CHAPTER 6

DISCUSSION AND CONCLUSION

The study reveals that technical and economic viability is there for a cogeneration plant using sawdust for the selected site of the AMW factory, Kalutara. Availability of sawdust is a potential amount to cater for the requirement of the plant energy source. As far as the site is concerned, generally it should have a fairly high heat-to-power ratio for potential viability of cogeneration instead of the existing separate electrical and thermal energy systems. This is basically highlighted in the significant increase of IRR for heat-to-power ratio of 2, from that for the case of heat to-power ratio of 1.5.

Steam turbine is the most suitable technology here as gas turbines are generally available only in higher capacities from the range of 20 MW and Internal combustion engines will be not much suitable as it is necessary to have highly purified gas for this for uninterrupted continuous power generation.

Even though sale of steam was not considered in the above analysis, for maximum benefits of cogeneration, there should be freedom to sell both electricity and steam for utility supplies. In Sri Lankan context, there are possibilities to cater for the utility grid of electricity, but it is not seen steam selling between industries. For instance, in the case of the selected site, if possibility is there to sell steam to the adjoining CEAT factory, it may be coupled to the cogeneration plant running in electrical load matching scenario, which obviously gives additional benefits in plant economics. Even in selling of electricity to the national grid, the existing structures of rates of price, it is not really a welcoming aspect at present. There are examples in the world, that utilities pay higher unit costs for electricity from biomass than from fuel oil.

Considering the results of economic analysis, all the four scenarios are feasible with favourable economic gains. Nevertheless, there are merits and demerits in each, and choice of the best scenario depends on the impacts of merits and demerits in each scenario. These are discussed below for the four scenarios considered.

(a) Base electrical load matching

As far as the economic parameters are concerned, base electrical load matching gives the most favourable results, which has an IRR of 34%. It also shows simple payback within 3 years. These are very much appreciable recovery parameters, and the capital investments too, being Rs. 81 million, is in the fairly acceptable range. However, there are disadvantages too here. One is, it caters only for a part of the total load and additional inputs should be there in terms of electricity and fuel oil. As these systems are already there it creates no problem here. On the other hand, as far as the excess availabilities are concerned, it generates 1300 kWh of excess thermal energy, which is equivalent to an excess steam load of 78 kg/hr. This is a fairly lower value and it will not create excess steam handling difficulties, and this can be even increased further. So, when considered the scenario for heat-to-power ratio 2, it further increases project economics and the IRR reaches 40%, which is highly welcoming in financial terms. The excess amount of steam here is 258 kg/hr.

The aspect leading to disadvantage in the above scenario is it consumes a lesser amount of sawdust. Therefore, if the concern is very significant in environmental management, it is necessary to go for peak scenarios. Economics of the base thermal load is poor for heat-to-power ratio of 1.5, but it is more favourable in the case of heat-to-power ratio 2. There, it is again highlighted because this matching scenario has the lowest capital investment and it gives a significant IRR for heat-to-power ratio 2. However, it has the lowest consumption of sawdust.

(b) Peak electrical load matching

The main constraint in going for peak electrical load matching is that there is no apparent possibility to sell excess electricity to outside parties. However, if it is possible to sell steam for the adjoining CEAT factory, which is a likely feasible option, it will give the most favourable results, as generation of the highest possible amount of electricity is the one leading to the highest national benefits. Otherwise, peak thermal matching is better compared to peak electrical matching because it is possible to transfer excess and deficit electricity to and from the grid respectively.

(c) Base thermal load matching

This is the scenario that uses the lowest amount of sawdust. Therefore it shows the lowest value of saving. Nevertheless, as it gives very small capital investments it shows comparable IRR values, and the value of IRR becomes more significant for the case of heat-to-power ratio 2. Anyhow, as the monthly saving and thereby the net present value of saving are yet too small, this scenario is not much significant.

(d) Peak thermal load matching

As far as the peak matching scenarios are concerned, thermal load matching shows more favourable benefits than electrical load matching, due to the fact that possibility is there to obtain electricity from the grid in electricity deficit times and to supply electricity to the grid when excess electricity is available. However, the economic parameters seem to be decreasing when the heat-to-power ratio is increased from 1.5 to 2, as meeting electrical requirements from the cogeneration plant is considerably reduced.

