Appendix A

Nomination of Potential Sites

မြန်မာနိုင်ငံအင်ဂျင်နီယာအသင်း
MYANMAR ENGINEERING SOCIETY
Hlaing Universities' Campus, Hlaing Township, Yangon, Myanmar
Tel : 95-1-519673~76, Fax : 95-1-519681
E-mail : mes@mptmail.net.mm, Website:www.mes.org.mm

Date : 20th August 2007
Ref. No. : Ma.Ah Tha/ Admin/ 185/ 2007

To

Mr. Panich Pongpirodom
Director General
Department of Alternative Energy Development and Efficiency,
Ministry of Energy

Project : **Study and Demonstration of Biomass Gasification for Electricity**

Subject : **Nomination of Potential Sites for Implementing Biomass Electrification Project.**

Dear sir,

Refering to memorandum of understanding between the Ministry of Energy of the Government of the Union of Myanmar and the Ministry of Energy of the Government of the Kingdom of Thailand on "Cooperation in the Field of Renewable Energy and Energy Conservation", Myanmar Engineering Society in cooperation with Ministry of Energy has identified the following sites in Yangon Division, Twan-Tay Township for implementation Biomass Electrification Project.

(1) Da Goon Daing
(2) Nyaung Da Gar
(3) Sann Ywar
(4) Kha-Lok

Looking forward to further cooperation with your esteemed organization.

Your Sincerely

U Win Khaing
Chairman
Energy & Renewable Energy Committee
Myanmar Engineering Society

CC : - Director General, Energy Planning Department, Ministry of Energy
- President, Myanmar Engineering Society (MES)

Address : MES Building, Hlaing Universities' Campus, Hlaing Township, Yangon 11052, Myanmar

Appendix B

Selection of Dagoon Daing Village

မြန်မာနိုင်ငံအင်ဂျင်နီယာဘာသင်း

MYANMAR ENGINEERING SOCIETY

Hlaing Universities' Campus, Hlaing Township, Yangon, Myanmar

Tel : 95-1-519673~76, Fax : 95-1-519681

E-mail : mes@mptmail.net.mm, Website:www.mes.org.mm

Date : 11th September 2007

Ref. No. : Ma Ah Tha/Admin/ 209 / 2007

To

Mr. Panich Pongpirodom
Director General
Department of Alternative Energy Development and Efficiency
Ministry of Energy

Project : **Study and Demonstration of Biomass Gasification for Electricity**

Reference : **Site Selection Summary Report Prepared By ERDI-CMU**

Subject : **Selection of Da-Goon-Daing Village, Twan-Tay Township, Yangon Division as development site for implementing Biomass Electricity Project.**

Dear Sir,

Referring to memorandum of understanding between the Ministry of Energy of the Government of the Union of Myanmar and the Ministry of Energy of the Government of the Kingdom of Thailand on "Cooperation in the Field of Renewable Energy and Energy Conservation", Myanmar Engineering Society under the guidance of the Ministry of Energy has selected Da-Goon-Daing Village, Twan-Tay Township, Yangon Division, based on the evaluation report conducted by ERDI-CMU on the four potential sites, namely (1) Da Goon Daing (2) Nyaung Da Gar (3) Sann Ywar (4) Kha-Lok.

Da-Goon-Daing was selected as the most favorable of choice based on the total marks earned (52). The other important points are-

(a) Da-Goon-Daing has surplus supply of ricehusk for the current electricity need.
(b) The surplus is enough for the next few years of predicted electricity consumption.
(c) The positive attitude and eagerness of the community.
(d) The Da-Goon-Daing community has shown their readiness and willingness to support the project.
(e) The village leaders and villagers are committed to make the project a successful and sustainable one.

Your Sincerely

U Win Khaing
General Secretary
(Chairman -Energy & Renewable Energy Committee)
Myanmar Engineering Society

CC : - Director General, Energy Planning Department, Ministry of Energy
- President, Myanmar Engineering Society (MES)
- Mr. Chatchawan Chaichana, Deputy Director, Energy Management and Conservation Center Chiang Mai University (ERDI-CMU)

Address : MES Building, Hlaing Universities' Campus, Hlaing Township, Yangon 11052, Myanmar

Appendix C

Biomass Fuel Analysis Results

1. Proximate Analysis

Results

	sample	Heating Value (cal/g)	Sulfur content (%)	Proximate analysis (as received, % wt/wt)				bulk density (g/cm^3)
				moisture	volatile matter	ash	fixed carbon	
1	Bamboo	4272	0.43	5.73	74.68	5.55	14.04	1.72
2	Rice straw	3656	0.75	7.76	65.58	12.44	14.22	nd
3	Rice husk	3315	0.04	5.60	56.41	13.45	24.54	nd
4	Wood	3921	0.06	7.49	74.82	6.36	11.33	1.91

nd = not determined

ลงชื่อ

(ผู้ช่วยศาสตราจารย์ ดร.ศุภรินทร์ ไชยกลางเมือง)

1.1 Heating value and % sulfur

Analysis No.	bamboo		rice straw		rice husk		wood	
	Hg(cal/g)	%S	Hg(cal/g)	%S	Hg(cal/g)	%S	Hg(cal/g)	%S
1	4557.00	0.47	3632.46	0.68	3339.87	0.05	3997.30	0.07
2	3987.01	0.41	3684.06	0.75	3212.75	0.04	3895.04	0.05
3	4641.03	0.43	3809.77	0.81	3189.70	0.05	3869.32	0.08
4	3887.21	0.38	3638.26	0.71	3729.67	0.05	3846.64	0.04
5	4565.25	0.49	3859.56	0.77	3349.89	0.05	4017.01	0.09
6	3786.30	0.38	3304.98	0.72	3349.64	0.03	3845.39	0.05
7	3894.12	0.39	3629.56	0.80	3217.01	0.05	4191.30	0.07
8	3968.30	0.43	3726.69	0.71	3219.52	0.03	3788.14	0.05
9	4778.10	0.49	3929.56	0.79	3410.60	0.05	3859.10	0.0 5
10	4657.79	0.39	3342.99	0.73	3129.45	0.03	3904.18	0.0 7
AV	4272.21	0.43	3655.79	0.75	3314.81	0.04	3921.34	0.06

1.2 Moisture

Sample	Crucible No.	Crucible Weight (g)	Total Crucible + Sample (g)	Sample weight before oven (g)	Total weight Crucible + Sample after oven (g)	Sample weight after oven (g)	% moisture	AV % moisture
Wood	1	32.80	33.80	1.00	33.72	0.08	7.73	7.49
	2	35.80	36.80	1.00	36.73	0.07	7.35	
	3	37.34	38.34	1.00	38.27	0.07	7.39	
	4	27.78	28.78	1.00	28.70	0.09	7.29	
	5	29.79	30.79	1.00	30.71	0.08	8.61	
	6	34.80	35.80	1.00	35.72	0.10	8.53	
	7	32.80	33.80	1.00	33.73	0.04	7.65	
	8	38.87	39.88	1.00	39.80	0.07	6.83	
	9	39.41	40.41	1.00	40.34	0.08	6.67	
	10	36.80	37.80	1.00	37.73	0.08	6.85	

Sample	Crucible No.	Crucible Weight (g)	Total Crucible + Sample (g)	Sample weight before oven (g)	Total weight Crucible + Sample after oven (g)	Sample weight after oven (g)	% moisture	AV % moisture
Bamboo	1	42.31	43.31	1.00	43.25	0.06	5.94	5.73
	2	32.31	33.32	1.00	33.26	0.06	5.77	
	3	37.14	38.14	1.00	38.08	0.06	5.71	
	4	58.02	59.04	1.01	58.99	0.05	5.85	
	5	46.78	47.78	1.01	47.73	0.05	5.59	
	6	51.60	52.61	1.01	52.55	0.05	5.59	
	7	33.31	34.32	1.00	34.26	0.07	5.97	
	8	41.96	42.96	1.01	42.91	0.06	5.75	
	9	46.78	47.78	1.01	47.73	0.05	5.69	
	10	36.14	37.14	1.00	37.08	0.05	5.41	

Sample	Crucible No.	Crucible Weight (g)	Total Crucible + Sample (g)	Sample weight before oven (g)	Total weight Crucible + Sample after oven (g)	Sample weight after oven (g)	% moisture	AV % moisture
Rice husk	1	33.41	34.41	1.00	34.36	0.06	5.72	5.60
	2	42.49	43.49	1.00	43.43	0.06	5.51	
	3	41.52	42.53	1.01	42.47	0.06	5.58	
	4	44.58	45.57	0.99	45.52	0.05	5.46	
	5	44.10	45.09	0.99	45.04	0.05	5.69	
	6	43.62	44.61	1.00	44.56	0.05	5.58	
	7	43.13	44.13	1.00	44.08	0.05	5.56	
	8	42.49	43.49	1.00	43.43	0.06	5.51	
	9	43.49	44.49	1.00	44.43	0.07	5.61	
	10	42.52	43.53	1.01	43.47	0.07	5.78	

