domestic level and are value-neutral; they do not feature directions, thresholds, or limits and do not prescribe standards. GSIs are not legally binding and cannot be applied to limit trade in bioenergy in a manner inconsistent with multilateral trade obligations. They are not policy instruments, but instead, they are designed to assist policymakers and stakeholders in undertaking analyses for assessing bioenergy sustainability.

GSIs are starting points from which policymakers and stakeholders can identify and develop measures and datasets that are relevant to their national circumstances and needs. GSIs do not provide value judgments or absolute values on sustainability, but rather present a set of factors to quantify the effects of bioenergy production and use in meeting national sustainable development goals.

3. Study site

3.1 Overview of the Kyoto BDF initiative

We chose a BDF processing and utilization initiative in Kyoto as a case study. In Kyoto, BDF processing from waste cooking oil (WCO) has been implemented since 1997. WCO is collected from households at collection points located throughout the city. Citizens bring WCO to a collection point. City government staffs collect WCO once per month on average. There were only 13 collection points in 1997, but the number has increased to 1352 in 2010. Along with an increase in the number of collection points, the amount of WCO collected has also increased from 4.2 kL in 1997 to 207 kL in 2010. However, as the 207 kL of WCO collected from households is insufficient to sustain BDF processing, the city government also purchases WCO at a rate of 45 JPY/L[2] from a variety of outlets in the city, including restaurants, food manufacturers, and hotels. The amount of WCO purchased from these sectors amounted to 1279 kL in 2010. In total, 1487 kL of WCO was used to process BDF in 2010.

BDF processing is undertaken in a BDF plant located next to the Nambu Clean Center, a garbage treatment plant based in the southern area of Kyoto. The annual production capacity of the BDF plant is 1500 kL. In 2010, 1405 kL of BDF was processed at the plant, which thus operated at 93.7% capacity. The overall construction costs of the plant were estimated at 7500 million JPY, including 4400 million JPY for the construction of the processing plant and a further 3100 million JPY for further costs, including costs of land procurement and construction of management offices.

BDF production cost, which is estimated by dividing the operation costs (excluding depreciation expenses) by the production amount, is 138 JPY/L of BDF. The cost is 100 JPY/L if labor costs of employees remunerated by the government are excluded. Glycerol glycerin, a by-product of BDF production, is incinerated at the Nambu Clean Center next to the BDF plant, and waste fluid is used to control burning temperature at the Nambu Clean Center; thus, no other substance is transferred to other waste treatment companies.

Processed BDF is used as fuel (B100; 100% BDF) for garbage collection trucks owned by the Kyoto City government. Some city-owned buses operating on regular routes also use BDF (B20; 20% BDF). Garbage collection trucks are filled with BDF at fuel pumps installed in all three garbage treatment plants in the city, including the Nambu Clean Center. Prior to 2010, the Kyoto City government operated 220 garbage collection tracks, but the number of vehicles reduced to 147 in 2010 (Table 2) due to planning of more efficient routes and increases in vehicle travel distances. BDF is used in all 95 city buses operating from the Yoko-oji depot. The Kyoto City Transportation Bureau operates 773 buses, of which 41 run on compressed natural

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(2) The price includes transportation cost.

gas (CNG) and 95 run on BDF. In garbage collection trucks, some mechanical parts, such as fuel hoses, are retrofitted to adapt to B100. However, no retrofitting was done in city buses.

Table 2 Number of vehicle by fuel type

	B100	**B20**	Diesel	CNG	Total
Garbage collecting truck	**147**	**0**	0	0	147
City-owned bus	**0**	**95**	637	41	773

Note: As of September 2011.

As both the BDF plant and garbage treatment division belong to the Environmental Bureau of the city government, no financial transactions are made during the transfer of BDF. However, financial contracts are made to transfer BDF to the bus service division of the Transportation Bureau. BDF is sold at the price of 85 JPY/L[3], which is much lower than the market price of diesel fuel. However, the Transportation Bureau purchases diesel fuel at a lower price than market price due to mass transactions based on an auction system. Therefore, the Environmental Bureau is concerned that BDF would not be used for city buses if it is more expensive than diesel fuel. Thus, BDF is cheaper than diesel fuel.

3.2 Impacts of BDF production in Kyoto

BDF processing and utilization by the city government has seven impacts: (1) promotion of WCO recycling, (2) mitigation of greenhouse gas (GHG) emissions, (3) reduction of air pollutants from garbage collection trucks and buses, (4) environmental education, (5) promotion of local community activities, (6) prevention of water pollution caused by WCO, and (7) prevention of competition between bioenergy and food. These seven impacts can be categorized into two main groups: the impacts of replacing fossil fuels with BDF and the impacts of collecting WCO.

The Kyoto City government emphasizes the promotion of local community

[3] Prices were determined by negotiations between the Environmental Bureau and Transportation Bureau and are mostly stable.

activities. Residents bring WCO to collection point in plastic bottles and pour WCO into large tanks. By doing so, residents talk and interact and form new relationships. This procedure creates issues for both residents and collection staff, but the Kyoto City government believes that it increases communication opportunities compared to just leaving bottles at collection points for them to be handled by collection staff. The costs of WCO collection are high, but in the absence of collection for BDF production, WCO would be treated as waste at a cost of 50 JPY/L according to data obtained from wastewater treatment plant. Collection of WCO using large tanks is on-going.

4. Methods

4.1 Indicators measured

Among the 24 GSIs mentioned in Section 2, 14 indicators considered to be relevant to the Kyoto case study were measured (Table 3). Within the set of environmental indicators, lifecycle GHG emissions (Indicator 1), Non-GHG air pollutants (Indicator 4) and Water use and efficiency (Indicator 5) were selected. As BDF processing in Kyoto uses WCO as its product source, soil quality (Indicator 2), Harvest level of wood resources (Indicator 3) and Land use and land use change related to bioenergy feedstock production (Indicator 8) were not relevant and were excluded. Water quality (Indicator 6) was also excluded because effluent generated by BDF processing is efficiently reused to control the temperature of incineration at the combustion facility of the Nambu Clean Center and therefore does not cause water pollution. Biological diversity in the landscape (Indicator 7) was also excluded as impacts on biodiversity are deemed negligible.

