Dynamic Management of Energy Cost and Selection of Supply Alternatives

12 September 2002

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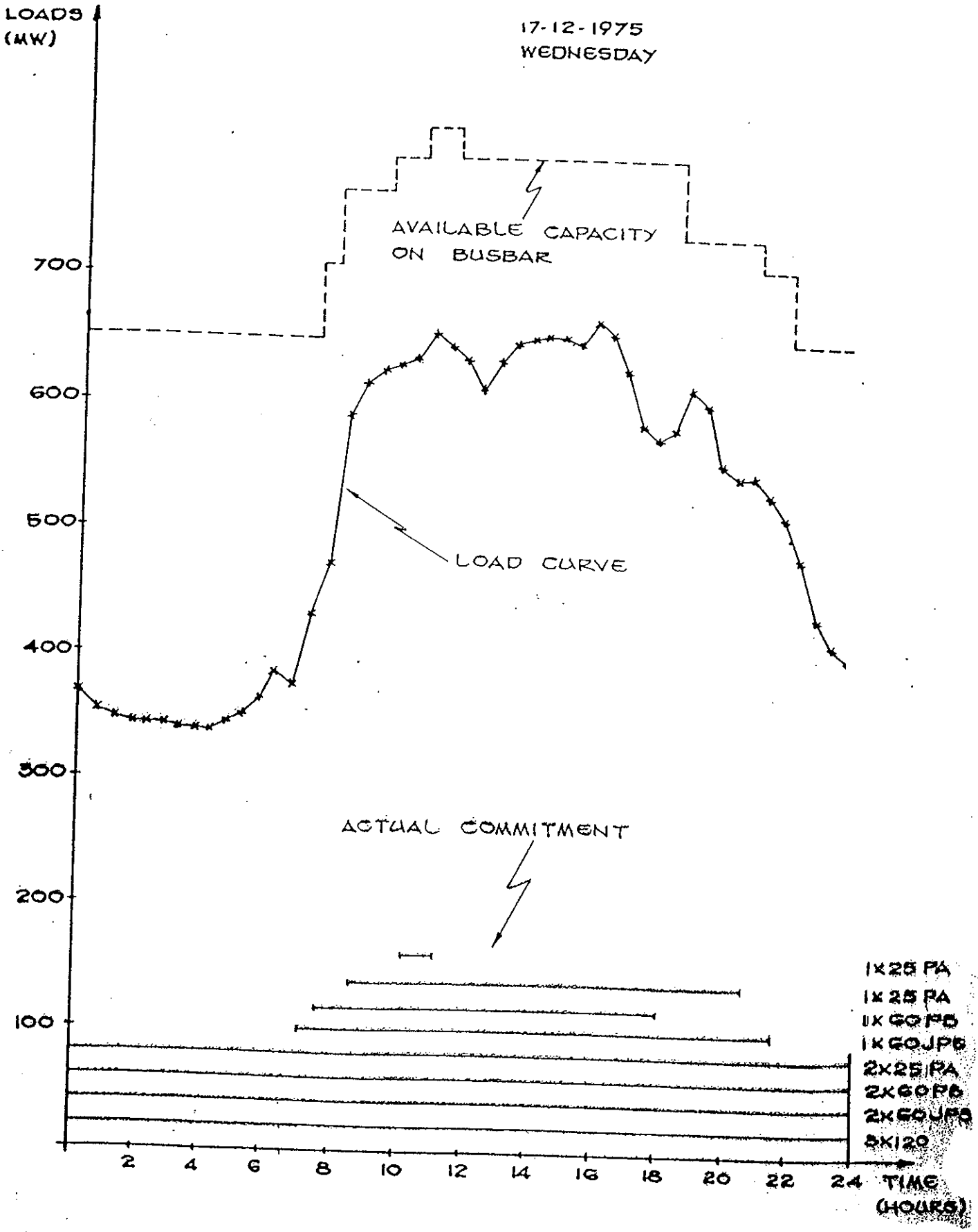
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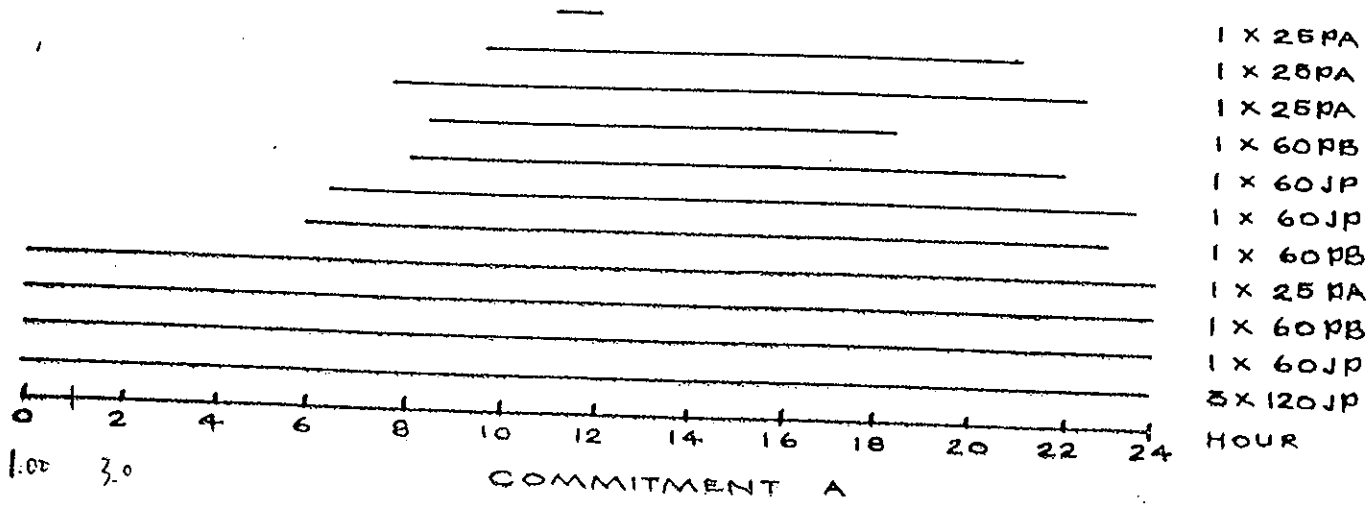
1. How to determine energy cost from fuel cost

Based on a real operating example (28 years ago in 1975), the process in meeting the forecasted system maximum demand of 665 MW for a particular weekday is illustrated. The process in unit commitment, economic load dispatch, constraints in spinning reserve, unit starting up and transmission network limitation are discussed. The details in each half hourly loading and costing are illustrated and the total daily energy cost for actual unit commitment and optimal commitment are summarized. The unit energy production cost based on a given fuel oil cost is then derived.

How to Determine Energy Cost from Fuel cost

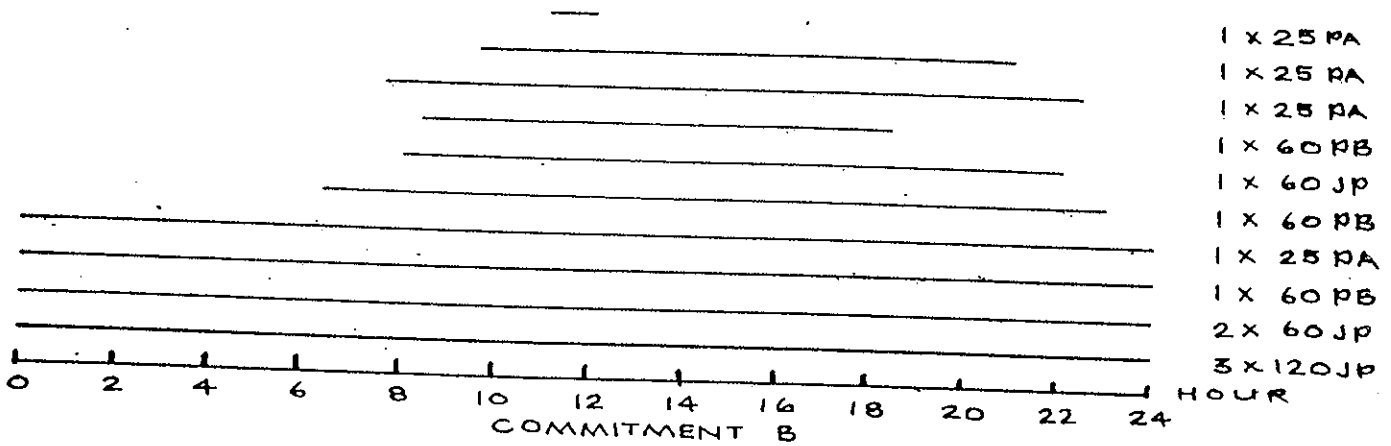


17 - 12 - 1975
WEDNESDAY.

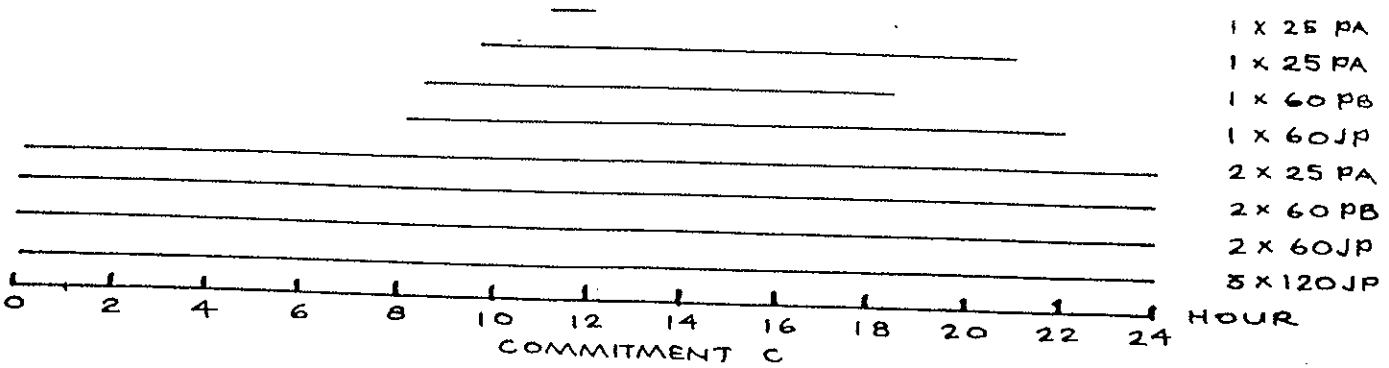


1.00 3.0

COMMITMENT A



COMMITMENT B



COMMITMENT C

OPTIMAL COMMITMENT WITH OPTIMAL LOADING (17.12.1975, WEDNESDAY)

TIME (HR)	LOAD DEMAND (MW)	JURONG POWER STATION						PASIR PANJANG POWER STATION						
		STAGE II (MW)			STAGE I (MW)			B (MW)			A (MW)			
1.00	369	96	96	96	39	0	0	30	0	0	12	0	0	0
1.30	352	96	96	88	30	0	0	30	0	0	12	0	0	0
2.00	349	96	96	85	30	0	0	30	0	0	12	0	0	0
2.30	343	96	96	79	30	0	0	30	0	0	12	0	0	0
3.00	343	96	96	79	30	0	0	30	0	0	12	0	0	0
3.30	342	96	96	78	30	0	0	30	0	0	12	0	0	0
4.00	340	96	96	76	30	0	0	30	0	0	12	0	0	0
4.30	340	96	96	76	30	0	0	30	0	0	12	0	0	0
5.00	339	96	96	75	30	0	0	30	0	0	12	0	0	0
5.30	348	96	96	84	30	0	0	30	0	0	12	0	0	0
6.00	351	96	93	60	30	0	0	30	0	0	12	0	0	0
6.30	365	96	77	60	30	30	0	30	30	0	12	0	0	0
7.00	386	96	96	62	30	30	0	30	30	0	12	0	0	0
7.30	376	96	76	60	30	30	0	30	30	0	12	0	0	0
8.00	432	96	96	66	30	30	30	30	30	0	12	12	0	0
8.30	472	96	96	76	30	30	30	30	30	30	12	12	0	0
9.00	591	96	96	96	48	48	48	48	48	39	12	12	0	0
9.30	618	96	96	96	48	48	48	48	48	48	14	14	14	0
10.00	628	105	97	96	48	48	48	48	48	48	14	14	14	0
10.30	630	105	99	96	48	48	48	48	48	48	14	14	14	0
11.00	647	105	102	96	48	48	48	48	48	48	14	14	14	14
11.30	655	105	105	101	48	48	48	48	48	48	14	14	14	14
12.00	646	105	101	96	48	48	48	48	48	48	14	14	14	14
12.30	635	105	104	96	48	48	48	48	48	48	14	14	14	0
13.00	610	96	96	96	48	48	48	48	48	46	12	12	12	0
13.30	633	105	102	96	48	48	48	48	48	48	14	14	14	0
14.00	649	105	105	105	52	48	48	48	48	48	14	14	14	0

OPTIMAL COMMITMENT WITH OPTIMAL LOADING
OPERATING CONDITION
(17.12.1975, WEDNESDAY)

TIME (HR)	LOAD (MW)	TOTAL GEN COST ($)	TOTAL BTU	EFFICIENCY ¢ per kWh		POWER TRAN (MW)	SPIN RES. (MW)	FAST SP RES. (M
1.00	369	7,985.56	1,838.30	34.24	4.328	124	136	83
1.30	352	7,629.55	1,756.34	34.19		116	153	83
2.00	349	7,571.04	1,742.87	34.16		115	156	83
2.30	343	7,449.99	1,715.01	34.12	4.344	112	162	83
3.00	343	7,449.99	1,715.01	34.12		112	162	83
3.30	342	7,429.69	1,710.33	34.11		111	163	83
4.00	340	7,389.07	1,700.98	34.10		110	165	83
4.30	340	7,389.07	1,700.98	34.10		110	165	83
5.00	339	7,368.76	1,696.31	34.09		110	166	83
5.30	348	7,551.54	1,738.38	34.15		114	157	83
6.00	351	7,759.92	1,786.35	33.52		85	214	95
6.30	365	8,161.03	1,878.69	33.14		92	260	107
7.00	386	8,577.83	1,974.64	33.35		101	239	107
7.30	376	8,493.10	1,955.13	32.81		85	274	112
8.00	432	9,730.23	2,239.92	32.90		110	278	124
8.30	472	10,687.60	2,460.31	32.78		98	298	136
9.00	591	13,337.31	3,070.28	32.84		106	179	136
9.30	618	14,055.56	3,235.63	32.5		92	177	141
10.00	628	14,202.96	3,283.37	32.63		96	167	141
10.30	630	14,304.44	3,292.92	32.64		97	165	141
11.00	647	14,770.79	3,400.27	32.46	4.566	91	173	146
11.30	655	14,936.71	3,438.47	32.50		94	165	146
12.00	646	14,750.05	3,395.50	32.46		90	174	146
12.30	635	14,408.15	3,316.79	32.66		99	160	141
13.00	610	13,853.54	3,189.12	32.63		96	185	141
13.80	633	14,366.67	3,307.24	32.65		98	162	141
14.00	649	14,712.69	3,386.90	32.69		106	146	141
14.30	651	14,761.26	3,398.08	32.68		106	144	141
15.00	654	14,834.12	3,414.85	32.67		108	141	141
15.30	652	14,785.55	3,403.67	32.68		107	143	141
16.00	648	14,688.41	3,381.31	32.69		105	147	141
16.30	665	15,110.72	3,478.53	32.61		105	130	130
17.00	655	14,858.40	3,420.44	32.67		108	140	140
17.30	628	14,262.96	3,288.37	32.63		96	167	141
18.00	586	13,291.81	3,059.81	32.67		109	209	141
18.30	576	13,057.75	3,005.93	32.69		115	219	141
19.00	583	13,128.85	3,022.30	32.85		123	153	129
19.30	615	13,884.20	3,196.18	32.83		132	120	120
20.00	604	13,609.96	3,133.05	32.89		133	131	129
20.30	557	12,560.92	2,891.56	32.86		125	178	129
21.00	549	12,373.68	2,848.45	32.88		130	186	129
21.30	549	12,302.16	2,831.99	33.07		130	161	124
22.00	535	11,974.48	2,756.56	33.11		137	175	124
22.30	518	11,564.48	2,662.17	33.19		109	132	112
23.00	481	10,643.76	2,450.22	33.49		119	144	107
23.30	432	9,444.76	2,174.21	33.90		146	133	95
24.00	413	8,969.70	2,064.85	34.12		123	92	83
24.30	401	8,720.81	2,007.55	34.08		118	104	83

RESULTS AND RECOMMENDATION

6.1 Typical weekday (Wednesday, 17.12.1975)

The detail half hourly loading condition for the actual commitment and the optimal commitment as obtained from the computer run is given in Table 2, 2A and Table 3, 3A. The results indicate that a saving of 5040 dollars per day and a 0.3% improvement of system thermal efficiency can be achieved. The results are summarised as follows :-

Summary Results For Wednesday

Case	Total fuel Cost ($)	System thermal efficiency (%)	Saving from actual case ($)	Improvement of actual thermal efficiency (%)	Cost per unit generated cents/kWH
C. Actual commitment with optimal loading.	560,251.79	32.73	0	0	4.529
B. Sub-optimal commitment with optimal loading.	556,522.09	32.95	3729.70	0.22	4.498
A. Optimal commitment with optimal loading.	555,211.55	33.03	5040.24	0.30	4.488

2. TCY Energy Cost in S$

Based on the optimal commitment with optimal loading and in satisfying various constraints, the total fuel cost including startup cost in the particular weekday is S$ 555,222. This is equivalent to an average energy product cost of 4.488 ¢/kWh at a system thermal efficiency of 33%. The average energy production cost in 1975 is based on fuel oil price of S$180/MT(in 1975) or equivalent to US $100/MT at an exchange rate of US $1 = S$1.8. The heat rate of fuel oil of Bunker C is 18500 BTU/lb. If the generating system has the same thermal efficiency, the energy production cost is actually proportional to the fuel oil cost. For an oil price of US $140 (S$252) today, the equivalent cost is 6.3 ¢/kWh. Since the thermal efficiency of the power plants to-day are much better than those in 1975, the energy production cost can thus be lower. By assuming an average thermal efficiency of 34.5%, the average energy production cost is 5.8 ¢/kWh. Thus, for various different fuel oil costs, the energy production cost can be calculated linearly as shown in Table 1.

