c.3 Three Contents (volatile matter, water and ash)

Measuring objects of the three contents analysis are only combustible matter (kitchen waste, paper, textile, grass & wood, plastics and rubber & leather) of the waste. Table C-24 shows results of the three contents analysis

Table C-24: Results of Three Contents Analysis (for combustible matter)

Category			Dry season				Rain season				Average			
			Volatile matter	Water	Ash	total	Volatile matter	Water	Ash	total	Volatile matter	Water	Ash	Total
Household		High income	42.6%	53.0%	4.3%	100.0%	42.3%	47.6%	10.1%	100.0%	42.4%	50.3%	7.2%	100.0%
		Middle income	34.8%	59.1%	6.2%	100.0%	39.4%	56.0%	4.7%	100.0%	37.1%	57.5%	5.4%	100.0%
		Low income	32.2%	59.1%	8.7%	100.0%	28.9%	61.1%	10.0%	100.0%	30.6%	60.1%	9.3%	100.0%
Restaurant			36.4%	60.4%	3.2%	100.0%	27.7%	64.8%	7.5%	100.0%	32.1%	62.6%	5.3%	100.0%
Commercial			59.2%	30.3%	10.4%	100.0%	59.6%	29.7%	10.7%	100.0%	59.4%	30.0%	10.5%	100.0%
Institution			60.0%	31.3%	8.7%	100.0%	66.3%	29.6%	4.1%	100.0%	63.2%	30.4%	6.4%	100.0%
Market			35.7%	58.8%	5.5%	100.0%	29.6%	68.8%	1.6%	100.0%	32.6%	63.8%	3.6%	100.0%
Street sweeping			51.6%	42.9%	5.5%	100.0%	34.4%	41.4%	24.3%	100.0%	43.0%	42.2%	14.9%	100.0%
Collection vehicle	Panama	High income	44.3%	49.6%	6.0%	100.0%	33.6%	60.1%	6.3%	100.0%	39.0%	54.9%	6.2%	100.0%
		Middle income	42.6%	50.7%	6.6%	100.0%	31.7%	56.8%	11.5%	100.0%	37.2%	53.8%	9.1%	100.0%
		Low income	37.5%	59.2%	3.2%	100.0%	38.9%	52.9%	8.2%	100.0%	38.2%	56.1%	5.7%	100.0%
	San Miguelito		48.8%	44.6%	6.7%	100.0%	34.5%	56.8%	8.7%	100.0%	41.6%	50.7%	7.7%	100.0%
	Arraijan		51.3%	39.1%	9.6%	100.0%	13.9%	69.2%	16.9%	100.0%	32.6%	54.2%	13.3%	100.0%

c.4 Chemical Analysis

c.4.1 Elementary Analysis

Measuring objects of the elementary analysis are only combustible matter (kitchen waste, paper, textile, grass & wood, plastics and rubber & leather) of the waste. Table C-25 shows results of the elementary analysis.