Sample	Crucible No.	Crucible Weight (g)	Total Crucible + Sample (g)	Sample weight before oven (g)	Total weight Crucible + Sample after oven (g)	Sample weight after oven (g)	% moisture	AV % moisture
Rice straw	1	41.72	42.72	1.00	42.65	0.07	7.60	7.76
	2	40.30	41.29	1.00	41.22	0.08	7.85	
	3	45.14	46.15	1.00	46.07	0.08	7.83	
	4	42.34	43.34	1.00	43.26	0.08	8.05	
	5	43.25	44.25	1.00	44.17	0.08	7.97	
	6	44.17	45.17	1.00	45.09	0.08	7.89	
	7	45.08	46.08	1.00	46.00	0.08	7.81	
	8	45.85	46.86	1.00	46.78	0.08	7.61	
	9	46.97	47.97	1.00	47.90	0.08	7.50	
	10	48.08	49.09	1.00	49.01	0.08	7.52	

1.3 Volatile Matter

Sample	Crucible No.	Crucible Weight (g)	Total Crucible + Sample (g)	Sample weight before oven (g)	Total weight Crucible + Sample after oven (g)	Sample weight after oven (g)	% VM	AV %VM
Wood	1	40.29	41.31	1.01	40.47	0.84	74.90	74.82
	2	41.52	42.53	1.01	41.69	0.84	75.50	
	3	45.15	46.15	1.00	45.33	0.82	75.85	
	4	32.61	33.64	1.03	32.78	0.86	73.52	
	5	35.04	36.07	1.02	35.21	0.86	73.99	
	6	37.47	38.49	1.02	37.64	0.85	74.47	
	7	40.29	41.31	1.01	40.47	0.84	74.90	
	8	43.12	44.13	1.01	43.31	0.83	75.33	
	9	45.95	46.95	1.01	46.14	0.81	74.57	
	10	48.77	49.78	1.00	48.97	0.80	75.20	

Sample	Crucible No.	Crucible Weight (g)	Total Crucible + Sample (g)	Sample weight before oven (g)	Total weight Crucible + Sample after oven (g)	Sample weight after oven (g)	% VM	AV %VM
Bamboo	1	35.80	36.81	1.00	36.00	0.81	74.52	74.68
	2	42.50	43.50	1.00	42.69	0.81	75.24	
	3	37.34	38.34	1.00	37.54	0.80	74.27	
	4	40.08	41.08	1.00	40.28	0.80	73.43	
	5	40.85	41.85	1.00	41.05	0.80	74.70	
	6	43.60	44.60	1.01	43.78	0.82	74.87	
	7	42.39	43.39	1.00	42.58	0.82	75.46	
	8	41.18	42.18	1.00	41.37	0.81	75.05	
	9	39.97	40.97	1.00	40.17	0.81	74.65	
	10	40.08	41.08	1.00	40.28	0.80	74.63	

Sample	Crucible No.	Crucible Weight (g)	Total Crucible + Sample (g)	Sample weight before oven (g)	Total weight Crucible + Sample after oven (g)	Sample weight after oven (g)	% VM	AV %VM
Rice husk	1	42.30	43.31	1.01	42.68	0.63	56.54	56.41
	2	37.13	38.15	1.01	37.53	0.62	55.31	
	3	42.30	43.31	1.01	42.68	0.63	56.24	
	4	53.29	54.30	1.01	53.60	0.60	53.04	
	5	52.63	53.64	1.01	52.99	0.65	58.00	
	6	31.97	32.98	1.02	32.38	0.61	54.08	
	7	37.13	38.15	1.01	37.53	0.62	55.31	
	8	47.47	48.48	1.01	47.84	0.64	57.07	
	9	54.35	55.37	1.01	54.71	0.66	59.28	
	10	52.10	53.11	1.01	52.44	0.58	59.26	

Sample	Crucible No.	Crucible Weight (g)	Total Crucible + Sample (g)	Sample weight before oven (g)	Total weight Crucible + Sample after oven (g)	Sample weight after oven (g)	% VM	AV %VM
Rice straw	1	41.69	42.40	0.71	41.88	0.51	64.48	65.58
	2	33.41	33.83	0.42	33.52	0.31	66.69	
	3	25.14	25.26	0.12	25.15	0.10	68.90	
	4	74.79	76.69	1.90	75.35	1.33	58.64	
	5	22.04	21.73	0.01	21.36	0.00	68.97	
	6	30.32	30.30	0.31	29.73	0.21	68.76	
	7	35.41	35.83	0.45	35.52	0.35	68.70	
	8	57.24	57.54	1.27	55.62	0.82	58.94	
	9	49.96	50.97	1.01	50.25	0.72	65.27	
	10	42.69	44.40	0.74	44.88	0.61	66.48	

1.4 Ash

Sample	Crucible No.	Crucible Weight (g)	Total Crucible + Sample (g)	Sample weight before oven (g)	Total weight Crucible + Sample after oven (g)	Sample weight after oven (g)	% ash	AV %ash
Wood	1.00	32.79	33.80	1.00	32.86	0.94	6.13	6.36
	2.00	35.80	36.80	1.00	35.87	0.94	6.20	
	3.00	37.33	38.33	1.00	37.40	0.93	6.75	
	4.00	45.37	46.37	1.00	45.44	0.93	7.28	
	5.00	30.77	31.77	1.00	30.83	0.94	5.74	
	6.00	28.50	29.51	1.00	28.56	0.95	5.43	
	7.00	26.24	27.24	1.00	26.29	0.95	5.12	
	8.00	23.97	24.97	1.00	24.02	0.95	4.81	
	9.00	50.24	51.24	1.00	50.32	0.92	7.79	
	10.00	58.67	59.67	1.00	58.76	0.91	8.72	

Sample	Crucible No.	Crucible Weight (g)	Total Crucible + Sample (g)	Sample weight before oven (g)	Total weight Crucible + Sample after oven (g)	Sample weight after oven (g)	% ash	AV %ash
Bamboo	1.00	42.31	43.31	1.00	42.36	0.96	4.62	5.55
	2.00	32.31	33.31	1.00	32.37	0.94	6.08	
	3.00	37.13	38.13	1.00	37.19	0.94	5.94	
	4.00	41.95	42.95	1.00	42.01	0.94	5.80	
	5.00	45.25	46.53	1.00	47.30	0.96	4.09	
	6.00	23.05	24.81	1.00	25.30	0.80	6.42	
	7.00	35.15	36.53	1.00	36.30	0.88	6.14	
	8.00	47.25	48.26	1.00	47.30	0.96	4.09	
	9.00	27.01	28.01	1.00	27.08	0.92	6.59	
	10.00	28.33	29.07	1.00	27.68	0.96	5.76	

Sample	Crucible No.	Crucible Weight (g)	Total Crucible + Sample (g)	Sample weight before oven (g)	Total weight Crucible + Sample weight after oven (g)	Sample weight after oven (g)	% ash	AV %ash
Rice husk	1.00	33.41	34.41	1.00	33.55	0.87	13.66	13.45
	2.00	42.49	43.49	1.00	42.61	0.88	12.39	
	3.00	41.51	42.52	1.00	41.66	0.86	14.29	
	4.00	40.54	41.55	1.01	40.70	0.84	15.19	
	5.00	42.16	43.17	1.00	42.29	0.87	13.02	
	6.00	54.70	55.70	1.00	54.80	0.90	11.49	
	7.00	30.28	31.28	1.00	30.42	0.86	14.29	
	8.00	53.40	54.40	1.00	53.53	0.87	13.32	
	9.00	42.16	43.17	1.00	42.29	0.87	13.42	
	10.00	30.92	31.93	1.00	31.05	0.87	13.43	

Sample	Crucible No.	Crucible Weight (g)	Total Crucible + Sample (g)	Sample weight before oven (g)	Total weight Crucible + Sample weight after oven (g)	Sample weight after oven (g)	% ash	AV %ash
Rice straw	1.00	41.72	42.72	1.00	41.84	0.88	11.92	12.44
	2.00	40.29	41.29	1.00	40.41	0.88	12.45	
	3.00	45.15	46.15	1.00	45.28	0.87	12.96	
	4.00	48.00	49.01	1.01	48.14	0.87	12.47	
	5.00	30.86	31.85	1.19	30.96	0.89	12.41	
	6.00	35.57	36.57	1.10	35.69	0.88	12.43	
	7.00	40.29	41.29	1.00	40.41	0.88	12.25	
	8.00	45.15	46.15	1.00	45.28	0.87	12.96	
	9.00	49.91	50.91	0.94	50.05	0.87	12.16	
	10.00	44.67	45.68	1.00	49.82	0.86	12.36	

1.5 Fixed carbon, Fc

% Fixed carbon = 100 – (% VM + % moisture + %ash)

