

**PUBLIC UTILITIES COMMISSION OF SRI LANKA**

**HEAT RATES OF THERMAL  
POWER PLANTS IN SRI LANKA**

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**JANUARY 2014**

This report consists of information on Heat Rates of thermal power plants in Sri Lanka.

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# **1 INTRODUCTION**

## **1.1 General**

Conducting Heat Rate tests for thermal power plant in Sri Lanka is a corporate plan activity of Public Utilities Commission of Sri Lanka (PUCSL). Under this activity, all the thermal power plants were studied with a basic Heat Rate test, covering the usual dispatch patterns of them.

Thermal Power plants owned by Ceylon Electricity Board (CEB) as well as thermal power plants operating under Independent Power Producers (IPPs) were taken into consideration in this assignment.

## **1.2 Approach**

A brief description of the procedure followed during the Heat Rate tests is given below.

### **Meters:**

Due to the unavailability of calibrated meters with PUCSL, the installed electricity meters and fuel flow meters at the respective premises were used to take readings.

### **Fuel Data:**

Fuel data (density, calorific value, temperature corrections, etc.) are principle requirements for the calculation of Heat Rates. Some of the IPPs sent fuel samples collected during the Heat Rate test to laboratories at their own cost, to get the required fuel data. Those data were used for the calculation of the Heat Rates of respective IPPs.

For other power plants, of which fuel samples had not been sent to laboratories, the fuel data in specifications of Ceylon Petroleum Corporation were used for the calculations of the respective Heat Rates.

### **Stabilization before the Test:**

All the generators were run for a sufficient period before starting to take readings, allowing the generators to be stabilized.

Further for some of the generators part load tests were carried out. At such instances, the generators were allowed to be stabilized at each of the part load stages.

**Involvement of an Independent agent:**

All the conducted Heat Rate tests were done under the supervision of the officers of PUCSL. However for some of the new power plants, commissioning reports prepared by independent parties were available. Therefore, details related to Heat Rates in those reports were accepted without conducting separate Heat Rate tests.

## **2 POWER PLANTS OWNED BY CEB**

Heat Rate tests were conducted under the supervision of PUCSL for the following power stations owned by CEB.

1. Kelanitissa Power Station (Gas Turbines and a combined cycle power station)
2. Sapugaskanda Power Station (heavy fuel)

Further, PUCSL received performance test results of the following power stations owned by CEB.

1. Lakvijaya Power Plant (coal)
2. Jaffna Power Plant (heavy fuel)

Since the tests had been conducted during the commissioning of those power stations, those informations were accepted by PUCSL. Therefore Heat Rate tests were not conducted for these plants under the supervision of PUCSL.

### **2.1 Kelanitissa Power Station**

Kelanitissa Power Station consists of 7 Gas Turbines (GT) (six 17MW GTs; one 115 MW GT) and a combined cycle power plant of capacity 165 MW.

- Heat Rate tests were conducted for a sample consisted of GT 02, GT 03, GT 04 and GT 05, representing small GTs.
- Also a Heat Rate test was carried out for the combined cycle power station.

For the calculations it was assumed that the calorific value of the fuel to be 10500 kcal/kg. Further it was assumed that the density of the fuel to be  $840 \text{ kgm}^{-3}$ , at  $15^{\circ}\text{C}$  for GTs and  $870 \text{ kgm}^{-3}$ , at  $15^{\circ}\text{C}$  for the combined cycle power plant.

### 2.1.1 GT 02

Table 1 shows the results of GT 02 and the Figure 1 depicts the results in graphical form.

Loading (MW) (Full load -17 MW)	Heat Rate (kcal/kWh)	Efficiency
6	6312.66	13.58%
8	5486.88	15.62%
10	4738.98	18.09%
12	4277.92	20.04%