Table C-25: Results of Elementary Analysis

		Household			Restaurant	Commercial	Institution	Market	Street sweeping	Collection vehicle				
										Panama			San Miguelito	Arrijan
		High income	Middle income	Low income						High income	Middle income	Low income		
Dry season	Carbon	44.952%	44.761%	49.297%	52.690%	46.889%	48.200%	55.046%	44.439%	46.828%	46.054%	46.918%	46.070%	48.684%
	Hydrogen	6.513%	6.469%	6.485%	6.292%	6.252%	6.244%	5.939%	5.735%	6.013%	6.383%	6.335%	6.300%	6.384%
	Nitrogen	0.190%	0.236%	0.167%	0.211%	0.178%	0.181%	0.236%	0.145%	0.136%	0.091%	0.146%	0.193%	0.240%
	Sulfur	0.022%	0.027%	0.034%	0.035%	0.017%	0.019%	0.052%	0.024%	0.015%	0.021%	0.014%	0.019%	0.024%
	Oxygen	48.323%	48.507%	44.017%	40.772%	46.665%	45.356%	38.728%	49.657%	47.008%	47.450%	46.587%	47.418%	44.667%
	Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Rain season	Carbon	46.734%	55.591%	61.104%	47.562%	56.519%	51.100%	45.732%	54.125%	55.514%	57.614%	56.112%	54.777%	53.543%
	Hydrogen	8.679%	8.391%	7.888%	7.567%	7.275%	6.674%	6.301%	9.637%	7.046%	7.343%	7.627%	8.107%	8.423%
	Nitrogen	0.286%	0.263%	0.278%	0.254%	0.179%	0.130%	0.147%	0.066%	0.137%	0.287%	0.177%	0.252%	0.271%
	Sulfur	0.087%	0.477%	0.087%	0.265%	0.060%	0.078%	0.044%	0.041%	0.047%	0.052%	0.076%	0.050%	0.064%
	Oxygen	44.214%	35.278%	30.643%	44.352%	35.966%	42.017%	47.776%	36.131%	37.256%	34.704%	36.008%	36.814%	37.699%
	Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Average	Carbon	45.843%	50.176%	55.201%	50.126%	51.704%	49.650%	50.389%	49.282%	51.171%	51.834%	51.515%	50.423%	51.114%
	Hydrogen	7.596%	7.430%	7.187%	6.929%	6.763%	6.459%	6.120%	7.686%	6.530%	6.863%	6.981%	7.203%	7.403%
	Nitrogen	0.238%	0.249%	0.222%	0.232%	0.178%	0.156%	0.192%	0.105%	0.136%	0.189%	0.161%	0.222%	0.255%
	Sulfur	0.054%	0.252%	0.060%	0.150%	0.039%	0.048%	0.048%	0.033%	0.031%	0.037%	0.045%	0.035%	0.044%
	Oxygen	46.269%	41.893%	37.330%	42.562%	41.316%	43.687%	43.252%	42.894%	42.132%	41.077%	41.297%	42.116%	41.183%
	Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

c.4.2 Calorific Value

Calorific value measured by "Bomb Meter" method. Results of "Bomb Meter" method are "Higher Calorific Value" of combustible part of the waste. Consequently, "Lower Calorific Value" is calculated according to the following formula.

$$Ho = Hcvc \times \frac{100 - w}{100}$$

where :
Ho : higher calorific value of combustible part of waste (kcal/kg)
Hcvc : results of "Bomb Meter" test (given higher calorific value of combustible part of waste) (kcal/kg)
W :water content of total combustible waste (%)

$$Hu = Ho - 6(9h + W)$$

where :
Hu : lower calorific value of combustible part of waste (kcal/kg)
h : hydrogen content of combustible part of waste (%)
M : moisture content of combustible part of waste (%)

Table C-26 shows results of the calorific value analysis in kilocalorie bases, also Table C-27 shows in kilojoules bases.

Table C-26: Results of Calorific Value Analysis (kilocalories)

		Household			Restaurant	Commercial	Institution	Market	Street sweeping	Collection vehicle				
										Panama			San Miguelito	Arraijan
		High income	Middle income	Low income						High income	Middle income	Low income		
Dry season	Water contents	53.04%	59.09%	59.10%	60.40%	30.32%	31.29%	58.83%	42.90%	49.64%	50.74%	59.22%	44.58%	39.10%
	Hydrogen contents	6.51%	6.47%	6.49%	6.29%	6.25%	6.24%	5.94%	5.73%	6.01%	6.38%	6.34%	6.30%	6.38%
	Hcvc (dry base) (kcal/kg)	3,239	3,045	4,146	4,862	3,521	3,728	4,749	3,642	4,050	4,257	1,012	3,482	4,024
	Ho (kcal/kg)	1,521	1,246	1,696	1,926	2,453	2,561	1,955	2,079	2,039	2,097	413	1,930	2,450
	Hu (kcal/kg)	**851**	**542**	**991**	**1,224**	**1,933**	**2,036**	**1,281**	**1,512**	**1,416**	**1,448**	**-284**	**1,322**	**1,871**
Rain season	Water contents	47.59%	55.97%	61.10%	64.78%	29.71%	29.58%	68.82%	41.40%	60.08%	56.83%	52.89%	56.76%	69.21%
	Hydrogen contents	8.68%	8.39%	7.89%	7.57%	7.27%	6.67%	6.30%	9.64%	7.05%	7.34%	7.63%	8.11%	8.42%
	Hcvc (dry base) (kcal/kg)	4,346	5,039	5,372	4,485	4,793	4,776	4,420	3,964	5,386	4,674	4,736	4,778	3,755
	Ho (kcal/kg)	2,278	2,219	2,090	1,580	3,369	3,363	1,378	2,323	2,150	2,018	2,231	2,066	1,156
	Hu (kcal/kg)	**1,524**	**1,430**	**1,297**	**783**	**2,798**	**2,825**	**625**	**1,554**	**1,409**	**1,280**	**1,502**	**1,288**	**286**
Average	Hcvc (dry base) (kcal/kg)	3,793	4,042	4,759	4,674	4,157	4,252	4,585	3,803	4,718	4,466	2,874	4,130	3,890
	Ho (kcal/kg)	1,900	1,733	1,893	1,753	2,911	2,962	1,667	2,201	2,095	2,058	1,322	1,998	1,803
	Hu (kcal/kg)	**1,188**	**986**	**1,144**	**1,004**	**2,366**	**2,431**	**953**	**1,533**	**1,413**	**1,364**	**609**	**1,305**	**1,079**