To get the total energy production, which is defined as TCY energy cost by me, we need to consider the capital cost of the generating plant and the annual operating and maintenance costs. Based on the published capital cost in $/kW, unit capacity in MW, assumed interest rate and number of years to recover the capital investment, the annual capital cost of a generating unit can be obtained. Adding the annual operating and maintenance costs, which include the plant annual maintenance cost and the staff salary, the total annual cost of the generating unit can be obtained. Based on the estimated loading and annual load factor of the unit, the power plant capital cost and non-fuel operating cost (CapNFc) is estimated as 2.5 cents/kWh and the total energy production cost is 5.8 +2.5 = 8.3 cents/kWh. Thus, the CapNFc is 30% of the total energy production cost which is similar to the statistic from a number of power utilities.

The energy production cost from fuel and TCY energy cost at various oil prices are listed in Table 1.

Table 1 TCY cost (total energy cost) for various oil prices

Oil price (US $/T)	*Oil price (S$ /T)*	*Energy production cost from fuel (¢/kWh)*	*CapNFc cost (¢/kWh)*	*TCY cost (¢/kWh)*
140	252	5.8	2.5	8.3
150	270	6.21	2.5	8.71
160	288	6.63	2.5	9.13
170	306	7.04	2.5	9.54
180	324	7.46	2.5	9.96

Alternative Method to Verify TCY Cost

Capital cost component

Items	Gas Turbine	Combined cycle	TCY
Capital Cost ($/kW)	450	800	
Annuity Factor	0.1	0.1	
Annual capital cost ($/kW/year)	45	80	
Non fuel O&M ($/kW/year)	22	26	
Load factor 20% at 1752 hr	3.824 ¢/kWh	6.050 ¢/kWh	
Load factor 30% at 2628 hr	2.550 ¢/kWh	4.035 ¢/kWh	
Load factor 40% at 3504 hr	1.912 ¢/kWh	3.025 ¢/kWh	
Load factor 50% at 4380 hr	1.530 ¢/kWh	2.420 ¢/kWh	
Load factor 60% at 5256 hr	1.275 ¢/kWh	2.017 ¢/kWh	
Load factor 70% at 6132 hr	1.093 ¢/kWh	1.729 ¢/kWh	
Overall capital cost			2.5 ¢/kWh

The annuity factor is based on 5% interest rate and a lift time of the plant at 15 years

Energy cost component

Items	Gas Turbine	Combined Cycle	TCY
Fuel cost	US $140 (S$ 252/MT)	US $140 (S$ 252/MT)	US $140 (S$ 252/MT)
Heat rate at full load (Kcal/kWh)	2847	2007	
Heat rate at base load (Kcal/kWh)	3132	2207	
Thermal efficiency at full load	30.21 %	42.85 %	
Thermal efficiency at base load	27.46 %	38.97 %	
Unit cost at base load	7.287 ¢/kWh	5.1347 ¢/kWh	
Overall unit cost including startup, work unit, spinning reserve and transmission constraints			5.8 ¢/kWh
Overall system thermal efficiency including startup, work unit spinning reserve and transmission constraints			34.5 %

The CV of fuel is 19500 BTU/lb, 1 BTU = 0.252 Kcal, 1 MT = 2205 lb

TCY cost (Total energy production cost in a utility) = 2.5 +5.8 = 8.3 ¢/kWh
For an oil price of US $140 (S$252/MT)

3. Ex Ante Pool Price

Ex Ante Pool Price Summary Report
(Thursday)
Settlement Date:
01/08/2002 Run No: 1
Production date and time:
31/07/2002 14:25:39

Abbreviations:
Pea - Ex-Ante Pool Purchase Price
Sea - Ex-Ante Pool Sales Price

End Period	Pea ($/MWh)	Sea ($/MWh)
04:30	106.0000	111.4593
05:00	106.0000	111.4588
05:30	106.0000	111.4597
06:00	106.0000	111.4601
06:30	106.0000	111.4551
07:00	106.0000	111.4599
07:30	106.0000	111.4602
08:00	106.0000	111.4594
08:30	106.0000	111.4713
09:00	106.0000	111.4751
09:30	106.0000	111.4806
10:00	106.0000	111.4838
10:30	106.0000	111.4861
11:00	106.0000	111.4877
11:30	106.0000	111.4869
12:00	106.0000	111.4881
12:30	106.0000	111.4858
13:00	106.0000	111.4851
13:30	106.0000	111.4870
14:00	106.0000	111.4876
14:30	106.0000	111.4857
15:00	106.0000	111.4861
15:30	106.0000	111.4881
16:00	106.0000	111.4871
16:30	106.0000	111.4875
17:00	106.0000	111.4875
17:30	106.0000	111.4851
18:00	106.0000	111.4798
18:30	106.0000	111.4742
19:00	106.0000	111.4732
19:30	1.9900	7.1864
20:00	1.9900	7.1864
20:30	1.9900	7.1864
21:00	1.9900	7.1864
21:30	1.9900	7.1863
22:00	1.9900	7.1861
22:30	1.9900	7.1861
23:00	1.9900	7.1862
23:30	1.9900	7.1861
00:00	1.9900	7.1861
00:30	1.9900	7.1862
01:00	1.9900	7.1862
01:30	1.9900	7.1862
02:00	1.9900	7.1860
02:30	1.9900	7.1860
03:00	1.9900	7.1860
03:30	0.0100	5.2011
04:00	0.0100	5.2011

(Thursday)

106 ($/MWh) = 10.6 ¢/kWh
1.9900 ($/MWh) = 0.199 ¢/kWh
0.01 ($/MWh) = 0.001 ¢/kWh = 1 ¢/MWh
Oil price = 155 for July 2002, TCY cost is 8.92 ¢/kWh
PSL(1) is 9.66 ¢/kWh and PSL(2) is 6.17 ¢/ kWh for June 2002

Ex Ante Pool Price Summary Report

Settlement Date
: 04/08/2002 Run No: 1
Production date and time:
03/08/2002 11:59:53

Abbreviations:
Pea - Ex-Ante Pool Purchase Price
Sea - Ex-Ante Pool Sales Price
(Sunday)

End Period	Pea ($/MWh)	Sea ($/MWh)
04:30	0.0100	5.5210
05:00	0.0100	5.5210
05:30	0.0100	5.5210
06:00	0.0100	5.5210
06:30	0.0100	5.5210
07:00	0.0100	5.5210
07:30	0.0100	5.5210
08:00	0.0100	5.5210
08:30	103.0000	108.7678
09:00	103.0000	108.7724
09:30	103.0000	108.7678
10:00	103.0000	108.7722
10:30	103.0000	108.7728
11:00	103.0000	108.7728
11:30	103.0000	108.7723
12:00	103.0000	108.7723
12:30	103.0000	108.7730
13:00	103.0000	108.7716
13:30	103.0000	108.7716
14:00	103.0000	108.7717
14:30	103.0000	108.7718
15:00	103.0000	108.7718
15:30	103.0000	108.7717
16:00	103.0000	108.7717
16:30	103.0000	108.7715
17:00	103.0000	108.7713
17:30	103.0000	108.7711
18:00	103.0000	108.7713
18:30	103.0000	108.7713
19:00	103.0000	108.7714
19:30	103.0000	108.7746
20:00	103.0000	108.7714
20:30	103.0000	108.7722
21:00	103.0000	108.7717
21:30	103.0000	108.7719
22:00	103.0000	108.7679
22:30	103.0000	108.7707
23:00	103.0000	108.7743
23:30	103.0000	108.7741
00:00	103.0000	108.7719
00:30	103.0000	108.7711
01:00	103.0000	108.7724
01:30	103.0000	108.7725
02:00	103.0000	108.7715
02:30	0.0100	5.5210
03:00	0.0100	5.5210
03:30	0.0100	5.5210
04:00	0.0100	5.5210

(Sunday)

103 ($/MWh) = 10.3 ¢/per kWh
0.01 ($/MWh) = 0.001 ¢/per kWh = 1 ¢/per MWh
Oil price = 155 for July 2002, TCY cost is 8.92 ¢/kWh
PSL(1) is 9.66 ¢/kWh and PSL(2) is 6.17 ¢/ kWh for June 2002

Ex Ante Pool Price Summary Report
(National day Eve)
Settlement Date:
08/08/2002 Run No: 1
Production date and time:
07/08/2002 14:21:55

Abbreviations:
Pea - Ex-Ante Pool Purchase Price
Sea - Ex-Ante Pool Sales Price

End Period	Pea ($/MWh)	Sea ($/MWh)
04:30	98.0000	103.4257
05:00	98.0000	103.4260
05:30	98.0000	103.4254
06:00	0.0100	5.1933
06:30	0.0100	5.1933
07:00	0.0100	5.1933
07:30	0.0100	5.1933
08:00	0.0200	5.2033
08:30	0.8100	5.9954
09:00	0.8100	5.9954
09:30	0.8600	6.0456
10:00	0.7500	5.9353
10:30	0.6300	5.8150
11:00	0.7500	5.9353
11:30	0.6300	5.8150
12:00	0.3500	5.5342
12:30	0.0200	5.2033
13:00	0.0200	5.2033
13:30	0.3500	5.5342
14:00	0.5200	5.7047
14:30	0.6300	5.8150
15:00	0.6400	5.8250
15:30	0.6300	5.8150
16:00	0.6400	5.8250
16:30	0.6400	5.8250
17:00	0.6300	5.8150
17:30	0.0200	5.2033
18:00	0.0200	5.2033
18:30	0.0100	5.1933
19:00	0.0100	5.1933
19:30	0.0100	5.1933
20:00	0.0100	5.1933
20:30	0.0100	5.1933
21:00	0.0100	5.1933
21:30	0.0100	5.1933
22:00	0.0100	5.1933
22:30	0.0100	5.1933
23:00	0.0100	5.1933
23:30	0.0100	5.1933
00:00	0.0100	5.1933
00:30	0.0100	5.1933
01:00	0.0100	5.1933
01:30	0.0100	5.1933
02:00	0.0100	5.1933
02:30	0.0100	5.1933
03:00	0.0100	5.1933
03:30	0.0100	5.1933
04:00	0.0100	5.1933

(National Day Eve)

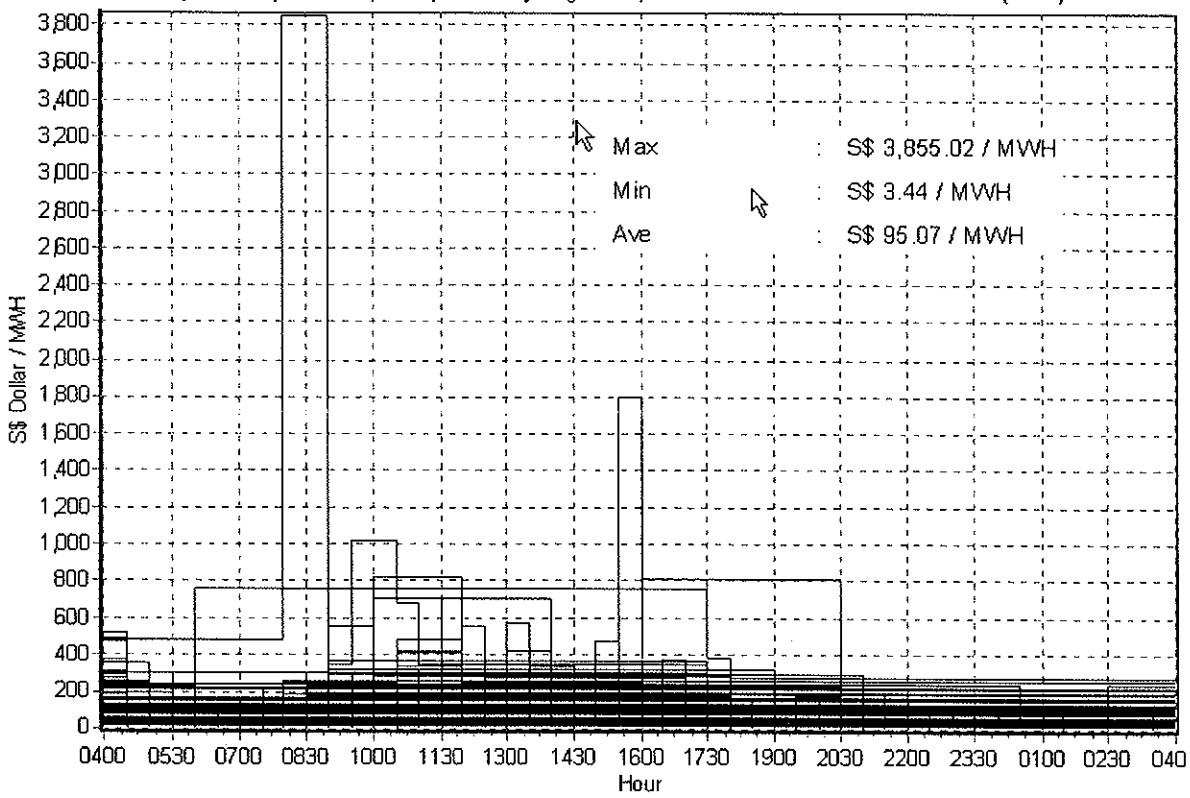
98 ($/MWh) = 9.8 ¢/kWh
0.81 ($/MWh) at 8:30 a.m. = 0.081 ¢/kWh
0.01 ($/MWh) from 6:30 p.m. to 4:00 a.m. = 0.001 ¢/kWh = 1 ¢/MWh
Oil price = 155 for July 2002, TCY cost is 8.92 ¢/kWh
PSL(1) is 9.66 ¢/kWh and PSL(2) is 6.17 ¢/ kWh for June 2002

4. Annual Pool Price

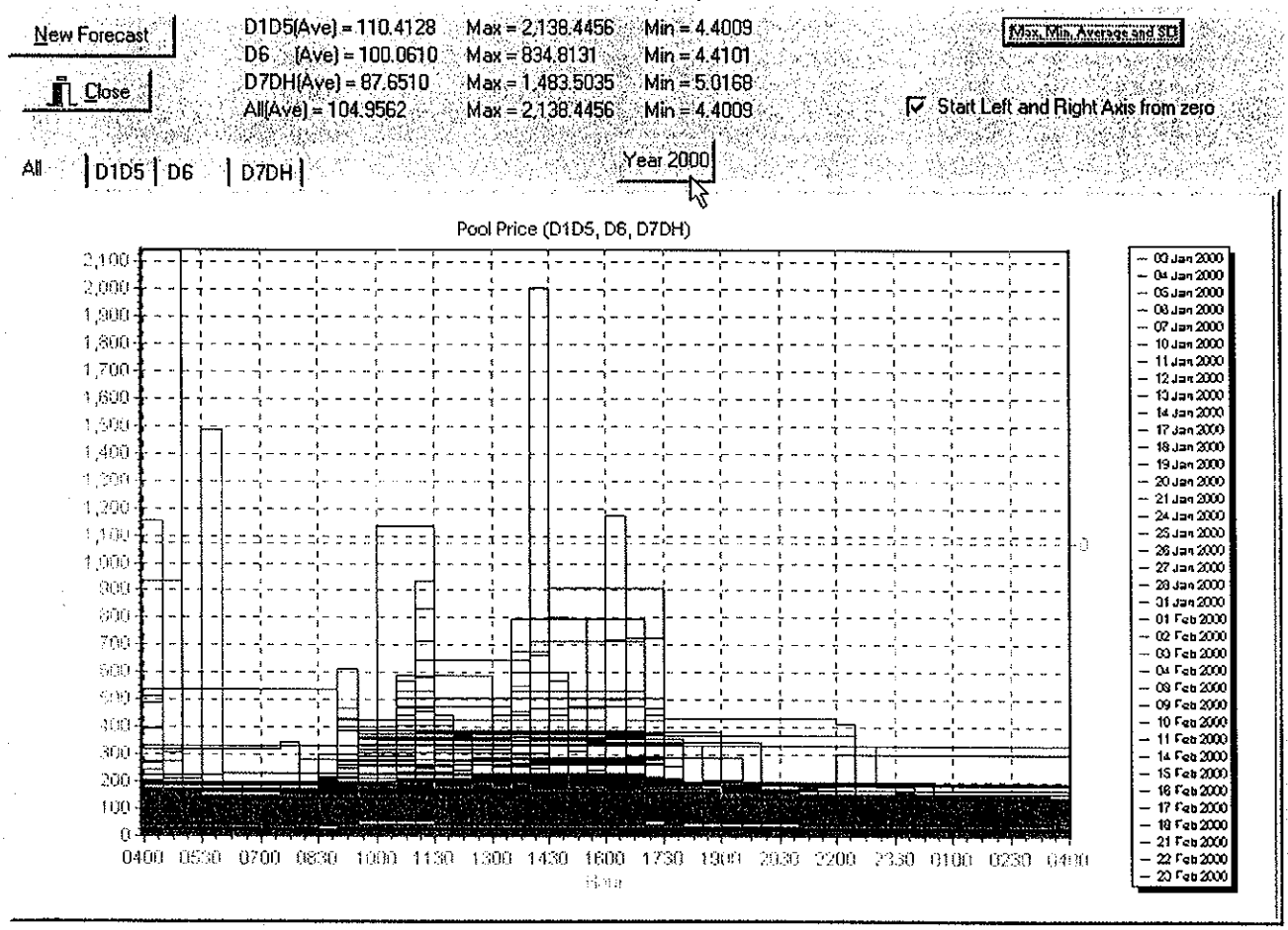
2001 (D1D5)

