CHAPTER VI
RESULTS

The Cumulative Energy/Exergy Consumption analysis results were determined by using computer spreadsheet models that was developed for the plant 2 of Bangchak refinery. These models simulate mass, energy and exergy balances around each of the plant sections that are described in Chapter V of this thesis. From the results of the mass, energy and exergy balances the Cumulative Energy/Exergy values of the products of the refinery processes were determined.

The Cumulative Energy/Exergy Consumption analysis results that are presented on the following pages are based on sets of operating parameters that are considered to be representative of the actual plant operating parameters.

Table 6.1 Topping unit – Mass, Energy and Cumulative Energy Balance

	Mass	Energy		Cumulative Energy	
	Kg/hr	kW	%	kW	%
Influents/Stream					
Crude oil	189,356.00	2,482,093.685	79.54	2,612,730.195	80.27
Wild gasoline	618.00	8,109.355	0.26	8,706.770	0.27
Fuel gas	467.20	7,703.039	0.25	8,811.158	0.27
Fuel oil	1,855.52	23,617.544	0.76	24,972.358	0.77
Air	35,707.78	19.990	0.00	19.990	0.00
Hot oil	45,574.00	599,933.511	19.23	599,933.511	18.44
BFW	2,547.34	-1,446.009	-0.05	-1,446.009	-0.04
Electricity		405.960	0.01	1,153.182	0.04
Sum	276,125.84	3,120,437.075	100.00	3,254,881.154	100.00
Useful Effluents /Stream					
Off gas	1,187.00	15,216.828	0.49	16,089.737	0.49
LPG to Deet.	920.00	11,723.463	0.38	12,395.976	0.38
Whole Naphtha	28,904.00	390,627.088	12.52	413,035.294	12.69
Kerosene	27,510.00	358,080.793	11.48	378,621.989	11.63
Diesel to GOHDU	55,801.00	736,069.476	23.59	778,293.879	23.91
Diesel to Plant 3	1,473.00	19,246.623	0.62	20,350.700	0.63
Light gas oil	856.00	11,247.355	0.36	11,892.556	0.37
Heavy gas oil	8,105.00	107,032.945	3.43	113,172.857	3.48
Residue oil	65,218.00	831,130.191	26.63	878,807.723	27.00
Flue gas	38,030.50	10,393.332	0.33	10,393.332	0.32
Hot oil	45,574.00	596,358.811	19.11	596,358.811	18.32
Cooling water		25,468.300	0.82	25,468.300	0.78
Loss					
Condensate water	2,547.34	-1,678.009	-0.05	0.000	0.00
others		9,519.881	0.30	0.000	0.00
Sum	276,125.84	3,120,437.075	100.00	3,254,881.154	100.00

Datum temperature: 25°C

Table 6.2 Deethanizer Unit – Mass, Energy and Cumulative Energy Balances

	Mass	Energy		Cumulative Energy	
	Kg/hr	kW	%	kW	%
Influents/Stream					
LPG from TPU	920.00	11,723.463	46.71	12,395.976	44.80
LPG from CRU	1,044.00	13,317.866	53.07	15,122.036	54.65
LP-steam	520.00	9.900	0.04	26.327	0.10
Electricity		44.756	0.18	127.136	0.45
Sum	2,484.00	25,095.985	100.00	27,671.474	100.00
Useful Effluents /Stream					
Off gas	78.00	1,008.599	4.02	1,117.993	4.04
LPG to LPGU	1,886.00	24,079.571	95.95	26,691.269	96.46
Condensate water	520.00	-337.788	-1.35	-337.788	-1.22
Cooling water		200.000	0.80	200.000	0.72
Loss					
Others		145.603	0.58	0.000	0.00
Sum	2,484.00	25,095.985	100.00	27,671.474	100.00

Datum temperature: 25°C

Table 6.3 LPG Treating unit – Mass, Energy and Cumulative Energy Balances

	Mass	Energy		Cumulative Energy	
	Kg/hr	kW	%	kW	%
Influents/Stream					
LPG from Deet.	1,886.00	24,079.571	32.18	26,691.269	32.17
LPG from Plant 3	3,960.00	50,760.225	67.82	56,265.738	67.82
Air	5.19	0.007	0.00	0.007	0.00
LP-steam	4.00	0.076	0.00	0.202	0.00
Electricity		2.100	0.00	5.965	0.01
Sum	5,855.19	74,841.979	100.00	82,963.174	100.00
Useful Effluents /Stream					
Vent gas & Disulfide	233.19	2,962.778	3.96	3,290.969	3.97
LPG Product	5,618.00	71,729.251	95.84	79,674.804	96.03
Condensate water	4.00	-2.598	-0.00	-2.598	-0.00
Losses					
Others		152.548	0.20	0.000	0.00
Sum	5,855.19	74,841.979	100.00	82,963.174	100.00