No.	Wood				Bamboo				Rice husk				Rice straw			
	% VM	% Moisture	% Ash	% FC	% VM	% Moisture	% Ash	% FC	% VM	% Moisture	% Ash	% FC	% VM	% Moisture	% Ash	% FC
1	74.90	7.73	6.13	11.24	74.52	5.94	4.62	14.92	56.54	5.72	13.66	24.08	64.48	7.60	11.92	16.00
2	75.50	7.35	6.20	10.95	75.24	5.77	6.08	12.91	55.31	5.51	12.39	26.79	66.69	7.85	12.45	13.01
3	75.85	7.39	6.75	10.01	74.27	5.71	5.94	14.08	56.24	5.58	14.29	23.89	68.90	7.83	12.96	10.31
4	73.52	7.29	7.28	11.91	73.43	5.85	5.80	14.92	53.04	5.46	15.19	26.31	58.64	8.05	12.47	20.85
5	73.99	8.61	5.74	11.66	74.70	5.59	4.09	15.62	58.00	5.69	13.02	23.28	68.97	7.97	12.41	10.65
6	74.47	8.53	5.43	11.57	74.87	5.59	6.42	13.13	54.08	5.58	11.49	28.85	68.76	7.89	12.43	10.92
7	74.90	7.65	5.12	12.33	75.46	5.97	6.14	12.43	55.31	5.56	14.29	24.83	68.70	7.81	12.25	11.24
8	75.33	6.83	4.81	13.03	75.05	5.75	4.09	15.11	57.07	5.51	13.32	24.10	58.94	7.61	12.96	20.50
9	74.57	6.67	7.79	10.97	74.65	5.69	6.59	13.07	59.28	5.61	13.42	21.69	65.27	7.50	12.16	15.07
10	75.20	6.85	8.72	9.23	74.63	5.41	5.76	14.20	59.26	5.78	13.43	21.54	66.48	7.52	12.36	13.64
AV				**11.33**				**14.04**				**24.54**				**14.22**

1.6 Bulk density

Sample	No.	D(g)	D + 1.67 (g)	S (g)	S + 0.04 (g)	V cm^3	B(g/cm^3)
Wood	1	0.45	2.12	0.78	0.82	1.30	1.63
	2	0.62	2.29	0.90	0.94	1.35	1.70
	3	0.60	2.27	1.15	1.19	1.08	2.10
	4	0.93	2.60	1.31	1.35	1.25	2.08
	5	0.95	2.62	1.29	1.43	1.29	2.03
	6	0.45	2.12	0.78	0.85	1.10	1.83
	7	0.62	2.29	1.60	0.94	1.30	1.85
	8	0.79	2.46	1.02	1.18	1.35	1.87
	9	0.96	2.51	1.14	1.18	1.42	2.10
	10	0.70	2.50	0.93	1.38	1.10	1.90
	AV	0.71	2.38	1.09	1.13	1.25	1.91

Sample	No.	D(g)	D + 1.67 (g)	S (g)	S + 0.04 (g)	V cm^3	B(g/cm^3)
Bamboo	1	0.58	2.25	0.97	1.01	1.24	1.81
	2	0.67	2.34	0.94	0.98	1.36	1.72
	3	0.57	2.24	0.90	0.94	1.30	1.72
	4	0.56	2.23	0.85	0.89	1.34	1.66
	5	0.60	2.27	0.88	0.92	1.35	1.68
	6	0.64	2.31	0.91	0.95	1.36	1.70
	7	0.68	2.35	0.94	0.98	1.37	1.74
	8	0.56	2.20	0.87	0.95	1.25	1.64
	9	0.52	2.46	0.92	0.94	1.28	1.72
	10	0.59	2.02	0.89	0.90	1.30	1.76
	AV	0.60	2.27	0.91	0.95	1.32	1.72

Note: initial wire weight = 1.67 g

Wire weight in water = 0.04 g

V = sample volume (cm^3)

D = Initial mass (g)

S = Mass in water (g)

B = bulk density (g/cm^3)

2. Ultimate Analysis

	Sample : Rice husk No. : CE 5919/50	Sample :Bamboo No. : CE 5920/50	Sample :Wood No. : CE 5921/50	Sample :Rice straw No. : CE 5922/50
C	35.145 %	45.66 %	44.925 %	39.875 %
H	3.706 %	4.32 %	4.935 %	5.1165 %
N	0.211 %	0.243 %	0.188 %	0.594 %
S	0.1215 %	0.064 %	0.074 %	0.216 %
0	60.438 %	48.329 %	49.616 %	53.829 %

ที่ ศธ 5632/ 2627

6 สิงหาคม 2550

Analytical Report

[illegible] : ห้องปฏิบัติการวิเคราะห์ธาตุและสารประกอบ [illegible] Report#0550423

[illegible] : 95/50 [illegible] : C 423/50

[illegible] : 24 กรกฎาคม 2550 [illegible] : 24 – 27 กรกฎาคม 2550

[illegible] : Carbon , Hydrogen ,Nitrogen & Sulfur analyzer Model CHNS - 932

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
C	35.145 %	48.66 %	44.935 %	39.875 %
H	3.706 %	4.32 %	4.935 %	5.1305 %
N	0.211 %	0.362 %	0.188 %	0.594 %
S	0.1315 %	0.094 %	0.074 %	0.216 %

[illegible] ....

[illegible]

[illegible]

[illegible] ....

[illegible]

[illegible]

[illegible] ....

[illegible]

[illegible]

[illegible] ....

[illegible]

[illegible]

- [illegible]
- [illegible]

111 ถนนมหาวิทยาลัย ตำบลสุรนารี อำเภอเมือง จังหวัดนครราชสีมา 30000 โทรศัพท์ (044) 223000 โทรสาร (044) 224070

SURANAREE UNIVERSITY OF TECHNOLOGY

111 UNIVERSITY AVENUE, SUB DISTRICT SURANAREE, MUANG DISTRICT, NAKHON RATCHASIMA 30000, THAILAND Tel. (044) 223000 Fax. (044) 224070

FM-510-01-01/Rev.No.2/20/08/2550 หน้า 1/1

ที่ ศธ 5632/ 2745

16 สิงหาคม 2550

Analytical Report

[illegible] : [illegible] | [illegible] Rep[illegible]050429 ([illegible])
[illegible] : 99/50 | [illegible] : C 423/50
[illegible] : 24 กรกฎาคม 2550 | [illegible] : 15 สิงหาคม 2550
[illegible] : Carbon , Hydrogen ,Nitrogen & Sulfur analyzer Model CHNS - 932 , VTF-900

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0	60.438 %	48.329 %	40.618 %	53.829 %

[illegible] .... | [illegible] ....
([illegible]) | ([illegible])
[illegible] | [illegible]

[illegible] .... | [illegible] ....
(อาจารย์ ดร. [illegible]) | (อาจารย์ ดร. [illegible])
[illegible] | [illegible]

- [illegible]
- [illegible]

111 ถนนมหาวิทยาลัย ตำบลสุรนารี อำเภอเมือง จังหวัดนครราชสีมา 30000 โทรศัพท์ (044) 223000 โทรสาร (044) 224070
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FM-610-01-01/Rev.No.3/23/09/2550 หน้า 1/1

2.1 Rice husk

No.	C	H	N	S	O
1	34.43	4.01	0.24	0.11	61.21
2	33.42	3.00	0.23	0.12	63.23
3	36.12	3.49	0.18	0.12	60.00
4	35.21	3.39	0.21	0.15	61.02
5	36.22	4.00	0.19	0.13	59.24
6	34.51	3.82	0.18	0.13	61.33
7	34.45	4.13	0.24	0.12	61.00
8	35.27	3.82	0.23	0.13	60.55
9	36.81	3.69	0.22	0.12	59.13
10	35.02	3.71	0.20	0.10	60.89
AV	35.15%	3.71%	0.21%	0.12%	60.44%

2.2 Bamboo

No.	C	H	N	S	O
1	45.65	4.53	0.26	0.06	48.01
2	42.10	4.21	0.23	0.05	47.23
3	46.95	3.49	0.24	0.04	49.12
4	44.92	4.56	0.21	0.06	50.12
5	45.74	4.00	0.23	0.04	49.24
6	44.88	4.67	0.28	0.07	49.87
7	44.25	4.13	0.24	0.09	47.21
8	46.53	4.20	0.23	0.07	48.21
9	47.42	4.62	0.24	0.06	47.13
10	48.20	4.75	0.20	0.10	47.26
AV	45.66%	4.32%	0.24%	0.06%	48.33%

2.3 Wood

No.	C	H	N	S	O
1	45.65	5.53	0.17	0.06	48.01
2	43.10	5.44	0.18	0.05	51.23
3	46.95	3.46	0.21	0.04	49.82
4	44.92	6.21	0.19	0.06	48.56
5	45.21	5.12	0.17	0.04	49.44
6	44.88	4.63	0.18	0.07	49.87
7	45.28	5.24	0.18	0.09	48.21
8	44.22	4.23	0.21	0.07	50.83
9	42.26	5.26	0.19	0.08	51.93
10	46.52	4.32	0.20	0.10	48.32
AV	44.93%	4.94%	0.19%	0.07%	49.62%