Existing Pool Price

January February March April May June July August September October November December (D1D5)

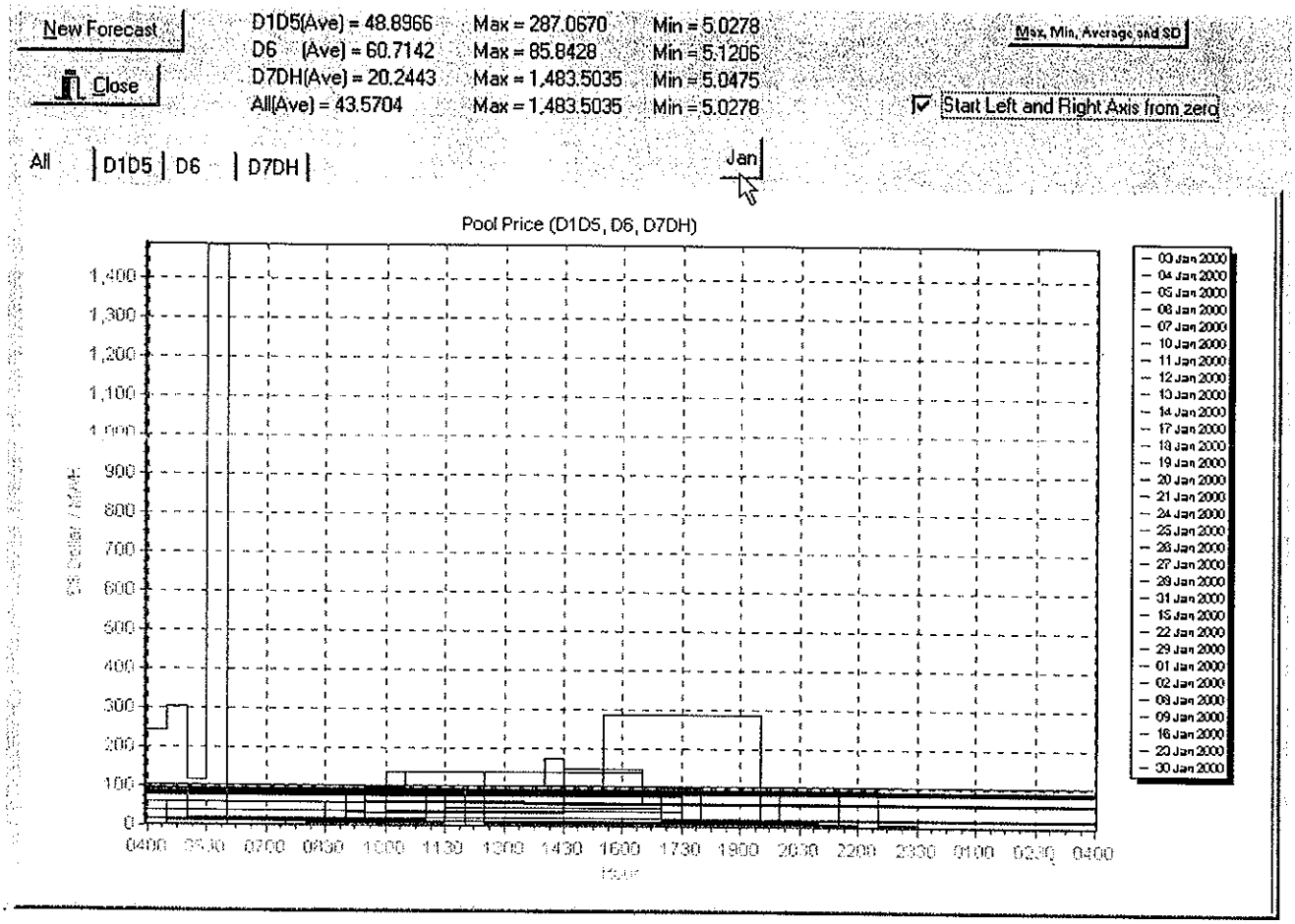


2000 (All)

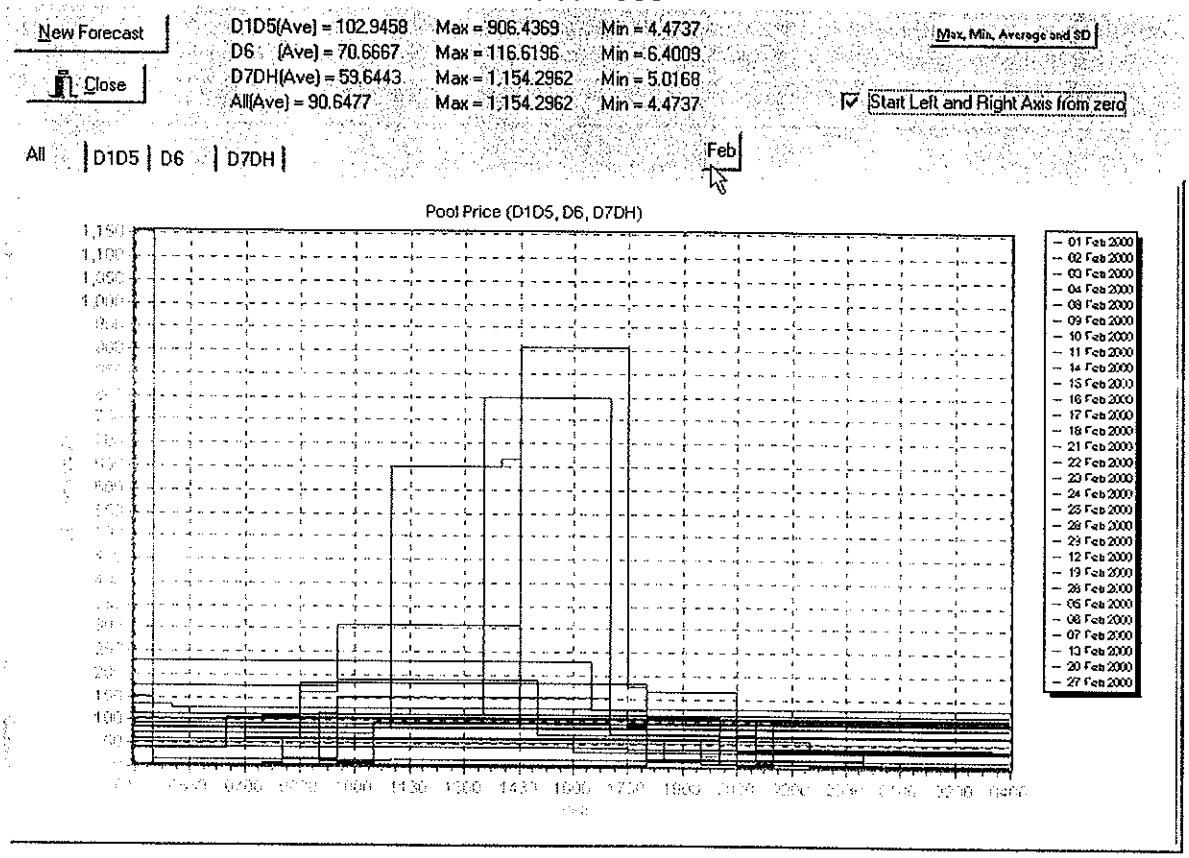


5. Monthly pool price

Jan 2000



Feb 2000



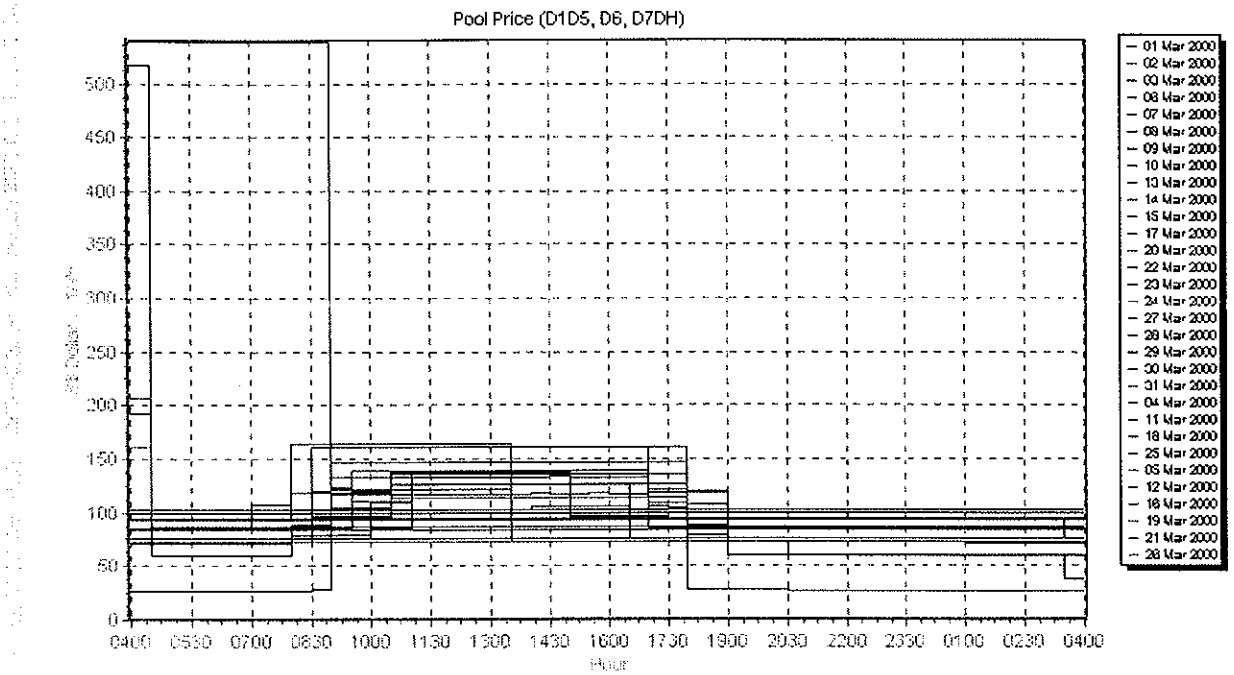
Mar 2000

New Forecast | Close

D1D5(Ave) = 103.1505 Max = 538.7118 Min = 26.2493
D6 (Ave) = 94.9624 Max = 193.0457 Min = 71.8577
D7DH(Ave) = 86.3041 Max = 207.2887 Min = 73.1112
All(Ave) = 98.8334 Max = 538.7118 Min = 26.2493

Max, Min, Average and SD | Start Left and Right Axis from zero

All | D1D5 | D6 | D7DH | Mar



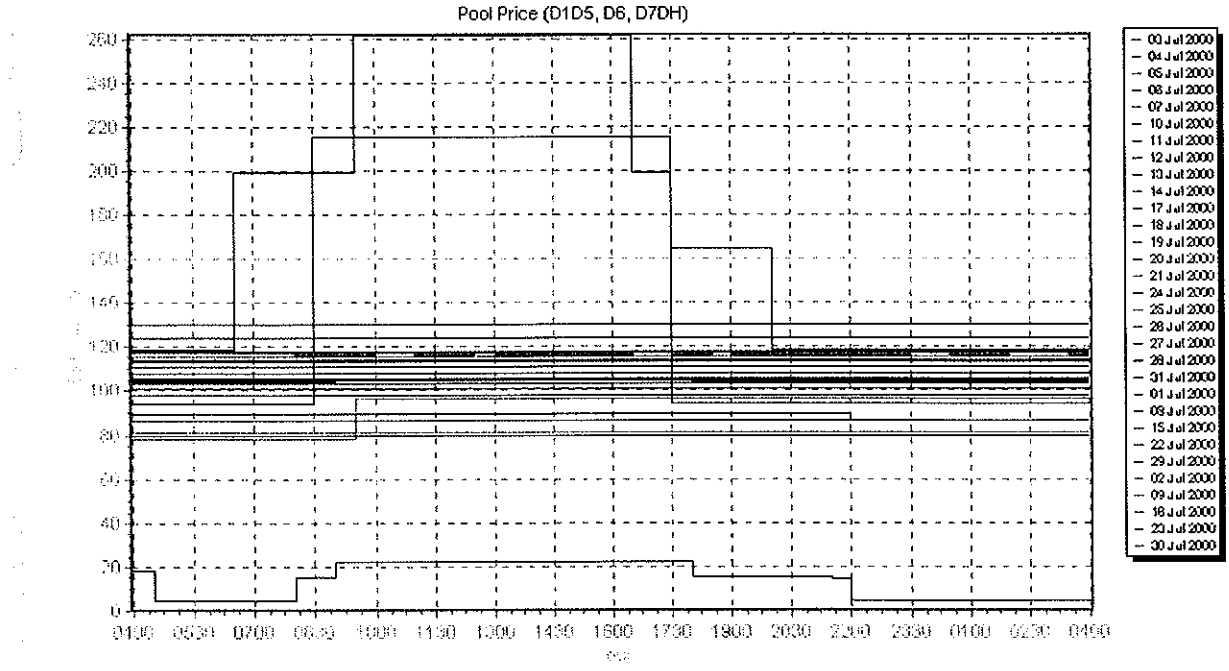
July 2000

New Forecast | Close

D1D5(Ave) = 110.2099 Max = 261.1626 Min = 4.4009
D6 (Ave) = 100.6224 Max = 117.2528 Min = 80.8439
D7DH(Ave) = 101.6673 Max = 117.2917 Min = 78.4128
All(Ave) = 107.2857 Max = 261.1626 Min = 4.4009

Max, Min, Average and SD | Start Left and Right Axis from zero

All | D1D5 | D6 | D7DH | Jul

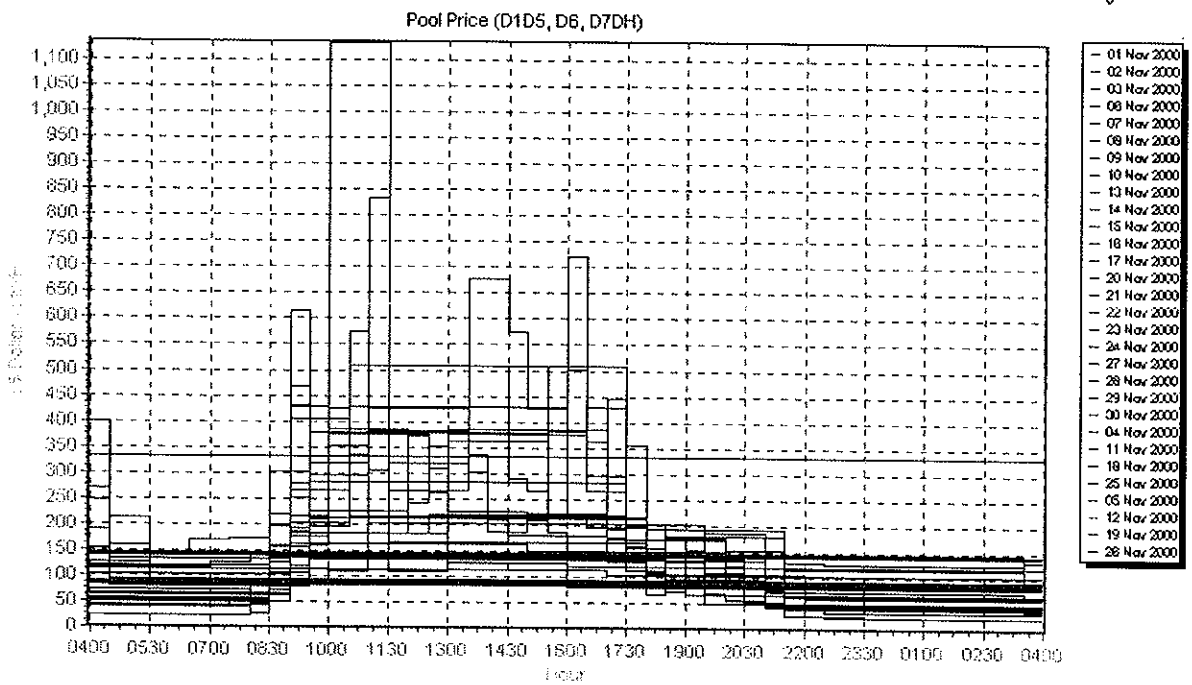


November 2000

New Forecast | Close

D1D5(Ave) = 150.9599	Max = 1,133.0783	Min = 23.7257	Max, Min, Average and SD
D6 (Ave) = 134.6022	Max = 834.8131	Min = 62.8942	
D7DH(Ave) = 163.8187	Max = 331.6716	Min = 86.7568	
All(Ave) = 150.4933	Max = 1,133.0783	Min = 23.7257	☑ Start Left and Right Axis from zero