Within the set social of indicators, change in income (Indicator 11), Jobs in the bioenergy sector (Indicator 12), and Incidence of occupational injury, illness and fatalities (Indicator 16) were selected. Allocation and tenure of land for new bioenergy production (Indicator 9) and Price and supply of a national food basket (Indicator 10) measure impacts caused by feedstock production and were excluded due to lack of relevance. Change in unpaid time spent by women and children collecting biomass (Indicator 13), Bioenergy used to expand access to modern bioenergy services (Indicator 14) and Change in mortality and burden of disease attributable to indoor smoke (Indicator 15) were excluded as these are mainly designed for use in developing countries.

Within the economic set of indicators, all eight indicators were relevant to the case study and were therefore selected.

Table 3 The Indicators measured

Environment	1	**Lifecycle GHG emissions**	✔	*
	2	Soil quality	N/R	
	3	Harvest level of wood resources	N/R	
	4	**Emissions of non-GHG air pollutants including air toxics**	✔	*
	5	**Water use and efficiency**	✔	
	6	Water quality	N/R	
	7	Biological diversity in the landscape	N/R	
	8	Land use and land use change related to bioenergy feedstock production	N/R	
Social	9	Allocation and tenure of land for new bioenergy production	N/R	
	10	Price and supply of a national food basket	N/R	
	11	**Change in income**	✔P	
	12	**Jobs in the bioenergy sector**	✔	
	13	Change in unpaid time spent by women and children collecting biomass	N/R	
	14	Bioenergy used to expand access to modern bioenergy services	N/R	
	15	Change in mortality and burden of disease attributable to indoor smoke	N/R	
	16	**Incidence of occupational injury, illness and fatalities**	✔	
Economic	17	**Productivity**	✔P	
	18	**Net energy balance**	✔P	*
	19	**Gross value added**	✔	
	20	**Change in the consumption of fossil fuel and traditional use of biomass**	✔P	
	21	**Training and requalification of the workforce**	✔P	
	22	**Energy diversity**	✔	
	23	**Infrastructure and logistics for distribution of bioenergy**	✔	
	24	**Capacity and flexibility of use of bioenergy**	✔	

✔: Measured.
✔P: Partly measured.
N/R: Not relevant to Kyoto case.
*: Measured based on Terakawa and Tohno (2008) and Terakawa (2009).

4.2 Data collection

Data used for assessing the 14 selected indicators were mainly provided by the Kyoto City government. Indicators 1, 4, and 18 are based on lifecycle assessment (LCA), so previous studies of the LCA of Kyoto BDF production were used

(Terakawa and Tohno, 2008; Terakawa, 2009). In these studies, LCA was conducted under different conditions than those occurring in the production system (Terakawa and Tohno, 2008; Terakawa; 2009); hence, modifications to the LCA were made in the present case study. The original studies assumed that BDF is only used in garbage collection trucks and not in city buses. The original studies also simulated changes in pollutants based on the rate of WCO collection (the rate of WCO collected in total WCO), setting 10 collection rates from 10% to 100% in 10% increments and calculating pollutants for each. According to our estimates, WCO collection rates are 10.5% for households and 6.6% for the food service and processing sector. Therefore, in this study, we used a collection rate of 10% in Terakawa, 2009.

5. Methods and results

5.1 Environmental pillar

5.1.1 Indicator 1: Lifecycle GHG emissions

Results of the assessment of eight environmental indicators are shown in Table 4. As Indicators 4 and 5 have Sub-indicators, their results are shown as Indicator 4.1, 4.2, 4.4 and 4.5, and Indicator 5.1a, 5.1b and 5.2 in the Table. To estimate Indicator 1, only CO_2 emission was considered as GHG and results from the studies conducted by Terakawa and Tohno (2008) and Terakawa (2009) were used. Terakawa (2009) used multiple WCO collection rates, but a 10% WCO collection rate was used in this study. This percentage can be disaggregated into six lifecycle stages: (1) collection of WCO (GHG emission from WCO collection trucks), (2) manufacturing of trucks for WCO collection, (3) construction of the BDF processing plant, (4) manufacturing of BDF processing facilities, (5) BDF processing, and (6) BDF consumption. In addition, GHG emissions were disaggregated into WCO collected from households and WCO collected from the food services and processing sector. GHG emission were converted to emission per BDF heat content and recorded as lifecycle GHG emissions. When considering carbon neutrality, GHG emissions from the consumption stage should not be included, so values including the consumption stage are recorded only as reference[4].

Table 4 Results of measurement of Indicators in environmental pillar

Indicators		Unit	Number
1	Lifecycle GHG emissions from bioenergy production	kg/GJ	11.7 [1]
4.1	Emissions of NO_x from waste collection	kg/GJ	1.5
	Emissions of SO_2 from waste collection	kg/GJ	0.4
4.2	Emissions of NO_x from conversion	kg/GJ	14.2
	Emissions of SO_2 from conversion	kg/GJ	14.5
4.3	Emissions of NO_x from transportation	kg/GJ	N/E
	Emissions of SO_2 from transportation	kg/GJ	N/E
4.4	Emissions of NOx from use	kg/GJ	547.7
	Emissions of SO_2 from use	kg/GJ	0.1
4.5	Emissions of NO_x from full lifecycle	kg/GJ	563.3
	Emissions of SO_2 from full lificycle	kg/GJ	15.0
5.1a	Percentage of total actual renewable water resources	--	0.0010%
5.1b	Percentage of total annual water withdrawal	--	0.0010%
5.2	Volume of water withdrawn from nationally-determined watershed(s)	m^3/MJ	0.000044 [2]

(shaded) Estimates based on Terakawa (2009).