Selection of the most suitable scenario needs to be done depending on the investment capabilities and the way environmental aspects are granted. Therefore, it is to be decided by the particular parties going to invest on the project. As it is given above all the necessary economic parameters and as the comparative merits and demerits are broadly discussed above, these will have to be thoroughly accounted for, in going for a particular scenario.

As far as the energy conservation measures are concerned as an industrial investment option, it is competitive with most of the other areas like raw material, labour, etc., because unless it is an energy-intensive industry, the contribution of energy cost to the overall production cost is not much significant. In such cases, the industrialists will not, and should not be expected from them for that matter, prioritize energy conservation methods in their checklists of investment options. Therefore, it is the duty of the energy managers and the authorities to give aspects like cogeneration the deserved attention to adopt it in industries. Specially when biomass cogeneration is concerned, environmental aspects too will come to the scene and it will be very helpful in taking decisions if there is a method to account for each and every aspect in economic terms.

Considering promotion of in-house power generation, it is the global experience that industrialists would rather be interested in taking power from another party than going for generating it in their own system because they think that it is an additional constraint for them. When it comes to bio-mass cogeneration it entails problems like, transportation and storage difficulties, maintenance difficulties, necessity of stand-by systems, etc. Therefore, what is really needed is to identify the real benefits and have a national interest, and address individual issues accordingly through financial benefits for industrialists. Better tariff structures, high unit costs for utility providers, and other necessary regulations will be essential for effective application of cogeneration in Sri Lanka for future energy requirements.

In thermal power generation using dendro resources, plant efficiencies are in the range of 18%. So, thermal power generation gives favourable economic parameters only for larger capacities and the respective corresponding economies-of-scale lie in capacities above 100 MW range. But when it comes to cogeneration it gives overall efficiencies of nearly 50%. Therefore, even for the topic of dendro thermal power, it would be better to think of cogeneration to have separate plants in industries with potential economies-of-scale. When considering petroleum energy resources, cogeneration is kind of a waste heat recovery in any form, and getting more use of the primary energy degraded for generation of value-added products.

As far as the project is considered in the point of view of a pilot project of cogeneration with biomass, it shows the relevance of cogeneration applications with a typical biomass industrial waste. In terms of energy and in environmental aspects as well it is a good application of the particular biomass residue which is available in massive amounts and which face serious problems in disposal at present.

In general, cogeneration is a potential area of energy management. However, it is more or less the economical aspects that govern the decision on going for cogeneration for a particular site. Therefore, it is very important to look for similar projects and address the necessary areas in order to bring the norm of cogeneration to the Sri Lankan context.

REFERENCES

1. Alan J S, 1979, Cogeneration - A Status Report of the Department Energy Industral Program, Department of Energy, Washington, USA

2. Anderson L L, Tillman D A, 1977, Fuels from Waste, Academic Press, 111, Fifth Avenue, New York

3. Annual Report 1999, The Central Bank of Sri Lanka

4. Arends G J, Donkersloot-Shouq S S, 1985, An Overview of Possible Uses of Sawdust, Entrepotdok 68 a, 1018 AD, Amsterdam, The Netherlands

5. Ballart G, Tremeer, Emissions of rural wood burning cooking devices, www.demon.nl

6. Brien J M O, Bansal B K, 2000, Modelling of Cogeneration Systems: Historical Perspective, Dept. of Mech. Engineering, University of Auckland, USA, ImechE

7. Cui S Q, Wu X S, Qu Y, 1988, Optimizing the Cogeneration Coefficient in District Heating and the Cogeneration of Heat and Electricity, Proc Instn Mech Engrs, Vol 202 No. A

8. Daranagama D A U, 2000, Assessment of Biomass Availability in Sri Lanka, UNDP Project, Draft Report

9. Duval Y, 2000, Environmental Impact of Modern Biomass Cogeneration in Southeast Asia, Department of Agricultural Economics, Washington State University, 203 F Hulbert Hall, P.O. Box 646210, Pullman, WA99164-6210, USA

10. Energy Audit Reports, Energy & Environmental Management Centre, NERD Centre of Sri Lanka

11. Energy Conservation in Chemical Plants, An Advanced International Training Programme, Malmo Sweden, October 16 – November 17, 2000