2.4 Rice straw

No.	C	H	N	S	O
1	41.50	5.29	0.61	0.23	52.16
2	38.14	5.44	0.57	0.20	55.15
3	40.25	4.86	0.63	0.25	53.21
4	39.12	5.67	0.62	0.23	54.22
5	40.03	5.42	0.59	0.22	53.42
6	41.32	4.86	0.58	0.20	52.81
7	41.23	5.24	0.57	0.24	52.43
8	37.05	4.84	0.59	0.26	56.83
9	38.84	5.26	0.61	0.21	54.60
10	41.23	4.32	0.57	0.20	53.46
AV	39.88%	5.12%	0.59%	0.22%	53.83%

3. Ash analysis

LAB NO.	50 x 0384	50 x 0385	50 x 0386	50 x 0387
Sample Name	**Bamboo**	**Rice straw**	**Rice husk**	**Wood**
Sample Condition	normal	normal	normal	normal
Sample Date	-	-	-	-
Receive Date	6/8/2007	6/8/2007	6/8/2007	6/8/2007
Analysed Date	10/8/04-3/9/07	10/8/04-3/9/07	10/8/04-3/9/07	10/8/04-3/9/07
1. ASH COMPOSITION (%)	**RESULT**			
Fe_2O_3	3.68	0.76	1.20	3.24
Al_2O_3	4.79	2.42	0.14	5.57
MgO	5.92	1.87	0.64	5.85
SiO_2	44.08	72.73	88.72	43.24
CaO	23.09	5.40	3.92	23.43
K_2O	12.69	12.87	2.58	12.21
Na_2O	0.44	0.24	0.25	1.73
TiO_2	0.28	0.01	0.07	0.29
Mn_3O_4	0.10	0.78	0.09	0.37
SO_3	1.61	0.28	0.00	2.39
2. ASH FUSION TEMPERATURE (^oC)				
2.1 Initial Deformation Temperature	1,142	1,000	1,440	1,138
2.2 Softening Temperature	1,152	1,194	1,500	1,183
2.3 Hemispherical Temperature	1,163	1,220	>1,500	1,189
2.4 Fluid Temperature	1,178	1,268	>1,500	1,205

การไฟฟ้าฝ่ายผลิตแห่งประเทศไทย

บันทึก

ที่ 140/4.9.60

จาก หปก-ช. เรียน

เรื่อง ผลวิเคราะห์เชื้อเพลิงชีวมวล มทช-พล.

วันที่ 6 กันยายน 2550

แผนก หปก-ช. ขอส่งผลการวิเคราะห์ของเชื้อเพลิงชีวมวลจากเถ้าไม้ไผ่, เถ้าฟางข้าว, เถ้าแกลบ และเถ้าไม้ รวมจำนวน 4 ตัวอย่าง (Lab No.50X0384-50X0387) ตามรายละเอียดของการวิเคราะห์ ดังนี้

- Ash Composition

-Ash Fusibility

จึงเรียนมาเพื่อโปรดทราบ

(นางบุญนิล โพธา)

หปก-ช.

สำเนา - แฟ้ม

ELECTRICITY GENERATING AUTHORITY OF THAILAND

TEST REPORT

FOR ASH COMPOSITION

Record No. [illegible]

Page 1 of 2

CUSTOMER : [illegible] [illegible]

LAB NO.	50X0384	50X0385	50X0386	50X0387
SAMPLE NAME	[illegible]	[illegible]	[illegible]	[illegible]
SAMPLE CONDITION	normal	normal	normal	normal
SAMPLED DATE	-	-	-	-
RECEIVED DATE	6/8/2007	6/8/2007	6/8/2007	6/8/2007
ANALYSED DATE	10/8/07-3/9/07	10/8/07-3/9/07	10/8/07-3/9/07	10/8/07-3/9/07
ASH COMPOSITION	**RESULT**			
Fe_2O_3 %	3.68	0.76	1.28	3.24
Al_2O_3 %	4.79	2.43	0.04	5.57
MgO %	5.93	1.87	0.64	5.88
SiO_2 %	44.88	72.73	88.73	43.34
CaO %	23.09	5.48	3.93	23.42
K_2O %	12.49	12.87	2.88	12.38
Na_2O %	0.44	0.24	0.25	1.23
TiO_2 %	0.28	4.84	0.07	0.29
Mn_3O_4 %	0.18	4.78	0.09	0.57
SO_3 %	1.63	0.28	0.00	2.39

Remark : The results relate only to the sample(s) tested. This document shall not be reproduced except in full.

Chemist : ....

(Mr. Amnuai [illegible])

[illegible]

[illegible]

ELECTRICITY GENERATING AUTHORITY OF THAILAND
TEST REPORT

Report No. 083/50
Page 2 of 2

CUSTOMER : [illegible] [illegible]

	LAB NO.	[illegible]	[illegible]	[illegible]	[illegible]
	SAMPLE NAME	[illegible]	[illegible]	[illegible]	[illegible]
	SAMPLE CONDITION	normal	normal	normal	normal
	SAMPLED DATE	-	-	-	-
	RECEIVED DATE	4/8/2007	6/8/2007	6/8/2007	4/8/2007
	ANALYSED DATE	[illegible]	[illegible]	[illegible]	[illegible]
ASH FUSION TEMPERATURE (°C)					
	INITIAL DEFORMATION TEMPERATURE	1142	[illegible]	1440	1138
	SOFTENING TEMPERATURE	1152	1194	1500	1183
	HEMISPHERICAL TEMPERATURE	1163	1220	>1500	1189
	FLUID TEMPERATURE	1178	1268	>1500	1205

Remark : [illegible]

Chemist : ....
(Mr. [illegible])
[illegible]

Laboratory Section Geology Department Mine Planning and Administration Division EGAT
[illegible]

3.1 ASH COMPOSITION (%)

3.1.1 Ash Composition–Bamboo

No.	Fe_2O_3	Al_2O_3	MgO	SiO_2	CaO	K_2O	Na_2O	TiO_2	Mn_3O_4	SO_3
1	3.76	4.89	6.08	43.55	23.31	12.75	0.42	0.24	0.08	1.60
2	3.78	4.75	5.76	47.62	20.33	11.98	0.43	0.25	0.09	1.69
3	3.65	4.96	6.24	43.15	23.07	13.12	0.42	0.29	0.09	1.69
4	3.55	4.75	5.48	42.96	25.19	12.34	0.45	0.29	0.10	1.57
5	3.68	4.61	6.24	46.90	21.01	11.87	0.41	0.27	0.12	1.57
6	3.69	4.68	5.67	44.75	22.46	13.01	0.42	0.26	0.11	1.63
7	3.78	4.78	5.74	44.25	22.81	12.84	0.46	0.28	0.09	1.65
8	3.72	4.96	5.47	43.57	23.27	13.25	0.45	0.28	0.08	1.63
9	3.49	4.73	5.81	42.15	25.34	12.73	0.46	0.31	0.09	1.57
10	3.71	4.81	6.74	41.85	24.15	12.98	0.47	0.29	0.14	1.54
AV	3.68	4.79	5.92	44.08	23.09	12.69	0.44	0.28	0.10	1.61

3.1.2 Ash Composition–Rice straw

No.	Fe_2O_3	Al_2O_3	MgO	SiO_2	CaO	K_2O	Na_2O	TiO_2	Mn_3O_4	SO_3
1	0.76	2.63	1.98	72.26	5.61	12.75	0.22	0.01	0.82	0.32
2	0.78	2.61	1.76	72.31	5.33	13.26	0.23	0.02	0.79	0.27
3	0.77	2.06	1.86	73.15	5.07	13.12	0.22	0.01	0.78	0.32
4	0.76	2.65	1.88	73.28	5.19	12.34	0.25	0.02	0.78	0.21
5	0.68	2.34	1.98	73.54	5.89	11.67	0.21	0.01	0.79	0.25
6	0.69	2.52	1.87	73.72	5.24	12.01	0.22	0.01	0.77	0.31
7	0.78	2.14	1.76	72.11	5.88	13.44	0.25	0.02	0.74	0.24
8	0.78	2.25	1.89	72.50	5.27	13.25	0.25	0.01	0.81	0.35
9	0.79	2.63	1.90	72.48	5.34	12.84	0.26	0.01	0.81	0.30
10	0.81	2.41	1.78	71.95	5.15	13.98	0.27	0.01	0.74	0.26
AV	0.76	2.42	1.87	72.73	5.40	12.87	0.24	0.01	0.78	0.28