Datum temperature: 25°C

Table 6.4 Naphtha Pretreating Unit – Mass, Energy, Cumulative Energy Balances

	Mass	Energy		Cumulative Energy	
	Kg/hr	kW	%	kW	%
Influents/Stream					
Naphtha from TPU	28,904.00	390,627.088	50.97	413,035.294	50.60
Naphtha from Plant 3	23,770.00	320,107.013	41,77	338,469.855	41.47
Hydrogen from CRU	2,482.00	43,633.055	5.69	49,544.019	6.07
Fuel gas	130.87	2,158.195	0.28	2,468.662	0.30
Fuel oil	669.06	8,523.190	1.11	9,012.120	1.10
Air	12,030.18	0.000	0.000	0.000	0.00
HP-steam	11,600.00	1,133.100	0.15	3,013.235	0.37
Electricity		230.1	0.03	653.629	0.09
Sum	79,586.11	766,411.741	100.00	816,196.814	100.00
Useful Effluents/Stream					
Off gas from D201	1,818.00	32,156.847	4.20	36,455.077	4.47
Off gas from D202	1,279.00	16,507.235	2.15	18,713.667	2.29
Off gas from D203	66.00	849.573	0.11	963.131	0.12
Treat light naphtha to Plant 3	8,181.00	103,012.772	13.44	116,781.925	14.31
Treat light naphtha to Isomerization unit	19,649.00	247,094.724	32.24	280,122.522	34.32
Treat Heavy naphtha	24,163.00	322,200.116	42.04	365,266.839	44.75
Flue gas	12,830.11	3,455.085	0.45	3,455.085	0.42
Condensate water	11,600.00	-7,422.332	-0.97	-7,422.332	-0.91
Cooling water		1,860.900	0.25	1,860.900	0.23
Loss					
Others		46,696.821	6.09	0.000	0.00
Sum	79,586.11	766,411.741	100.00	816,196.814	100.00

Datum temperature: 25°C

Table 6.5 Isomerization unit – Mass, Energy and Cumulative Energy Balances

	Mass	Energy		Cumulative Energy	
	Kg/hr	kW	%	kW	%
Influents/Stream					
Treated light naphtha	19,649.00	247,094.724	96.67	280,122.522	96.36
Hydrogen from plant 3	453.00	7,961.181	3.11	9,039.681	3.11
HP-stream	2,900.00	283.300	0.11	753.357	0.26
Electricity		280.100	0.11	795.660	0.27
Sum	23,002.00	255,619.305	100.00	290,711.238	100.00
Useful Effluents/Stream					
Off gas	853.00	11249.157	4.40	12,887.808	4.43
Isomerate product	19,249.00	243,114.725	95.11	278,528.963	95.81
Condensate water	2,900.00	-1,855.533	-0.73	-1,855.533	-0.64
Cooling water		1,150.000	0.45	1,150.000	0.40
Loss					
Others		1,960.956	0.77	0.000	0.00
Sum.	23,002.00	255,619.305	100.00	290,711.238	100.00

Datum temperature: 25°C

Table 6.6 Catalytic Cracking Unit – Mass, Energy and Cumulative Energy Balances

	Mass	Energy		Cumulative Energy	
	Kg/hr	kW	%	kW	%
Influents/Stream					
Treated heavy naphtha	24,163.00	322,200.116	34.59	365,266.829	37.36
Hydrogen from plant 3	288.00	5,063.608	0.54	5,749.575	0.59
Fuel gas	515.59	8,502.909	0.91	9,726.093	1.00
Air	9,954.39	0.000	0.00	0.000	0.00
Hot oil	45,574.00	596,358.811	64.02	596,358.811	60.98
BFW	2,180.00	-1,271.458	-0.14	-1,271.458	-0.13
HP-steam	5,900.00	576.300	0.06	1,532.546	0.16
Electricity		147.702	0.02	419.565	0.04
Sum	88,574.98	931,577.988	100.00	977,781.972	100.00
Useful Effluents/Stream					
Off gas	2,279.00	32,226.633	3.46	36,592.371	3.74
Hydrogen	2,482.00	43,633.055	4.68	49,544.019	5.07
LPG to Deet.	1,044.00	13,317.866	1.43	15,122.036	1.55
Reformate product	18,646.00	230,881.141	24.78	262,158.578	26.81
Flue gas	10,469.98	2,665.445	0.29	2,665.445	0.27
Hot oil	45,574.00	599,933.511	64.40	599,933.511	61.36
HP-steam	1,769.90	1,769.900	0.19	4,706.668	0.48
LP-steam	5,900.00	228.800	0.03	608.444	0.06
Cooling water		6,450.900	0.69	6,450.900	0.66
Loss					
Others		470.736	0.05	0.000	0.00
Sum	88,574.98	931,577.988	100.00	977,781.972	100.00