12. Evans R L, Anastasiou R B, 1985, On the Performance of Pressurized Fluidized-bed for Power Generation, Department of Mechanical Engineering, The University of British Colombia, Vancouver, Canada, ImechE

13. Foster D, 1987, Economic Performance Optimization of a Combined Heat and Power Station, Imperial Chemical Industries plc, Billingham, Cleveland, Proc Instn Mech Engrs Vol 201 No. A3

14. Fridh J, Kyhistron T, Defining an Optimization System and Applying it on a Heat and Power Plant in Poland, Technical Report, Department of Energy Technology, Chair of Heat and Power Technology, Royal Institute of Technology, 100 44, Stockholm

15. Guidebook on Cogeneration as a Means of Pollution Control and Energy Efficiency in Asia, Economic & Social Commission for Asia & Pacific, Bangkok, Thailand, 2000

16. Gurney J D, Hyde R G F, Pickering S J, Shute M, 1988, Industrial Combined Heat and Power : Investment, Savings and Decision-making, Ove Arup and Partners, 13 Fitzroy Street, London W1

17. Haywood R D, 1990, Large-scale Combined Heat and Power, NEI International Research and Development Limited, Fossway, Newcastle upon Tyne, ImehE

18. Horlock J H, 1987, Approximate Analyses of Feed and District Heating Cycles for Steam Combined Heat and Power Plant, The Open University, Walton Hall, Milton Keynes, Buckinghamshire

19. Huang Y C, Hung C I, Chen C K, 2000, Exergy Analysis for a Combined System of Steam Injected Gas Turbine Cogeneration and Multiple-effect Evaporation, Department of Mechanical Engineering, National Cheng Kung University, Tainan, Taiwan, ImechE

20. Hughes, R A, Ramsay B, Rossini C, 1996, A knowledge-based Decision Support System for Combined Heat and Power Investment Appraisal and Plant Selection, Proc Instn Mech Engrs, Vol 210

21. Industrial Energy and Electrical Power from Wood Residues, Bioenergy Systems Report, Dean B Mahin, International Energy Projects, P.O. Box 591, Front Royal, VA 22630, USA, June 1991

22. Kotas T J, Kibiikyo D S, 1989, Thermoeconomic Optimization of a Ventilation Air Heater in a Backpressure Combined Heat and Power Plant, Departmentment Mechanical Engineering, Queen Mary College, University of London

23. Liversidge R M, 1981, Wood fired energy systems, Gottstein Fellow

24. Marilyn J, 1990, Power Generation, Energy Management and Environmental Sourcebook, Fairmount Press Inc., 700, Indian Trail, Lilburn, GA 30247

25. Nag P K, De S, 1998, Study of Thermodynamic Performance of an Integrated Gasification Combined Cycle Power Plant, Department of Mechanical Engineering, Indian Institite of Technology, Kharagpur, India

26. Nash F, 1992, The Development and First Commercial Application of an Innovative Diesel Engine based Cogeneration System, Mclellan and Partners Limited, West Byfleet, Surrey, ImechE

27. Oliker I, 1980, Steam Turbines for Cogeneration Power Plants, Burns and Roe Inc., 496, Kinderkamack Road, Oradell, N J 07649, Mem. ASME, Vol. 102

28. Orlando J A, 1995, Cogeneration Planner's Handbook, Penwell Publishing Company, 1421, South Sheridan, Tulsa, Oklahoma

29. Osborn P D, 1985, Handbook of Energy Data and Calculations, Butterworth and Co., Robert Hartnoll, Bodmin, Cornwall

30. Paivi L, 2000, Quality Properties of Sawdust, Logging Residues and Bark, Department of Forest Management and Products, Swedish University of Agricultural Sciences, SLU, Box 7060, 75007, Uppsala, Sweden

31. Payne J H, 1990, Cogeneration in the Cane Sugar Industry, Sugar Series 12, Elsevier Science Publishing Company Inc., 655, Avenue of the Americas, Newyork, NY 10010, U.S.A.