3.1.3 Ash Composition – Rice husk

No.	Fe_2O_3	Al_2O_3	MgO	SiO_2	CaO	K_2O	Na_2O	TiO_2	Mn_3O_4	SO_3
1	1.20	0.14	0.62	89.16	3.67	2.45	0.22	0.07	0.09	0.00
2	1.18	0.13	0.61	89.00	3.87	2.46	0.21	0.07	0.08	0.00
3	1.19	0.11	0.63	88.65	3.98	2.69	0.22	0.06	0.09	0.00
4	1.18	0.15	0.58	88.85	3.90	2.52	0.26	0.08	0.09	0.00
5	1.20	0.15	0.67	88.91	3.87	2.41	0.24	0.07	0.08	0.00
6	1.19	0.17	0.62	88.82	3.94	2.44	0.26	0.08	0.09	0.00
7	1.15	0.13	0.58	89.11	3.78	2.51	0.21	0.07	0.09	0.00
8	1.21	0.16	0.68	88.60	3.97	2.58	0.25	0.07	0.10	0.00
9	1.28	0.18	0.68	88.17	4.01	2.84	0.29	0.08	0.09	0.00
10	1.26	0.12	0.70	87.95	4.21	2.88	0.30	0.09	0.09	0.00
AV	1.20	0.14	0.64	88.72	3.92	2.58	0.25	0.07	0.09	0.00

3.1.4 Ash Composition - Wood

No.	Fe_2O_3	Al_2O_3	MgO	SiO_2	CaO	K_2O	Na_2O	TiO_2	Mn_3O_4	SO_3
1	3.26	5.74	6.08	42.55	23.60	12.05	1.72	0.29	0.38	2.65
2	3.28	6.45	6.46	43.12	22.43	11.50	1.93	0.30	0.39	2.46
3	3.25	5.26	5.94	42.15	23.97	13.12	1.72	0.29	0.39	2.23
4	3.25	5.75	5.48	43.46	23.19	12.28	1.75	0.30	0.35	2.51
5	3.08	5.52	5.20	44.11	24.01	11.87	1.81	0.29	0.32	2.11
6	3.19	5.12	5.67	44.25	22.56	13.01	1.82	0.26	0.36	2.08
7	3.18	5.30	5.94	42.90	24.57	11.87	1.46	0.28	0.39	2.43
8	3.12	5.58	5.47	43.21	23.57	12.21	1.79	0.30	0.38	2.69
9	3.24	5.25	5.49	44.12	23.84	12.03	1.70	0.30	0.40	1.95
10	3.54	5.75	6.74	42.50	22.53	12.20	1.60	0.29	0.34	2.83
AV	3.24	5.57	5.85	43.24	23.43	12.21	1.73	0.29	0.37	2.39

3.2 ASH FUSION TEMPERATURE (^{o}C)

3.2.1 Bamboo

No.	Initial Deformation Temperature	Softening Temperature	Hemispherical Temperature	Fluid Temperature
1	1,150	1,162	1,170	1,165
2	1,121	1,143	1,181	1,187
3	1,132	1,138	1,163	1,192
4	1,138	1,141	1,148	1,168
5	1,153	1,156	1,183	1,183
6	1,126	1,141	1,156	1,176
7	1,141	1,181	1,172	1,165
8	1,120	1,140	1,136	1,160
9	1,159	1,158	1,141	1,189
10	1,180	1,160	1,180	1,195
AV	1,142	1,152	1,163	1,178

3.2.2 Rice straw

No.	Initial Deformation Temperature	Softening Temperature	Hemispherical Temperature	Fluid Temperature
1	950	1,185	1,270	1,260
2	990	1,180	1,250	1,285
3	1,050	1,195	1,230	1,290
4	950	1,200	1,180	1,240
5	995	1,200	1,200	1,285
6	1,000	1,195	1,180	1,275
7	1,025	1,200	1,220	1,260
8	1,120	1,180	1,260	1,260
9	968	1,190	1,160	1,275
10	950	1,210	1,250	1,250
AV	1,000	1,194	1,220	1,268

3.2.3 Rice husk

No.	Initial Deformation Temperature	Softening Temperature	Hemispherical Temperature	Fluid Temperature
1	1,550	1,550	>1,500	>1,500
2	1,450	1,500	>1,500	>1,500
3	1,400	1,500	>1,500	>1,500
4	1,410	1,400	>1,500	>1,500
5	1,400	1,475	>1,500	>1,500
6	1,420	1,500	>1,500	>1,500
7	1,400	1,600	>1,500	>1,500
8	1,500	1,450	>1,500	>1,500
9	1,450	1,475	>1,500	>1,500
10	1,420	1,550	>1,500	>1,500
AV	1,440	1,500	>1,500	>1,500

3.2.4 Wood

No.	Initial Deformation Temperature	Softening Temperature	Hemispherical Temperature	Fluid Temperature
1	1,140	1,160	1,170	1,200
2	1,125	1,200	1,150	1,250
3	1,120	1,180	1,150	1,200
4	1,130	1,250	1,250	1,150
5	1,150	1,175	1,250	1,200
6	1,145	1,190	1,200	1,350
7	1,140	1,180	1,250	1,200
8	1,140	1,140	1,160	1,230
9	1,150	1,200	1,160	1,150
10	1,140	1,155	1,150	1,120
AV	1,138	1,183	1,189	1,205

Appendix D

Questionnaires

Village Information

1. General information

1. Name of village.....

2. Number of populations…….. Households (number).....

3. Tribal Type (if) ……..Males (number) ……Females (number)……

An estimation of the population growth rate over the past decade (%)…….

4 Number of population who can read / writing / speaking (%)

English……/……/……/

5. Provide an estimate of the population growth rate over the past decade……

……

6. Public Services in the village

1. Kindergartens /Childcare	□ Yes	□ No
2. Primary school	□ Yes	□ No
3. Public Phone	□ Yes	□ No
4. Spots Center/Village Recreation	□ Yes	□ No
5. Places of Worship	□ Yes	□ No
6. Other (please specify)……	□ Yes	□ No

7. Public Utilities or Infrastructure in community

1. Hospital/health care center □ Yes patients (numbers)……..... □ No

2. School □Yes: level of Education…… students (numbers)..... □ No

8. Transportation

1. Road from village to Town □ Yes (please specify)..... □ No

2. How long does it take to town (one way)? ..... hour or minute.

3. Does it able to use the road for whole year? □Yes □No between……to..... (Month)

9. Enterprises/Store

1. Store □ Yes □ No (script 2.)

2. Appliances □ Yes □ No

3. If not (from 1) how far from the village to the closest store? .....km or how long does it take to the store……..…… hour or minute. By using……

10. No. of appliance's repair store..... (Store/person)

11 .How many empty or public area for destroying used appliances proposes).....Aere

12. Respective persons in the village

1. Village representative □ Yes □ No

2. NGOs □ Yes □ No

3. Religion Leader □ Yes □ No

4. Others (please specify).....

13. Top 3 of Respective persons in the community (Most – Least)

1. Please specify/ position.....

2. Please specify/ position.....

3. Please specify/ position.....

14. Communication with the government □ Yes (radio/telephone)..... □ No

15. Does your village have economic household activities in your household?

□ Yes, specify……..…….. □ No

16. Population career

1. Agriculture .....household (numbers) annual income…….……..... kyat

2. Merchant.....household (numbers) annual income…….....kyat

3. Employee…..... household (numbers) daily wage..... kyat

4. Household industry household (numbers) annual income.....kyat

5. Others (specify) ..... household (numbers)

5.1.....

5.2.....

5.3.....

2. Main Income of the community

2.1 Source of Financial Aids

	project	Type (Lending, funding, payment in kinds.....)	Frequencies and Amount of money	
			Frequencies	Amount of money
Government organization	1.			
	2.			
	3.			
	4.			
	5.			
Private	1.			
	2.			

	3.			
	4.			
	5.			
International organization	1.			
	2.			
	3.			
	4.			
	5.			

2.2 Any possibility for the village to share the cost of grid electricity installation?

□ No

□ Yes amount..... kyat

From any sources? .....

3. Financial Plan for Borrowing of villager

Sources, Maximum loans and Pay-back period

Lending Source	Maximum loans (kyat)	Per month payment (kyat)	Household debt
Official lenders			
commercial banks			
others (specify)			
Unofficial lenders			
Siblings			
Neighbor			
Other (specify)……			

Household Information

(One for each house)

1. Household General Details

1. Name of villager.....
2. Number of members in your household.....
3. Number of Workers in your household.....
4. Interviewer's gender □ Male □ Female
5. Occupation
   - □ 5.1 Farmer
   - □ 5.2 Fisherman
   - □ 5.3 Other (please specify)……...
6. Workdays/week……
7. Typical time of day worker: From ……..…..…To……..….
8. Household income……..Kyat (per week / month/year)
9. Average Amount of Household Savings……..Kyat (per week / month/year)
10. Household Expenditure……..Kyat (per week / month /year)
    - □ Food
    - □ Water
    - □ Household
    - □ Schooling
    - □ Medicine
    - □ Other (Provide details)
11. Enterprises
    - 11.1 Economic activity……..…
    - 11.2 Revenue ……. (Kyat/month)
    - 11.3 Operation Cost…… (Kyat/month)
    - 11.4 Location of Markets…….…….
    - 11.5 Is there potential for expansion? □ Yes □ No

      Details: ……..……..