(1) 80.8 if carbon neutral is not considered.

(2) =43.8cm^3/MJ.

Indicator 1 also required information on the reduction rate of GHG from fossil fuels (diesel fuel in this case). The amount of GHG emissions from diesel fuel was estimated from the study by Terakawa (2009), where GHG emissions were estimated for WCO treated at a wastewater treatment plant. Terakawa (2009) assumed that WCO would be treated at the wastewater treatment plant had it not been collected for BDF production, leading to additional GHG emissions. We relied on the same assumption and used GHG emissions from the wastewater treatment plant. Reduction of emissions created by replacing diesel fuel with BDF was calculated for both carbon neutral and non-carbon neutral scenarios (Table 5). The reduction rate was 87.2% in the scenario assuming carbon neutrality and 12.3% in

(4) Terakawa (2009) also calculated values with and without assumptions on carbon neutrality. Only carbon emissions derived from WCO were excluded from calculations in that study. However, as we could not determine the quantity of carbon derived from WCO, we excluded all GHG emissions from BDF consumption in this study.

the scenario not assuming carbon neutrality.

Table 5 Lifecycle GHG (CO_2) emission per GJ from BDF

	Unit	Total
Travelling of WCO collecting trucks	kg/GJ = g/MJ	0.3
Manufacturing of trucks for collecting WCO	kg/GJ	0.3
Construction of BDF processing plant	kg/GJ	0.8
Manufacturing of BDF processing facilities	kg/GJ	1.4
Processing of BDF	kg/GJ	8.9
Consumption of BDF	kg/GJ	69.1 (1)
Indicator 1 Total	**kg/GJ**	**11.7**
Total (without carbon neutral consideration)	**kg/GJ**	**80.8**
Lifecycle GHG emission from diesel	kg/GJ	92.2
	Reduction rate	**87.3%**
	w/o carbon neutral	**12.3%**

(1) Excluded if carbon neutral is considered.

5.1.2 Indicator 4: Emission of non-GHG pollutants including air toxics

Emissions of NO_x and SO_2 were considered in Indicator 4. These pollutants are produced in six stages in the BDF lifecycle: (1) manufacturing of WCO collection trucks, (2) operation of WCO collection trucks, (3) construction of the processing plant, (4) manufacturing of processing facilities, (5) BDF processing and (6) BDF consumption. Data used for estimating emissions were extracted from the studies by Terakawa and Tohno (2008) and Terakawa (2009). Based on these studies, we estimated total lifecycle NO_x and SO_2 emissions during BDF processing and utilization and calculated emissions per GJ of BDF. We also estimated emissions from diesel fuel for both total lifecycle emissions and per GJ of diesel. Emissions from the treatment of WCO as waste were included in the diesel calculation because WCO would be treated in a wastewater treatment plant if diesel was used. Finally, we calculated emission reductions due to the use of BDF as fuel instead of diesel.

We found that 563.3 g/GJ of NO_x and 15.0 g/GJ of SO_2 were emitted from BDF and that 369.8 g/GJ of NO_x and 55.2 g/GJ of SO_2 were emitted from diesel (Table 6). When using BDF instead of diesel, SO_2 emission decreased by 73% but NO_x emission increased by 52%.

Table 6 Results of measurement of Indicator 4

		NO_x g/GJ	SO_2 g/GJ	Sub-Indicator
BDF	Travelling of oil collecting trucks	1.0	0.2	**Ind. 4.1**
	Manufacturing of WCO collecting trucks	0.4	0.3	
	Construction of processing plant	1.9	1.0	**Ind. 4.2**
	Manufacturing of processing facilities	1.9	1.2	
	Processing of BDF	10.5	12.3	
	Consumption of BDF	547.7	0.1	**Ind. 4.4**
	Total	**563.3**	**15.0**	**Ind. 4.5**
Diesel	Treatment of WCO by sewage	14.5	11.7	
	Emission from substituted diesel fuel (well to tank)	32.8	21.0	
	Emission by combustion	322.5	22.5	
	Total	**369.8**	**55.2**	
Reduction rate		**+52.3%**	**-73%**	

5.1.3 Indicator 5: Water use and efficiency

Identifying watersheds supplying water for bioenergy processing is necessary to measure Indicator 5 (GBEP, 2011). All the water used in Kyoto originates from Lake Biwa, so we used the lake as the relevant watershed for BDF processing in Kyoto (Table 7). The next step involved estimating total annual water withdrawal (TAWW). According to data from the Kyoto City Waterworks Bureau (Kyoto City, 2013), the total water supply in Kyoto in 2006 was 213.45 million m^3, so we used this value as TAWW[5]. As Kyoto benefits from large amounts of precipitation and no water scarcity problems have occurred in the Kyoto and Lake Biwa area, total actual renewable water resources (TARWR) were considered equal to TAWW[6] when measuring the indicator. Data on water use in the plant were obtained from Kyoto City (2011)[7]. We assumed that all the water used in BDF processing was

(5) Although water withdrawal does not exactly equate to water supply, we regard TAWW as equal to total water supply due to limited data availability.

(6) One consideration in the estimation of TARWR is that in some cases, bioenergy is produced in the area with scarce water; its production might, therefore, not be sustainable in terms of efficient water use. As Kyoto receives plenty of precipitation and has ample underground water, the estimation of TARWR might not matter.

(7) Data used in this study were deleted during an update of the Kyoto City website. Data are available from the authors on request.

renewable.

We calculated Indicators 5.1a, 5.1b, and 5.2 based on available data (Table 7). The proportion of total TAWW and TARWR used for BDF processing and utilization were negligible (Table 7). The volume of water per MJ used for BDF production is required in GSI reporting. However, given the very small value found in our study (Table 7), we believe that the indicator should be reformulated and expressed as volume of water per TJ used for BDF production.