All | D1D5 | D6 | D7DH | Nov

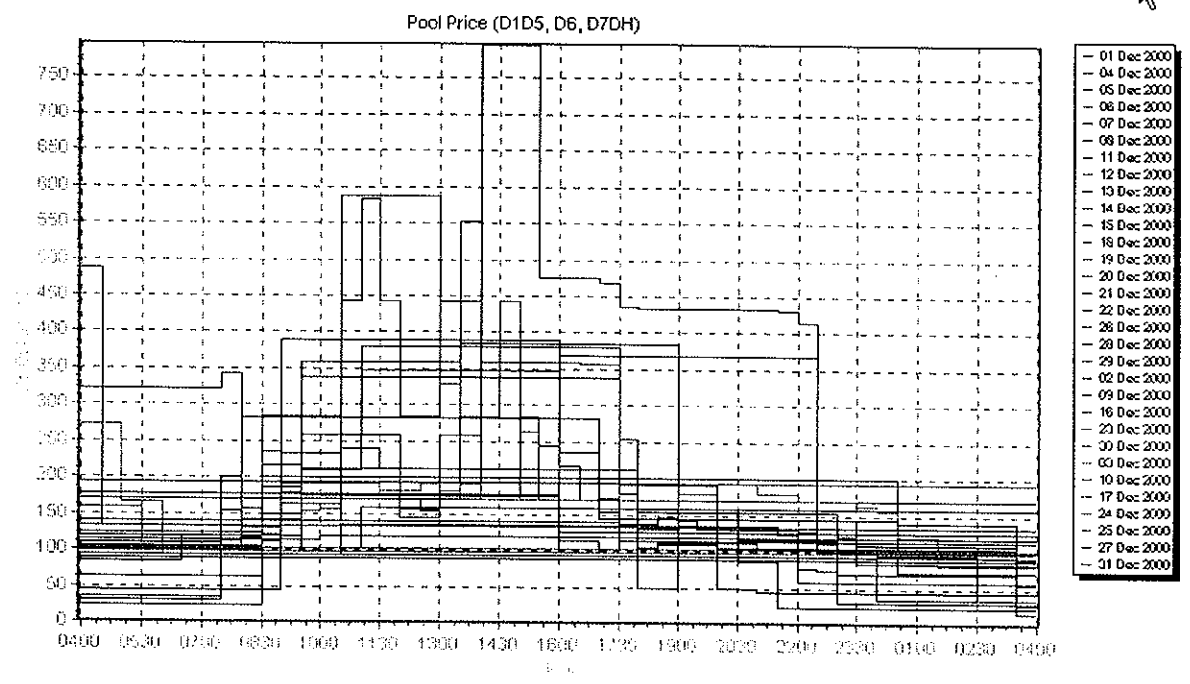


December 2000

New Forecast | Close

D1D5(Ave) = 171.5625	Max = 795.2497	Min = 15.9164	Max, Min, Average and SD
D6 (Ave) = 127.3699	Max = 586.7733	Min = 59.3364	
D7DH(Ave) = 119.7570	Max = 273.9215	Min = 81.0385	
All(Ave) = 152.7367	Max = 795.2497	Min = 15.9164	☑ Start Left and Right Axis from zero

All | D1D5 | D6 | D7DH | Dec



6. Tabulated Oil, Pool, PSL and TCY Prices

Year 2000

Month	*Oil price (US $/T)*	*Pool (¢/kWh)*	*PSL1 (¢/kWh)*	*PSL2 (¢/kWh)*	*TCY (¢/kWh)*
Jan	136	4.36	9.54	7.95	8.13
Feb	143	9.07	9.54	7.95	8.42
Mar	170	9.88	9.54	7.95	9.54
Apr	152	9.83	9.54	7.95	8.78
May	163	8.96	9.99	8.32	9.25
Jun	175	10.56	9.99	8.32	9.75
Jul	152	10.73	9.99	8.32	8.80
Aug	149	11.05	13.17	10.98	8.67
Sep	171	11.53	13.17	10.98	9.58
Oct	181	9.75	13.17	10.98	10.00
Nov	168	15.05	13.17	10.98	9.46
Dec	136	15.27	13.17	10.98	8.13
Average	158	10.496	11.17	9.31	9.05

7. Proposals from 4 supply retailers

Proposal 1:

Two Tier (2T-Se) for oil price at S$140/T and US $1=S$1.8

Peak (0700-2300) 10.5 ¢/per kWh

Off peak (2300-0700) 9.59 ¢/per kWh

If oil price deviates from S$140/T and exchange rate from S$1.8, the price will be adjusted according to a given table (similar to Table 1 TCY energy cost)

Proposal 2:

Three Tier (3T-Tu) for oil price at S$140/T and exchange rate not specify

Peak 1 (0700-1900) 12.10 ¢/per kWh

Peak 2 (1900-2300) 11.0 ¢/per kWh

Off peak (2300-0700) 9.85 ¢/per kWh

For oil price deviates from S$140/T, the price will be adjusted by

0.04 ¢/per kWh for every US $1 deviation.

Proposal 3:

One price flat rate (Flat-Sm)

All day price: 10.3 ¢/per kWh

Proposal 4:

Pool price (Other_1). Based on the published pool price and at a higher UoS and a higher MD charges

TCY Energy cost reference 8.3 ¢/kWh for oil price at US $140

9.13 ¢/kWh for oil price at US $160

9.96 ¢/kWh for oil price at US $180

8. Daily utility cost analysis

One Monday in July 2000

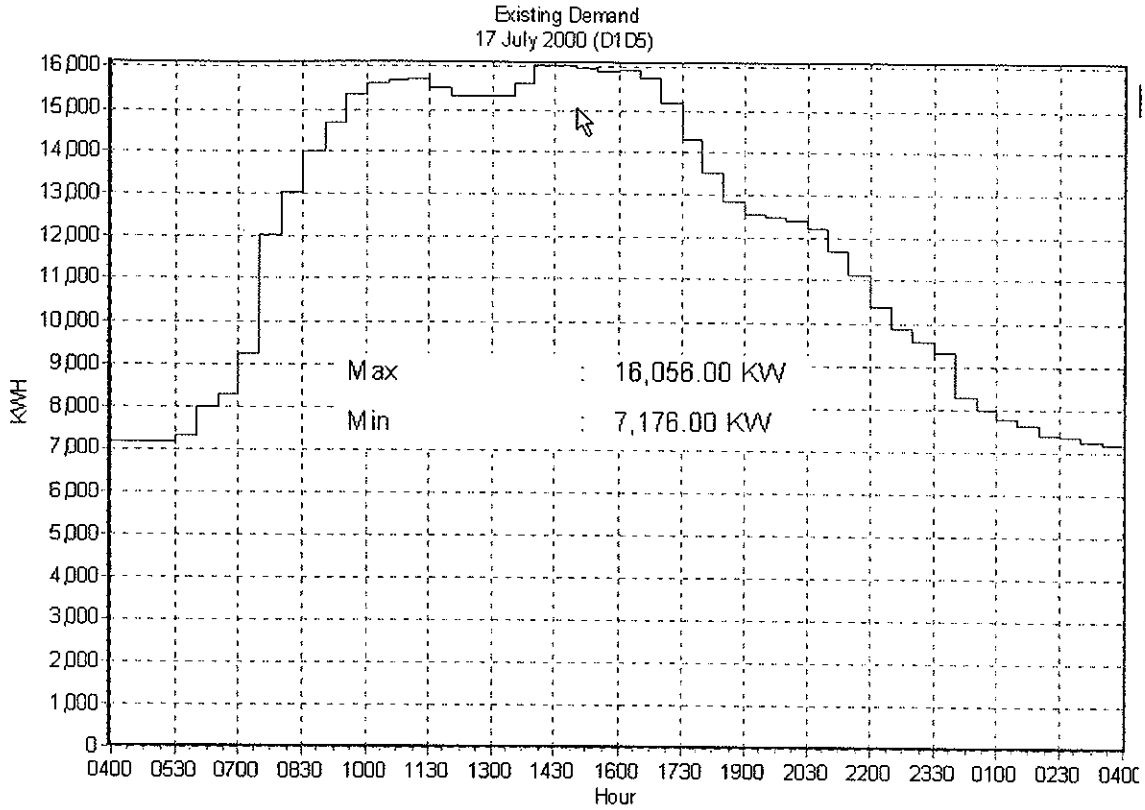
Year : 2000
Company : Demand\NTU
Supplier : Pool\PowerSupply.DBF
Day : 17 Jul 2000 (D1D5)

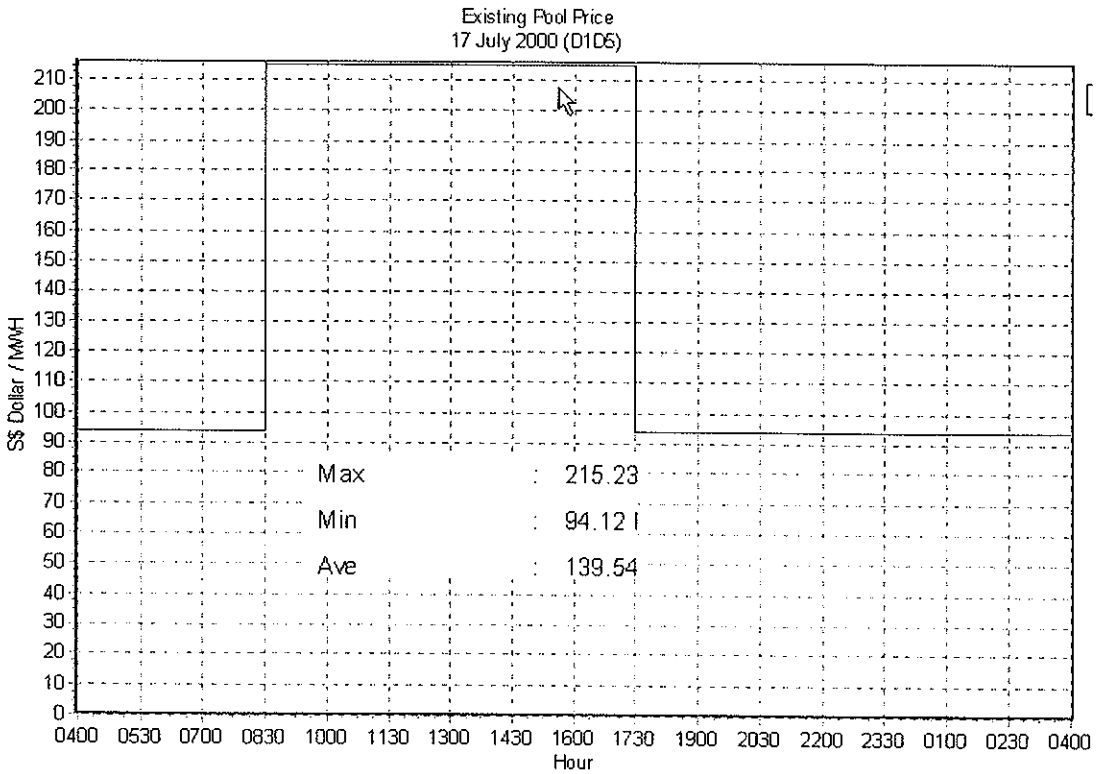
Energy Cost	Energy (MWH)	Cost ($)	2T Se Cost ($)	2T Se Difference	2T Se %	Ex-Antedb Cost ($)	Ex-Antedb Difference	Ex-Antedb %
Peak	223.28	$22,306.07	$23,843.00	1,536.93	106.9	$38,284.64	15,978.57	171.6
Off Peak 1	62.56	$5,204.66	$5,600.94	396.28	107.6	$5,497.31	292.65	105.6
Off Peak 2	0.00	$0.00	$0.00	0.00	NA	$0.00	0.00	NA
Total	285.84	$27,510.73	$29,443.94	1,933.21	107.0	$43,781.95	16,271.22	159.1
Average (cents/kWh)		9.62	10.30			15.32		

Energy Cost	Energy (MWH)	Cost ($)	3T Tu Cost ($)	3T Tu Difference	3T Tu %	Flat Sem Cost ($)	Flat Sem Difference	Flat Sem %
Peak	223.28	$22,306.07	$27,027.27	4,721.20	121.2	$23,425.91	1,119.84	105.0
Off Peak 1	62.56	$5,204.66	$5,752.79	548.13	110.5	$6,015.61	810.95	115.6
Off Peak 2	0.00	$0.00	$0.00	0.00	NA	$0.00	0.00	NA
Total	285.84	$27,510.73	$32,780.06	5,269.33	119.2	$29,441.52	1,930.79	107.0
Average (cents/kWh)		9.62	11.47			10.30		

Tariff for July 2000

Supplier	Peak (Cents/kwh)	Off Peak 1 (Cents/kwh)	Off peak 2 (Cents/kwh)
2T	10.5	9.59	0
3T	12.10	11.00	9.85
Ex-Ante	11.02 (D1D5)	10.06 (D6)	10.17 (D7DH)
Flat	10.3	10.3	10.3
PSL	9.99	8.32	0


Existing Demand
17 July 2000 (D1D5)
KWH
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Max : 16,056.00 KW
Min : 7,176.00 KW
0400 0530 0700 0830 1000 1130 1300 1430 1600 1730 1900 2030 2200 2330 0100 0230 040
Hour


Existing Pool Price
17 July 2000 (D1D5)
S$ Dollar / MWH
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
Max : 215.23
Min : 94.12
Ave : 139.54
0400 0530 0700 0830 1000 1130 1300 1430 1600 1730 1900 2030 2200 2330 0100 0230 0400
Hour

One Sunday in July 2000

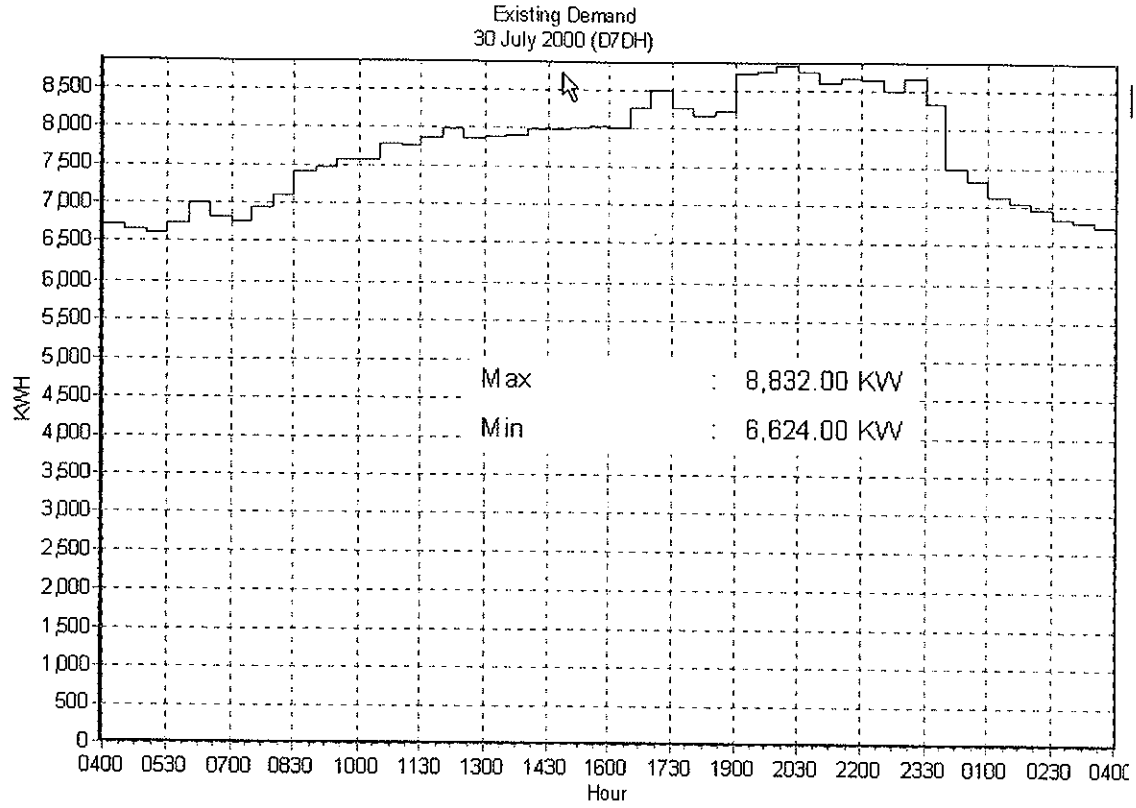
Year : 2000
Company : Demand\NTU
Supplier : Pool\PowerSupply.DBF
Day : 30 Jul 2000 (D7DH)

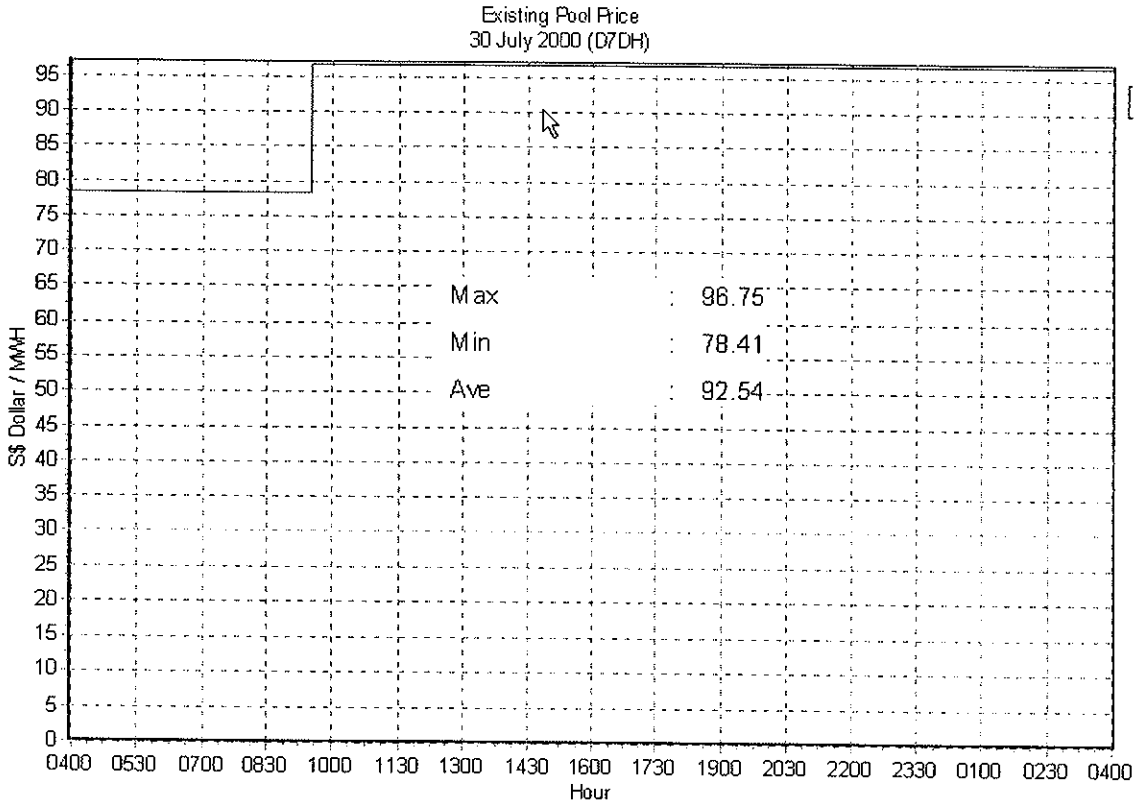
Energy Cost	Energy (MWH)	Cost ($)	2T Se Cost ($)	2T Se Difference	2T Se %	Ex-Antedb Cost ($)	Ex-Antedb Difference	Ex-Antedb %
Peak	128.36	$12,823.56	$13,805.05	981.49	107.7	$12,357.88	-465.68	96.4
Off Peak 1	56.96	$4,739.40	$5,136.02	396.62	108.4	$4,871.70	132.30	102.8
Off Peak 2	0.00	$0.00	$0.00	0.00	NA	$0.00	0.00	NA
Total	185.33	$17,562.97	$18,941.07	1,378.10	107.8	$17,229.58	-333.39	98.1
Average (cents/kWh)		9.48	10.22			9.30		

