Introduction of Biomass Accounting as an Evaluation Tool of Biomass Utilization Systems: a Case Study on Domestic Animal Waste Treatment-Oriented Biomass Activities

著者	BESPYATKO Lyudmyla, SAGA Kiyotaka, YANAGIDA Takashi, AUNG Win, FUJIMOTO Shinji, MINOWA Tomoaki
journal or publication title	Journal of Integrated Field Science
volume	8
page range	1-6
year	2011-03
URL	http://hdl.handle.net/10097/50386

JIFS, 8 : 1 − 6 (2011) Symposium Paper

Introduction of Biomass Accounting as an Evaluation Tool of Biomass Utilization Systems: a Case Study on Domestic Animal Waste Treatment-Oriented Biomass Activities

Lyudmyla BESPYATKO*, Kiyotaka SAGA, Takashi YANAGIDA, Win AUNG,
Shinji FUJIMOTO and Tomoaki MINOWA

National Institute of Advanced Industrial Science and Technology (AIST),
Biomass Technology Research Center, AIST Chugoku
3-11-32, Kagamiyama, Higashihiroshima, Hiroshima, 739-0046, Japan
***e-Mail: lyu05665@yahoo.co.jp**

Keywords: biomass, waste treatment, biomass town, biomass accounting

Received 24 December 2010; accepted 1 February 2011

Abstract

Traditionally, primary industry's biomass leftovers had been treated with the purpose of waste reduction. However, nowadays, efficient utilization of biomass resources is regarded as an efficient tool of rural economy revival, zero-emission society establishment, and reduction of greenhouse gas emissions. In Japan, the necessity of biomass utilization for sustainable society was declared in Biomass Nippon Strategy, 2002. Based on this document, many rural towns and villages all around the country has adopted a "Biomass Town" concept and started to develop biomass utilization systems with multiple activities, including material, energy, and education biomass-related projects.

However, no comprehensive evaluation of economic and environmental efficiency of already existing biomass utilization systems is conducted. One of the reasons is that there exist no guidelines, which could assist in such estimation process.

In this paper, first, brief introduction on biomass accounting concept, suggested by authors in our previous works as an accounting tool to assist in decision-making related to biomass activities, is made. Next, the results of a case study on domestic animal waste treatment-oriented biomass activities (composting) are presented. The biomass accounting form is applied in the case study to account for four compost facilities built and managed by local government. Finally, discussion on the possibility of economic and environmental efficiency improvement of the biomass activities under the case study is conducted.

1. Introduction

Biomass resources had been used by humans as energy (direct burning, carbonization) or materials (compost, forage) since ancient times. Technology development caused shift to fossil fuel and chemical fertilizer consumption, and the main purpose of primary industry's biomass leftover treatment became waste reduction. However, nowadays, efficient utilization of biomass resources is regarded as an important tool of rural economy revival, zero-emission society establishment, and reduction of greenhouse gas emissions. In Japan, the necessity of biomass utilization for sustainable society was declared in Biomass Nippon Strategy, 2002. Based on this document, many rural towns and villages all around the country has adopted a "Biomass Town" concept and started to develop biomass utilization systems with multiple activities, including material, energy, and education biomass-related projects. These activities include traditional biomass treatment technologies, as well as modern ones, including bioplastic and wood block production (material), biodiesel and bioethanol production (energy), biomass events and tours (education), among others.

However, no comprehensive evaluation of economic and environmental efficiency of already existing biomass utilization systems is conducted. One of the reasons is that there exist no guidelines, which could assist in such estimation process. Taking this into account, a biomass accounting concept was suggested in our previous works as an accounting tool to assist in decision-making related to biomass activities.