Table C-27: Results of Calorific Value Analysis (kilojoules)

			Dry season			Rain season			Average		
			Hcvc kj/kg)	Ho(kj/kg)	Hu (kj/kg)	Hcvc kj/kg)	Ho(kj/kg)	Hu (kj/kg)	Hcvc kj/kg)	Ho(kj/kg)	Hu (kj/kg)
Household		High income	13,559	6,367	3,562	18,193	9,536	6,380	15,876	7,952	4,971
		Middle income	12,747	5,216	2,269	21,094	9,289	5,986	16,921	7,253	4,128
		Low income	17,355	7,100	4,148	22,487	8,749	5,429	19,921	7,925	4,789
Restaurant			20,353	8,062	5,124	18,774	6,614	3,278	19,564	7,338	4,201
Commercial			14,739	10,268	8,092	20,064	14,103	11,713	17,402	12,186	9,903
Institution			15,606	10,720	8,523	19,993	14,078	11,826	17,800	12,399	10,175
Market			19,880	8,184	5,362	18,502	5,768	2,616	19,191	6,976	3,989
Street sweeping			15,246	8,703	6,329	16,594	9,724	6,505	15,920	9,214	6,417
Collection vehicle	Panama	High income	16,954	8,535	5,927	22,546	9,000	5,898	19,750	8,768	5,913
		Middle income	17,820	8,778	6,061	19,566	8,447	5,358	18,693	8,613	5,710
		Low income	4,236	1,729	-1,189	19,825	9,339	6,287	12,031	5,534	2,549
	San Miguelito		14,576	8,079	5,534	20,001	8,648	5,392	17,289	8,364	5,463
	Arraijan		16,845	10,256	7,832	15,719	4,839	1,197	16,282	7,548	4,515

C.1.3 Findings

a. Waste Generation Rate

a.1 Household waste

It is not suitable to take mean values as representative values for waste generation rates, as the mean values vary widely with taking into account the 95 % confident interval as the following table shows.

Table C-28: Results of Waste Generation Rate Survey

Category	Waste generation rate (g/person/day)
High income	635.5 to 898.3 (average 766.9)
Middle income	505.8 to 655.8 (average 580.8)
Low income	334.0 to 440.2 (average 387.1)

The following table compares the results of this survey and household waste generation rates of other Latin American countries. Household waste generation rates in those countries range between 500～700g/person/day.