      ……

11.6 What kinds of facility that you need for business expansion (please specify and describe your reason)

a) ……..……

b) ……...

c)…….

2. Present Energy Sources and Use

2.1 Diesel

1. Access to a diesel generator (Yes/ No) (If No go to next section: Gas)

2. Do you own the diesel generator (Yes/ No) (If No go to 4)

Diesel motor size ……generator size……..

Make…….……

3 .Cost……. Purchased new / second-hand

Generator age……. Expected Life…….……

4. Amount of fuel used? (L/day)……..……..……

Fuel Cost (kyat/L)……...……..

Number of breakdowns / year……..……..

Average cost to repair (kyat/repair)…….……..……

5. List of the details from every appliance in your home (or business) that are powered by diesel generation (except appliances run from batteries)

Appliances	Number	Power Consumption (W)	Days/ week used	Time of day used				Total (hours/ day)
				From	To	From	To	

2.2 Gas

1. Do you used gas in the household Access to a diesel generator (Yes/ No) (If No go to next section: Kerosene)

Gas Bottle Size (kg)	No. of Gas Bottles	Cost to Refill (kyat)	How often refilled (weeks)

2. Gas appliances used (included only those for household use)

Appliances	Number	Power Consumption (W)	Days/ week used	Time of day used				Total (hours/ day)
				From	To	From	To	

2.3 Kerosene

1. Do you kerosene in your household? (Yes/ No) (If no go to next section: Candles)

Amount of Kerosene used…… (L/month) Cost…….. (Kyat/L)

Appliances	Number	Description

2.4 Candles

1. Do you candle your household? (Yes/ No) (If no go to next section: Biomass)

Amount used…… (Candles/month) Cost……..…….. (Kyat/L)

2.5 Biomass (e.g. wood/drift wood, rice husks, dung, coconut, charcoal, etc)

1. Do you burn biomass in your household? (Yes / No) (If no go to next section: Batteries)

Amount used…… (Candles/month) Cost…….. (Kyat/L)

Type	Purpose	Amount used (kg/day)	Source	Cost (kyat/kg)

2.6 Batteries

1. Do you use car batteries? (Yes / No) (If no go to next question: disposable batteries)

Battery size (Ah)……...Number of batteries…….……

Cost……... (Kyat/L) Life (Years)…….

Means of Charging…….

Cost of Charging (kyat/charge)…….……

How often charged (Days)…….……

2. Appliances used (included only those for household use)

Appliances	Number	Power Consumption (W)	Days/ week used	Time of day used From	To	From	To	Total (hours/ day)

2.7 Do you used disposable batteries (If, no go to next section)

Size	Number/month	Cost (Baht/Battery)	Purpose

3. Future Energy Use

Do you intend to purchase any appliances in the future if there is grid electricity?

Appliance	Number	Expected Cost (kyat/Appliance)	Source of Funds

Appendix E

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TECHNOLOGY &SCIENCE

DISTRIBUTED ELECTRICITY GENERATION FROM BIOMASS GASIFICATION AS A SUSTAINABLE ENERGY OPTION FOR RURAL MYANMAR

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Keywords: biomass energy, cost analysis, distributed generation, electrification, gasification, mini-grid, rural development

ABSTRACT

Myanmar is known for her natural diversity and abundance in agricultural and forestry products. Major biomass residues available include paddy husk, straw, fuelwood and bamboo. These renewable energy sources have great potential to be utilized for power generation, considering the fact that the country experiences shortage in electricity supply, especially in rural areas. In this paper, a demonstration project for sustainable development of biomass energy sources to fulfill energy demand of remote villages in Myanmar is presented. A biomass gasifier, coupled with an engine-generator system has been deployed to supply electricity to a local community with a demand of about 100 kWh/day. An installed capacity of 50 kWe is believed to be sufficient for current and future domestic use. The gasification and electricity generation system, as well as line distribution and connection to households have been successfully demonstrated. The electricity cost has been estimated to be in the range between $0.12-0.23/kWh (150-300 kyat/kWh) in comparison to $0.60/kWh (800 kyat/kWh) from an existing diesel system.

1 INTRODUCTION

Bioenergy is a promising strategic resource in the effort to fulfill the Kyoto agreement to mitigate greenhouse gas emissions. Biomass production represents about 14 % of the World's primary energy supply. About 75 % of its usage is in developing countries [1]. Virtually all South and Southeast Asian countries are major biomass energy producers, as well as consumers. In countries like Myanmar, Bangladesh, Cambodia and Laos, biomass fuels are the most significant indigenous source of energy [2]. Most Southeast Asian countries have a fast growing economy and are interested in the possibilities for increased use of renewables. They have potential to implement a substantial number of biomass energy plants using agro-industrial residues as feedstock, which are currently largely untapped. There exist several studies reporting on biomass energy projects in Asian countries [3, 4]. Nonetheless, a notable exception is Myanmar, in which relatively little information is known.

Myanmar is located in the eastern part of the Asian continent, bordering India, Bangladesh, China, Laos and Thailand. The country is rich in natural and mineral resources that provide significant economic potential. Myanmar is known for her natural diversity and abundance in agriculture and forestry products. Major biomass residues include fuelwood, rice husk and straw These renewable energy resources have great potential for power generation, considering the fact that Myanmar experiences shortage in electricity supply, especially in rural areas. The per capita consumption of electricity in Myanmar during the year 2005 was approximately 70 kWh [5]. The present installed generating capacity of the country is merely about 1,200 MW of which the share of hydropower accounts for 31 %. Most of the electrified villages are in and around major cities or along the main national highways. While grid extension is critical to rural electrification, there are currently no plans confirmed to undertake it. This is due mainly to large capital investment costs. Consequently, alternative opportunities for electricity generation in rural areas are crucially important.

An alternative to large scale sources of power production is the distributed generation technology Direct combustion steam turbines are the most commonly used method for generating electricity from solid fuels, but it is relatively large (in the MW range). It is considered to be too big for rural Myanmar. Alternatively, gasification systems are simple to build and commercially available at a relatively small scale (in the kW range). An internal combustion engine was found to be among the most cost-effective solutions for isolated power generation [6, 7, 8]. It is recognized that access to energy services could bring about sustainable development and poverty reduction among disadvantaged rural people. It is apparent that adoption of appropriate renewable energy technology will not only make efficient and affordable energy available to villagers, but also lead to improvement in their standard of living. During an international renewable energy and energy conservation cooperation project between Thailand and neighboring countries initiated by the Department of Alternative Energy Development and Efficiency under the Ayeyawady - Chaophraya - Mekong Economic Cooperation

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Strategy, a sustainable energy project was coordinated between Thailand and Myanmar. A rural village in Myanmar was selected and a techno-economic study as well as a demonstration of biomass gasification system are reported in the present study.

2 STUDY AREA

A village called Dagoondaing in Twantay Township was chosen as the study area based upon availability of biomass resources, electricity consumption, ease of access and transport, as well as local support. Twantay township is situated 25 km to the west of Yangon at latitude 16o 42' and longitude 95o 56', as shown in Figure 1. Normal forms of transport between the township and Yangon are either by road with a distance of about 50 km, or by river. Most of the town is a green area. Agriculture, especially rice farming and fishing are the main occupations. The study area has about 350 households with a population of 1,500. There is surplus supply of biomass materials for their current electricity need. In addition, the surplus is enough for the next several years of projected electricity consumption. It should be pointed out that the key factor added to the selection is the attitude and eagerness of the community. Dagoondaing community has shown that they are ready and willing to support the project in every possible ways. Their community leaders want to make the project a successful and sustainable one.

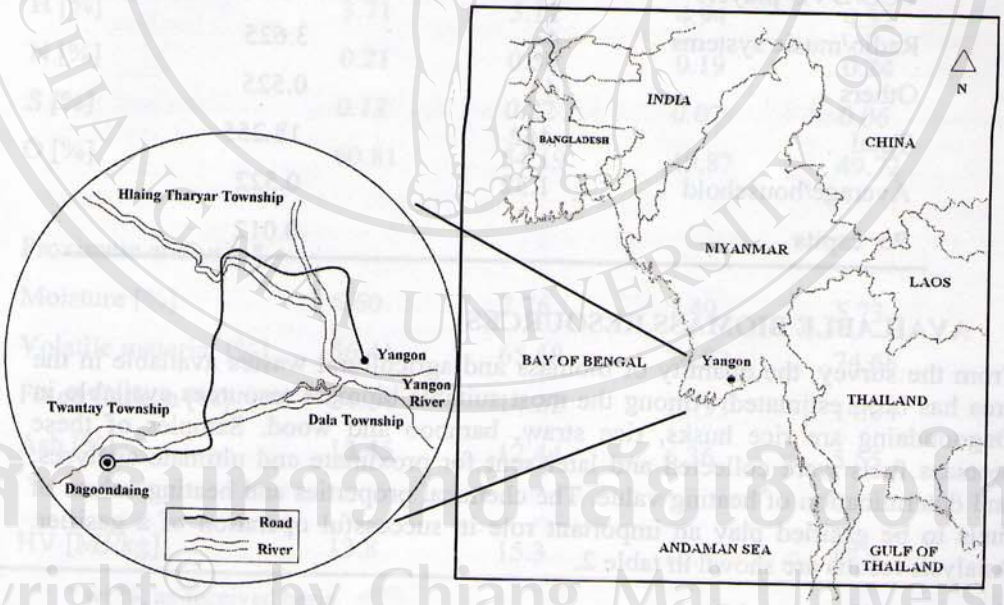

Figure 1: *Map of Myanmar and location of the study site.*

2.1 Existing Energy Scenario

A door to door survey was carried out, covering almost all households in the study area, in order to understand the energy scene. The following data were collected:

number of family members, house area, average monthly income, energy consumption, appliances used, electricity requirement, etc. It was found that peak electricity demand occurs between 1800 and 2300, when villagers are at home after work. The majority of the demand consists of lighting.