Table 7 Data for and results of Indicator 5: Water efficiency

		Unit	Number
	Nationally determined watershed	--	Lake Biwa (1)
	TAWW	m^3	213,445,000 (2)
	TARWR	m^3	213,445,000 (3)
	TARWR for feedstock production	m^3	N/R
	Non-TARWR for feedstock production	m^3	N/R
	TARWR for processing	m^3	2206.4 (4)
	Non-TARWR for processing	m^3	0
	TAWW for processing	m^3	2,206.4
	Amount of BDF produced	MJ	50,348,736
5.1a	Share of BDF production in TARWR	%	**0.0010%**
5.1b	Share of BDF production in TAWW	%	**0.0010%**
5.2	Volume of water per MJ used for BDF product	m^3/MJ	**0.000044**
5.2	Volume of water per MJ used for BDF product	cm^3/MJ	**43.8**

(1) All of water used in Kyoto is taken from Lake Biwa.
(2) As of 2006.
(3) All of TAWW used in Kyoto Coty supposed to be renewable.
(4) Including water used in management sections.
N/R: Not relevant to Kyoto case.

5.2 Social pillar

5.2.1 Indicator 11: Change in income

Indicator 11 includes two Sub-indicators: Wages paid for employment in the bioenergy sector in relation to comparable sectors (11.1) and Net income from the sales, barter and/or own-consumption of bioenergy including feedstocks, by self-employed households/individuals. (11.2; Table 8). To calculate sub-indicator 11.1, data on labor costs for staff collecting WCO were extracted from Kyoto City

(2011)[8]. Measurement of indicator 11.2 was not relevant to the Kyoto case study and was therefore not implemented.

Table 8 Results of measurement of Indicators in social pillar

	Indicators	Unit	Number
11.1	Wages paid for employment in the bioenergy sector in relation to comparable sectors	1000JPY	9,338.7
11.2	Net income from the sales, barter and/or own-consumption of bioenergy products	--	N/R
12.1	Total employment per GJ	Person/TJ	0.00012
12.2	Skilled employment per GJ	Person/TJ	0.00008
12.3	Temporary employment per GJ	Person/TJ	0.00000
16.	Incidence of occupational injury, illness and fatalities	Number	0

(1) As of 2010, data for six staffs including four exclusive staffs.
(2) Six total staffs.
(3) Four skilled staffs.
(4) All six staffs are indefinite.
(5) No accidents, injury, illness nor fatalities so far.
N/R: Not relevant to Kyoto case.

5.2.2 Indicator 12: Jobs in the bioenergy sector

Indicator 12 assesses the number of job creations resulting from bioenergy production and is composed of five Sub-indicators: Total number (12.1), skilled/unskilled (12.2), Indefinite/temporary (12.3), Consistency with ILO "Declaration on Fundamental Principles and Rights at Work" (12.4), and Their percentages (12.5). We only assessed sub-indicators 12.1, 12.2, and 12.3. Six staffs are in charge of BDF processing (12.1), two of whom are working for the headquarters of Kyoto City government and the BDF plant. The remaining four are exclusively employed by the plant on indefinite contracts (12.3)[9].

(8) Although data on labor costs from Kyoto City (2011) included staff working for both the municipality headquarters and for the BDF plant, labor costs were assessed for each location based on relative allocations of working time for both sections.

(9) Five staff members among the six are contracted as temporary, but none are employed under part-time or unstable contracts. As they have been continuously employed for long periods of time, we consider the staff as indefinite workers for the purpose of this study.

5.2.3 Indicator 16: Incidence of occupational injury, illness and fatalities

There have been no incidental accidents, injuries, illnesses, or fatalities since the start of operations at the Kyoto BDF plant. Therefore, the value of indicator 16 is recorded as zero.

5.3 Economic Pillar

All eight economic Indicators were assessed (Table 9). These Indicators are composed of 19 Sub-indicators, 12 of which were deemed relevant to the Kyoto case study and were therefore assessed.

Table 9 Results of measurement of Indicators in economic pillar

	Indicator	Unit	Number
17.1	Productivity of bioenergy feedstocks by feedstock or by farm/plantatio	tons/ha	N/R
17.2	Processing efficiencies by technology and feedstock	MJ/L-WCO	33.9
17.3	Amount of bioenergy end product by mass, volume or energy content per hectare per year	tons/ha	N/R
17.4	Production cost per unit of bioenergy	JPY/L-BDF	133.5
18.1	Net energy balance of feedstock production	--	N/R
18.2	Net energy balance of processing of feedstock into bioenergy	--	4.2
18.3	Net energy balance of bioenergy use	--	N/R
18.4	Net energy balance in lifecycle analysis	--	N/R
19	Gross value added per unit of bioenergy produced and as a percentage of gross domestic product	JPY/L-BDF	4.4 (1)
20.1	Substitution of fossil fuels with domestic bioenergy measured be energy content	GJ/year	38,343.2
20.1	Substitution of traditional use of biomass with modern domestic bioenergy measured by energy content	--	N/R
21.1	Share of trained workers in the bioenergy sector out of total bioenergy workforce	--	0.67 (2)
21.2	Share of re-qualified workers out of the total number of jobs lost in the bioenergy sector	--	N/R
22	Energy diversity (Harfindahl index with bioenergy)	--	0.73
22	Energy diversity (Harfindahl index without bioenergy)	--	0.86
23.1	Number of routes for critical distribution systems	number	2
23.2	Capacity of routes for critical distribution systems	GJ/year	50,349
23.3	Percentage for both 23.1 and 23.2	--	100%
24.1	Ratio of potential capacity for using bioenergy compared with actual use for each significant utilization route	--	11.1
24.2	Ratio of flexible capacity which can use either bioenergy or other fuel sources to total capacity	--	21.2%

(1) Including treatment cost of WCO at garbage treatment plant (50JPY/L-WCO).