Datum temperature: 25°C

Table 6.7 Gas Oil Hydrodesulfurization Unit – Mass, Energy and Cumulative Energy Balances

	Mass	Energy		Cumulative Energy	
	Kg/hr	kW	%	kW	%
Influents/Stream					
Hydrogen from NPU	854.00	15,021.120	1.28	17,028.911	1.37
Gas oil from Plant 3	22,994.00	303,515.419	25.77	320,926.489	25.72
Diesel oil from TPU	55,801.00	736,069.476	62.50	778,293.879	62.37
Light gas oil	856.00	11,247.355	0.96	11,892.556	0.95
Heavy gas oil	8,105.00	107,032.945	9.09	113,172.857	9.07
Fuel gas	357.11	5,889.206	0.50	6,736.397	0.54
Fuel oil	70.89	903.084	0.07	954.889	0.08
Air	8,235.26	0.000	0.00	0.000	0.00
Process water	2,506.40	-1,686.424	-0.14	-1,686.424	-0.14
BFW	1,368.04	-797.893	-0.07	-797.893	-0.06
Electricity		469.000	0.04	1,332.255	0.10
Sum	101,147.70	1,177,663.287	100.00	1,247,853.916	100.00
Useful Effluents/Stream					
Off gas from D3702					
Off gas from D3703	444.00	8,019.029	0.21	8,609.790	0.69
Wild gasoline	178.00	2,487.644	0.68	2,670.908	0.21
Diesel oil product	618.00	8,109.355	0.69	8,706.770	0.70
to Tank	31,365.00	409,866.287	34.80	440,061.058	35.27
Diesel oil product					
to Plant 3	56,005.00	731,852.570	62.14	785,768.007	62.97
Flue gas					
Condensate water	8,663.26	1,843.308	0.16	1,843.308	0.15
Cooling water	2,506.40	-1,568.824	-0.13	-1,568.824	-0.13
		1,762.900	0.15	1,762.900	0.14
Loss					
Sour water					
Others	1,368.04	-904.644	-0.08	0.000	0.00
		16,195.663	1.38	0.000	0.00
Sum	101,147.70	1,177,663.287	100.00	1,247,853.916	100.00

Datum temperature: 25°C

Table 6.8 Fuel Gas Treating Unit – Mass, Energy, Cumulative Energy Balances

	Mass	Energy		Cumulative Energy	
	Kg/hr	kW	%	kW	%
Influents/Stream					
Off gas	3,741.00	55,111.176	99.66	61,622.977	99.17
LP-steam	1,750.00	67.800	0.12	180.300	0.29
Electricity		118.609	0.22	336.925	0.54
Sum	5,491.00	55,297.585	100.00	62,140.201	100.00
Useful Effluents/Stream					
Fuel gas	2,363.00	39,058.872	70.63	44,677.678	71.90
Acid gas	282.00	2,147.496	3.88	2,456.424	3.95
Hydrocarbon	1,096.00	13,910.336	25.16	15,911.405	25.61
Condensate water	1,750.00	-1,165.106	-2.10	-1,165.106	-1.88
Cooling water		259.800	0.47	259.800	0.42
Loss					
Others		1,086.186	1.96	0.000	0.00
Sum	5,491.00	55,297.585	100.00	62,140.201	100.00

Datum temperature: 25°C

Table 6.9 Sulfur Recovery Unit – Mass, Energy, Cumulative Energy Balances

	Mass	Energy		Cumulative Energy	
	Kg/hr	kW	%	kW	%
Influents/Stream					
Acid gas from Plant 2	282.00	2,147.496	46.44	2,456.424	43.77
Acid gas from Plant 3	266.00	2,028.126	43.86	2,319.881	41.34
Fuel gas	34.50	571.262	12.35	653.440	11.64
Air	1,995.00	85.000	1.84	85.000	1.51
BFW	800.00	-373.806	-8.08	-373.806	-6.66
Electricity		165.861	3.59	471.150	8.40
Sum	3,377.50	4,623.938	100.00	5,612.089	100.00
Useful Effluents/Stream					
Liquid Sulfur	472.00	2,979.944	64.45	3,075.584	54.80
HP-steam	583.00	744.803	16.10	1,861.499	33.17
LP-steam	174.00	246.803	5.34	656.319	11.70
LLP-steam	43.00	2.139	0.05	5.688	0.10
Cooling water		13.000	0.28	13.000	0.23
Loss					
Stack gas	2,105.50	587.890	12.71	0.000	0.00
Others		49.663	1.07	0.000	0.00
Sum	3,377.50	4,623.938	100.00	5,612.089	100.00