Fig. 1 presents a biomass accounting framework. It can be divided into “Stock” and “Flow” parts. “Stock” consists of “Initial Cost” and “Natural Capital” and is aimed to record for human-made and natural stock. “Flow” part includes “Running Cost”, “Benefit”, and “Fossil Resources Substitution”. It records for economic and material inputs and outputs during a certain period of time (generally one year). Both “Stock” and “Flow” contain “Economy” and “Environment” areas. “Economy” records actual data on capital asset cost, running cost, and economic benefits. “Environment” records estimated environmental load and effect. “Flow” part contains “Resources” area as well, which traces the amount of material input and output. Biomass accounting framework is discussed in details in Bespyatko et al, 2009. Further, based on the concept of biomass accounting, a biomass accounting form was suggested by authors (Bespyatko et al, 2010). The form was designed in order to simplify data input and to automatize output and visualization of the results.

In this study, the biomass accounting form is applied to account for four compost facilities built and managed by local government. The next two sections explain the methodology and present the results of a case study.

2. Estimation methodology: assumptions and preliminary conditions

For the case study Shobara biomass town in Hiroshima prefecture was chosen. Biomass accounting form was applied in order to estimate economic and environmental performance of four compost facilities, construction of which was subsidized by government. Preliminary calculations of composting-related activities in this biomass town were conducted and presented in Bespyatko et al, 2009. In this study we improve the reliability of the results by re-considering a part of the calculation methodology. Namely, 1) not only CO_2 but such greenhouse gases as CH_4 and N_2O are considered as well to estimate environmental load and effect; 2) environmental load of the fermentation process is taken into account; 3) calculation of asset depreciation is based on actual durable years of capital instead of legislative ones; 4) diesel price is set at 118 yen/l (last 5 years average) instead of 150 yen/l (representative price of 2008).

Regarding the environmental load associated with compost (fermentation process), 0.00044 t-CH_4/t-manure and 0.0039 t-N_2O/t-N set in “Calculation methods and list of emission indices for calculation, reporting, and disclosure systems” (Ministry of Environment, 2010) are used (Table 1).

As to durable years of capital assets, though certain years are set by the law, actually such assets as buildings or machinery are used for much longer period. Because biomass-related activities do not consume large amount of fossil fuels, the most of environmental load coming from such an activity is the environmental load embodied in its initial cost. Hence, it is important to use actual durable years for environmental load estimation wherever possible. Table 2 lists legislative durable years and actual durable years, which were applied in this study. Actual durable years were set based on the information, obtained during hearings and conversations with related stakeholders.

Prices, used to estimate costs and benefits when actual data were not available, are listed in Table 3. For diesel, August 2005 - July 2010 average price of 118 yen/l is taken. Electric power is set at 15 yen/kWh. Regarding compost price, actual data of profit from sales are used; however, for barter exchange and captive use, the price is assumed to be 5,000 yen/t.

<table>
<tr><th rowspan="4">Stock</th><th rowspan="3">Economy</th><th rowspan="3">Environment</th><th rowspan="4">Flow</th><th>Economy</th><th colspan="7">Resources</th><th rowspan="3">Environment</th></tr>
<tr><th rowspan="3">10,000 yen</th><th colspan="3">Use/Production</th><th colspan="2">Within Region</th><th colspan="2">Outside Region</th></tr>
<tr><th rowspan="2">Type</th><th rowspan="2">Quantity</th><th rowspan="2">Unit</th><th colspan="2">Use/Supply</th><th colspan="2">Import/Export</th></tr>
<tr><th>10,000 yen</th><th>Load</th><th>Quantity</th><th>Unit</th><th>Quantity</th><th>Unit</th><th>Load & Effect</th></tr>
<tr><td>1. Initial Cost</td><td colspan="2"></td><td>1. Running Cost</td><td colspan="9"></td></tr>
<tr><td>Building</td><td rowspan="5">Capital asset cost breakdown</td><td rowspan="10">Capital assets' lifecycle environmental load (energy consumed and GHG emitted) ☆Estimated only for capital assets☆</td><td>Material</td><td rowspan="6">Running cost break down</td><td colspan="3" rowspan="6">Total utilization amount of biomass and other resources</td><td colspan="2" rowspan="6">Utilization amount of local resources</td><td colspan="2" rowspan="6">Utilization amount of imported resources</td><td rowspan="6">Energy consumed and GHG emitted during biomass production activities</td></tr>
<tr><td>Truck</td><td>Auxiliary material</td></tr>
<tr><td>Equipment</td><td>Fuel</td></tr>
<tr><td>Subsidy</td><td>Electricity</td></tr>
<tr><td>Real Cost</td><td>Depreciation</td></tr>
<tr><td>2. Natural Capital</td><td rowspan="5">Natural capital area (ha)</td><td>Other</td></tr>
<tr><td>Recultivated land</td><td>2. Benefit</td><td rowspan="3">Benefit break down</td><td colspan="3" rowspan="3">Total amount of bio products manufactured</td><td colspan="2" rowspan="3">Bio products supplied within the region</td><td colspan="2" rowspan="3">Bio products exported to other regions</td><td rowspan="3"></td></tr>
<tr><td>Recultivated forest</td><td>Direct</td></tr>
<tr><td rowspan="2"></td><td>Indirect</td></tr>
<tr><td>3. Fossil Resources' Substitution</td><td>Substitution Value</td><td colspan="3">Amount of fossil fuels substituted</td><td colspan="4"></td><td>Effect of substitution</td></tr>
</table>