Energy Cost	Energy (MWH)	Cost ($)	3T Tu Cost ($)	3T Tu Difference	3T Tu %	Flat Sem Cost ($)	Flat Sem Difference	Flat Sem %
Peak	128.36	$12,823.56	$15,550.17	2,726.61	121.3	$13,572.52	748.96	105.8
Off Peak 1	56.96	$4,739.40	$5,275.27	535.87	111.3	$5,516.27	776.87	116.4
Off Peak 2	0.00	$0.00	$0.00	0.00	NA	$0.00	0.00	NA
Total	185.33	$17,562.97	$20,825.44	3,262.47	118.6	$19,088.78	1,525.81	108.7
Average (cents/kWh)		9.48	11.24			10.30		

Tariff for July 2000

Supplier	Peak (Cents/kwh)	Off Peak 1 (Cents/kwh)	Off peak 2 (Cents/kwh)
2T	10.5	9.59	0
3T	12.10	11.00	9.85
Ex-Ante	11.02 (D1D5)	10.06 (D6)	10.17 (D7DH)
Flat	10.3	10.3	10.3
PSL	9.99	8.32	0


Existing Demand
30 July 2000 (D7DH)
KWH
8,500
8,000
7,500
7,000
6,500
6,000
5,500
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Max : 8,832.00 KW
Min : 6,624.00 KW
0400 0530 0700 0830 1000 1130 1300 1430 1600 1730 1900 2030 2200 2330 0100 0230 040
Hour


Existing Pool Price
30 July 2000 (D7DH)
S$ Dollar / MWH
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
Max : 96.75
Min : 78.41
Ave : 92.54
0400 0530 0700 0830 1000 1130 1300 1430 1600 1730 1900 2030 2200 2330 0100 0230 0400
Hour

9. Monthly utility cost analysis

Bench Mark 1 (Feb 2000)

Month: Feb 2000 Company: NTU
Reference Supplier: Power Supply
Power Factor: 0.89 Reactive: 3,450,084 kVarh
Max Demand: 15,072 kW Contracted Demand: 14,000 kW
Peak: 5,029.686 MWh Off-peak: 1,612.698 MWh Total: 6,642.384 MWh
Oil Price: US $143/MT

Supplier	Energy cost ($)	Energy cost (cents/kWh)	UOS Plus ($)	Total cost ($)	Total cost (cents/kWh)	Difference ($)	(%)
Other 2							
PSL	608,042	9.15	158,308	766,350	11.54	0	100
Ex-Ante	671,309	10.11	157,221	828,530	12.47	62,180	108.1
2T_Se	682,775	10.28	157,221	839,996	12.65	73,646	109.6
Flat_Sem	684,166	10.3	157,391	841,557	12.67	75,207	109.8
Other 1	671,309	10.11	233,458	904,767	13.62	138,417	118.1
3T_Tu	757,843	11.41	157,221	915,064	13.78	148,715	119.4

Tariff for Feb 2000

Supplier	Peak (Cents/kwh)	Off Peak 1 (Cents/kwh)	Off peak 2 (Cents/kwh)	MD $/kW-Month	UOS $/kWh	Other
2T	10.5	9.59	0	6.9/10.35	0.85/0.42	N
3T	12.10	11.00	9.85	6.9/10.35	0.85/0.42	N
Ex-Ante	10.3 (D1D5)	7.07(D6)	5.96 (D7DH)	6.9/10.35	0.85/0.42	N
Flat	10.3	10.3	10.3	6.9/10.35	0.85/0.42	M&S
Other 1	Pool	Pool	Pool	9.01/13.51	1.57/0.86	N
Other 2	10.7 (7 MW)	8.70 (7 MW)	Pool (> 7 MW)	9.01/13.51	1.57/0.86	N
PSL	10.39	8.37	0	6.97/10.45	0.85/0.42	N

Year : 2000

Company : Demand\NTU

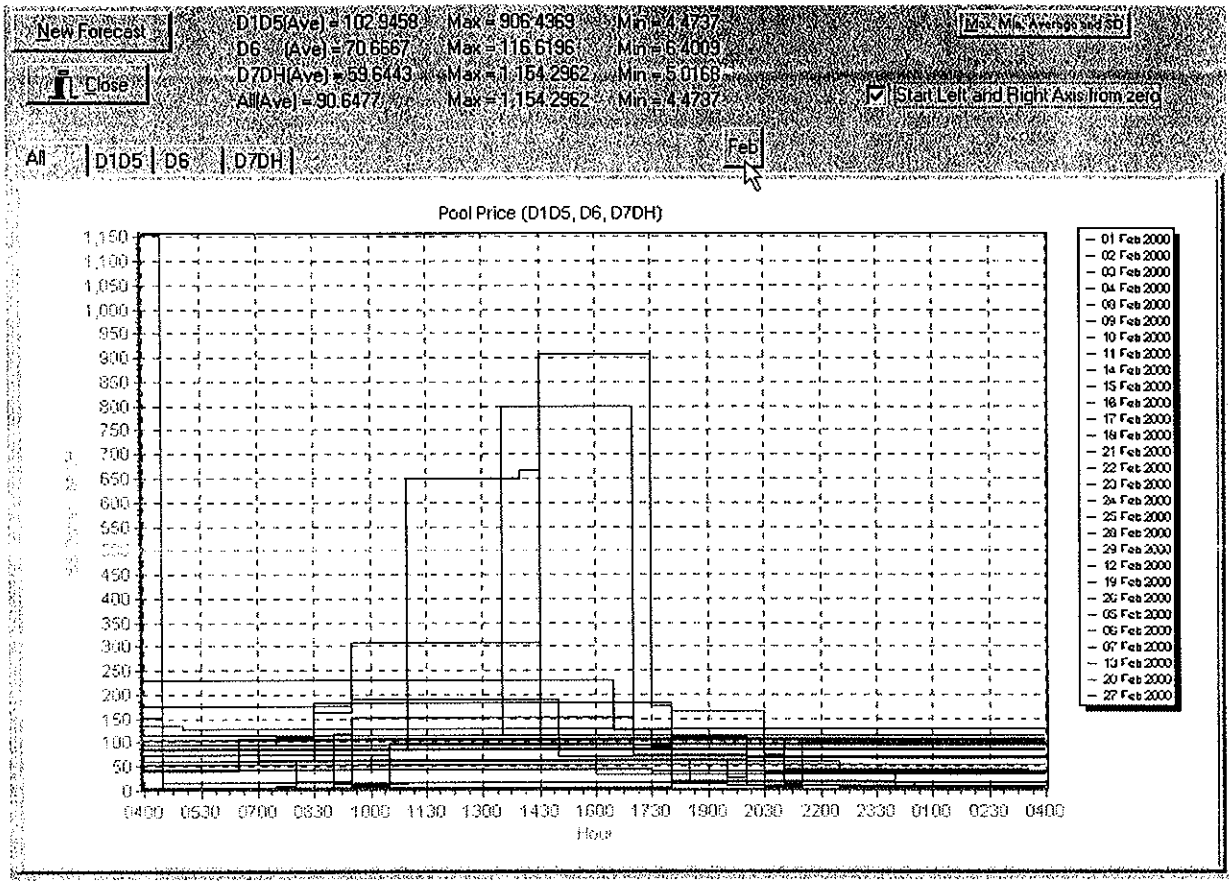
Supplier : Pool\PowerSupply.DBF

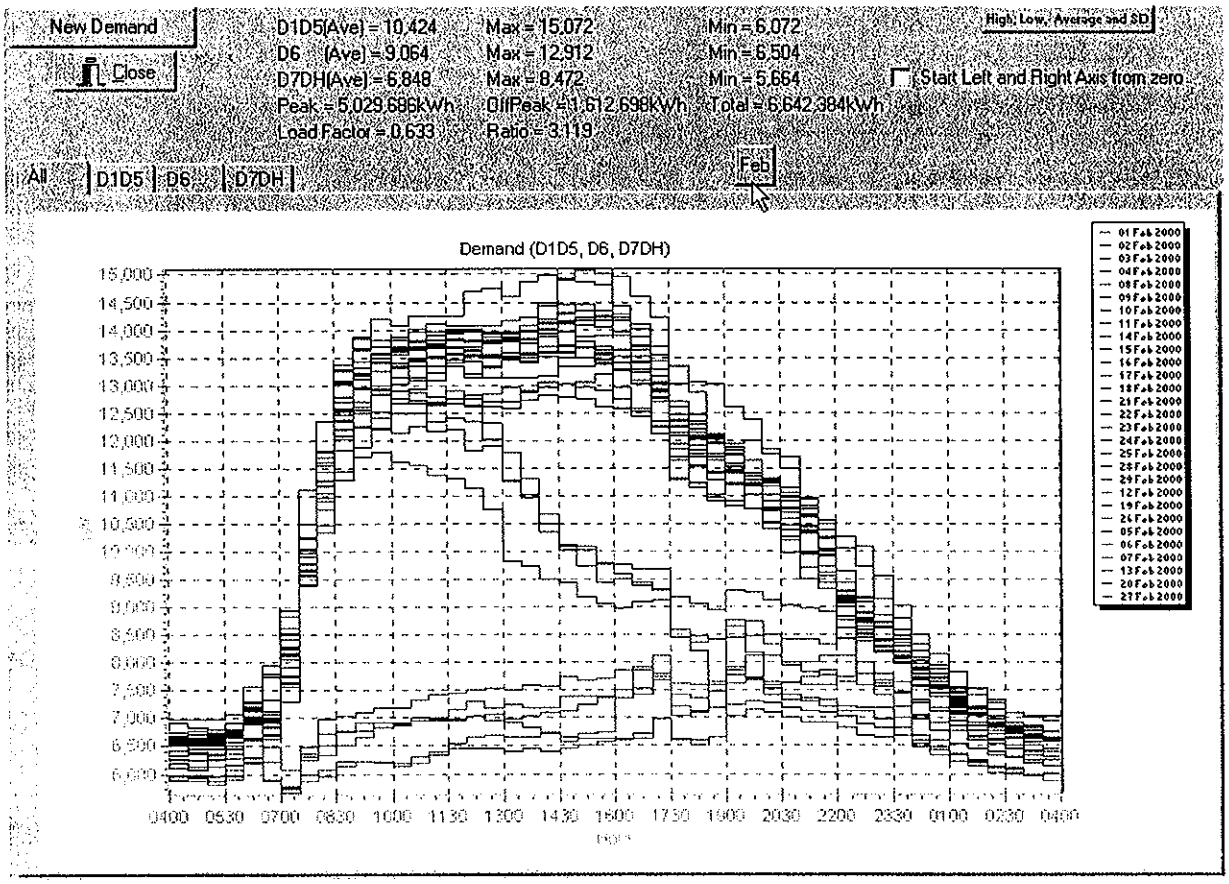
Month : Feb 2000 Power Factor : 0.89

Max Demand : 15,072.00 kW Reactive : 3,450,084.00 kVArh

Energy Cost	Energy (MWH)	Cost ($)	Ex-Antedb Cost ($)	Difference	%	2T: Se Cost ($)	Difference	%
Peak	5,029.686	$479,832.04	$561,454.72	81,622.68	117.0	$528,117.03	48,284.99	110.1
Off Peak 1	1,612.698	$128,209.49	$109,853.87	-18,355.62	85.7	$154,657.74	26,448.25	120.6
Off Peak 2	0.000	$0.00	$0.00	0.00	NA	$0.00	0.00	NA
Total	6,642.384	$608,041.54	$671,308.59	63,267.05	110.4	$682,774.77	74,733.23	112.3
Average Energy (¢/kWh)		9.15	10.11			10.28		
Other Cost								
Contracted		$97,580.00	$96,600.00	-980.00	99.0	$96,600.00	-980.00	99.0
Uncontracted		$11,202.40	$11,095.20	-107.20	99.0	$11,095.20	-107.20	99.0
Reactive		$0.00	$0.00	0.00	NA	$0.00	0.00	NA
UOS Peak		$42,752.33	$42,752.33	0.00	100.0	$42,752.33	0.00	100.0
UOS Off Peak		$6,773.33	$6,773.33	0.00	100.0	$6,773.33	0.00	100.0
Total		$158,308.06	$157,220.86	-1,087.20	99.3	$157,220.86	-1,087.20	99.3
Utility Cost		$766,349.60	$828,529.46	62,179.86	108.1	$839,995.63	73,646.03	109.6
Average Energy (¢/kWh)		11.54	12.47			12.65		

Energy Cost	Energy (MWH)	Cost ($)	Flat Sem Cost ($)	Difference	%	3T: Tu Cost ($)	Difference	%
Peak	5,029.686	$479,832.04	$518,057.66	38,225.62	108.0	$598,992.48	119,160.44	124.8
Off Peak 1	1,612.698	$128,209.49	$166,107.89	37,898.40	129.6	$158,850.75	30,641.26	123.9
Off Peak 2	0.000	$0.00	$0.00	0.00	NA	$0.00	0.00	NA
Total	6,642.384	$608,041.54	$684,165.55	76,124.01	112.5	$757,843.24	149,801.70	124.6
Average Energy (¢/kWh)		9.15	10.30			11.41		
Other Cost								
Contracted		$97,580.00	$96,600.00	-980.00	99.0	$96,600.00	-980.00	99.0
Uncontracted		$11,202.40	$11,095.20	-107.20	99.0	$11,095.20	-107.20	99.0
Reactive		$0.00	$0.00	0.00	NA	$0.00	0.00	NA
UOS Peak		$42,752.33	$42,752.33	0.00	100.0	$42,752.33	0.00	100.0
UOS Off Peak		$6,773.33	$6,773.33	0.00	100.0	$6,773.33	0.00	100.0
Total		$158,308.06	$157,391.28	-916.78	99.4	$157,220.86	-1,087.20	99.3
Utility Cost		$766,349.60	$841,556.83	75,207.23	109.8	$915,064.10	148,714.50	119.4
Average Energy (¢/kWh)		11.54	12.67			13.78		


New Forecast
Close
D1D5(Ave) = 102.9458
D6 (Ave) = 70.6567
D7DH(Ave) = 59.6443
All(Ave) = 90.6477
Max = 906.4369
Max = 116.6196
Max = 1,154.2962
Max = 1,154.2962
Min = 4.4737
Min = 6.4009
Min = 5.0168
Min = 4.4737
Max, Min, Average and SD
Start Left and Right Axis from zero
All
D1D5
D6
D7DH
Feb
Pool Price (D1D5, D6, D7DH)
Hour


New Demand
Close
D1D5(Ave) = 10,424
D6 (Ave) = 9,064
D7DH(Ave) = 6,848
Peak = 5,029,686kWh
Load Factor = 0.633
Max = 15,072
Max = 12,912
Max = 8,472
OffPeak = 1,612,698kWh
Ratio = 3.119
Min = 6,072
Min = 6,504
Min = 5,664
Total = 6,642,384kWh
High, Low, Average and SD
Start Left and Right Axis from zero
All
D1D5
D6
D7DH
Feb
Demand (D1D5, D6, D7DH)

Bench Mark 2 (Dec 2000)

Month: Dec 2000 Company: NTU
Reference Supplier: Power Supply
Power Factor: 0.90 Reactive: 4,074,684 kVarh
Max Demand: 18,048 kW Contracted Demand: 14,000 kW
Peak: 6,287.586 MWh Off-peak: 2,015.982 MWh Total: 8,303.568 MWh
Oil Price: US $136/MT

Supplier	Energy cost ($)	Energy cost (cents/kWh)	UOS Plus ($)	Total cost ($)	Total cost (cents/kWh)	Difference ($)	(%)
Other 2							
2T_Se	853,529	10.28	200.408	1,053,938	12.69	-197,286	84.2
Flat_Sem	855,267	10.3	200,580	1,055,848	12.72	-195,375	84.4
3T_Tu	948,654	11.42	200,408	1,149,062	13.84	-102,161	91.8
PSL	1,049,430	12.64	201,793	1,251,223	15.07	0	100
Ex-Ante	1,403,189	16.90	200,408	1,603,597	19.31	352,374	128.2
Other 1	1,403,189	16.9	296,881	1,700,070	20.47	448,847	135.9

Tariff for Dec 2000

Supplier	Peak (Cents/kwh)	Off Peak 1 (Cents/kwh)	Off peak 2 (Cents/kwh)	MD $/kW-Month	UOS $/kWh	Other
2T	10.5	9.59	0	6.9/10.35	0.85/0.42	N
3T	12.10	11.00	9.85	6.9/10.35	0.85/0.42	N
Ex-Ante	17.16 (D1D5)	12.74 (D6)	11.98 (D7DH)	6.9/10.35	0.85/0.42	N
Flat	10.3	10.3	10.3	6.9/10.35	0.85/0.42	M&S
Other 1	Pool	Pool	Pool	9.01/13.51	1.57/0.86	N
Other 2	10.7 (7 MW)	8.70 (7 MW)	Pool (> 7 MW)	9.01/13.51	1.57/0.86	N
PSL	13.17	10.98	0	6.97/10.45	0.85/0.42	N