(2) Calculated based on four trained staffs.

5.3.1 Indicator 17: Productivity

Only the Processing efficiencies by technology and feedstock (Sub-indicator 17.2) and Production cost per unit of bioenergy (Sub-indicator 17.4) were measured. Conversion efficiency from WCO to BDF was calculated to assess Sub-indicator 17.2 (Table 9). Production costs per BDF unit were measured under Sub-indicator 17.4 (Table 9).

5.3.2 Indicator 18: Net energy balance

Sub-indicator 18.1 is defined as the ratio of input to output energy for collecting WCO, but because WCO collection does not have any energy outputs, the Sub-indicator was not applied. Sub-indicator 18.3 calculates the energy balance of BDF use. Because the energy input for BDF transportation from the BDF plant to the Yoko-oji bus depot was not estimated by Terakawa (2009), the Sub-indicator was not assessed. As a result, Net energy balance in whole lifecycle (Sub-indicator 18.4) also remained unassessed. Only net energy balance of processing (Sub-indicator 18.2) was measured (Table 10).

Table 10 Assessment of Indicator 18: Net energy balance

		Unit	Number
	Energy input for collection of WCO	GJ/year	627.1
	Energy output at collection of WCO	GJ/year	N/R
18.1	**Net energy balance of feedstock production**	----	**N/R**
	Energy input for construction and manufacturing of building and facilities in BDF plant	GJ/year	1,171
	Energy input for processing BDF per liter of WCO	GJ/t-WCO	9
	Amount of WCO used for processing BDF	t/year	1,905
	Amount of energy produced by energy content	GJ	17,602
	Amount of total energy input for processing of BDF	GJ/year	18,773
	Amount of total energy output by processing of BDF	GJ/year	78,730
18.2	**Net energy balance of processing**	----	**4.2**
18.3	**net energy balance of use of BDF**	----	**N/R**
18.4	**Net energy balance in lifecycle analysis**	----	**N/R**

[shaded] Data are referred from Terakawa (2009) and Terakawa and Tohno (2008).

N/R: Not relevant to Kyoto case.

5.3.3 Indicator 19: Gross value added

Table 11 shows data requirements of Indicator 19. As explained in Section 3.1, B20 was sold to the Transportation Bureau at the price of 85 JPY/L in 2010. The total costs, including labor costs and costs of diesel mixing with BDF, amounted to 134 JPY/L. as mentioned in Section 3.2, treating WCO in a wastewater treatment plant would cost 50 JPY/L. Wastewater treatment plants avoid this cost when WCO is collected for BDF processing; therefore, 50 JPY/L was subtracted from BDF production costs. As a result, gross value added was 4.4 JPY/L of BDF.

Table 11 Data requirements for Indicator 19: Gross value added

		Unit	Number
	Amount of BDF produced	L-BDF	1,405,761
	Price of BDF sold to transportation bureau	JPY/L-B20	85 (1)
	Cost of intermediate inputs including labor and diesel oil	1000JPY	187,685 (2)
	Cost of intermediate inputs per liter of BDF	JPY/L-BDF	134 (3)
	Reduction in treatment cost in garbage treatment plant per liter of WCO	JPY/L-WCO	50 (4)
	Amount of WCO collected	L-WCO	1,486,723
	Reduction in treatment cost in garbage treatment plant (total)	1000JPY	74,336
	Reduction in treatment cost in garbage treatment plant per liter of BDF	JPY/L-BDF	53
19	**Gross value added**	**JPY/L-BDF**	**4.4** (5)

(1) As of 2010.
(2) As of 2010, including cost for diesel oil for blending.
(3) Including cost for diesel oil for blending.
(4) Data provided by Kyoto government office.
(5) Including reduction in treatment cost of WCO at garbage treatment plant.

5.3.4 Indicator 20: Change in consumption of fossil fuels and traditional use of biomass

Indicator 20 is composed of two Sub-indicators: Substitution of fossil fuel with bioenergy (Sub-indicator 20.1) and Substitution of traditional use of biomass with modern domestic bioenergy (Sub-indicator 20.2). To evaluate Sub-indicator 20.1, we calculated the quantity of diesel replaced by BDF using the equation provided in the GSI report (GBEP, 2011, p.187). We used data on net energy balance estimated for Sub-indicator 18.2 (Table 9). Sub-indicator 20.2 was not measured as no substitution of traditional bioenergy could be made.

5.3.5 Indicator 21: Training and re-qualification of the workforce

Six staffs work in the BDF processing plant, four of which are trained. Therefore, the proportion of trained workers was 0.67. This value was used as the share of trained workers in the bioenergy sector out of the total bioenergy workforce (Sub-indicator 21.1). The share of re-qualified workers out of the total number of jobs lost in the bioenergy workforce (Sub-indicator 21.2) was not relevant to the Kyoto case study as no staff had lost their jobs in the past.

5.3.6 Indicator 22: Energy diversity

As mentioned in Section 3.1, BDF is used in garbage collection trucks and city buses and three types of fuel are used in these vehicles (BDF, diesel, and CNG). Indicator 22 measures energy diversity by estimating the Herfindahl index (HI) of energy sources with and without bioenergy. We considered all three fuel options for calculating HI with bioenergy. We only considered diesel and CNG for calculating HI without bioenergy. HI with bioenergy was lower than that without bioenergy as a higher diversity of energy sources results in lower HI (Table 12).