32. Peter A, 1978, Advances in Energy systems and Technology, Volume 1, Academic Press, New York, San Francisco, London

33. Philips A L, 1989, Cogeneration Energy Centres in Diverse Production Facilities, Unilrver Engineering London, Brandon House, Southwark, London, SEI, IMechE

34. Pilavachi, P A, 2000, Power Generation with Gas Turbine Systems and Combined Heat and Power, European Commission, Applied Thermal Engineering

35. Price M E, 1988, The Fort Dunlop Combined Heat and Power Plant, Midlands Electricity Board, Mucklow Hill, Halesowen, West Midlands, Proc Instn Mech Engrs Vol 203

36. Richard H T, 1978, District Heating with Combined Heat and Electric Power Generation, Stone & Webster Engineering Corporation, New York

37. Rix D. H., 1996, Some Aspects of the Outline Design Specification of a 0.5 MW Stirling Engine for Domestic Scale Cogeneration, Department of Engineering, University of Cambridge, Proc Instn Mech Engrs Vol 210

38. Robson A, Turner W J, 1994, Environmental Economics and Electricity Generation, Nuclear Electric plc, Barnwood, Gloucester

39. Somasundaram S, Turner W D, Katipamula S, 1989, A Simplified Self-help Way to Size small-scale Cogeneration Systems, Energy Systems Laboratory, Department of Mechanical Engineering, Texas A&M University

40. Sri Lanka Energy Balance – 1998, Energy Conservation Fund

41. Techno-economic Impact of Cogeneration, Mechanical Engineering Publications Limited for The Institution of Mechanical Engineers, London, 1985

42. The Feasibility Study on cogeneration possibility in Sri Lanka, Draft Final Report, Volume 1, Korea International Co-operation Agency, Republic of Korea, Hyundai Engineering Co. Ltd., 1995

43. Tolley D L, Fowler G J, 1987, Commercial Arrangements for Cogeneration in the UK and USA, Proc Instn, Mech Engrs, Vol 201, No. A4

44. Wijewardana R., Joseph P G, 1999, Fuel Options for Power Generation in the Next Millenium – Dendro, The Institution of Engineers, Sri Lanka

APPENDIX

Table A-1 - Data used in analysis

Parameter	Value
Power plant details	
Specific capital cost (US$/kW)	1500
Plant life (Years)	20
Electricity Tarriffs	
Maximum demand charge (Rs./kVA)	240
Peak unit price (Rs./kWh)	8.70
Off-peak unit price (Rs./kWh)	3.70
Selling price (Rs./kWh)	5.00
Fuel oil details	
Price (Rs./lit.)	16.00
Calorific value (MJ/kg)	42.9
Density (kg/lit.)	0.85
Saw dust costs	
Transport cost of saw dust (Rs./ton)	200
Economic indicators	
Exchange rate (Rs./US$)	90
Discount rate	10

Table A-2 - Sample survey data sheet

1. Name of the factory	
2. Contact person	
3. Address	
4. Telephone No.	
5. i. Available amount of saw dust per day	
ii. How presently saw dust is disposed	
iii. Is it a problem now ?	
iv. How feasible saw dust is taken for this project	
6. Types of sews and No. of sews operating	
7. Any other information	

Table A 3a : Electricity logged data - sample 1
Electrical power measurements at CEB panel
From 0000 hrs to 2400 hrs on 27.03.2001