Year : 2000

Company : Demand\NTU

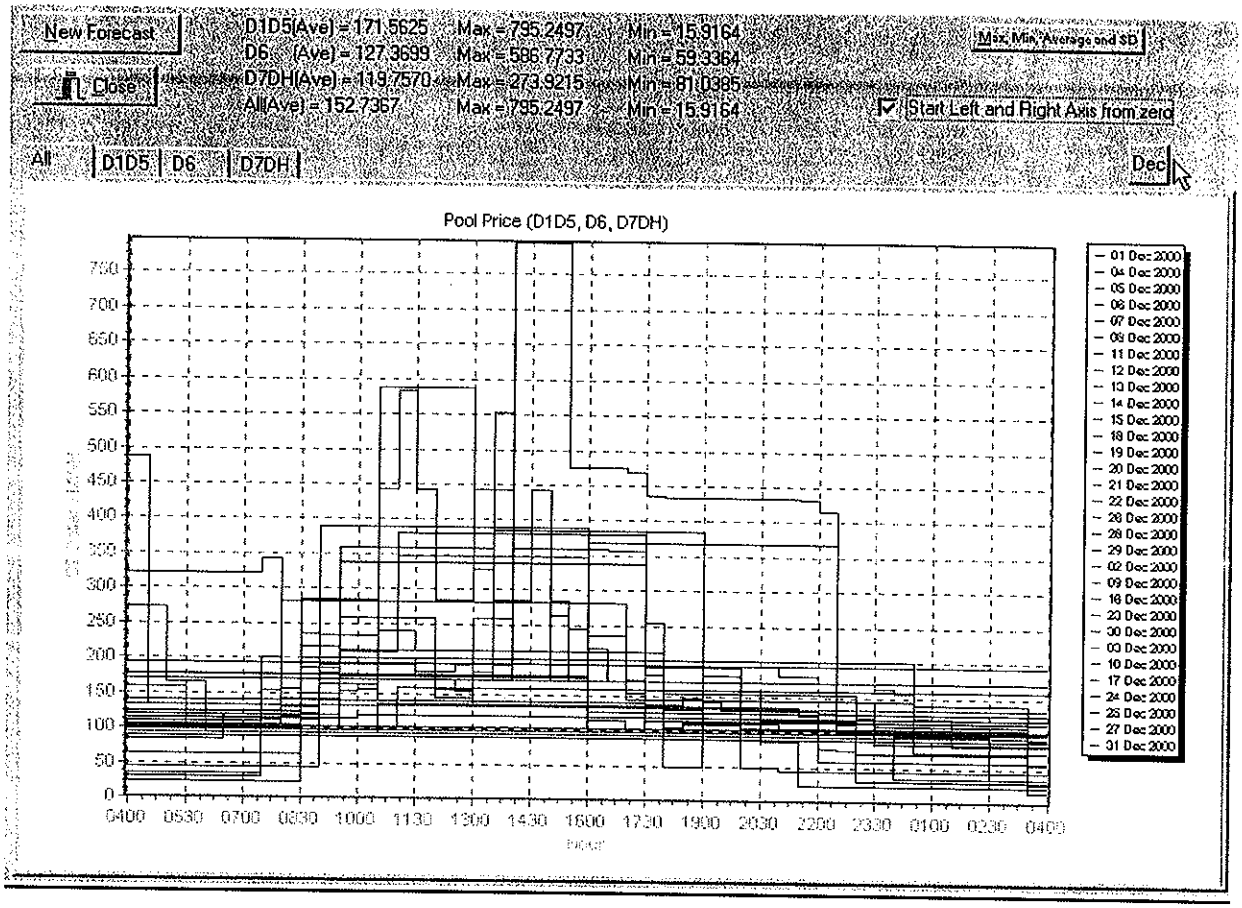
Supplier : Pool\PowerSupply.DBF

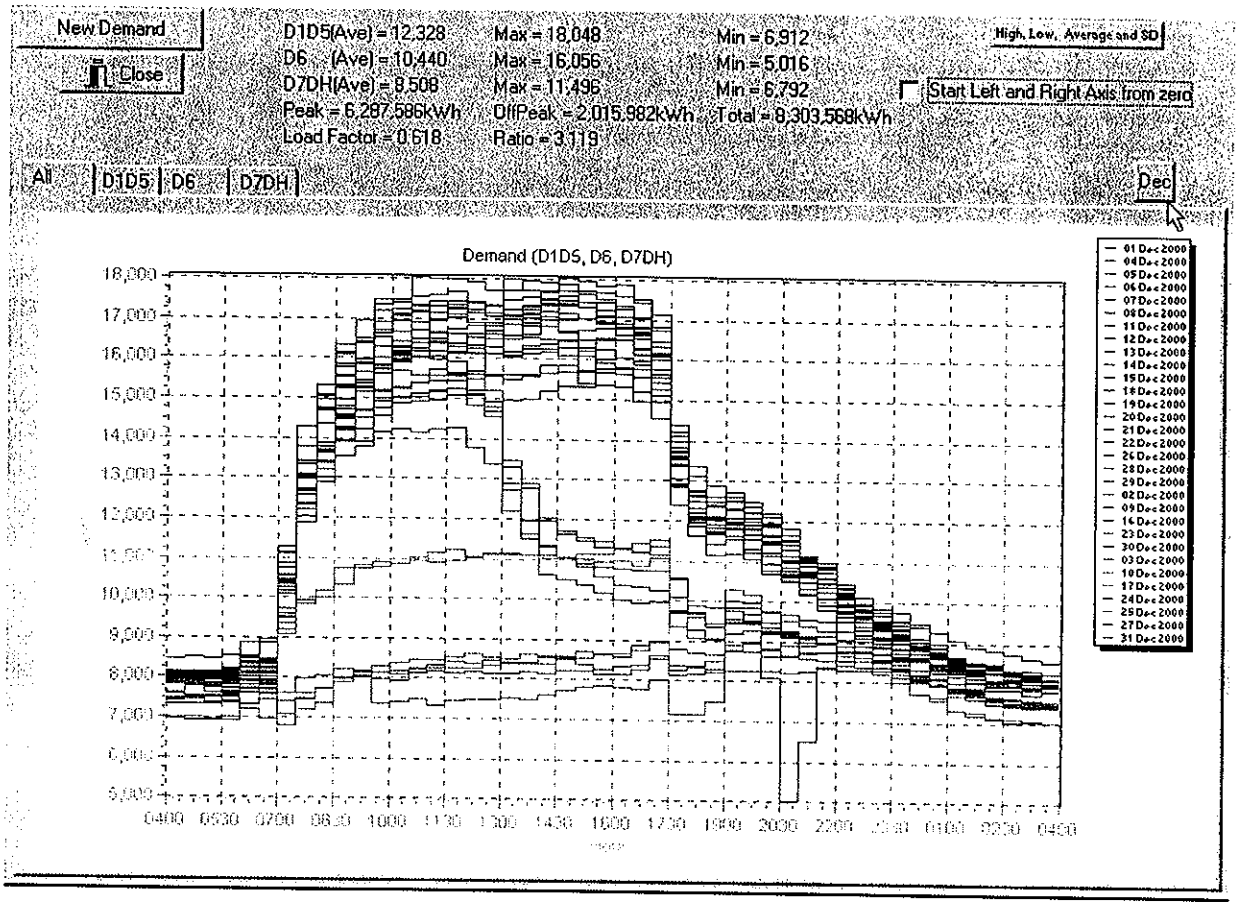
Month : Dec 2000 Power Factor : 0.90

Max Demand : 18,048.00 kW Reactive : 4,074,684.00 kVArh

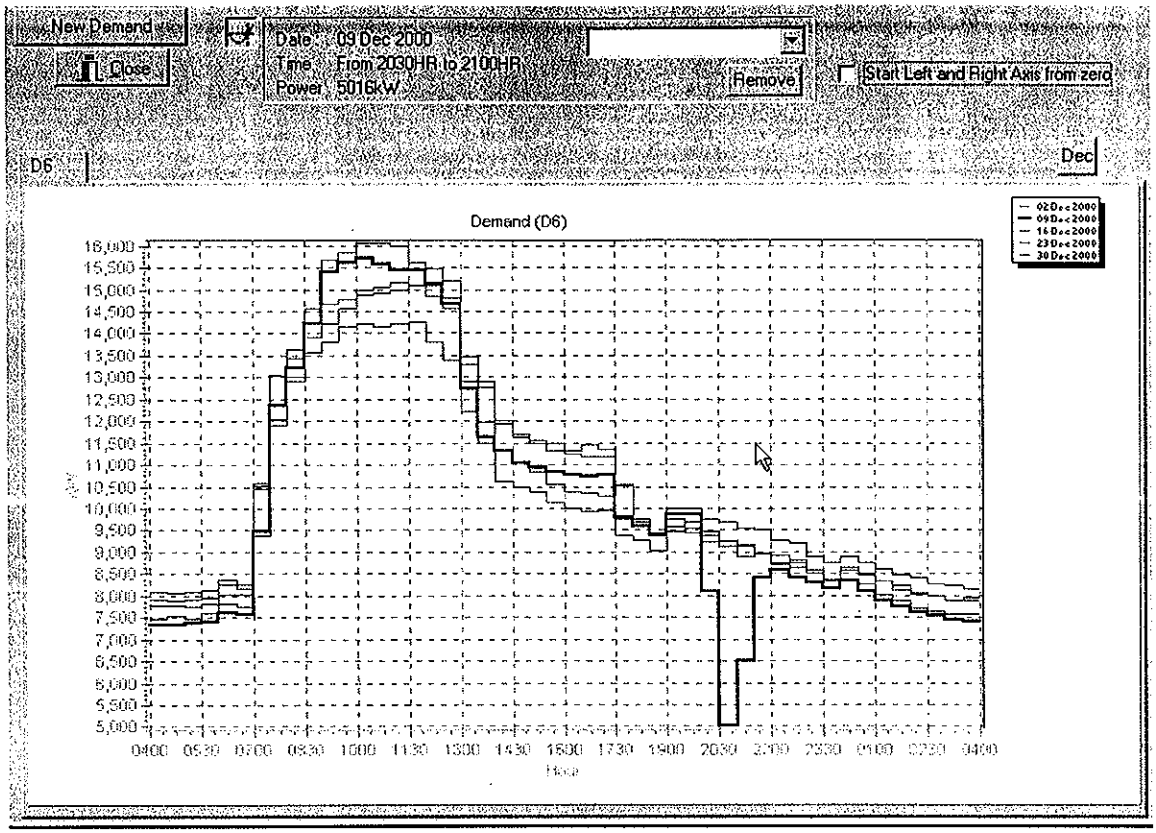
Energy Cost	Energy (MWH)	Cost ($)	2T Se Cost ($)	Difference	%	Flat Sem Cost ($)	Difference	%
Peak	6,287.586	$828,075.08	$660,196.53	-167,878.55	79.7	$647,621.36	-180,453.72	78.2
Off Peak 1	2,015.982	$221,354.82	$193,332.67	-28,022.15	87.3	$207,646.15	-13,708.67	93.8
Off Peak 2	0.000	$0.00	$0.00	0.00	NA	$0.00	0.00	NA
Total	8,303.568	$1,049,429.90	$853,529.20	-195,900.70	81.3	$855,267.50	-194,162.40	81.5
Average Energy (¢/kWh)		12.64	10.28			10.30		
Other Cost								
Contracted		$97,580.00	$96,600.00	-980.00	99.0	$96,600.00	-980.00	99.0
Uncontracted		$42,301.60	$41,896.80	-404.80	99.0	$41,896.80	-404.80	99.0
Reactive		$0.00	$0.00	0.00	NA	$0.00	0.00	NA
UOS Peak		$53,444.48	$53,444.48	0.00	100.0	$53,444.48	0.00	100.0
UOS Off Peak		$8,467.12	$8,467.12	0.00	100.0	$8,467.12	0.00	100.0
Total		$201,793.21	$200,408.41	-1,384.80	99.3	$200,580.79	-1,212.42	99.4
Utility Cost		$1,251,223.11	$1,053,937.61	-197,285.50	84.2	$1,055,848.29	-195,374.82	84.4
Average Energy (¢/kWh)		15.07	12.69			12.72		

Energy Cost	Energy (MWH)	Cost ($)	3T Tu Cost ($)	Difference	%	Ex-Antedb Cost ($)	Difference	%
Peak	6,287.586	$828,075.08	$750,079.79	-77,995.29	90.6	$1,183,238.11	355,163.03	142.9
Off Peak 1	2,015.982	$221,354.82	$198,574.23	-22,780.59	89.7	$219,950.89	-1,403.93	99.4
Off Peak 2	0.000	$0.00	$0.00	0.00	NA	$0.00	0.00	NA
Total	8,303.568	$1,049,429.90	$948,654.01	-100,775.89	90.4	$1,403,189.00	353,759.10	133.7
Average Energy (¢/kWh)		12.64	11.42			16.90		
Other Cost								
Contracted		$97,580.00	$96,600.00	-980.00	99.0	$96,600.00	-980.00	99.0
Uncontracted		$42,301.60	$41,896.80	-404.80	99.0	$41,896.80	-404.80	99.0
Reactive		$0.00	$0.00	0.00	NA	$0.00	0.00	NA
UOS Peak		$53,444.48	$53,444.48	0.00	100.0	$53,444.48	0.00	100.0
UOS Off Peak		$8,467.12	$8,467.12	0.00	100.0	$8,467.12	0.00	100.0
Total		$201,793.21	$200,408.41	-1,384.80	99.3	$200,408.41	-1,384.80	99.3
Utility Cost		$1,251,223.11	$1,149,062.42	-102,160.69	91.8	$1,603,597.41	352,374.30	128.2
Average Energy (¢/kWh)		15.07	13.84			19.31		

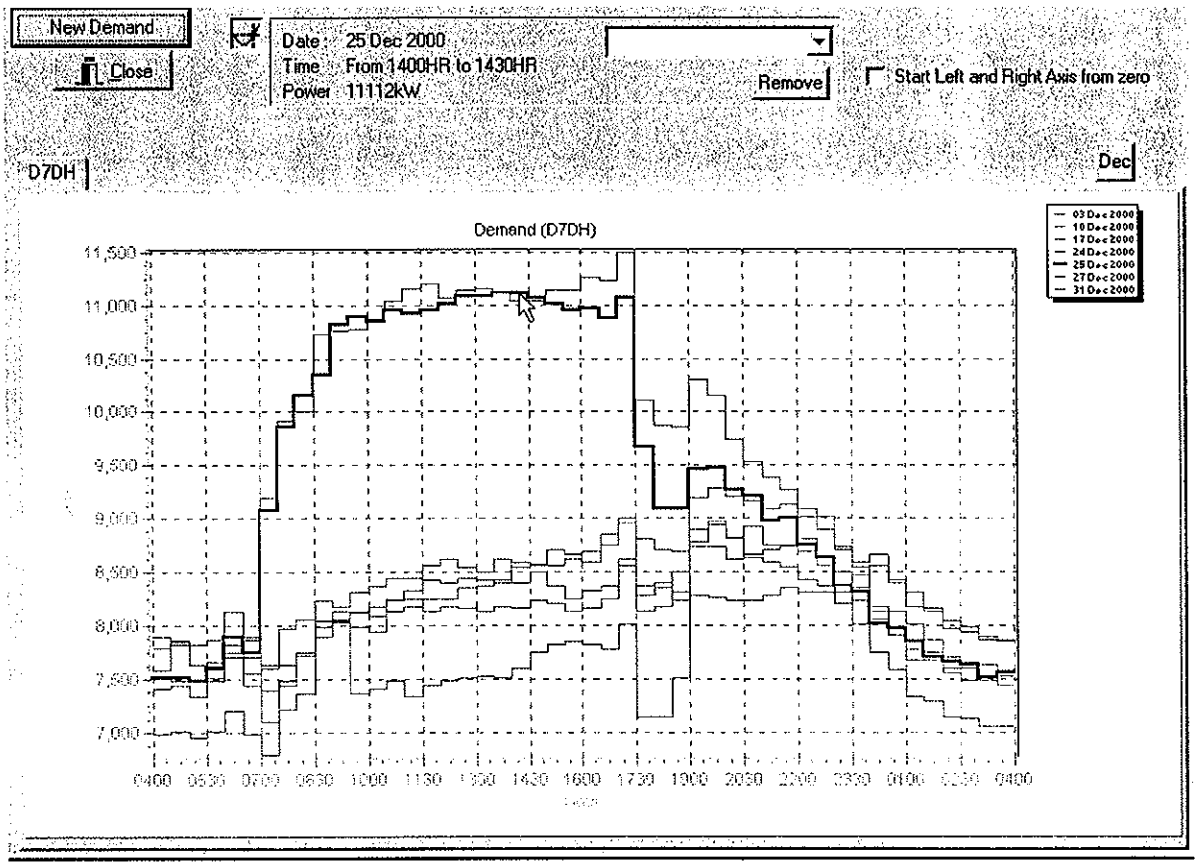

New Forecast
Close
D1D5(Ave) = 171.5625
D6 (Ave) = 127.3699
D7DH(Ave) = 119.7570
All(Ave) = 152.7367
Max = 795.2497
Max = 586.7733
Max = 273.9215
Max = 795.2497
Min = 15.9164
Min = 59.3364
Min = 81.0385
Min = 15.9164
Max, Min, Average and SD
Start Left and Right Axis from zero
All
D1D5
D6
D7DH
Dec
Pool Price (D1D5, D6, D7DH)
01 Dec 2000
04 Dec 2000
05 Dec 2000
06 Dec 2000
07 Dec 2000
08 Dec 2000
11 Dec 2000
12 Dec 2000
13 Dec 2000
14 Dec 2000
15 Dec 2000
18 Dec 2000
19 Dec 2000
20 Dec 2000
21 Dec 2000
22 Dec 2000
26 Dec 2000
28 Dec 2000
29 Dec 2000
02 Dec 2000
09 Dec 2000
16 Dec 2000
23 Dec 2000
30 Dec 2000
03 Dec 2000
10 Dec 2000
17 Dec 2000
24 Dec 2000
25 Dec 2000
27 Dec 2000
31 Dec 2000