Fig. 1. Biomass accounting framework.

Table 1. Emission indices[1].

Item	Unit	Energy MJ	CO_2 kg	Unit	CH_4 g	N_2O g
Agricultural machinery	10,000 yen	828	65	10,000 yen	84	**
Nonresidential building (nonwooden)	10,000 yen	612	56	10,000 yen	94	**
Car body	10,000 yen	1,060	84	10,000 yen	253	**
Urea	t	9,083	966	t	1,102	35.4
Electricity	kW	10.490	0.544	MW	2.25	1.62
Diesel	kl	41,514	2,812	kl	355	882
Compost (dairy cow manure)	---	---	---	t	440	13.1

[1] Energy consumption, CO_2 and CH_4 emission indices for agricultural machinery, nonresidential building, car body, and urea are taken from JEMAI, 1999. N_2O emission index for urea was not available, hence, N_2O emission index for ammonia is taken from JEMAI-LCA Pro, 2005 (hearing data). Energy consumption, CO_2, CH_4, and N_2O emission indices for electricity and diesel are based on CGER, 2010. Energy and CO_2 embodied in compost is calculated separately by aggregating method in biomass accounting form. In order to calculate the amount of N_2O embodied in 1t of manure, the index of 3.358 g-N/kg manure (LEIO, 1998) was used.

Table 2. Legislative and actual durable years.

	Legislative durable years	Actual durable years[1]
Non-residential building	20	40
Equipment	7	25
Truck	5	15

[1] Actual durable years are set based on information obtained during hearings

Table 3. Prices used for estimation.

	Price	
Diesel	118	yen/l
Electric power	15	yen/kWh
Urine	300	yen/kg
Compost (barter, captive use)	5,000	yen/t

Estimation of chemical fertilizer substitution by compost is based on data taken from LEIO, 1998 (Table 4) and hearing data on the manure amount utilized by each facility (Table 5).

3. Results

Total cost-benefit and environmental performance of the four composting facilities under the case study is summarized in the form of accounting table in Fig. 2 and visualized in Graph 1-2.

Totally, 7,601 t of compost is produced from 16,475 t of cow manure annually. Most of the product is sold (4,188 t/year) or distributed freely (indirect captive use, 1,198 t/year). Total amount of urea substituted is 94 t[1]. Economic value of substitution equals to 28,260 thousand yen assuming that urea unit price is 300 yen/kg.