TIME	A-1 (Amp.)	A-2 (Amp.)	A-3 (Amp.)	V_L (Volt)	PF	kW	kVA	kWh
0:00	71.2	70.3	73.7	10883	0.88	1185	1352	0
0:15	68.8	68.4	70.7	10756	0.97	1257	1291	314
0:30	71.7	66.2	68.2	10895	0.82	1066	1296	581
0:45	72.6	71.9	77.2	10924	0.80	1116	1398	860
1:00	49.8	48.3	50.8	10999	0.84	796	946	1059
1:15	63.3	61.8	65.8	11005	0.81	984	1213	1305
1:30	48.9	47.2	48.1	11080	0.82	753	922	1493
1:45	81.4	80.9	83.8	10976	0.80	1241	1559	1803
2:00	62.0	59.7	62.3	10947	0.78	902	1163	2029
2:15	52.3	50.0	53.0	11010	0.80	794	987	2227
2:30	39.6	37.2	41.9	11033	0.85	644	756	2388
2:45	80.1	77.6	82.5	10964	0.78	1183	1520	2684
3:00	50.5	47.8	52.4	11074	0.83	795	963	2883
3:15	55.9	53.6	57.2	11074	0.82	877	1066	3102
3:30	57.7	54.8	58.0	10912	0.80	856	1074	3316
3:45	56.0	54.2	55.7	10930	0.79	830	1047	3523
4:00	57.7	55.7	58.1	10930	0.82	883	1082	3744
4:15	43.3	41.4	44.8	11045	0.86	711	826	3922
4:30	53.8	52.7	54.6	10866	0.80	805	1011	4123
4:45	53.7	50.7	52.3	10895	0.84	828	986	4330
5:00	46.4	43.4	46.4	11028	0.81	704	867	4506
5:15	53.7	50.4	52.6	10935	0.79	786	989	4703
5:30	46.3	43.4	46.1	10906	0.78	668	855	4870
5:45	34.1	31.8	34.1	10826	0.82	513	625	4998
6:00	35.5	34.0	36.6	10843	0.83	549	664	5135
6:15	26.8	25.7	27.6	10803	0.87	433	499	5243
6:30	24.3	23.1	25.0	10901	0.91	413	455	5347
6:45	27.1	25.7	27.8	10889	0.88	447	506	5459
7:00	26.3	25.4	26.9	10918	0.90	446	495	5570
7:15	33.4	32.6	35.0	10999	0.92	588	641	5717
7:30	47.4	46.1	46.9	10982	0.90	804	890	5918
7:45	77.3	71.6	75.7	10964	0.81	1156	1422	6207
8:00	93.5	91.0	99.2	10843	0.77	1369	1776	6549
8:15	111.0	108.6	114.7	10745	0.78	1626	2074	6956
8:30	101.4	98.2	102.9	10774	0.82	1537	1882	7340
8:45	118.5	115.6	119.6	10797	0.79	1748	2205	7777
9:00	110.5	108.1	114.8	10687	0.82	1691	2057	8200
9:15	83.9	81.8	85.0	10785	0.83	1296	1561	8524
9:30	107.6	102.5	105.3	10687	0.79	1539	1946	8909
9:45	101.2	97.4	102.5	10831	0.79	1489	1883	9281
10:00	87.6	85.6	92.4	10733	0.81	1336	1646	9615
10:15	89.1	86.0	91.0	10831	0.85	1411	1664	9968
10:30	111.0	108.2	115.4	10670	0.83	1719	2061	10398
10:45	113.9	110.5	117.7	10722	0.82	1741	2118	10833
11:00	110.5	109.0	114.9	10595	0.93	1904	2045	11309
11:15	118.1	116.4	121.4	10577	0.89	1936	2173	11793
11:30	63.8	61.6	65.0	10855	0.93	1105	1193	12069
11:45	53.1	49.5	55.4	10883	0.87	864	993	12285
12:00	51.7	48.4	52.3	10895	0.88	847	959	12497
12:15	63.6	60.8	66.9	10745	0.81	960	1187	12737
12:30	96.2	94.2	99.3	10739	0.77	1374	1796	13080
12:45	106.8	102.2	108.2	10768	0.77	1520	1972	13460

Table A 3a : Electricity logged data - sample 1 (Contd.)
Electrical power measurements at CEB panel
From 0000 hrs to 2400 hrs on 27.03.2001