New Demand
Close
D1D5(Ave) = 12,328
D6 (Ave) = 10,440
D7DH(Ave) = 8,508
Peak = 6,287.586kWh
Load Factor = 0.618
Max = 18,048
Max = 16,056
Max = 11,496
Diff Peak = 2,015.982kWh
Ratio = 3.119
Min = 6,912
Min = 5,016
Min = 6,792
Total = 8,303,568kWh
High, Low, Average and SD
Start Left and Right Axis from zero
All
D1D5
D6
D7DH
Dec
Demand (D1D5, D6, D7DH)

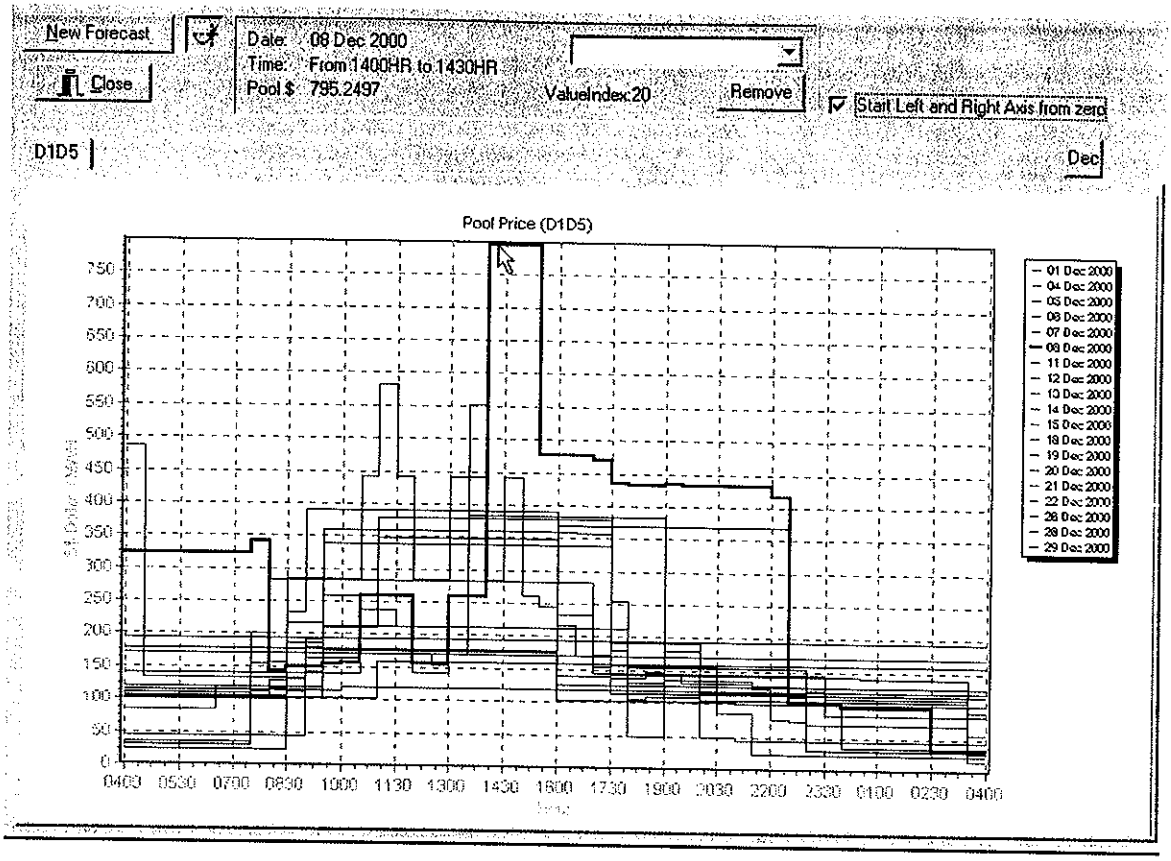
Find out which day and at what time the lowest load occurred



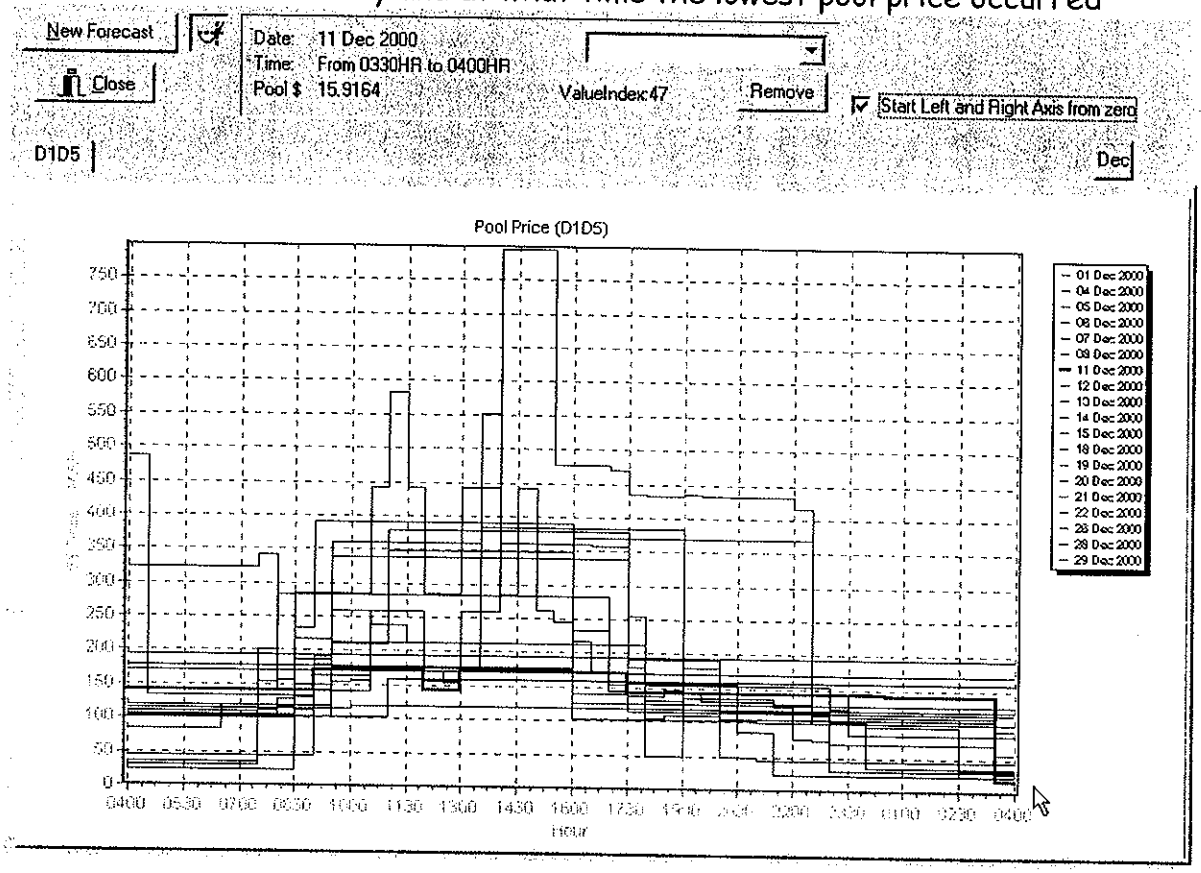
Find out why there is a special day



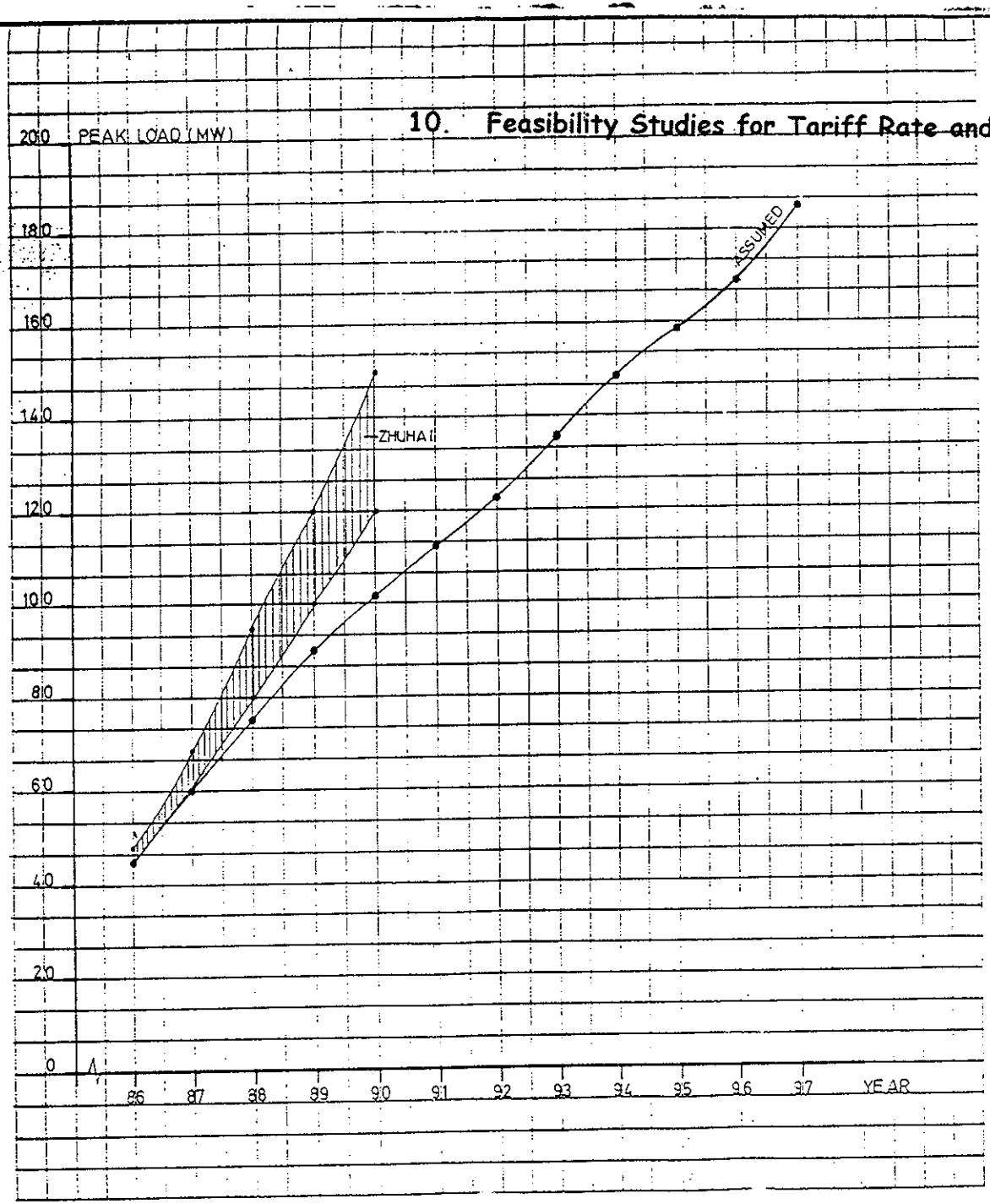
Find out which day and at what time the highest pool price occurred



Find out which day and at what time the lowest pool price occurred



10. Feasibility Studies for Tariff Rate and Investment

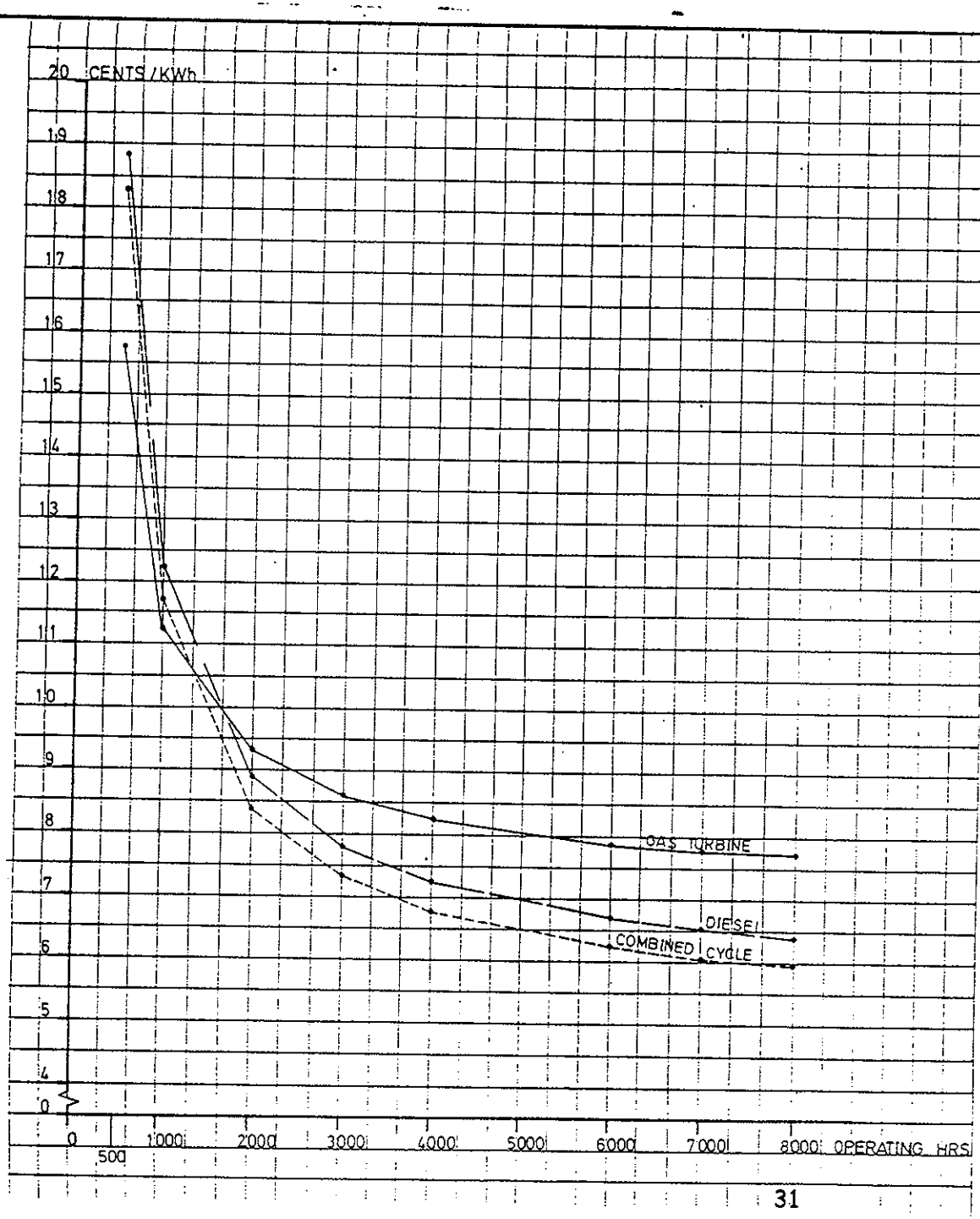


ESTIMATED MAXIMUM SYSTEM DEMAND

YEAR	PEAK LOAD (MW) ASSUMED	GIVEN BY ZHUHAI
1986	45	45 - 48
1987	60	60 - 68
1988	75	80 - 95
1989	90	100 - 120
1990	102	120 - 150
1991	112	NA
1992	123	NA
1993	135	NA
1994	148	NA
1995	159	NA
1996	169	NA
1997	185	NA

FEASIBILITY STUDY FOR POWER STATION IN ZHUHAI

DRAWING TITLE:
ESTIMATED MAXIMUM SYSTEM DEMAND.