Table 1: Results – GT 02, Kelanitissa

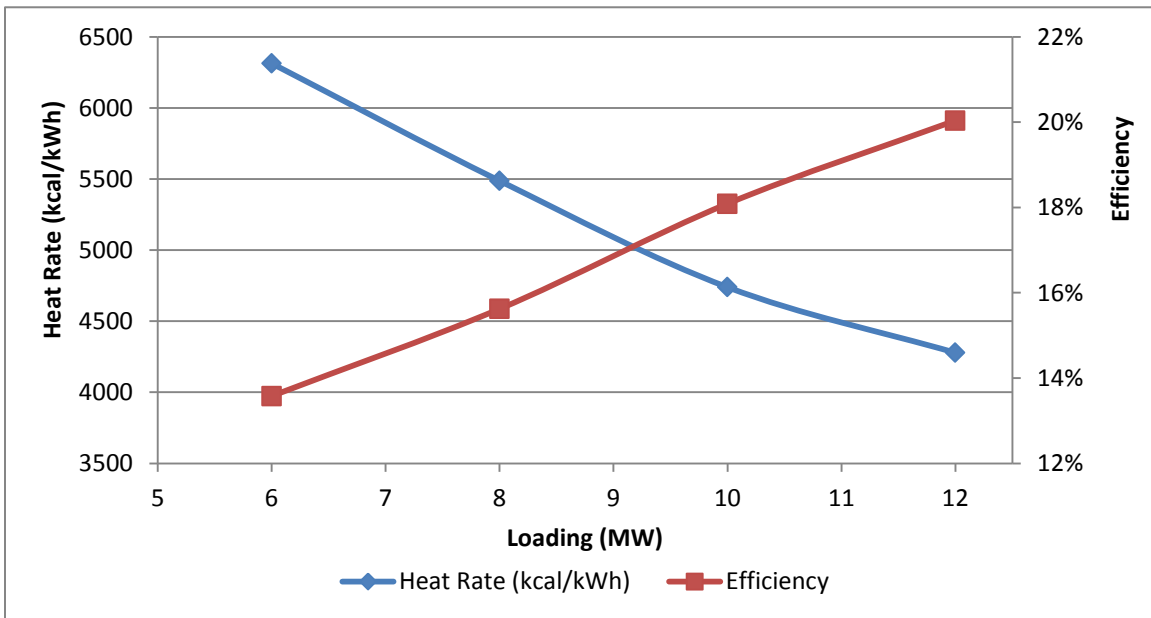


Figure 1: Results – GT 02, Kelanitissa

### 2.1.2 GT 03

Table 2 shows the results of GT 03 and the Figure 2 depicts the results in graphical form.

Loading (MW) (Full load -17 MW)	Heat Rate (kcal/kWh)	Efficiency
8	5555.76	15.43%
10	4956.19	17.29%
12	4554.47	18.82%
14	4084.59	20.98%