TIME	A-1 (Amp.)	A-2 (Amp.)	A-3 (Amp.)	V_L (Volt)	PF	kW	kVA	kWh
13:00	93.9	91.8	97.6	10791	0.82	1449	1765	13823
13:15	115.3	113.9	120.8	10658	0.81	1751	2154	14260
13:30	104.1	101.8	108.1	10658	0.80	1538	1932	14645
13:45	97.4	95.3	100.7	10779	0.85	1554	1826	15033
14:00	88.2	85.5	88.2	10756	0.80	1306	1626	15360
14:15	77.3	73.8	79.3	10768	0.85	1222	1432	15665
14:30	86.6	84.0	89.2	10803	0.80	1303	1620	15991
14:45	98.3	98.2	104.4	10739	0.77	1440	1866	16351
15:00	116.9	110.4	116.6	10618	0.85	1781	2108	16796
15:15	96.2	93.8	95.7	10739	0.90	1592	1771	17195
15:30	121.4	120.4	126.4	10606	0.88	1975	2255	17688
15:45	106.0	105.1	109.3	10595	0.92	1811	1960	18141
16:00	72.4	70.5	75.4	10751	0.91	1228	1355	18448
16:15	81.1	80.8	84.8	10727	0.85	1291	1528	18771
16:30	83.9	82.3	86.7	10774	0.86	1356	1573	19110
16:45	68.5	66.4	69.7	10855	0.83	1062	1282	19375
17:00	84.2	81.0	85.3	10820	0.80	1247	1565	19687
17:15	71.3	71.1	72.8	10889	0.77	1039	1353	19947
17:30	49.7	48.4	50.6	11016	0.79	742	946	20132
17:45	38.0	37.4	39.8	11010	0.88	640	732	20292
18:00	60.1	58.1	61.2	10953	0.89	1012	1134	20545
18:15	24.0	22.5	23.9	11057	0.90	405	449	20646
18:30	23.8	22.6	24.0	10935	0.91	406	444	20748
18:45	24.0	22.3	24.0	10987	0.90	403	446	20849
19:00	24.1	22.9	25.6	10797	0.90	409	453	20951
19:15	23.0	21.1	23.1	10797	0.91	382	419	21047
19:30	23.8	21.9	23.9	10652	0.87	371	428	21139
19:45	28.4	25.8	27.9	10664	0.86	434	505	21248
20:00	25.7	24.0	26.9	10716	0.85	404	474	21349
20:15	24.5	22.7	25.6	10687	0.86	386	449	21445
20:30	21.1	19.6	21.9	10612	0.85	328	384	21527
20:45	26.3	24.3	27.0	10676	0.89	427	478	21634
21:00	29.5	27.4	29.9	10733	0.87	469	538	21751
21:15	27.2	25.3	27.8	10658	0.89	438	494	21861
21:30	24.8	22.8	25.2	10722	0.90	405	450	21962
21:45	28.9	26.6	29.6	10779	0.89	472	529	22080
22:00	29.2	27.0	29.5	10791	0.90	478	534	22199
22:15	50.6	49.1	52.1	10843	0.78	736	950	22383
22:30	58.7	57.4	59.8	10791	0.76	827	1096	22590
22:45	45.7	44.9	47.4	10918	0.86	745	870	22776
23:00	66.8	65.5	67.9	10785	0.77	956	1247	23015
23:15	64.6	63.8	67.7	10895	0.74	913	1233	23244
23:30	61.2	60.2	62.5	10924	0.81	935	1160	23477
23:45	52.9	51.2	53.1	10987	0.86	862	997	23693
24:00	51.8	52.1	52.9	10795	0.87	850	977	23905
Min.	*21.1*	*19.6*	*21.9*	*10577*	*0.74*	*328*	*384*	---
Max.	*121.4*	*120.4*	*126.4*	*11080*	*0.97*	*1975*	*2255*	---
Avg.	*64.3*	*62.2*	*65.7*	*10834*	*0.84*	*998*	*1199*	---

Table A 3b :Electricity loggged data - sample 2
Electrical Power Measurements at Generator 1
From 730 hrs to 2200 hrs on 27.03.2001