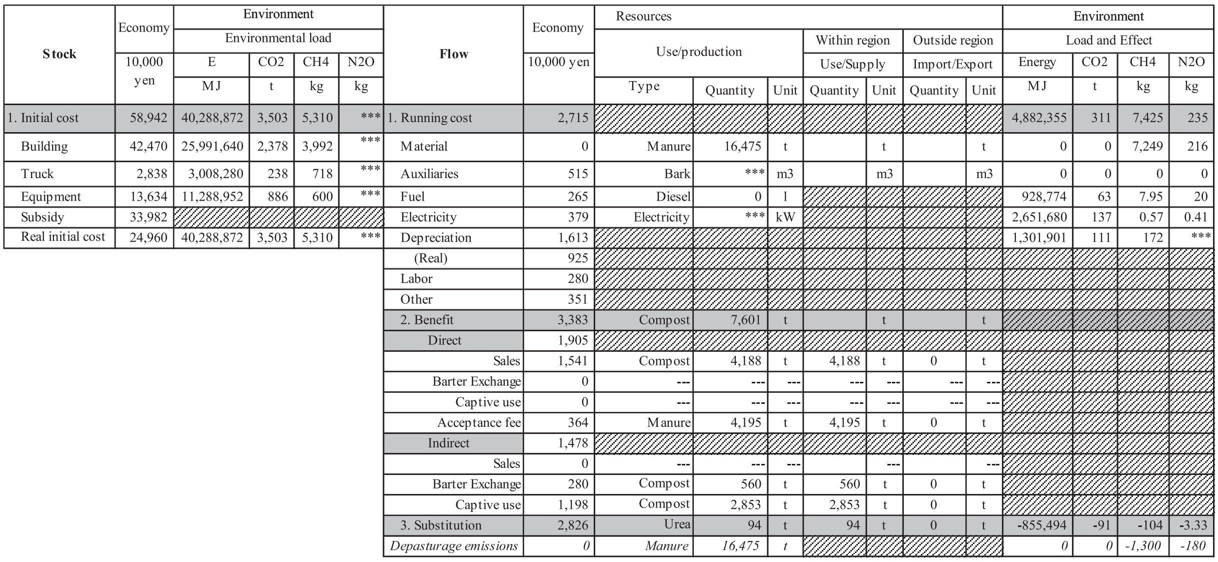
Regarding economic profitability, total benefit was 33,830 thousand yen/year comparing to 27,150 thousand yen/year of running cost. Here, total benefit

Table 4. Cow manure compost element composition and chemical fertilizer substitution rate.

Cow manure compost	T-N	P_2O_5	K_2O
Compost element composition (%)	1.9	2.3	2.4
Chemical fertilizer substitution (%)	30	70	90

Table 5. Manure amount utilized and chemical fertilizer substituted by each facility.

	Facility A			Facility B			Facility C			Facility D		
Manure amount (t/year)	3,200			5,181			1,094			7,000		
	N	P	K	N	P	K	N	P	K	N	P	K
Active element amount (t)	30.40	36.80	38.40	13.30	16.10	16.80	4.94	5.98	6.24	52.25	63.25	66.00
Chemical fertilizer substituted (t)	9.12	25.76	34.56	3.99	11.27	15.12	1.48	4.19	5.62	15.68	44.28	59.40



Stock	Economy	Environment			
		Environmental load			
	10,000 yen	E	CO2	CH4	N2O
		MJ	t	kg	kg
1. Initial cost	58,942	40,288,872	3,503	5,310	***
Building	42,470	25,991,640	2,378	3,992	***
Truck	2,838	3,008,280	238	718	***
Equipment	13,634	11,288,952	886	600	***
Subsidy	33,982	▨	▨	▨	▨
Real initial cost	24,960	40,288,872	3,503	5,310	***