Table C-29: Comparison of Waste Generation Rate in Latin American Countries

Sources		unit	Municipality of PANMA by WACS	San Salvador / El Salvador [1]	Mexico [2] D.F/1998	Nicaragua principal cities [3] 1996	Nicaragua Managua [4] / 1995	Paraguay Asuncion [5] /1994
Household	High income	g/person/day	898.3(635.5 to 898.3)*	600	616	675	664	682
	Middle income		655.8(505.8 to 655.8)*	540				
	Low income		440.2(334.0 to 440.2)*	420				
Commercial	Restaurant	g/employee/day	6,373	NA	NA	NA	NA	NA
	Others		1,918	482	NA	1,676	NA	NA
Institutional			201	NA	NA	NA	NA	NA
Market			4,178	1,674	1,025	2,827	NA	NA
Street sweeping		g/m/day	16	198	NA	NA	50	NA

*: 95% reliable value, NA : not available
Source : [1] JICA study 2001, [2] JICA study 1999, [3] JICA study 1997, [4] JICA study 1995, [5] JICA study 1996

The following table shows a result of calculation of waste generation rate on the basis of the highest value of the 95% confident interval with taking into account population distribution by income level.

Table C-30: Weighing Average of Waste Generation Rate

Income level	Share (%)	Generation rate (g/person/day)	Weighing average (g/person/day)
High income	11%	898.3	98.8
Muddle income	46%	655.8	301.7
Low income	43%	440.2	189.3
Total	100%		**590 (589.8)**

Although the waste generation rate of 590 g/person/day means the highest value obtained from the survey results, it is a reasonable value in comparison with ones of other Latin American counties. The IDB study concluded that waste generation rate of the metropolitan area (Panama, San Miguelito and Colon) was 620 g/person/day.

Consequently, the waste generation rate of 590 g/person/day is regarded as appropriate.

a.2 Commercial, Institutional, Market, Street Sweeping wastes

Results show that waste generation rate of commercial waste (restaurant) is about 6,370 g/employee/day, one of commercial waste (others) is about 1,920 g/employee/day, one of institutional waste is about 200 g/employee/day, market waste is about 4,180 g/employee/day and one of street sweeping waste is about 16 g/m/day. These waste generation rates vary widely depending on urban and industrial structures, then, it is not recommendable to estimate representative values by comparing them with data of other countries. Consequently, those waste generation rates obtained the survey results are directly used in the Study.

a.3 Collection Vehicle waste

It should be noted that a fairy large amount of medical waste was found in waste of collection vehicle from Veranillo Viejo. Therefore, it is conjectured that a considerable amount of medical waste are collected from ordinary collection routes other than the medical waste collection work.

b. Waste Composition

b.1 Physical Composition (wet base)

Considerable portion of household waste is occupied with paper and plastics (about 65 to 70% in volume and 30-40% in weight at wet base).

Non-combustible items occupy about 11 to 16 % of waste from business establishments (commercial and institutional establishments). Meanwhile, non-combustible items are 8 to 10 % of household waste. Recyclable materials such as metals and glass occupy more than 10

to 16 % of waste from business establishments. In addition, a large amount of cardboards for transporting and storing products were found.

The table bellow presents waste composition in generation categories.

Table C-31: Summary of Waste Composition

	Household			Commercial		Institutional	Market	Street Sweeping	Overall
	High income	Middle income	Low income	Restaurant	Others				
Waste amount (ton/day)	73.3	224.9	141	106.4	115.6	29.3	23.5	8.4	722.4
Kitchen Waste (%)	32.9%	53.3%	43.9%	46.4%	25.0%	14.0%	64.1%	14.8%	42.2%
Paper (%)	25.0%	20.3%	17.8%	32.7%	37.3%	58.7%	15.9%	24.6%	26.3%
Textile (%)	7.5%	3.3%	9.7%	1.5%	1.9%	0.7%	2.5%	3.5%	4.3%
Grass Wood (%)	9.5%	4.9%	4.5%	0.2%	2.5%	2.3%	2.3%	21.7%	4.2%
Plastic (%)	15.4%	9.5%	11.5%	8.1%	20.5%	8.4%	7.0%	16.7%	12.0%
Rubber Leather (%)	1.4%	0.1%	3.1%	0.0%	0.0%	0.0%	0.0%	1.3%	0.8%
Metal (%)	3.3%	3.3%	4.3%	1.9%	5.5%	9.1%	2.3%	2.4%	3.8%
Bottles Glass (%)	4.6%	5.0%	4.6%	9.3%	5.9%	6.8%	5.6%	6.3%	5.8%
Soil Stone (%)	0.4%	0.1%	0.4%	0.0%	0.9%	0.0%	0.0%	8.7%	0.4%
Others (%)	0.0%	0.3%	0.2%	0.0%	0.5%	0.2%	0.3%	0.0%	0.2%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

b.2 Water Content

Water content of household waste was about 50 to 60% in wet base as well as restaurant and market wastes. Meanwhile, water contents of commercial (others), institutional wastes were about 30%, restaurant, market were 63% and street sweeping waste was 42%.