Table 2: Results – GT 03, Kelanitissa

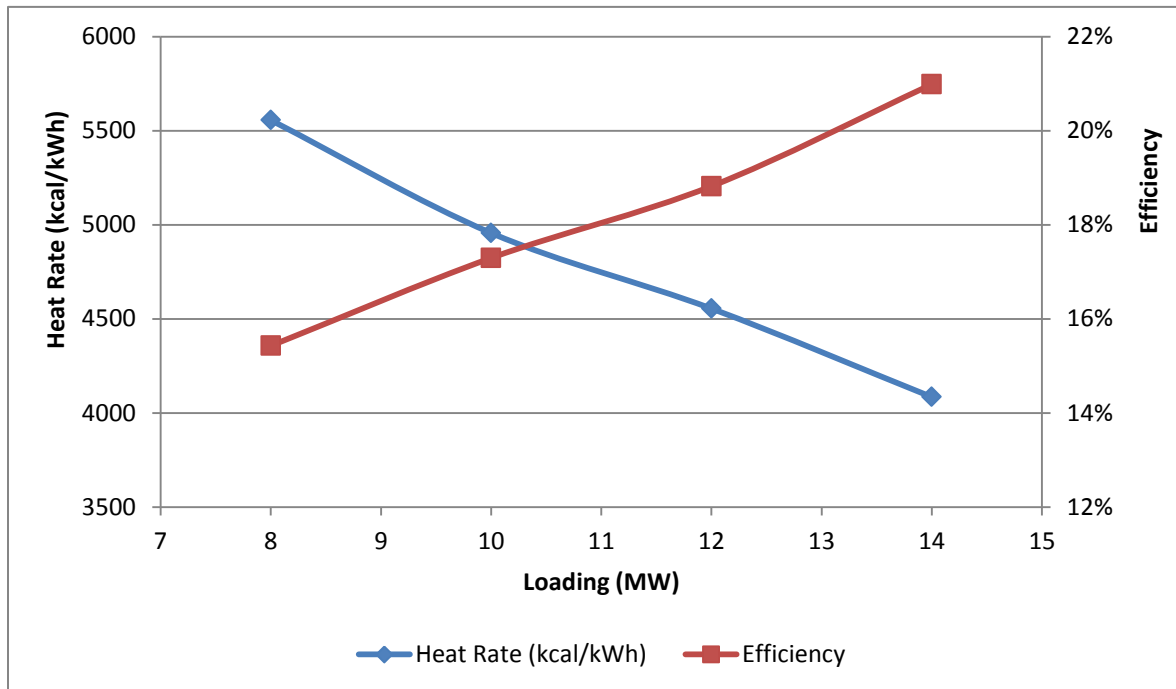


Figure 2: Results – GT 03, Kelanitissa



### 2.1.3 GT 04

Table 3 shows the results of GT 04 and the Figure 3 depicts the results in graphical form.

Loading (MW) (Full load -17 MW)	Heat Rate (kcal/kWh)	Efficiency
10	4914.11	17.44%
12	5209.22	16.45%
15	4319.54	19.84%
17	3980.79	21.53%

Table 3: Results – GT 04, Kelanitissa

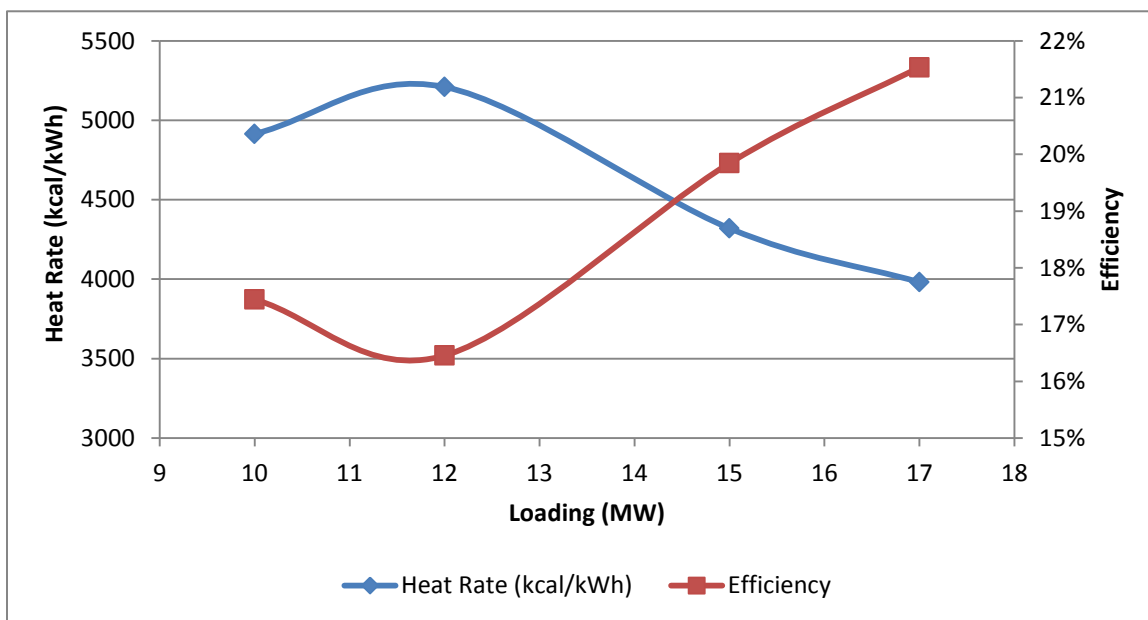


Figure 3: Results – GT 04, Kelanitissa

## 2.1.4 GT 05

Table 4 shows the results of GT 05 and the Figure 4 depicts the results in graphical form.

Loading (MW) (Full load -17 MW)	Heat Rate (kcal/kWh)	Efficiency
10	4867.96	17.61%
12	4464.37	19.20%
15	3989.25	21.49%
17	3992.06	21.47%