Table 12 Results of estimation of Indicator 22

	Unit	Number	Share with BDF	Share without BDF
BDF	GJ	50,349	8.4%	
Diesel	GJ	507,140	84.5%	92.3%
CNG	GJ	42,468	7.1%	7.7%
Total		599,957		
22 Herfindahl index (HI)			**0.73**	**0.86**

5.3.7 Indicator 23: Infrastructure and logistics for distribution of bioenergy

This indicator identifies critical points for the distribution and logistics of bioenergy and is composed of three Sub-indicators: Number of routes for critical distribution systems (Sub-indicator 23.1), Capacity of routes for critical distribution systems (Sub-indicator 23.2), and Proportion of bioenergy associated with each (Sub-indicator 23.3). BDF is only consumed by garbage collection trucks and city buses, and fuel pumps for garbage collection trucks are located next to the plant (0 km; Figure 1)[10].

[10] Although there are fuel pumps in an additional two garbage treatment plants using BDF, we assumed that only the pumps located in the Nambu Clean Center were used to fuel garbage collection trucks.

BDF for city buses is transported to the Yoko-oji bus depot located 1.2 km from the BDF plant (Figure 1). The two fueling points are critical distribution points, so the number of critical distribution systems was two (23.1). As all of processed BDF is consumed via these two critical fueling points, the capacity of routes for critical distribution systems was 50,349 GJ/year (23.2), and the proportion of bioenergy associated with critical points was 100% (23.3).

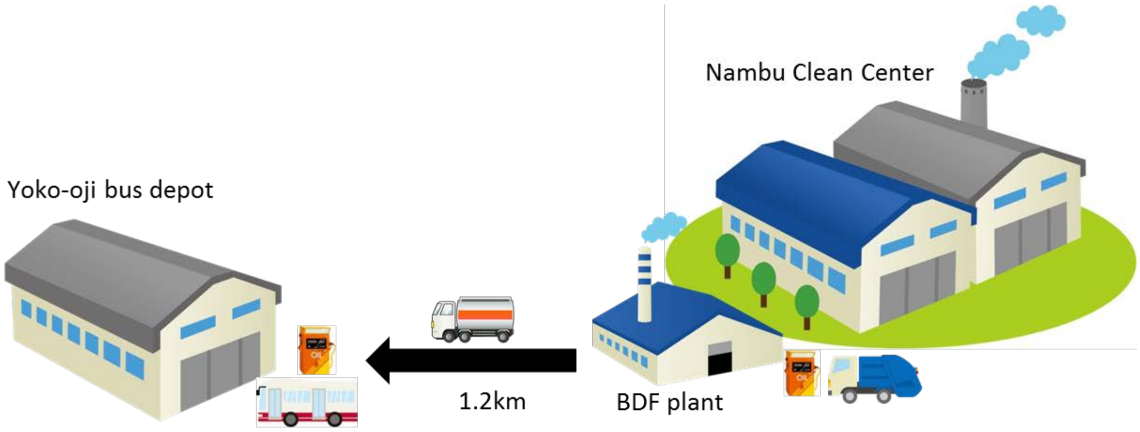

Figure 1 Distribution system of BDF

5.3.8 Indicator 24: Capacity and flexibility of use of bioenergy

Indicator 24 measures the potential to expand bioenergy (Sub-indicator 24.1) and replace conventional (fossil) fuels with bioenergy in the absence of system modifications (Sub-indicator 24.2). Potential capacity was defined as the potential of bioenergy to replace diesel fuel, and flexible capacity was defined as the quantity of BDF that could immediately be used to replace diesel. BDF100 is used for all garbage collection trucks, and there is no opportunity to expand BDF consumption (Figure 2). B20 is used for 95 of 773 city buses. These 95 buses can be fueled with B100 without retrofitting and can therefore contribute to the flexible capacity of the distribution system (Figure 2). Sub-indicator 24.1 accounts for the capacity to increase blending rate from B20 to B100; therefore, this sub-indicator was estimated as the amount of BDF that could be consumed by the 95 buses if blending ratio was raised to 100% (Table 13). On the other hand, potential capacity refers to the potential to use BDF in all 773 buses. Sub-indicator 24.2 was estimated as the amount of BDF consumed if all buses used B100 (Table 13). If all of the diesel and CNG used in buses was replaced with BDF, the amount of BDF consumed would increase 11-fold (Sub-indicator 24.1). If the BDF blending ratio used in 95 buses increased from 20% to 100%, the amount of BDF consumed would increase 2.3-fold (Sub-indicator 24.2).

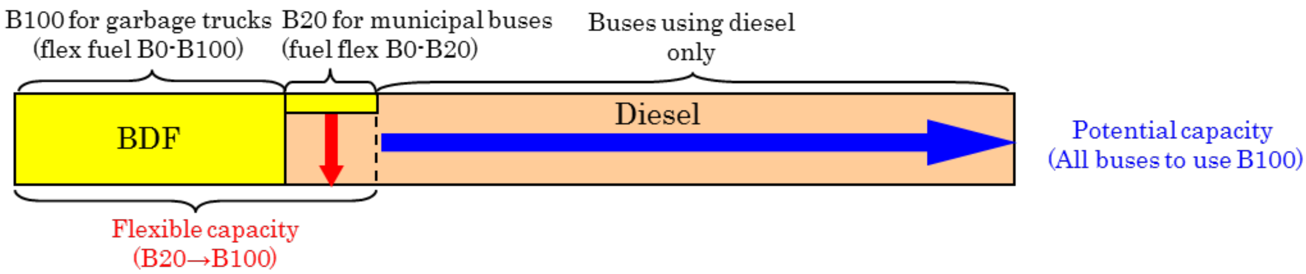

Figure 2 Potential and flexible capacities of BDF distribution system

Table 13 Result of measurement of Indicator 24

	Unit	Number
Annual transport bioenergy use	GJ/year	50,349
Transport bioenergy capacity	GJ/year	557,489
Flexible transport capacity	GJ/year	117,920
24.1 Potential capacity ratio	----	**11.1**
24.2 Flexible capacity ratio	----	**2.3**

6. Challenges in the application of GSIs

6.1 Limitations of the Kyoto case study

Based on the Kyoto BDF case study, we identified challenges and factors to consider when applying GSIs in Japan. First, we identified two factors that limited the application of GSIs to the Kyoto BDF case study. One is a problem of aggregation at national level vs. local or plant level. In our case study, GSIs were applied to a single plant operated by Kyoto City. Two BDF plants were in operation as of 2011 in Kyoto Prefecture(11): one in Kyoto City and one private company. We selected the plant operated by Kyoto City because data (e.g. budgets, costs, prices, and sales) were more

(11) Kyoto City is one of the municipalities in Kyoto Prefecture. Note that both administrative organizations are completely different.

easily available for measuring GSIs. Our measurements, therefore, refer to a single plant and were derived from micro (plant)-level data. GSIs are designed for application at the national or regional level and require national or regional data that are developed by aggregating micro-level data. However, aggregation methods and data coverage have not yet been discussed by the GBEP Task Force.