2.2 Present Electricity Consumption

There is no national grid power available in the village of Dagoondaing. They are electrified using either small, stand-alone diesel generators or rechargeable lead acid batteries. Table 1 shows details of electricity used. These are the peak requirement. It was revealed from the survey that 300 light bulbs constitute nearly 50 % of total load. Demand of the local community was estimated to be about 100 kWh/day.

Table 1: *Details of Electricity Loads*

Devices	*Number*	*Load [kW]*
Light bulbs	300	9.000
Color televisions	5	0.430
Black & white televisions	86	3.140
VCD/DVD players	63	1.535
Radio/music systems	4	3.625
Others	4	0.525
Total	462	18.255
Average/household	1.32	0.522
Per capita		0.012

3 AVAILABLE BIOMASS RESOURCES

From the survey, the quantity of biomass and agricultural wastes available in the area has been estimated. Among the most suitable biomass resources available in Dagoondaing are rice husks, rice straw, bamboo and wood. Samples of these biomass fuels were collected and later sent for proximate and ultimate analyses, and determination of heating value. The chemical properties and heating values of fuels to be gasified play an important role in successful operation of a gasifier. Analysis results are shown in table 2.

3.1 Rice Husks and Straw

Rice is by far the dominant staple food of Myanmar and the major cash crop in terms of area planted, production capacity and income. In 2004, paddy rice production was 24.8 million metric tons [5], accounting for more than 50 % of food grain production. There are a large number of rice mills in the country. When paddy rice is separated from harvested paddy, rice straw is produced. In the process

of conversion from paddy at a rice mill, rice husk and rice bran are generated as byproducts. The straw and husks are generally discarded, but they can be used as fuels for generating heat or other applications such as soil cover. The quantity of husk generated depends on the husk to paddy ratio, which was reported in the range between 0.14-0.27 by weight [9].

3.2 Wood

Wood is the most important carrier of solar energy. It can be processed into wood logs, wood chip and pellets. The most convenient means of wood processing is the preparation of short logs and split logs for small volume, hand charged stoves. Fuelwood is widely available in Myanmar. Over 23.5 million metric tons of fuelwood were reported used for 1999 domestic consumption [2]. The majority of fuelwood originated from forests. Any difference between fuelwood demand and the amount forests could supply on a sustainable basis would lead to deforestation.

Table 2: *Characteristics of Selected Biomass Materials*

	Rice husks	*Straw*	*Wood*	*Bamboo*
Ultimate analysis *				
C [%]	35.15	39.88	44.93	45.66
H [%]	3.71	5.12	4.94	4.32
N [%]	0.21	0.59	0.19	0.24
S [%]	0.12	0.22	0.07	0.06
O [%]	60.81	54.19	49.87	49.72
Proximate analysis *				
Moisture [%]	5.60	7.76	7.49	5.73
Volatile material [%]	56.41	65.58	74.82	74.68
Fixed Carbon [%]	24.54	14.22	11.33	14.04
Ash [%]	13.45	12.44	6.36	5.55
HV [MJ/kg]	13.8	15.3	16.4	17.8

* wt %, as-received basis.

3.3 Bamboo

Bamboo is the common term applied to a broad group of woody grasses ranging from 10 cm to 40 m in height. Bamboo is distributed mostly in the tropics, comprising natural stands of native species. Myanmar is one of the nations with significant bamboo production and utilization, mostly for fiber, food and

construction materials. Bamboo has long been neglected or ignored, but it may have potential as a bioenergy crop. Literature on the use of bamboo as energy feedstock remains scarce [10].

4 ELECTRIFICATION SYTEM

A village power plant was set up, based on biomass gasification technology coupled with an engine generator to produce electricity from renewable sources. A system with installed capacity of 50 kW_e was assembled and housed in a building close to the center of the village. The main components are a biomass gasifier, an engine driven generator, and distribution lines.

4.1 Biomass Gasifier

Gasification is a suitable conversion technology for the biomass residues available. Conversion of crop residues into energy increases the value of agricultural output and reduces the need for fossil fuel imports. The technology is a relatively economical alternative for small scale industrial and utility power generation in countries that are suffering from high petroleum prices. Many types of biomass gasifiers have been developed and installed. The production of a gaseous fuel from a solid fuel to fire internal combustion engines makes gasification very appealing. Biomass gasification is a thermochemical conversion of a solid, such as paddy husk, wood, straw or agricultural residues into a fuel gas known as *producer gas*. Reactions involved include pyrolysis, oxidation and reduction, which produce CO, CO_2, H_2 and CH_4.

A downdraft gasifier for rice husks with cooling and cleaning equipment was used, as shown in figure 2. Biomass is introduced from the top and is piled inside the gasifier. The reactor wall was made of firebrick. Air is supplied by means of a downstream suction blower or from an engine. The gasifier core was not provided with any throat or constriction to avoid fuel flow problem. Ash formed was removed from the gasifier continuously by an automatic, motor-driven ash removal system. Producer gas was cleaned by passing it through a cyclone, wet scrubbers, and a series of fine filters, prior to entering the surge tank connected to an engine intake manifold.

4.2 Engine and Generator

Producer gas is utilized in dual fuel operation mode with a diesel engine. The details of the engine are given in table 3. The engine used was an imported used diesel engine which was designed for a truck. It is classified as a high speed engine. Because of its low cost, it is used in various applications such as electricity generation, water pumping and agricultural machinery. A simple producer gas air mixer in the form of a T-connection was used. Air was mixed with producer gas at a right angle, and the mixture was sucked into the engine intake manifold. The engine was coupled to a Jewelway model JWX-50-4, 50 kW generator. Under producer gas/diesel dual operation, an effort was made to keep the pilot amount of diesel fuel to a minimum, while the engine power output was adjusted through the

amount of gas inflow. To represent the percentage of diesel replacement rate by producer gas as, r, the following expression is adopted:

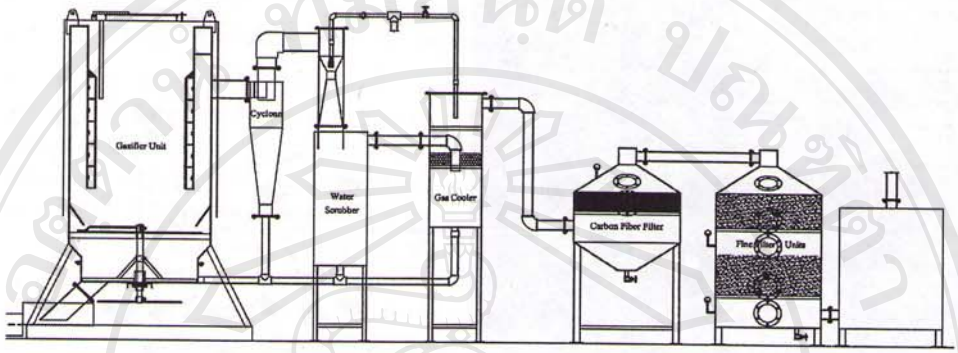

Figure 2: *Rice husk gasifier.*

Table 3: *Technical Data of the Engine Used*

Engine	: Mitsubishi 4M40
Type	: Inline, 4-stroke, SOHC
Number of cylinders	: 4
Bore x Stroke [mm]	: 95 x 100
Displacement	: 2835 cc
Compression ratio	: 21:1
Rated power	: 92 kW / 4000 rpm
Torque	: 294 Nm / 2000 rpm

on energy basis,

$$r_{energy} = \frac{\dot{m}HV_{rice\ husk}}{\dot{m}HV_{diesel} + \dot{m}HV_{rice\ husk}} \quad (1)$$

The overall efficiency is:

$$\eta = \frac{P}{\dot{m}HV_{diesel} + \dot{m}HV_{rice\ husk}} \quad (2)$$

where $\dot{m}_{diesel}$ is the diesel consumption rate (kg/s) in dual fuel operation, $\dot{m}_{rice\ husk}$ is the rice husk consumption rate (kg/s), HV is the fuel heating value (MJ/kg) and, P is the electrical power produced from the generator (kW).