Datum temperature: 25°C

Table 6.10 Energy Section – Mass, Energy, Cumulative Energy Balances

	Mass	Energy		Cumulative Energy	
	Kg/hr	kW	%	kW	%
Influents/Stream					
BFW to Boiler A&B	76,000.00	-42,232.832	-82.56	-42,232.832	-71.02
BFW to WHB	9,320.00	-5,289.150	-10.34	-5,289.150	-8.89
Sat. Steam to WHB	2,180.00	290.600	0.57	772.788	1.30
Fuel gas	770.90	12,713.214	24.85	14,542.071	24.45
Fuel oil	4,961.00	66,115.440	129.25	69,908.132	117.56
Air	86,610.73	0.000	0.00	0.000	0.00
Flue gas from all furnace	69,993.85	18,357.160	35.88	3,408.755	5.73
Electricity		1,200.000	2.35	18,357.160	30.87
Sum	249,836.48	51,154.432	100.000	59,466.924	100.00
Useful Effluents/Stream					
Electricity from GT 1&2		5,200.000	10.17	13,828.280	23.25
Electricity from GT 3		5,500.000	10.75	14,626.066	24.60
HP-steam to Plant 2	36,100.00	4,811.400	9.41	12,794.882	21.52
HP-steam to Plant 3	51,400.00	6,850.600	13.39	18,217.696	30.63
Loss					
Stack gas from Boiler A&B	92,342.63	10,248.350	20.03	0.000	0.00
Stack gas from WHB	69,993.85	6,902.760	13.49	0.000	0.00
Others		11,641.322	22.76	0.000	0.00
Sum	249,836.48	51,154.432	100.00	59,466.924	100.00

Datum temperature: 25°C

Table 6.11 Overall Plant – Mass, Energy, Cumulative Energy Balances

	Mass	Energy		Cumulative Energy	
	kg/hr	kW	%	kW	%
Influents/Stream					
Crude oil	189,356.00	2,482,093.685	76.90	2,612,730.195	76.53
LPG Plant 3	3,960.00	50.760.225	1.57	56,265.738	1.65
Naphtha Plant 3	23,770.00	320,107.013	9.92	338,469.855	9.91
Hydrogen Plant 3	741.00	13,024.789	0.40	14,789.255	0.43
Gas oil Plant 3	22,994.00	303,515.419	9.40	320,926.489	9.40
Acid gas Plant 3	266.00	2,028.126	0.06	2,319.881	0.07
Fuel gas	1,505.27	24,822.146	0.77	28,395.750	0.83
Fuel oil	2,595.47	33,043.819	1.02	34,939.367	1.02
Air	67,927.80	104.997	0.00	104.997	0.00
BFW	6,895.38	-3,889.166	-0.12	-3,889.166	-0.11
Process water	2,506.40	-1,686.424	-0.05	-1,686.424	-0.05
HP-steam	20,400.00	1,992.700	0.06	5,299.157	0.16
LP-steam	2,274.00	77.776	0.00	209.828	0.01
Electricity		1,864.188	0.06	5,295.466	0.16
Sum	345,191.32	3,227,859.291	100.00	3,414,167.389	100.00
Useful Effluents/Stream					
Off gas	3,587.00	49,589.250	1.54	55,448.593	1.62
Fuel gas	2,363.00	39,058.872	1.21	44,677.678	1.31
LPG product	5,618.00	71,729.251	2.22	79,674.804	2.33
Treated light naphtha	8,181.00	103,012.772	3.19	116,781.925	3.42
Isomerate	19,249.00	243,114.725	7.53	278,528.963	8.16
Reformate	18,646.00	230,881.141	7.15	262,158.578	7.68
Kerosene	27,510.00	358,080.793	11.09	378,621.989	11.09
Diesel to plant 3 (untreated)	1,473.00	19,246.623	0.60	20,350.700	0.60
Diesel product to plant 2	31,365.00	409,866.287	12.67	440,061.058	12.89
Diesel product to plant 3	56,005.00	731,852.570	22.67	785,768.007	23.02
Fuel oil	65,218.00	831,130.191	25.75	878,807.723	25.74
Hydrogen	1,096.00	13,910.336	0.43	15,911.405	0.47
Sulfur	472.00	2,979.940	0.09	3,075.584	0.09
Flue gas	69,993.85	18,357.169	0.57	18,357.169	0.54
Vent gas&Disulfide	233,.19	2,962.778	0.09	3,290.969	0.10
HP-Steam	2,763.00	2,469.900	0.08	6,568.167	0.19
LP-Steam	6,074.00	475.603	0.02	1,264.763	0.04
LLP-Steam	43.00	2.139	0.00	5.688	0.00
Condensate	21,827.74	-14,030.192	-0.44	-12,352.183	-0.36
Cooling water		37,165.800	1.15	37,165.800	1.09
Loss					
Sour water	1,268.04	-904.644	-0.03	0.000	0.00
Stack gas	2,105.50	587.890	0.02	0.000	0.00
Others		76,320.097	2.36	0.000	0.00
Sum	345,191.32	3,227,859.291	100.00	3,414,167.381	100.00