c. Chemical Analysis

c.1 Three contents

Three contents (volatile matter, water and ash) of each category of waste were obtained from the chemical analysis, then, three contents for the whole waste generated in Panama Municipality were estimated with taking into account amount of waste generated from each category based on the WACS data. Consequently, the three contents of waste generated in Panama Municipality are regarded as follows.

- volatile matter (combustible matter) : 40%
- water contents : 53%
- ash contents : 7%

Table C-32: Weighing Average of Three Contents for Combustible Matter

	Volatile matter (%)	Water contents (%)	Ash contents (%)	Total	Generation amount (ton/day)	Volatile matter (%)	Water contents (%)	Ash contents (%)
Household high income	42.4%	50.3%	7.2%	100.0%	73.3	4.3%	5.1%	0.7%
Household middle income	37.1%	57.5%	5.4%	100.0%	224.9	11.6%	17.9%	1.7%
Household low income	30.6%	60.1%	9.3%	100.0%	141.0	6.0%	11.7%	1.8%
Commercial/restaurant	32.1%	62.6%	5.3%	100.0%	106.4	4.7%	9.2%	0.8%
Commercial/others	59.4%	30.0%	10.5%	100.0%	115.6	9.5%	4.8%	1.7%
Institutional	63.2%	30.4%	6.4%	100.0%	29.3	2.6%	1.2%	0.3%
Market	32.6%	63.8%	3.6%	100.0%	23.5	1.1%	2.1%	0.1%
Street sweeping	43.0%	42.2%	14.9%	100.0%	8.4	0.5%	0.5%	0.2%
Total	-	-	-	-	722.4	40.3%	52.5%	7.3%

notes: Generation amount is based on WACS in the study, not correspondence with actual waste stream.

c.2 Elementary components and Calorific Value

Results of elementary analysis are shown in the table below.

Table C-33: Results of Elementary Analysis

		Household			Restaurant	Commercial	Institution	Market	Street sweeping	Collection vehicle				
										Panama			San Miguelito	Arrijan
		High income	Middle income	Low income						High income	Middle income	Low income		
Dry season	Carbon	44.952%	44.761%	49.297%	52.690%	46.889%	48.200%	55.046%	44.439%	46.828%	46.054%	46.918%	46.070%	48.684%
	Hydrogen	6.513%	6.469%	6.485%	6.292%	6.252%	6.244%	5.939%	5.735%	6.013%	6.383%	6.335%	6.300%	6.384%
	Nitrogen	0.190%	0.236%	0.167%	0.211%	0.178%	0.181%	0.236%	0.145%	0.136%	0.091%	0.146%	0.193%	0.240%
	Sulfur	0.022%	0.027%	0.034%	0.035%	0.017%	0.019%	0.052%	0.024%	0.015%	0.021%	0.014%	0.019%	0.024%
	Oxygen	48.323%	48.507%	44.017%	40.772%	46.665%	45.356%	38.728%	49.657%	47.008%	47.450%	46.587%	47.418%	44.667%
	Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Rain season	Carbon	46.734%	55.591%	61.104%	47.562%	56.519%	51.100%	45.732%	54.125%	55.514%	57.614%	56.112%	54.777%	53.543%
	Hydrogen	8.679%	8.391%	7.888%	7.567%	7.275%	6.674%	6.301%	9.637%	7.046%	7.343%	7.627%	8.107%	8.423%
	Nitrogen	0.286%	0.263%	0.278%	0.254%	0.179%	0.130%	0.147%	0.066%	0.137%	0.287%	0.177%	0.252%	0.271%
	Sulfur	0.087%	0.477%	0.087%	0.265%	0.060%	0.078%	0.044%	0.041%	0.047%	0.052%	0.076%	0.050%	0.064%
	Oxygen	44.214%	35.278%	30.643%	44.352%	35.966%	42.017%	47.776%	36.131%	37.256%	34.704%	36.008%	36.814%	37.699%
	Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Average	Carbon	45.843%	50.176%	55.201%	50.126%	51.704%	49.650%	50.389%	49.282%	51.171%	51.834%	51.515%	50.423%	51.114%
	Hydrogen	7.596%	7.430%	7.187%	6.929%	6.763%	6.459%	6.120%	7.686%	6.530%	6.863%	6.981%	7.203%	7.403%
	Nitrogen	0.238%	0.249%	0.222%	0.232%	0.178%	0.156%	0.192%	0.105%	0.136%	0.189%	0.161%	0.222%	0.255%
	Sulfur	0.054%	0.252%	0.060%	0.150%	0.039%	0.048%	0.048%	0.033%	0.031%	0.037%	0.045%	0.035%	0.044%
	Oxygen	46.269%	41.893%	37.330%	42.562%	41.316%	43.687%	43.252%	42.894%	42.132%	41.077%	41.297%	42.116%	41.183%
	Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