Flow	Economy	Resources							Environment			
		Use/production			Within region		Outside region		Load and Effect			
	10,000 yen				Use/Supply		Import/Export		Energy	CO2	CH4	N2O
		Type	Quantity	Unit	Quantity	Unit	Quantity	Unit	MJ	t	kg	kg
1. Running cost	2,715	▨	▨	▨	▨	▨	▨	▨	4,882,355	311	7,425	235
Material	0	Manure	16,475	t		t		t	0	0	7,249	216
Auxiliaries	515	Bark	***	m3		m3		m3	0	0	0	0
Fuel	265	Diesel	0	l	▨	▨	▨	▨	928,774	63	7.95	20
Electricity	379	Electricity	***	kW	▨	▨	▨	▨	2,651,680	137	0.57	0.41
Depreciation	1,613	▨	▨	▨	▨	▨	▨	▨	1,301,901	111	172	***
(Real)	925	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Labor	280	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Other	351	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
2. Benefit	3,383	Compost	7,601	t		t		t	▨	▨	▨	▨
Direct	1,905	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Sales	1,541	Compost	4,188	t	4,188	t	0	t	▨	▨	▨	▨
Barter Exchange	0	---	---	---	---	---	---	---	▨	▨	▨	▨
Captive use	0	---	---	---	---	---	---	---	▨	▨	▨	▨
Acceptance fee	364	Manure	4,195	t	4,195	t	0	t	▨	▨	▨	▨
Indirect	1,478	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Sales	0	---	---	---		---		---	▨	▨	▨	▨
Barter Exchange	280	Compost	560	t	560	t	0	t	▨	▨	▨	▨
Captive use	1,198	Compost	2,853	t	2,853	t	0	t	▨	▨	▨	▨
3. Substitution	2,826	Urea	94	t	94	t	0	t	-855,494	-91	-104	-3.33
Depasturage emissions	*0*	*Manure*	*16,475*	*t*	▨	▨	▨	▨	*0*	*0*	*-1,300*	*-180*

Fig. 2. Total economic and environmental performance of the four composting facilities.

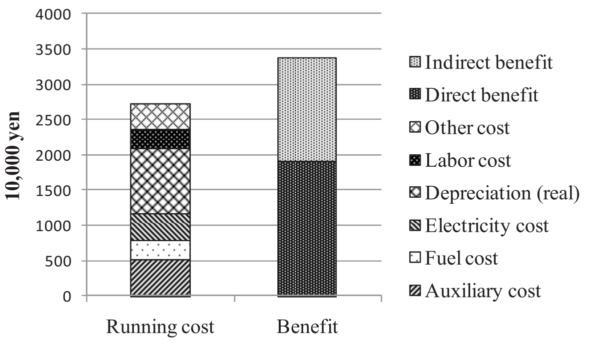
includes direct and indirect benefit[2]. However, if consider only direct benefit (19,050 thousand yen), the activity turns to be unprofitable. Yet, because there is a considerable (hidden) economic gain from indirect profit (such as barter exchange and captive use), which is usually not recorded in orthodox accounting tools, we suggest that it has to be paid attention and included into calculations as well.

From the table and graphs it is clear that total environmental performance of the biomass activities under the case study is poor. Total emission is 540 t of CO_2 equivalent per year, which is much higher than total CO_2 reduction from urea substitution (94 t CO_2 equivalent/year). Most of the emissions are coming from manure fermentation process (219 t CO_2 equivalent/year), electricity consumption (138 t CO_2 equivalent/year), and depreciation (114 t CO_2 equivalent/year). From this, it becomes clear that en-

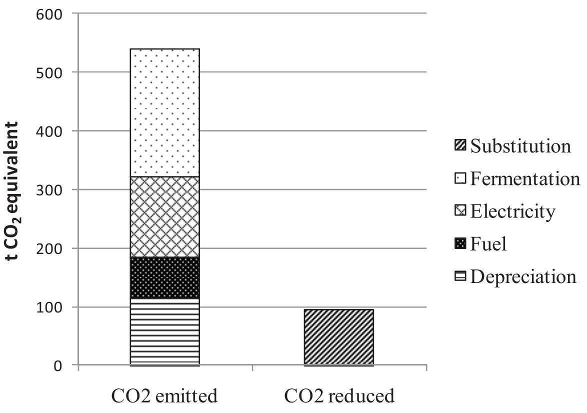
---

[1] Based on Table 4-5, amount of nitrogen containing in 7,601 t of compost is calculated to be 43 t (chemical fertilizer substitution coefficient (30%) is considered). This substitutes 94 t of urea assuming that urea nitrogen content is 46%.

[2] Direct benefit: benefit gained by an economic activity from the same activity. For example, product sale or consumption of a part of the product in order to produce more of the same product.
Indirect benefit: benefit, which is brought by an economic activity to another economic activity. For example, captive use of pellets with a purpose other than to produce more pellets.