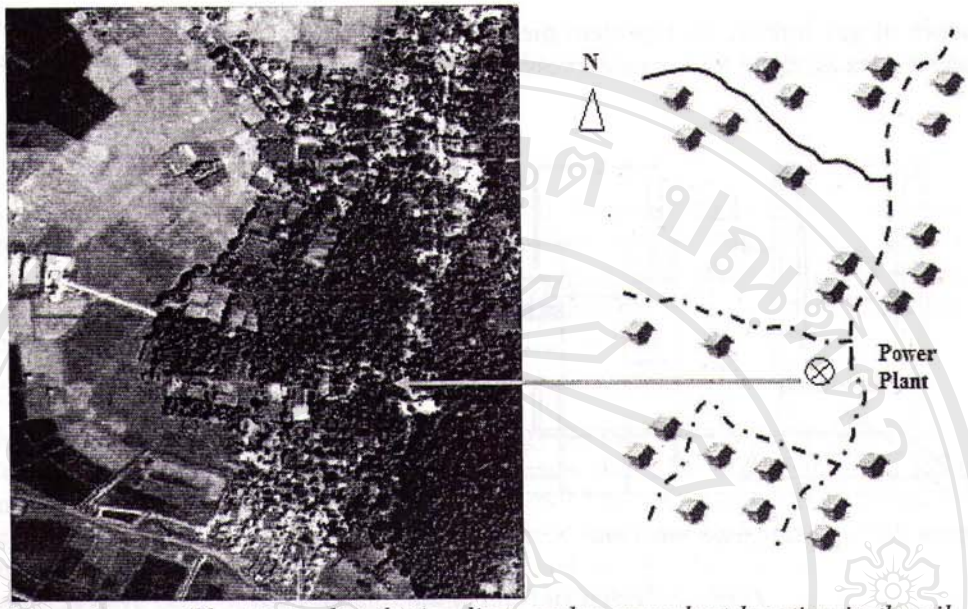

Figure 3: *Electricity distribution lines and power plant location in the village.*

4.3 Electricity Distribution Lines

The power plant is located near the centre of the village. Lamp posts and power poles were erected with assistance from the villagers and electricity distribution lines were connected from the power plant to households in the village under supervision of qualified engineers and electricians. The single-phase lines were installed along the main roads, as shown in figure 3.

5 COST ANALYSIS

An attempt has been made to estimate the unit cost of electricity obtained from rice husk gasification and the dual fuel engine generator in $/kWh. It should be noted that this is the operating cost for villagers running the system. It does not include capital investment cost in setting up the mini-grid electrification system. The amount of rice husks and diesel required to generate one kWh of electricity were determined, which depends on the performance of the engine, as well as the gasifier and the generator. The unit cost of electricity, UCE, can be determined from:

$$UCE = \frac{\sum m_f c_f + c_L + c_M}{Pt} \quad (3)$$

where m_f is fuel mass consumption (kg), c_f is fuel cost for both diesel and rice husks ($/kg), c_L and c_M are total labor and maintenance costs ($) during the speci-

fied operation time, t. While rice husk is available free of charge in the village, the diesel price is \$0.85/liter (1,100 kyat/liter)[1].

6 RESULTS AND DISCUSSION

6.1 System Operation and Performance

Several villagers with technical experience were trained to run the system for a month. During the demonstration run, a team of engineers and technicians was in charge with the operation under the watchful eyes of the trainees. The gasifier was able to start within 30 min and attain steady state operation from cold start in about two hours. With operation every evening, the gasifier normally retains some heat from the previous day, hence, its startup time is less than 15 min, and the engine can be connected and electricity generated shortly afterwards. Although feeding was done intermittently, gasification seemed to operate well and in oxidation and reduction reactions proceeded continuously. The engine was designed to operate in either dual fuel or diesel modes. It was found to operate well in both modes. The engine was able to run smoothly without any sign of deterioration or excessive emissions, and no tar problem was observed. To maintain a satisfactory gasification process, regular cleaning of gas lines and piping, as well as engine maintenance must be undertaken.

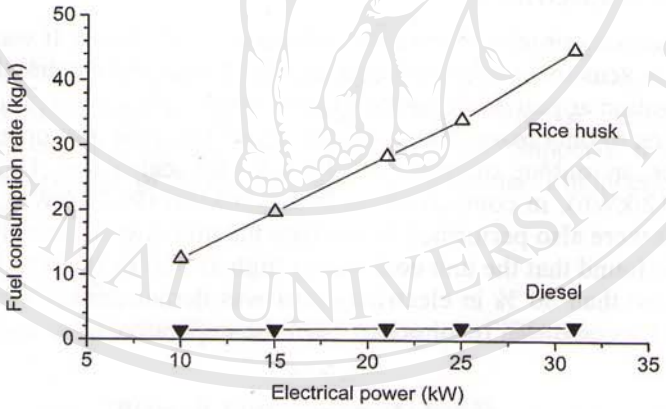

Figure 4: *Variation of fuel consumption rate with power output.*

A number of limited test runs on the system were carried out. Figure 4 shows rice husk and diesel consumption rates for a range of electrical power produced. At higher power output, rice husk consumption was found to increase markedly while diesel usage rate was relatively stable between 1.8 - 2.7 kg/h. Figure 5 shows the percentage of diesel replacement by producer gas from rice husk gasification. The

[1] In 2007, the average exchange rate was about US \$1.0 for 1300 Myanmar kyat.

replacement rate was above 70 % on an energy basis for all power output levels considered. It was evident that significant saving in diesel fuel due to its replacement by producer gas was obtained. Also shown in figure 5 is the system efficiency in the range between 15 and 17 %.

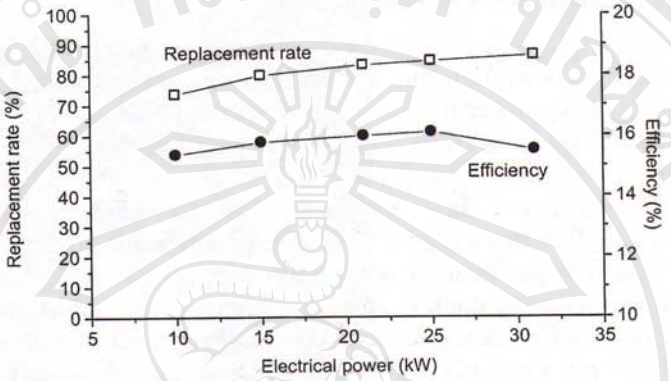

Figure 5: *Variation of diesel replacement rate by producer gas and efficiency with power output.*

6.2 Unit Cost of Electricity

Unit cost of electricity produced from the system was calculated. It was found that the unit cost was sensitive to the fuel cost and the connected electrical load. With the system operation at part-load (figure 4), the diesel replacement ratio was found to be low, leading to only marginal savings on diesel fuel cost. For operation nearly at full load, or an output of about 25-30 kW, the calculated UCE was 150 kyat/kWh ($0.12/kWh), in comparison to 300 kyat/kWh ($0.23/kWh) at part load operation. Tests were also performed to estimate the unit cost when only diesel was used, and it was found that the unit cost was as high as 800 kyat/kWh ($0.60/kWh). A saving of more than 80 % in electricity cost was demonstrated. With a present increasing tendency in diesel retail price, it will be imperative to shift generation to renewable energy.

6.3 Preliminary Socio-economic Impact

Converting from low quality fuels to electricity is expected to generate a range of social, environmental and economic benefits. Prior to the installation of the biomass gasification power plant, most households in the village used kerosene lamps or candles for lighting. After the installation, each household was provided with a compact fluorescent lamp, and it was expected that a number of other electrical appliances will arrive. Electrification has improved people's quality of life in similar ways to that reported in literature [11], resulting in getting rid of dirty and dangerous kerosene lamps, increased ability to study and do productive activities in the evenings, improved safety and security, etc. So far, it is not clear if the project has a significant impact on extra income generation and economic

activities. The only direct employment opportunity was to four technicians who operate the power plant.

7 CONCLUSION

Myanmar has immense potential of biomass sources that can be utilized to augment the growing demand of energy. A biomass gasification engine generator system was successfully installed and operated in a rural village to replace a conventional diesel power plant. The system can be run without major problems. Even through operating the system was relatively simple, dedicated operators with good technical backgrounds were required. The use of rice husk gasification as a bioenergy substitute for diesel can reduce the fossil fuel consumption by more than 70 %. There is a great opportunity to generate electricity for households and other productive activities.

Biomass gasification technology could be suitable for rural mini-grid electrification. Most equipment can be developed locally and biomass feedstocks are widely available. The mini-grid electrification project was found to contribute to upgrading the living standards of villagers in terms of quality of life, longer study hours, safer environment, and improved productive and income-generating activities. This distributed generation model should be promoted by the government so that it can reach its goal of providing safe and reliable power supply.

8 ACKNOWLEDGMENTS

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