The following formulas are in general proposed to estimate lower calorific value of waste from its elementary components.

Dulong formula $: Ho = 81C + 342.5(H - \frac{O}{8}) + 22.5S$

Scheurer-Kestner formula $: Ho = 81(C - 3 \times \frac{O}{4}) + 342.5H + 22.5S + 57 \times 2 \times \frac{O}{4}$

where *C: Carbon content (%)*

H: Hydrogen content (%)

O: Oxygen content (%)

S: Sulfur content (%)

Table C-34 shows the lower calorific values of wastes based on the results of elementary analysis with the use of the above formulas.

Table C-34: Comparison of Lower Calorific Value

unit kcal/kg

		Household			Restaurant	Commercial	Institution	Market	Street sweeping	Collection vehicle				
										Panama			Sam Miguelito	Arrijan
		High income	Middle income	Low income						High income	Middle income	Low income		
Dry season	Dulong (Hcvc)	3,803	3,765	4,331	4,678	3,942	4,101	4,836	3,438	3,840	3,886	3,976	3,860	4,218
	Scheurer-Kestner (Hcvc)	2,266	2,191	2,835	3,244	2,585	2,762	3,466	1,980	2,374	2,385	2,443	2,401	2,837
	Dulong (Ho)	1,786	1,540	1,771	1,853	2,747	2,818	1,991	1,963	1,934	1,914	1,621	2,139	2,569
	Scheurer-Kestner (Ho)	1,064	896	1,160	1,285	1,801	1,898	1,427	1,131	1,195	1,175	996	1,331	1,728
	Dulong (Hu)	1,116	836	1,066	1,151	2,227	2,293	1,317	1,396	1,311	1,265	924	1,531	1,990
	Scheurer-Kestner (Hu)	394	192	455	583	1281	1373	753	564	572	526	299	723	1149
	Measured	851	542	991	1,224	1,933	2,036	1,281	1,512	1,416	1,448	-284	1,322	1,871
Rain season	Dulong (Hcvc)	4,867	5,877	6,341	4,551	5,531	4,628	3,818	6,139	5,316	5,697	5,617	5,639	5,609
	Scheurer-Kestner (Hcvc)	3,318	4,445	4,997	2,953	4,314	3,335	2,207	4,721	3,906	4,336	4,241	4,199	4,061
	Dulong (Ho)	2,551	2,588	2,466	1,603	3,888	3,259	1,190	3,597	2,122	2,459	2,646	2,438	1,727
	Scheurer-Kestner (Ho)	1,739	1,957	1,944	1,040	3,032	2,349	688	2,767	1,559	1,872	1,998	1,816	1,250
	Dulong (Hu)	1,797	1,799	1,673	806	3,317	2,721	437	2,828	1,381	1,721	1,917	1,660	857
	Scheurer-Kestner (Hu)	985	1168	1151	243	2461	1811	-65	1998	818	1134	1269	1038	380
	Measured	1,524	1,430	1,297	783	2,798	2,825	625	1,554	1,409	1,280	1,502	1,288	286
Average	Dulong (Hcvc)	4,335	4,821	5,336	4,615	4,736	4,365	4,327	4,789	4,578	4,791	4,797	4,749	4,914
	Scheurer-Kestner (Hcvc)	2,792	3,318	3,916	3,098	3,449	3,049	2,837	3,351	3,140	3,360	3,342	3,300	3,449
	Dulong (Ho)	2,154	2,048	2,129	1,727	3,314	3,037	1,565	2,770	2,066	2,214	2,108	2,343	2,253
	Scheurer-Kestner (Ho)	1,387	1,409	1,562	1,159	2,414	2,121	1,026	1,938	1,417	1,553	1,469	1,628	1,581
	Dulong (Hu)	1,442	1,302	1,380	977	2,769	2,506	852	2,102	1,384	1,521	1,395	1,650	1,528
	Scheurer-Kestner (Hu)	675	663	813	409	1869	1590	313	1270	735	860	756	935	856
	Measured	1,188	986	1,144	1,004	2,366	2,431	953	1,533	1,413	1,364	609	1,305	1,079