Graph 1. Total cost-benefit performance of the four compost facilities



Graph 2. Total GHG balance of the four compost facilities

Table 6. Environmental load embodied in composting, urea production, and depasturage[1].

	CO_2 (t)	CH_4 (t)	N_2O (t)	Total (t) CO_2 equivalent
Compost (1)[2]	311	7.425	0.235	540
Compost (2)	111	7.249	0.216	330
Urea	91	0.104	0.003	100
Depasturage	0	1.300	0.180	83

[1] Utilized or substituted manure amount is the same for each process (16,475 t)
[2] Compost(1) is composting technology of the facilities under the case study
Compost(2) is possible composting technology which consumes renewable energy

vironmental load of compost facilities under the case study is much higher comparing to that one of urea production or depasturage (Table 6).

4. Discussion

The results of the case study briefly described in the previous section showed that total economic performance of the four facilities is considerably high if indirect benefits are taken into account. However, they also indicated low environmental efficiency of the composting technology under investigation.

One of the possibilities of environmental efficiency improvement of the biomass activities under the case study is shift to renewable energy consumption. Assuming that amount and cost of biofuel (bioethanol or biodiesel) and green electricity necessary for compost production is the same as that one of fossil fuel and electricity which is consumed at present, total environmental load could be reduced from 540 t CO_2 equivalent/year to 330 t CO_2 equivalent/year (Table 6).

Another option is to increase the concentration of nitrogen in compost. Table 7 presents urea amount, profit and CO2 reduced due to substitution of chemical fertilizer with compost with different nitrogen concentration. Here, substitution profit is calculated based on assumption that production cost is not influenced by nitrogen-enhancing technology. From the table it is clear that increasing of nitrogen concentration to 5%-10% (wet value) leads to considerable improvement in economic and environmental efficiency of compost production.

Taking the above into consideration, it can be suggested that shift to renewable energy consumption and increase of nitrogen concentration in compost can considerably raise economic benefit, as well as significantly lower environmental load by means of larger amount of chemical fertilizer substitution. However, the cost of nitrogen-enhancing technology has to be taken into account, as well as more precise estimation of environmental load embodied in urea production need to be conducted to increase the reliability of estimation result. This is the topic for our further research.

Table 7. Influence of nitrogen concentration on compost profitability and environmental efficiency

Nitrogen content (wet value %)	Total nitrogen amount (t)	Urea substituted (t)	Substitution profit (10,000 yen)	CO_2 reduction (t CO_2 equivalent)
0.35	27	17	520	17
1.90	43	94	2,826	94
5	380	248	7,436	248
10	760	496	14,872	496

References

Bespyatko, L. Y., K. Saga, T. Yanagida, W. Aung, S. Fujimoto and T. Minowa (2010) Research on a biomass accounting form with an accent on biomass towns in Japan, Proceedings of 5th Biomass Conference, Lyon, France, 178-179.

Bespyatko, L. Y., C. Tada, T. Yanagida, K. Saga, E. Bautista, S. Fujimoto and T. Minowa (2009) Research on a Biomass Accounting Framework as a Biomass Town Assessment and Information Provision Tool. J. Jpn. Inst. Energy, 88: 1081-1094.

CGER (2010) National Greenhouse Gas Inventory Report of Japan.

http://www-gio.nies.go.jp/aboutghg/nir/nir-j.html (date of access: August 10, 2010)

JEMAI (1999) Introduction to LCA Practic, JEMAI, pp. 194.

JEMAI (2005) JEMAI-LCA Pro, CD data.

LEIO (1998) Livestock manure treatment and utilization guide, LEIO, pp. 202.

Ministry of Agriculture, Forestry and Fisheries (2006) Biomass-Nippon Strategy. http://www.maff.go.jp/biomass/eng/biomass_honbun.htm (date of access: August 13, 2010)

Ministry of Environment (2010) Calculation methods and list of emission indices for calculation, reporting, and disclosure systems. http://www.env.go.jp/earth/ghg-santeikohyo/material/itiran.pdf (date of access: August 26, 2010)