Data availability was also an issue in the Kyoto BDF case study. We selected Kyoto City to increase data availability as private companies may be reluctant to provide data required for measuring GSIs due to confidentiality issues. For example, to estimate Lifecycle GHG emissions (Indicator 1), LCA of GHG emissions is necessary. We could obtain data on the LCA of the Kyoto City plant from previous studies, but when this is not possible, an LCA should be conducted. Policymakers and government officers are the main users of GSIs and may not be able to conduct a LCA. Some software promotes the wider use of LCA, but technical skills and knowledge remain necessary. In addition, LCA requires large amounts of data derived from plant-level experiments and surveys, and if no data can be obtained, the measurement of GSIs may be compromised. Similarly, collection of data on biomass and bioenergy is necessary for the successful application of GSIs. The collection of data on soil condition and lifecycle emissions of GHG and other air toxics also requires technical skills and knowledge. Such data should be prepared prior to measuring GSIs.

6.2 Challenges in the application of GSIs in Japan

Three challenges should be considered when applying GISs to the Japanese context. First is the treatment of bioenergy production from waste. In Japan, waste-based bioenergy dominates bioenergy production. As our case study was waste-based, some indicators relating to feedstock production [e.g., Soil quality (Indicator 2) and Land use and land-use change (Indicator 8)] were excluded from the analysis. When applying GSIs to waste-based bioenergy production, it is necessary to consider the definition of waste, the collection of waste, and the usage and treatment of waste unless it is not used for bioenergy production[12].

The second challenge is the relationships among rural development, promotion of agroforestry activities, and bioenergy production. One of the selling points used in the promotion of bioenergy is the mitigation of declining trends in agriculture and forestry, which result in depopulation of communities struggling to maintain their social dynamics (e.g., ceremonial occasions). High levels of wood biomass are found in Japan as approximately 70% of public land is covered by forests. Even in areas where forestry was once active, timber production is declining due to the replacement of domestic timbers by cheaper, imported timbers. Effective forest maintenance is not implemented due to high costs, and as a result, disasters (e.g., damages caused by wild animals and landslides and floods)[13] are common. Therefore, promoting the use of wood biomass for bioenergy, with the intention of reinvigorating forestry and implementing effective forest maintenance, is common in Japan. Bioenergy also contributes to rural development and reactivation of agroforestry, and these impacts should be included in sustainability assessments with GSIs under the set of social pillar.

Third, energy security and diversity of energy sources are also critically important to the Japanese context. In March 2011, Japan experienced a huge earthquake and a related energy crisis in the Fukushima-1 nuclear power plant. Since then, discussions on alternative energy sources to nuclear and on diversity of energy sources have increased. Renewable energy sources, including biomass, are expected to be major options for substituting nuclear power sources. Solar and wind power are unstable renewable energy sources, but bioenergy is not affected by weather and climate and is therefore a relatively stable renewable energy source. Currently, Japan is required to develop an optimal balance of energy sources taking the characteristics of each energy

(12) GBEP provides a checklist of questions to compare methodologies for assessing GHG emissions of bioenergy systems (GBEP, 2009). The definition of waste is included in the checklist.

(13) Unless proper forest maintenances, such as thinning and logging, are implemented, competition among trees becomes severe, causing trees to weaken and become unable to root deeply. This phenomenon results in landslides as well as treefalls during typhoons and strong winds.

source into account.

GSIs measure energy security and diversity using three indicators: Energy diversity (Indicator 22), Infrastructure and logistics of bioenergy (Indicator 23), and Potential and flexible capacities (Indicator 24). These indicators are essential for assessing the sustainability of bioenergy in Japan. Energy diversity (Indicator 19) assesses the portion of total national energy supplied by bioenergy, but bioenergy in Japan relies on both traditional biomass (e.g., fuel wood, charcoal, pellets, wooden waste, and forest residue) and biogas from livestock waste. Biomass use also varies from large-scale industrial biogas plants to small-scale farms or households. Assessing scale diversity, variety of feedstock, and use (e.g., direct combustion and biogas) is, therefore, important in Japan.

Finally, the treatment of imported biomass and bioenergy should be considered. Japan imports large quantities of energy from abroad, and some feedstocks and forms of bioenergy are also imported. As a target for 2010, 2 million kL of bioethanol-blended fuel was to be used in Japan. To this end, 0.84 million kL of bioethanol was supplied by the Petroleum Association of Japan (PAJ), of which 0.03 million kL was supplied from two domestic bioethanol plants in Hokkaido(14). The remaining bioethanol was imported and subsequently processed in Japan. GSIs are designed to assess the impacts on home-produced bioenergy. As Japan depends to a large extent on imported energy, more attention should be paid to sustainability impacts in the countries of origin of bioenergy products.