TIME	A-1 (Amp.)	A-2 (Amp.)	A-3 (Amp.)	V-12 (Volt)	V-23 (Volt)	V-31 (Volt)	kW	kVA	kVAr	PF	kWh
7:30	199	196	211	406	407	407	128	142	63	0.90	0
7:45	423	434	458	402	403	402	273	305	137	0.89	47
8:00	399	405	408	403	404	402	247	282	136	0.88	108
8:15	361	373	377	404	404	402	207	259	155	0.80	175
8:30	601	596	585	402	403	401	362	413	199	0.88	252
8:45	523	529	533	402	403	402	311	368	196	0.85	329
9:00	508	521	517	402	403	402	309	360	184	0.86	408
9:15	491	515	498	401	403	401	290	349	194	0.83	487
9:30	477	498	476	403	403	403	290	337	173	0.86	560
9:45	458	509	477	402	402	402	286	335	174	0.85	634
10:00	430	464	429	403	404	403	255	308	173	0.83	708
10:15	537	561	528	401	402	401	314	377	208	0.83	784
10:30	626	662	643	400	401	401	388	447	222	0.87	868
10:45	559	575	558	401	402	402	327	392	217	0.83	950
11:00	650	666	652	399	400	400	373	454	259	0.82	1029
11:15	512	513	514	401	403	402	293	357	203	0.82	1111
11:30	425	450	444	402	403	402	255	306	169	0.83	1170
11:45	221	251	232	404	405	405	129	164	101	0.79	1218
12:00	235	255	230	404	405	405	126	168	111	0.75	1261
12:15	471	505	481	402	402	403	284	338	184	0.84	1329
12:30	498	528	510	402	403	401	306	356	182	0.86	1402
12:45	549	561	553	402	403	403	338	386	187	0.88	1477
13:00	724	740	724	399	401	400	424	505	275	0.84	1567
13:15	620	629	629	401	402	399	362	434	240	0.83	1670
13:30	747	762	741	400	401	400	439	519	277	0.85	1771
13:45	598	596	594	401	402	400	342	414	233	0.83	1858
14:00	564	570	571	401	402	400	304	395	252	0.77	1947
14:15	451	486	457	402	403	402	273	324	174	0.84	2025
14:30	474	484	483	402	403	403	289	335	169	0.86	2102
14:45	601	619	597	401	402	401	338	421	250	0.80	2187
15:00	532	546	534	401	402	402	303	374	219	0.81	2274
15:15	599	607	585	401	402	401	339	414	239	0.82	2358
15:30	504	525	495	402	402	403	277	354	221	0.78	2438
15:45	629	671	625	399	401	399	378	444	233	0.85	2517
16:00	480	523	477	401	402	402	270	343	212	0.79	2590
16:15	523	543	512	401	402	403	282	366	233	0.77	2662
16:30	436	457	440	402	403	404	241	310	195	0.78	2727
16:45	468	487	451	401	402	402	249	326	211	0.76	2790
17:00	350	364	346	403	404	405	161	247	188	0.65	2845
17:15	397	412	398	403	403	403	223	281	171	0.79	2894
17:30	308	326	308	403	404	403	155	219	155	0.71	2940
17:45	233	262	235	404	405	404	131	170	109	0.77	2974
18:00	201	210	202	405	405	405	94	143	108	0.65	3001
18:15	191	212	191	405	405	405	100	139	97	0.72	3026
18:30	138	155	138	405	406	406	69	101	73	0.69	3046
18:45	130	147	127	406	406	406	74	95	59	0.78	3065
19:00	102	126	106	406	407	406	67	78	40	0.86	3083
19:15	147	156	142	405	405	406	72	104	75	0.70	3100
19:30	142	153	138	405	406	406	61	101	81	0.60	3118

Table A 3b :Electricity loggged data - sample 2 (Contd.)
Electrical Power Measurements at Generator 1
From 730 hrs to 2200 hrs on 27.03.2001

TIME	A-1 (Amp.)	A-2 (Amp.)	A-3 (Amp.)	V-12 (Volt)	V-23 (Volt)	V-31 (Volt)	kW	kVA	kVAr	PF	kWh
19:45	138	151	142	405	406	405	64	101	78	0.64	3136
20:00	203	206	182	403	405	406	104	138	91	0.75	3162
20:15	231	213	193	404	403	405	112	148	97	0.76	3190
20:30	202	206	182	403	405	405	104	138	91	0.75	3216
20:45	201	206	180	403	404	407	103	137	90	0.75	3242
21:00	256	262	236	404	405	404	133	176	116	0.75	3275
21:15	312	324	295	404	404	406	191	217	103	0.88	3322
21:30	359	378	345	405	405	406	232	253	100	0.92	3380
21:45	278	265	270	405	405	405	163	190	98	0.86	3421
22:00	91	107	87	406	407	408	58	67	34	0.86	3436
Min.	*91*	*107*	*87*	*399*	*400*	*399*	*58*	*67*	*34*	*0.60*	---
Max.	*747*	*762*	*741*	*406*	*407*	*408*	*439*	*519*	*277*	*0.92*	---
Avg.	*402*	*418*	*401*	*403*	*403*	*403*	*232*	*283*	*161*	*0.80*	---