Datum temperature: 25°C

Table 6.12 Topping unit – Mass, Exergy and Cumulative Exergy Balance

	Mass	Exergy		Cumulative Exergy	
	Kg/hr	kW	%	kW	%
Influents/Stream					
Crude oil	189,356.00	2,618,714.380	79.64	2,756,541.452	80.34
Wild gasoline	618.00	8,542.069	0.26	9,291.979	0.27
Fuel gas	467.20	7,930.802	0.24	9,481.633	0.28
Fuel oil	1,855.52	26,024.726	0.79	27,961.506	0.82
Air	35,707.78	1.500	0.00	1.500	0.00
Hot oil	45,574.00	626,485.907	19.05	626,485.907	18.26
BFW	2,547.34	73.378	0.00	73.378	0.00
Electricity		405.960	0.01	1,053.505	0.03
Sum	276,125.84	3,288,178.722	100.00	3,430,890.860	100.00
Useful Effluents/Stream					
Off gas	1,187.00	16,043.500	0.49	17,237.469	0.50
LPG to Deet.	920.00	12,380.687	0.38	13,302.067	0.39
Whole Naphtha	28,904.00	411,119.624	12.50	441,715.453	12.88
Kerosene	27,510.00	377,124.733	11.47	405,190.637	11.81
Diesel to GOHDU	55,801.00	769,896.235	23.41	827,192.486	24.11
Diesel to Plant 3	1,473.00	20,278.816	0.62	21,787.980	0.64
Light gas oil	856.00	11,846.253	0.36	12,727.860	0.37
Heavy gas oil	8,105.00	112,263.920	3.41	120,618.684	3.52
Residue oil	65,218.00	873,334.330	26.56	938,328.521	27.35
Flue gas	38,030.50	7,759.695	0.24	7,759.695	0.23
Hot oil	45,574.00	624,942.107	19.01	624,942.107	18.22
Cooling water		87.900	0.00	87.900	0.00
Loss					
Condensate water	2,547.34	87.900	0.00	0.000	0.00
others		51,063.764	1.55	0.000	0.00
Sum	276,125.84	3,288,178.722	100.00	3,430,890.860	100.00

Datum temperature: 25°C

Table 6.13 Deethanizer Unit – Mass, Exergy and Cumulative Exergy Balances

	Mass	Exergy		Cumulative Exergy	
	Kg/hr	kW	%	kW	%
Influents/Stream					
LPG from TPU	920.00	12,380.687	46.42	13,302.067	43.17
LPG from CRU	1,044.00	14,066.412	52.74	16,986.286	55.13
LP-steam	520.00	176.630	0.66	408.821	1.33
Electricity		44.756	0.18	116.146	0.37
Sum	2,484.00	26,668.485	100.00	30,813.320	100.00
Useful Effluents/Stream					
Off gas	78.00	1,074.926	4.03	1,249.485	4.06
LPG to LPGU	1,886.00	25,426.274	95.34	29,555.274	95.92
Condensate water	520.00	7.861	0.03	7.861	0.02
Cooling water		0.700	0.00	0.700	0.00
Loss					
Others		158.723	0.60	0.000	0.00
Sum	2,484.00	26,668.485	100.00	30,813.320	100.00

Datum temperature: 25°C

Table 6.14 LPG Treating unit – Mass, Exergy and Cumulative Exergy Balances

	Mass	Exergy		Cumulative Exergy	
	Kg/hr	kW	%	kW	%
Influents/Stream					
LPG from Deet.	1,886.00	25,426.274	32.18	29,555.274	32.18
LPG from Plant 3	3,960.00	53,580.535	67.82	62,281.535	67.81
Air	5.19	0.000	0.00	0.000	0.00
LP-steam	4.00	1.359	0.00	3.145	0.00
Electricity		2.100	0.00	5.450	0.01
Sum	5,855.19	79,010.268	100.00	91,845.404	100.00
Useful Effluents/Stream					
Vent gas & Disulfide	233.19	3,133.002	3.97	3,648.344	3.97
LPG Product	5,618.00	75,738.855	95.85	88,197.000	96.03
Condensate water	4.00	0.060	0.00	0.060	0.00
Losses					
Others		138.350	0.18	0.000	0.00
Sum	5,855.19	79,010.268	100.00	91,845.404	100.00