6.3 Challenges in the application of GSI framework

We identify four main challenges for the global development and application of GSIs. First, the use of GSIs in policymaking remains uncertain. GSIs are voluntary and "do not feature directions, thresholds or limits and do not constitute a standard, nor are they legally binging on users" (GBEP, 2011, p.11). The GBEP foresees policymakers and other stakeholders as the user of GSIs and expects them to develop bioenergy

(14) These two plants stopped their operation in 2015 due to a lack of economic feasibility.

sectors that help meet national goals of sustainable development (GBEP, 2011, acknowledgments). Considering this, the GBEP does not intend to provide international frameworks or standards based on GSIs. Instead, the GBEP expects policymakers in each country to use GSIs for their own policy design and target-setting. The use of GSIs would, therefore, vary among countries, reducing the significance of GSIs at an international level. The independent use of GSIs in each country and the international promotion of GSIs by GBEP, therefore, seem to be at odds with one another.

Second, reflecting national and local processes in the measurement of GSIs is important. We mentioned conditions specific to Japan in Section 6.3, and the same approach should be taken in each country in which GSIs are applied. Effects were also visible when calculating the proportion of total TAWW and TARWR used for BDF processing and utilization, which were negligible (Table 7). This may be due to the fact that GSIs are designed for national-level application; therefore, scaling issues may occur in applications at the plant level. As the GBEP does not expect each country to make international comparisons with GSIs, GBEP allows some flexibility in modifying the indicators so that they can reflect national and local factors and can be more easily measured. For instance, suppose that a country produces two types of bioenergy: bioenergy A and B. Bioenergy A is produced in a sustainable manner and bioenergy B is not. A national assessment would mask differences between the two energy types, and it would be difficult to understand the nature of each bioenergy. This problem is specific to national- and regional-level aggregation within a large area with multiple bioenergy types. A solution to this problem is disaggregation by regional or local level and by energy type.

The third challenge is that of timeframe. Bioenergy conversion technology proceeds on a daily basis, and the results of sustainability assessments change according to progress in technologies. GSIs should, therefore, be assessed at multiple time points. Required timespans of updates were not mentioned in the GSI report (GBEP, 2011). In our opinion, updates should be made at intervals of 5 years. Some Indicators such as Change in consumption of fossil fuels and traditional use of biomass (Indicator 20) require much longer timespans to be measured, and updates within short time periods may lead to a waste of resources with little information gain. This challenge is closely related to that of data availability and may be further addressed when several countries start applying GISs.

Table 14 Data required for the assessment of Indicator 1: Lifecycle GHG emissions

Items	Unit
Data on WCO collection	
Amount of WCO collected (actually measured)	t
Amount of WCO collected (parameter in Terakawa, 2009)	t
Amonut of cooking oil consumed (estimate in Terakawa, 2009)	t
Share of WCO collected (actually measured)	%
Share of WCO collected (estimated from Terakawa, 2009)	%
Data on BDF production	
Amount of BDF processed (actually measured, volume)	KL/year
Amount of BDF processed (actually measured, heat content)	GJ/year
Amount of BDF processed (parameter in Terakawa, 2009, in volume)	KL/year
Amount of BDF processed (parameter in Terakawa, 2009, in heat content)	GJ/year
GHG emission from BDF processing (total)	
Emission from WCO collecting trucks	t/year
Manufacturing of trucks	t/year
Construction of BDF plant	t/year
Manufacturing of BDF processing facilities	t/year
Processing of BDF	t/year
Consumption of BDF	t/year
GHG emission from BDF processing (per unit of BDF heat content)	
Emission from WCO collecting trucks	kg/GJ = g/MJ
Manufacturing of trucks	kg/GJ
Construction of BDF plant	kg/GJ
Manufacturing of BDF processing facilities	kg/GJ
Processing of BDF	kg/GJ
Consumption of BDF	kg/GJ
GHG emission from diesel oil processing (total)	
Lifecycle GHG emission from diesel oil (well-to-tank)	t-CO_2/KL
Amount of diesel oil replaced by BDF (in volume)	KL/year
Amount of diesel oil replaced by BDF (in heat content)	GJ/year
GHG emission from diesel oil processing (per unit of diesel oil heat content)	
Lifecycle GHG emission from diesel oil (well-to-tank)	t-CO_2/year
Amount of diesel oil replaced by BDF (in volume)	t-CO_2/year
Amount of diesel oil replaced by BDF (in heat content)	t-CO_2/year

Finally, organizing the large amounts of data required for GSI assessment is also problematic. Large datasets are sometimes required to measure one indicator [e.g., lifecycle GHG emissions (Indicator 1); Table 14], and much bigger datasets are needed to assess all 24 GSIs. In Japan, data for GSI assessment are limited because the Japanese bioenergy sector is not classified as one single sector but is distributed into the energy and agricultural sectors. When assessing GSIs in Japan, data on bioenergy and biomass must be individually collected from different sectors. The GBEP also recognizes data collection as an important issue, and advice on data collection is provided in the "practicality" section of the GSI report (GBEP, 2011). Some indicators use common datasets, such as Lifecycle GHG emissions (Indicator 1) and Emission of non-GHG pollutants and toxics (Indicator 4). Databases to organize data should be developed so that data can be shared easily among indicators. Application of environmental accounting techniques, such as the System of Economic and Environmental Accounting of the United Nations, could be a potential solution (United Nations et al., 2014).

7. Conclusions

In this report, we described the assessment of GSIs in Japan using the case study of BDF processing and utilization in Kyoto. We identified several challenges and solutions for the application of GSIs in Japan, as well as issues with the GSI framework itself. Issues with aggregation to national-level application and data availability were apparent in the Kyoto BDF case study. When applying GSIs to the Japanese context, impacts on rural development should be considered to provide recommendations for optimal energy production. In addition, the case study may benefit from considering a larger variety of biomass feedstocks, conversion technologies, and types of use, as well as imported biomass and bioenergy. Policy applications, consideration of national and local issues, timeframes of updates, and data organization tools are main areas for growth in the development of GSIs. These points should be discussed further by GBEP member countries, and lessons should be shared from the application of GSIs in different countries.

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