GENERATION COST (CENTS/KWh) AT VARIOUS OPERATING HOURS PER YEAR

OPERATING HOURS	GAS TURBINE	COMBINED CYCLE	DIESEL PLANT
500	15.55	13.31	18.85
1000	11.39	11.70	12.23
2000	9.31	8.41	8.92
3000	8.62	7.30	7.81
4000	8.27	6.75	7.26
6000	7.92	6.20	6.71
7000	7.82	6.04	6.55
8000	7.75	5.92	6.43

GT US $247/kW 27.46 to 30.2 %

Com: US $440/kW 38.97 to 42.85 %

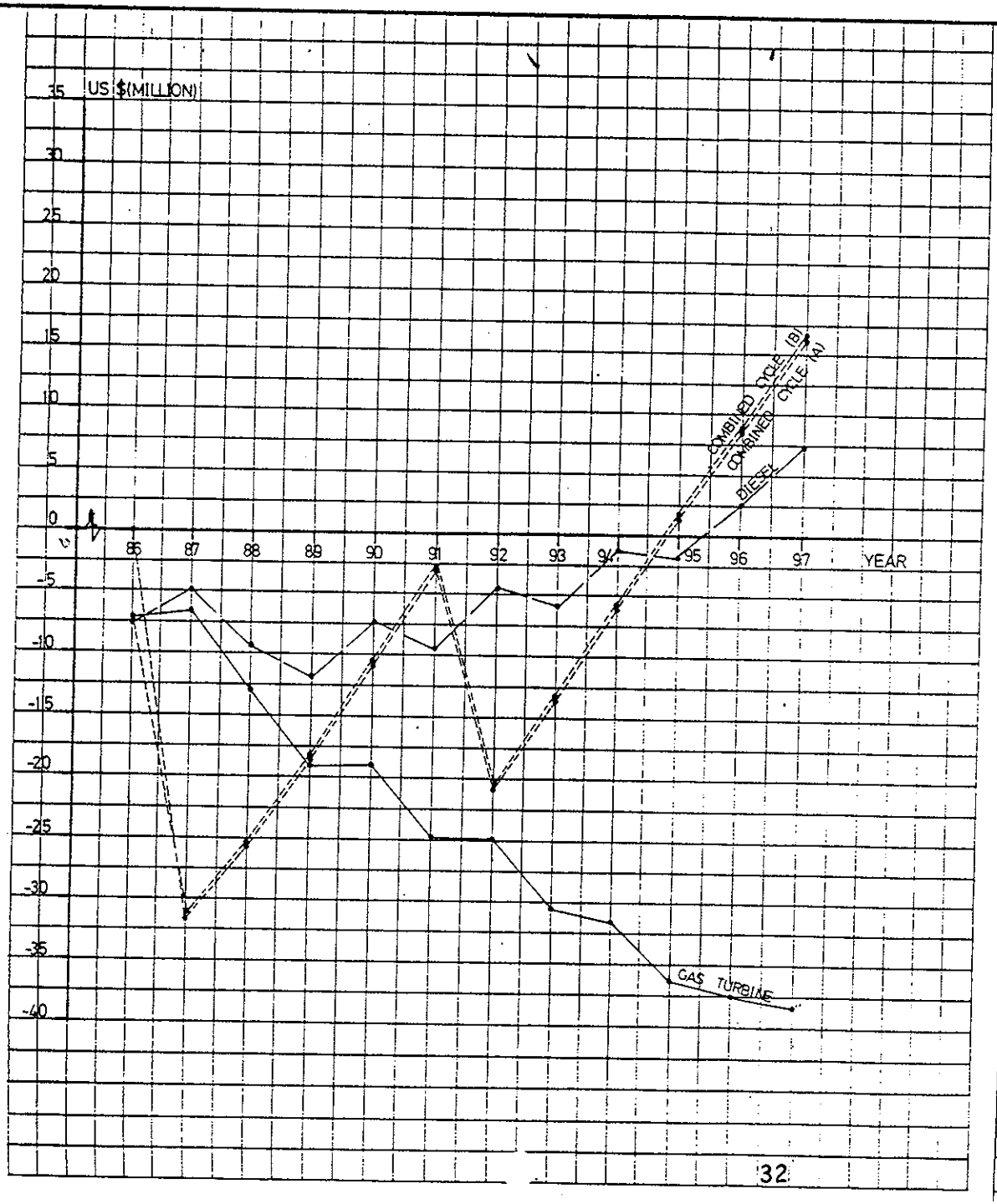
Diesel: US $ 326/kW 35.43 to 37.29%

Fuel price: US $250/MT

19500 BTU/lb

FEASIBILITY STUDY FOR POWER STATION IN ZHUHAI

DRAWING TITLE:
GENERATION COST (CENTS/KWh) AT VARIOUS OPERATING HOURS



OVERALL OBJECTIVE FUNCTION FOR VARIOUS PLANS

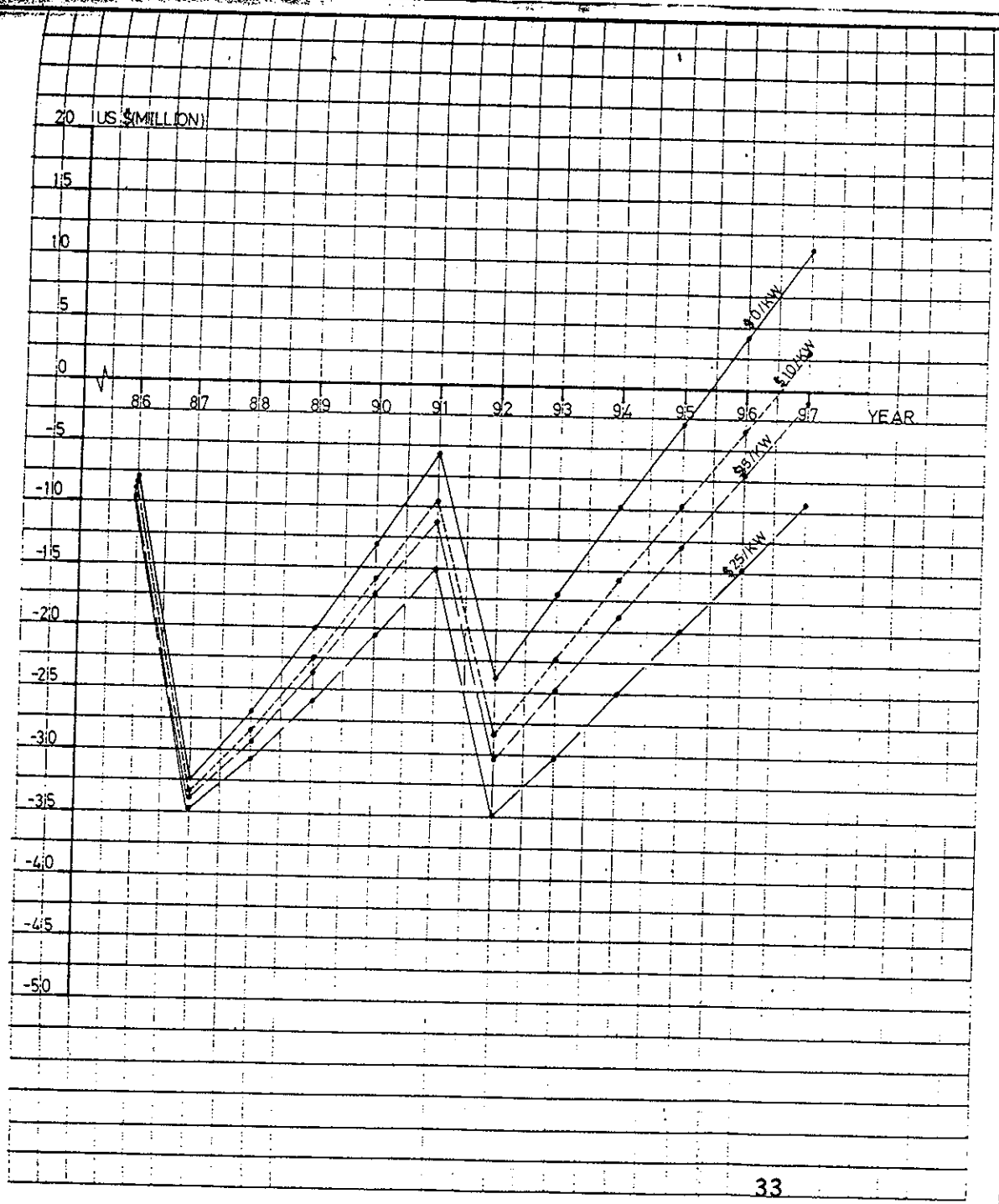
YEAR	GAS TURBINE	COMBINED CYCLE A	COMBINED CYCLE B	DIESEL
1986	-7.201	0	-7.201	-7.526
1987	-6.670	-31.681	-31.47	-4.992
1988	-12.788	-25.796	-25.588	-9.619
1989	-19.096	-18.674	-18.466	-12.032
1990	-18.972	-10.908	-10.700	-7.392
1991	-24.706	-3.137	-2.929	-9.473
1992	-24.934	-20.771	-20.563	-4.621
1993	-30.482	-13.597	-13.389	-6.059
1994	-31.454	-6.163	-5.955	-1.410
1995	-36.448	1.258	1.466	-2.006
1996	-37.543	8.664	8.872	+2.475
1997	-38.309	16.359	16.567	7.315

ASSUMPTION

TARIFF RATE = 7.5 CENTS/KWH
TRANSMISSION AND DISTRIBUTION LOSS = 0
GENERATION LOSS = 4%
A : WHOLE PLANT COMMISSIONED IN 1987
B : GAS TURBINE PORTION COMMISSIONED IN 1986

FEASIBILITY STUDY FOR POWER STATION IN ZHUHAI

DRAWING TITLE:
OVERALL OBJECTIVE FUNCTION FOR VARIOUS PLANS



OVERALL OBJECTIVE FUNCTION FOR DIFFERENT TRANSMISSION AND DISTRIBUTION COSTS.

YEAR	T&D COST IN $/KW/YEAR			
	0	10	15	25
1986	-7.688	-8.121	-8.337	-8.770
1987	-32.221	-33.188	-33.672	-34.640
1988	-26.732	-28.318	-29.111	-30.697
1989	-20.084	-22.358	-23.495	-25.768
1990	-12.844	-15.839	-17.337	-20.332
1991	-5.674	-9.403	-11.267	-14.996
1992	-23.687	-28.161	-30.399	-34.875
1993	-16.885	-22.117	-24.734	-29.966
1994	-9.836	-15.838	-18.839	-24.841
1995	-2.806	-9.569	-12.950	-19.713
1996	+4.189	-3.326	-7.084	-14.600
1997	+11.445	+3.162	-0.973	-9.253

ASSUMPTION:

TARIFF RATE = 8CENTS / KWh

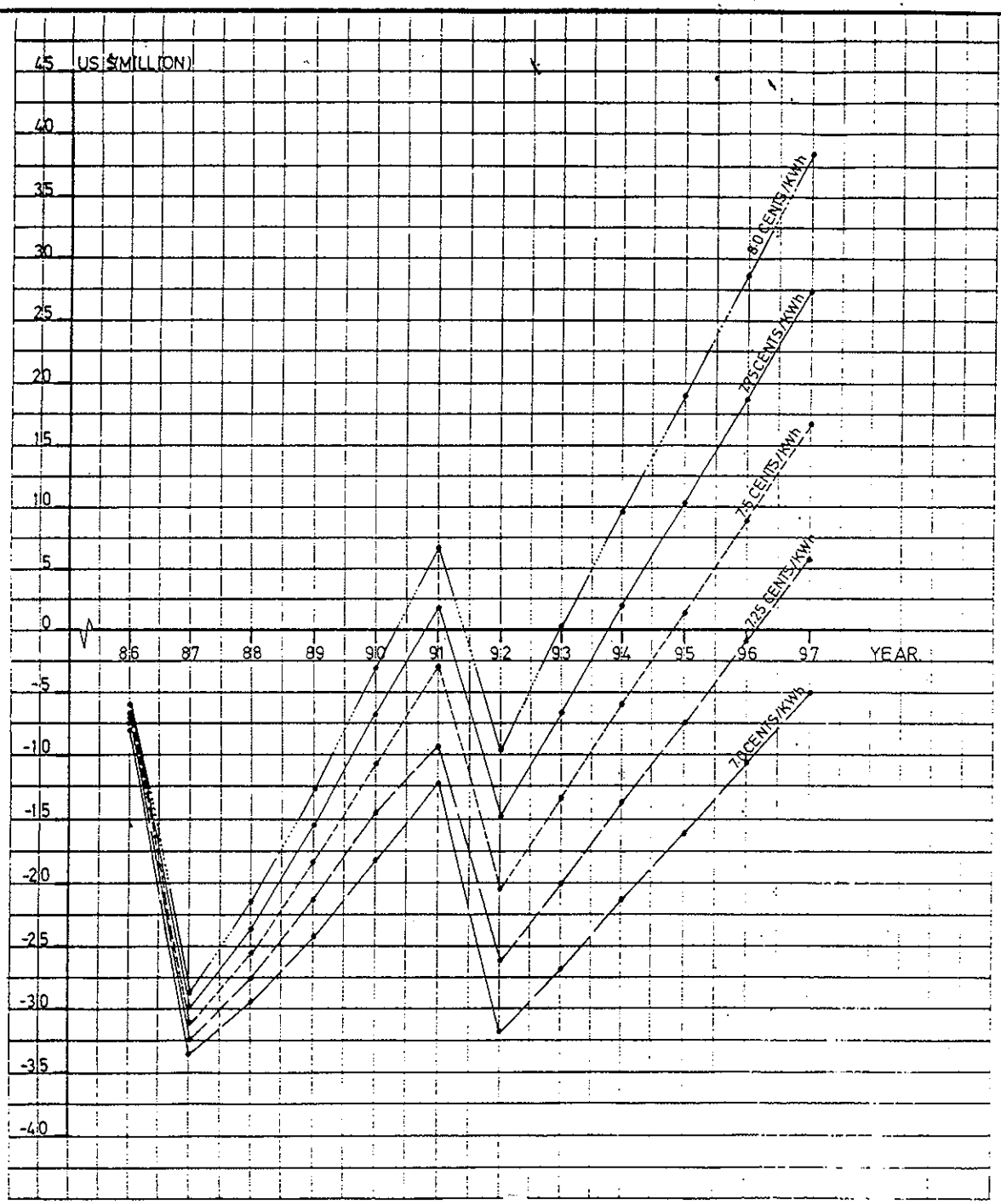
TRANSMISSION AND DISTRIBUTION LOSS = 7 %.

GENERATION LOSS = 4 %.

FEASIBILITY STUDY FOR POWER STATION IN ZHUHAI

DRAWING TITLE:

OVERALL OBJECTIVE FUNCTION FOR DIFFERENT TRANSMISSION AND



VARIATION OF OVERALL OBJECTION FUNCTION FROM TARIFF SENSITIVITY STUDY

YEAR	7.0¢/KWH	7.25¢/KWH	7.5¢/KWH	7.75¢/KWH	8.0¢/KWH
1986	-8.138	-7.670	-7.201	-6.733	-6.265
1987	-33.871	-32.672	-31.473	-30.274	-29.075
1988	-29.611	-27.600	-25.588	-23.577	-21.566
1989	-24.273	-21.369	-18.466	-15.562	-12.659
1990	-18.346	-14.523	-10.700	-6.878	-3.055
1991	-12.370	-7.650	-2.929	+1.790	+6.510
1992	-32.097	-26.330	-20.563	-14.796	-9.029
1993	-26.948	-20.168	-13.389	-6.609	+0.170
1994	-21.562	-13.758	-5.955	+1.348	+9.652
1995	-16.152	-7.343	+1.466	10.275	19.084
1996	-10.713	-0.920	8.872	18.665	28.458
1997	-4.934	+5.791	16.567	27.343	38.119

ASSUMPTION:

SALVAGE VALUE = 0

TRANSMISSION AND DISTRIBUTION LOSS = 0

TRANSMISSION AND DISTRIBUTION COST = 0

GENERATION LOSS = 4 %.

FEASIBILITY STUDY FOR POWER STATION IN ZHUHAI

DRAWING TITLE:
VARIATION OF OVERALL OBJECTIVE FUNCTION FROM TARIFF SENSITIVITY STUDY.

11. Conclusion

☺ If the offer **flat** rate equal or lower than TCY energy cost, the proposal should be accepted without any hesitation. However for multi-tier tariff, some of the off peak tariff may be lower than TCY cost as TCY cost is calculated based on a monthly average rate. For comparison, the ratio of the peak and off peak energy of your monthly demand can be estimated and a weighted flat rate can be used to compare.

☺ Offer price identical to pool price may not be necessary be a good option

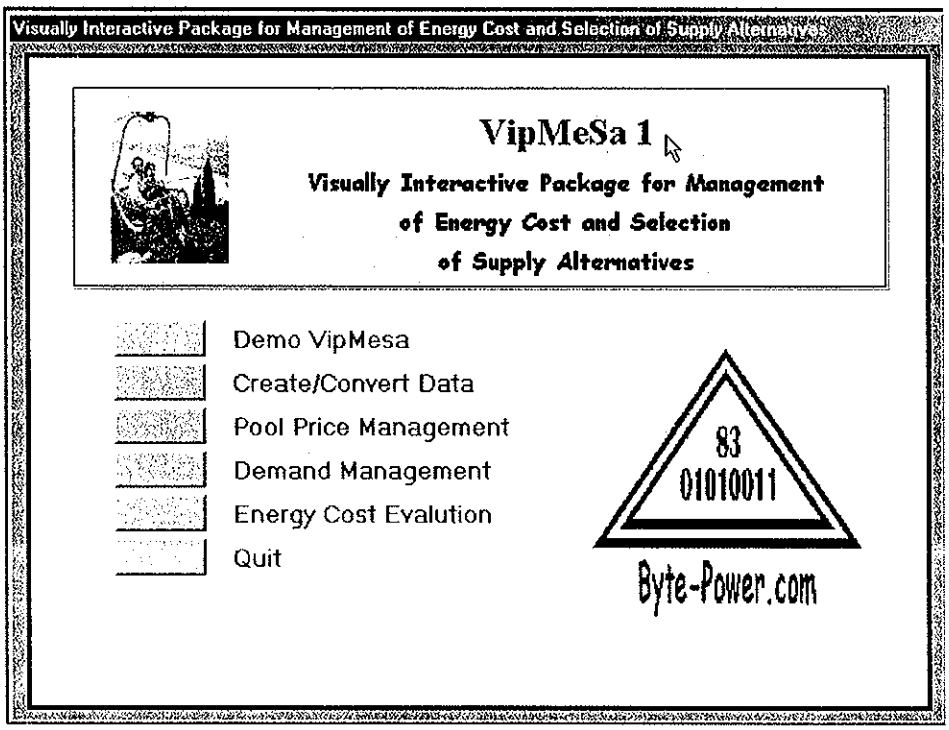
☺ Should not simply based on the energy charge on cents per kWh for 2T or 3T duration, any other non-standard charge should be added in the total consideration and a simulation is required to calculate the monthly cost and average monthly unit cost in cents per kWh for comparisons.

☺ Appoint technical consultant to simulate and compare the total cost and average unit cost for each proposal from supply retailers with special attention to the sensitivity studies of the cost of fuel oil and exchange rate. The consulting fee is only a negligible percentage of the total monthly utility cost.

☺ These totally neutral and un-biased studies can be used to verify and compare the calculation given by any retailers.

Proposed studies to Model Energy cost and Evaluate Supply Alternatives

- Pool Price Analysis for years 2000 and 2001
- Review of current demand and forecast of demand for the next 6 months
- Create data file for pool price and various supply alternatives
- Ranking of unit cost from various supply alternatives
- Detailed modeling and comparison of energy costs from various options
- Sensitivity studies for fuel price adjustment and demand variation
- Recommendation



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