Datum temperature: 25°C

Table 6.15 Naphtha Pretreating Unit – Mass, Exergy, Cumulative Exergy Balances

	Mass	Exergy		Cumulative Exergy	
	Kg/hr	kW	%	kW	%
Influents/Stream					
Naphtha from TPU	28,904.00	411,119.624	50.69	441,715.453	49.95
Naphtha from Plant 3	23,770.00	337,957.156	41.67	363,108.179	41.06
Hydrogen from CRU	2,482.00	45,174.679	5.57	54,551.937	6.17
Fuel gas	130.87	2,222.800	0.27	2,657.459	0.30
Fuel oil	669.06	9,384.522	1.16	10,082.925	1.14
Air	12,030.18	0.000	0.00	0.000	0.00
HP-steam	11,600.00	4,998.456	0.62	11,569.241	1.31
Electricity		230.100	0.03	597.132	0.07
Sum	79,586.11	811,087.338	100.00	884,282.325	100.00
Useful Effluents/Stream					
Off gas from D201	1,818.00	33,169.057	4.09	38,323.453	4.33
Off gas from D202	1,279.00	17,388.785	2.14	20,090.963	2.27
Off gas from D203	66.00	893.374	0.11	1,032.203	0.12
Treat light naphtha to Plant 3	8,181.00	108,806.572	13.42	125,714.864	14.22
Treat light naphtha to Isomerization unit	19,649.00	261,304.199	32.22	301,910.273	34.14
Treat Heavy naphtha	24,163.00	339,378.528	41.84	392,117.174	44.34
Flue gas	12,830.11	2,592.064	0.32	2,592.064	0.29
Condensate water	11,600.00	2,494.932	0.31	2,494.932	0.28
Cooling water		6.400	0.00	6.400	0.00
Loss					
Others		45,053.425	5.56	0.000	0.00
Sum	79,586.11	811,087.338	100.00	884,282.325	100.00

Datum temperature: 25°C

Table 6.16 Isomerization unit – Mass, Exergy and Cumulative Exergy Balances

	Mass	Exergy		Cumulative Exergy	
	Kg/hr	kW	%	kW	%
Influents/Stream					
Treated light naphtha	19,649.00	261,304.199	96.39	301,910.273	95.70
Hydrogen from plant 3	453.00	8,248.202	3.04	9,960.345	3.16
HP-stream	2,900.00	1,249.575	0.47	2,892.219	0.92
Electricity		280.100	0.10	726.886	0.24
Sum	23,002.00	271,082.076	100.00	315,489.724	100.00
Useful Effluents/Stream					
Off gas	853.00	11,836.634	4.37	13,902.523	4.41
Isomerate product	19,249.00	256,237.485	94.52	300,959.517	95.39
Condensate water	2,900.00	623.719	0.23	623.719	0.20
Cooling water		3.965	0.00	3.965	0.00
Loss					
Others		2,380.274	0.88	0.000	0.00
Sum.	23,002.00	271,082.076	100.00	315,489.724	100.00

Datum temperature: 25°C

Table 6.17 Catalytic Cracking Unit – Mass, Exergy and Cumulative Exergy Balances

	Mass	Exergy		Cumulative Exergy	
	Kg/hr	kW	%	kW	%
Influents/Stream					
Treated heavy naphtha	24,163.00	339,378.528	34.59	392,117.174	37.70
Hydrogen from plant 3	288.00	5,223.321	0.53	6,307.457	0.61
Fuel gas	515.59	8,757.578	0.89	10,470.081	1.01
Air	9,954.39	0.000	0.00	0.000	0.00
Hot oil	45,574.00	624,942.107	63.70	624,942.107	60.08
BFW	2,180.00	54.315	0.01	54.315	0.00
HP-steam	5,900.00	2,542.324	0.26	5,884.370	0.56
Electricity		147.702	0.02	383.300	0.04
Sum	88,574.98	981,045.785	100.00	1,040,158.804	100.00
Useful Effluents/Stream					
Off gas	2,279.00	33,691.222	3.43	40,684.770	3.91
Hydrogen	2,482.00	45,174.679	4.60	54,551.937	5.24
LPG to Deet.	1,044.00	14,066.412	1.43	16,986.286	1.63
Reformate product	18,646.00	242,287.200	24.70	292,580.627	28.13
Flue gas	10,469.98	1,924.870	0.20	1,924.870	0.18
Hot oil	45,574.00	626,485.907	63.86	626,485.907	60.23
HP-steam	1,769.90	939.395	0.10	2,174.288	0.21
LP-steam	5,900.00	2,051.324	0.21	4,747.919	0.46
Cooling water		22.200	0.00	22.200	0.00
Loss					
Others		14,402.575	1.47	0.000	0.00
Sum	88,574.98	981,045.785	100.00	1,040,158.804	100.00

Datum temperature: 25°C

Table 6.18 Gas Oil Hydrodesulfurization Unit – Mass, Exergy and Cumulative Exergy Balances