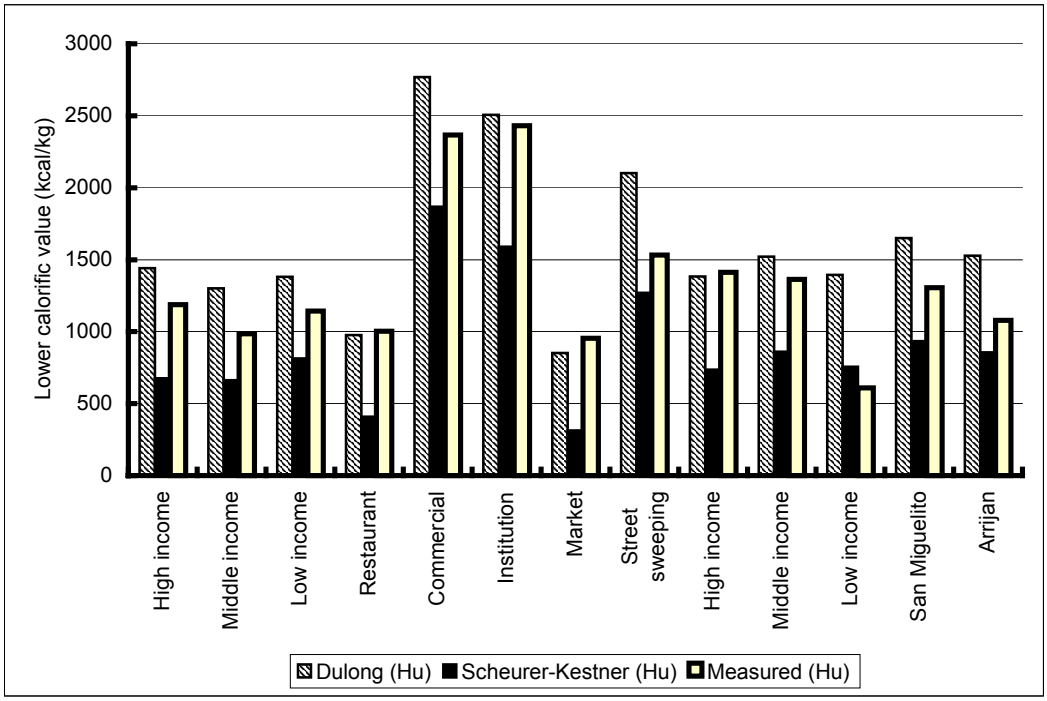

Figure C-2: Comparison of Lower Calorific Value

According to the results of the calculation, it is found that lower calorific values obtained by various manners are distributed between 70 and 100% of values obtained by the Dulong Formula.