Table 4: Results – GT 05, Kelanitissa

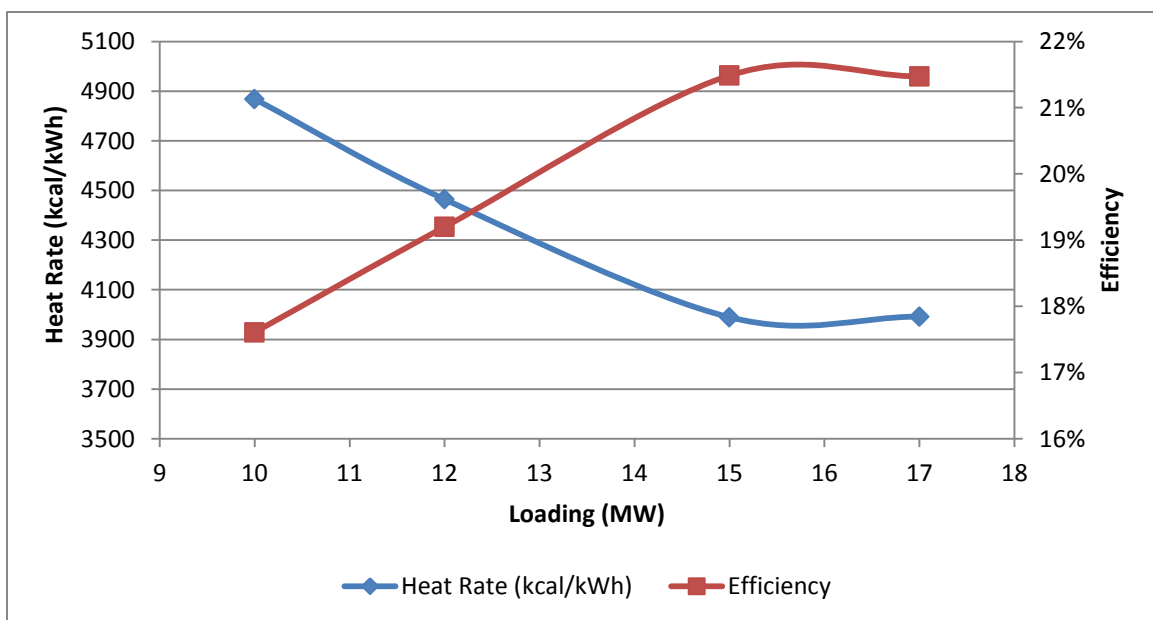


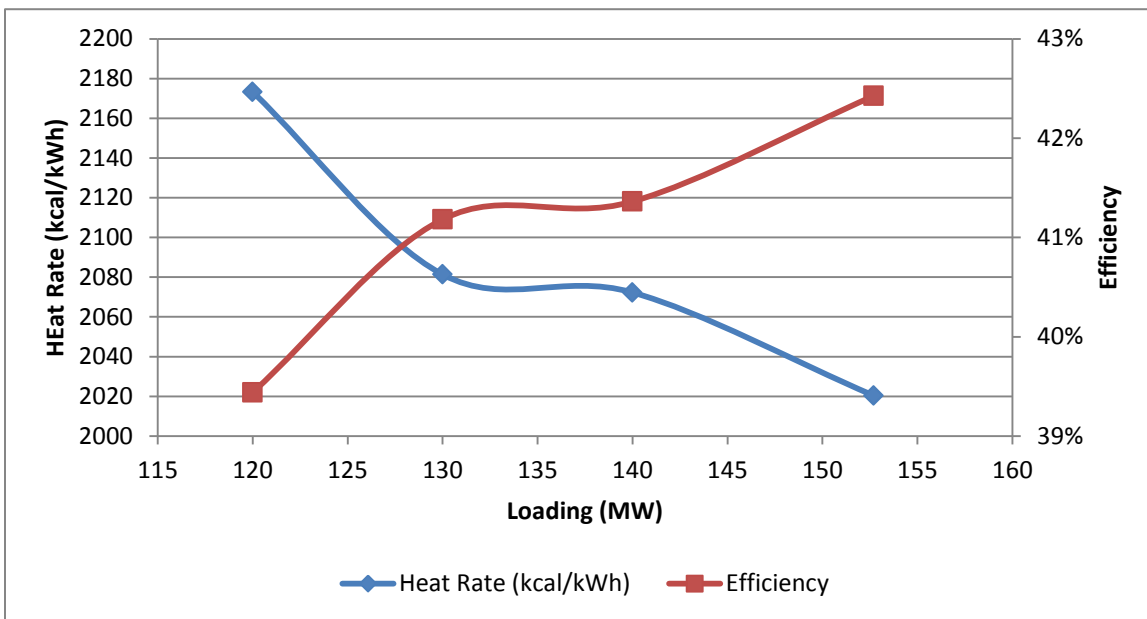
Figure 4: Results – GT 05, Kelanitissa

### 2.1.5 Combined Cycle Power Plant

Table 5 shows the results of Combined Cycle Power Plant and the Figure 5 depicts the results in graphical form.