	Mass	Exergy		Cumulative Exergy	
	Kg/hr	kW	%	kW	%
Influents/Stream					
Hydrogen from NPU	854.00	15,508.858	1.26	17,918.899	1.35
Gas oil from Plant 3	22,994.00	318,377.215	25.77	342,071.084	25.72
Diesel oil from TPU	55,801.00	769,896.235	62.32	827,192.486	62.19
Light gas oil	856.00	11,846.253	0.96	12,727.860	0.96
Heavy gas oil	8,105.00	112,263.920	9.09	120,618.684	9.07
Fuel gas	357.11	6,065.650	0.49	7,251.760	0.54
Fuel oil	70.89	994.352	0.08	1,068.353	0.08
Air	8,235.26	0.000	0.00	0.000	0.00
Process water	2,506.40	34.903	0.00	34.903	0.00
BFW	1,368.04	34.485	0.00	34.485	0.00
Electricity		469.000	0.04	1,217.100	0.09
Sum	101,147.70	1,235,490.871	100.00	1,330,135.614	100.00
Useful Effluents/Stream					
Off gas from D3702					
Off gas from D3703	444.00	8,302.421	0.67	9,031.292	0.68
Wild gasoline	178.00	2,603.655	0.21	2,832.231	0.21
Diesel oil product	618.00	8,542.069	0.69	9,291.979	0.70
to Tank	31,365.00	431,525.763	34.93	469,409.506	35.29
Diesel oil product					
to Plant 3	56,005.00	770,527.669	62.37	838,172.465	63.01
Flue gas					
Condensate water	8,663.26	1,345.513	0.11	1,345.513	0.10
Cooling water	2,506.40	46.529	0.00	46.529	0.00
		6.100	0.00	6.100	0.00
Loss					
Sour water					
Others	1,368.04	19.857	0.00	0.000	0.00
		12,571.395	1.02	0.000	0.00
Sum	101,147.70	1,235,490.871	100.00	1,330,135.614	100.00

Datum temperature: 25°C

Table 6.19 Fuel Gas Treating Unit – Mass, Exergy, Cumulative Exergy Balances

	Mass	Exergy		Cumulative Exergy	
	Kg/hr	kW	%	kW	%
Influents/Stream					
Off gas	3,741.00	57,414.747	98.75	66,313.556	97.48
LP-steam	1,750.00	608.462	1.05	1,408.324	2.07
Electricity		118.609	0.20	307.802	0.45
Sum	5,491.00	58,141.819	100.00	68,029.682	100.00
Useful Effluents/Stream					
Fuel gas	2,363.00	40,321.654	69.35	48,206.365	70.86
Acid gas	282.00	1,869.144	3.22	2,234.646	3.28
Hydrocarbon	1,096.00	14,690.298	25.27	17,562.917	25.82
Condensate water	1,750.00	24.853	0.04	24.853	0.04
Cooling water		0.900	0.00	0.900	0.00
Loss					
Others		1,234.969	2.12	0.000	0.00
Sum	5,491.00	58,141.819	100.00	68,029.682	100.00

Datum temperature: 25°C

Table 6.20 Sulfur Recovery Unit – Mass, Exergy, Cumulative Exergy Balances

	Mass	Exergy		Cumulative Exergy	
	Kg/hr	kW	%	kW	%
Influents/Stream					
Acid gas from Plant 2	282.00	1,866.998	41.40	2,234.646	39.89
Acid gas from Plant 3	266.00	1,765.065	39.14	2,110.215	37.67
Fuel gas	34.50	588.450	13.05	703.518	12.55
Air	1,995.00	90.000	2.00	90.000	1.61
BFW	800.00	33.634	0.74	33.634	0.60
Electricity		165.861	3.67	430.425	7.68
Sum	3,377.50	4,510.008	100.00	5,602.439	100.00
Useful Effluents/Stream					
Liquid Sulfur	472.00	2,511.924	55.70	4,507.768	80.46
HP-steam	583.00	374.122	8.30	865.930	15.46
LP-steam	174.00	91.114	2.02	210.888	3.76
LLP-steam	43.00	7.564	0.17	17.508	0.31
Cooling water		0.345	0.01	0.345	0.01
Loss					
Stack gas	2,105.50	337.265	7.47	0.000	0.00
Others		1,187.674	26.33	0.000	0.00
Sum	3,377.50	4,510.008	100.00	5,602.439	100.00

Datum temperature: 25°C

Table 6.21 Energy Section – Mass, Exergy, Cumulative Exergy Balances

	Mass	Exergy		Cumulative Exergy	
	Kg/hr	kW	%	kW	%
Influents/Stream					
BFW to Boiler A&B	76,000.00	2,434.077	2.41	2,434.077	2.17
BFW to WHB	9,320.00	270.837	0.27	270.837	0.24
Sat. Steam to WHB	2,180.00	939.395	0.93	2,174.288	1.94
Fuel gas	770.90	13,094.109	12.95	15,654.601	13.97
Fuel oil	4,961.00	69.585.134	68.80	74,763.712	66.73
Air	86,610.73	0.000	0.00	0.000	0.00
Flue gas from all furnace	69,993.85	13,622.135	13.46	13,622.135	12.17
Electricity		1,200.000	1.18	3,114.115	2.78
Sum	249,836.48	101,145.687	100.00	112,033.765	100.00
Useful Effluents/Stream					
Electricity from GT 1&2		5,200.000	5.14	12,035.728	10.74
Electricity from GT 3		5,500.000	5.44	12,730.097	11.36
HP-steam to Plant 2	36,100.00	15,555.532	15.38	36,004.258	32.14
HP-steam to Plant 3	51,400.00	22,148.319	21.90	51,263.682	45.76
Loss					
Stack gas from Boiler A&B	92,342.63	9,974.630	9.86	0.000	0.00
Stack gas from WHB	69,993.85	6,753.735	6.67	0.000	0.00
Others		36,013.471	35.61	0.000	0.00
Sum	249,836.48	101,145.687	100.00	112,033.765	100.00