Lower calorific values of combustible matter vary between about 990 and 2,400 kcal/kg depending on waste generation sources. Table C-35 shows a lower calorific value of the whole waste generated in Panama Municipality with taking into account non-combustible matter and waste amount from each generation source.

Table C-35: Lower Calorific Value of Waste

	Lower calorific value (kcal/kg)	Non-combustible matter (%)	Combustible part (%)	Waste lower calorific value (kcal/kg)	Generation amount (ton/day)	Weighing average (kcal/kg)
Household high income	1,188	8.3%	91.7%	1,089	73.3	110
Household middle income	986	8.7%	91.3%	900	224.9	280
Household low income	1,144	9.5%	90.5%	1,035	141.0	202
Commercial/restaurant	1,004	11.2%	88.8%	892	106.4	131
Commercial/others	2,366	12.8%	87.2%	2,063	115.6	330
Institutional	2,431	16.1%	83.9%	2,040	29.3	83
Market	953	8.2%	91.8%	875	23.5	28
Street sweeping	1,533	17.4%	82.6%	1,266	8.4	15
Total	-	-	-	-	722.4	1,179

notes: Generation amount is based on WACS in the study, not correspondence with actual waste stream.

The lower calorific value of about 1,180 kcal/kg (4,939 kj/kg) was obtained from the calculation above. It is similar to the lower calorific value of waste sampled from collection vehicles of Panama Municipality, about 1,130 kcal/kg (4,730 kj/kg).

The lower calorific value 1,179 kcal/kg was obtained based on proportion of estimated waste generation amount by sources acquired from the results of WACS. However, the waste stream analysis after-mentioned tells that there is difference in waste collection amount from the WACS. That is, in the waste stream analysis 832 ton/day is obtained as combustible waste subtracting amounts of hospital, bulky, demolition wastes and sewage sludge from total waste collection amount of 965 ton/day. Meanwhile, 687 ton/day can be acquired from the results of WACS by applying 92% of collection rate for household wastes. Here, there is a difference of 145 ton/day between them. Then, it is supposed that this 145 ton/day would come from business entities (institutional, commercial and industrial wastes). With taking into account the aforementioned, a lower calorific value of mixed waste collected from Panama District at present are considered in the following tables.

Table C-36: Estimated Lower Calorific Value of Wastes from Institution and Business Entities

	Lower calorific value of combustible part (kcal/kg)	Non-combustible matter (%)	Combustible part (%)	Lower calorific value of waste (kcal/kg)	Generation amount (ton/day)	Weighing average of lower calorific value (kcal/kg)
Commercial/restaurant	1,004	11%	89%	892	106.4	378
Commercial/others	2,366	13%	87%	2,063	115.6	949
Institutional	2,431	16%	84%	2,040	29.3	238
Total	-	-	-	-	251.3	1,565

Table C-37: Lower Calorific Value of Mixed Waste Collected

	Raw waste lower calorific value (kcal/kg)	Collection amount (ton/day)	Weighing average (kcal/kg)
Household high income	1,089	67.4	88
Household middle income	900	206.9	224
Household low income	1,035	129.7	161
Institution and business	1,565	396.1	745
Market	875	23.5	25
Street sweeping	1,266	8.4	13
Total	-	832.0	1,256

Table C-38:Comparison of Waste Calorific Value

	Assumed waste amount (ton/day)	Weighing average of calorific value (kcal/kg)
Original WACS results	722.4	1,179
Collection vehicle by WACS	-	1,130
Mixed Waste Collected	832.0	1,256

The table above compares the lower calorific values resulted in the respective considerations. It can be said that lower calorific value of mixed waste collected in the Panama District is about 1,200 kcal/kg (5,024 kj/kg). This is around the lowest value where mixed waste could be burnable without auxiliary fuel. However, it should be noted that the samples contained in plastic bags were collected directly from the sources except the samples from the markets and the collection vehicles, then, those had not opportunities to be soaked with rain. No significant difference in water content between samples in dry season and in rain season proved this matter. In practice, waste has many chances to be wet in the rain season. Consequently, it can be said that lower calorific value of mixed waste collected will be lower than 1,200 kcal/kg with taking into account the pluvious climate of Panama District.