Datum temperature: 25°C

Table 6.22 Overall Plant – Mass, Exergy, Cumulative Exergy Balances

	Mass	Exergy		Cumulative Exergy	
	kg/hr	kW	%	kW	%
Influents/Stream					
Crude oil	189,356.00	2,618,714.380	76.62	2,756,541.452	75.74
LPG Plant 3	3,960.00	53,580.535	1.57	62,281.535	1.71
Naphtha Plant 3	23,770.00	337,957.156	9.89	363,108.179	9.98
Hydrogen Plant 3	741.00	13,471.432	0.39	16,267.802	0.45
Gas oil Plant 3	22,994.00	318,377.215	9.32	342,071.084	9.40
Acid gas Plant 3	266.00	1,765.065	0.05	2,110.215	0.06
Fuel gas	1,505.27	25,563.131	0.75	30,564.542	0.84
Fuel oil	2,595.47	36,403.601	1.07	39,112.784	1.08
Air	67,927.80	91.500	0.00	91.500	0.00
BFW	6,895.38	195.811	0.01	195.811	0.00
Process water	2,506.40	34.903	0.00	34.903	0.00
HP-steam	20,400.00	8,790.355	0.26	20,345.830	0.56
LP-steam	2,274.00	786.451	0.02	1,820.290	0.05
Electricity		1,864.188	0.06	4,837.746	0.13
Sum	345,191.32	3,417,595.721	100.00	3,639,383.583	100.00
Useful Effluents/Stream					
Off gas	3,587.00	52,079.971	1.52	60,151.933	1.65
Fuel gas	2,363.00	40,321.654	1.18	48,206.365	1.32
LPG product	5,618.00	75,738.855	2.22	88,197.000	2.42
Treated light naphtha	8,181.00	108,806.572	3.18	125,714.864	3.45
Isomerate	19,249.00	256,237.485	7.50	300,959.517	8.27
Reformate	18,646.00	242,287.200	7.09	292,581.627	8.04
Kerosene	27,510.00	377,124.733	11.04	405,190.637	11.13
Diesel to plant 3 (untreated)	1,473.00	20,278.816	0.59	21,787.980	0.60
Diesel product to plant 2	31,365.00	431,487.546	12.62	469,409.506	12.90
Diesel product to plant 3	56,005.00	770,459.979	22.54	838,172.465	23.03
Fuel oil	65,218.00	873,334.330	25.55	938,328.521	25.78
Hydrogen	1,096.00	14,690.298	0.43	17,562.917	0.48
Sulfur	472.00	2,511.920	0.07	4,507.768	0.12
Flue gas	69,993.85	13,622.141	0.40	13,622.141	0.37
Vent gas&Disulfide	233,.19	3,133.002	0.09	3,648.344	0.10
HP-Steam	2,763.00	1,313.517	0.04	3,040.218	0.08
LP-Steam	6,074.00	2,142.438	0.06	4,958.808	0.14
LLP-Steam	43.00	7.564	0.00	17.508	0.00
Condensate	21,827.74	3,235.111	0.10	3,197.955	0.09
Cooling water		128.510	0.00	128.510	0.00
Loss					
Sour water	1,268.04	19.857	0.00	0.000	0.00
Stack gas	2,105.50	337.265	0.01	0.000	0.00
Others		128,296.956	3.75	0.000	0.00
Sum	345,191.32	3,417,595.721	100.00	3,639,383.583	100.00

Datum temperature: 25°C

Table 6.23 Exergetic Efficiency and Degree of Perfection

Unit Operation	Exergetic Efficiency* (%)	Degree of Perfection# (%)
1. Topping Unit	11.85	-
2. Deethanizer Unit	27.84	-
3. LPG Treating Unit	-	99.82
4. Naphtha Pretreating Unit	-	94.45
5. Isomerization Unit	-	99.12
6. Catalytic Reforming Unit	-	98.53
7. Gas Oil Hydrodesulfurization Unit	-	98.98
8. Fuel Gas Treating Unit	-	97.88
9. Sulfur Removal Unit	-	73.67
10. Energy Section	55.41	-
11. Boiler	31.61	-

* Exergetic Efficiency evaluated for Thermal Process
\# Degree of Perfection evaluated for Chemical Process