Loading (MW) (Full load -165 MW)	Heat Rate (kcal/kWh)	Efficiency
120	2173	39.44%
130	2081	41.18%
140	2072	41.36%
152.7	2020	42.43%

**Table 5: Results – Combined Cycle Power Plant, Kelanitissa**



**Figure 5: Results – Combined Cycle Power Plant, Kelanitissa**

## 2.2 Sapugaskanda Power Station

Sapugaskanda Power Station consists of four 20 MW generators and eight 10MW generators run on heavy fuel oil.

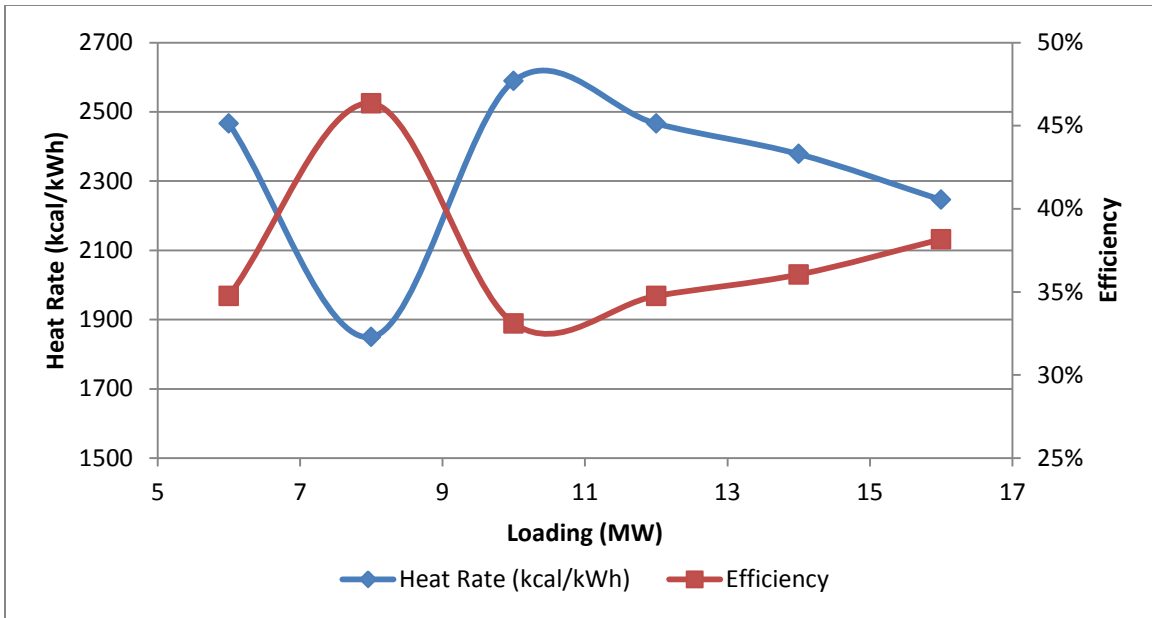
- There are four generators (Generator 1 to Generator 4) each having the capacity of 20MW. From these four, only the Generator 04 was available for the test since others were under maintenance.
- There are eight generators (Generator 5 to Generator 12) each having the capacity of 10MW. A sample of 4 generators was selected for the test. They are Generator 07, Generator 08, Generator 11 and Generator 12.
- For the calculations it was assumed that the calorific value of the fuel to be 10500 kcal/kg and density of the fuel to be  $962.2 \text{ kgm}^{-3}$ , at  $15^{\circ}\text{C}$ .

### 2.2.1 Generator 03

Table 6 shows the results of Generator 03 and the Figure 6 depicts the results in graphical form.

<b>Loading (MW) (Full load - 20 MW)</b>	<b>Heat Rate (kcal/kWh)</b>	<b>Efficiency</b>
6	2466.07	34.76%
8	1849.55	46.34%
10	2589.38	33.10%
12	2466.07	34.76%
14	2378.00	36.04%
16	2245.89	38.17%

**Table 6: Results – Generator 03, Sapugaskanda**



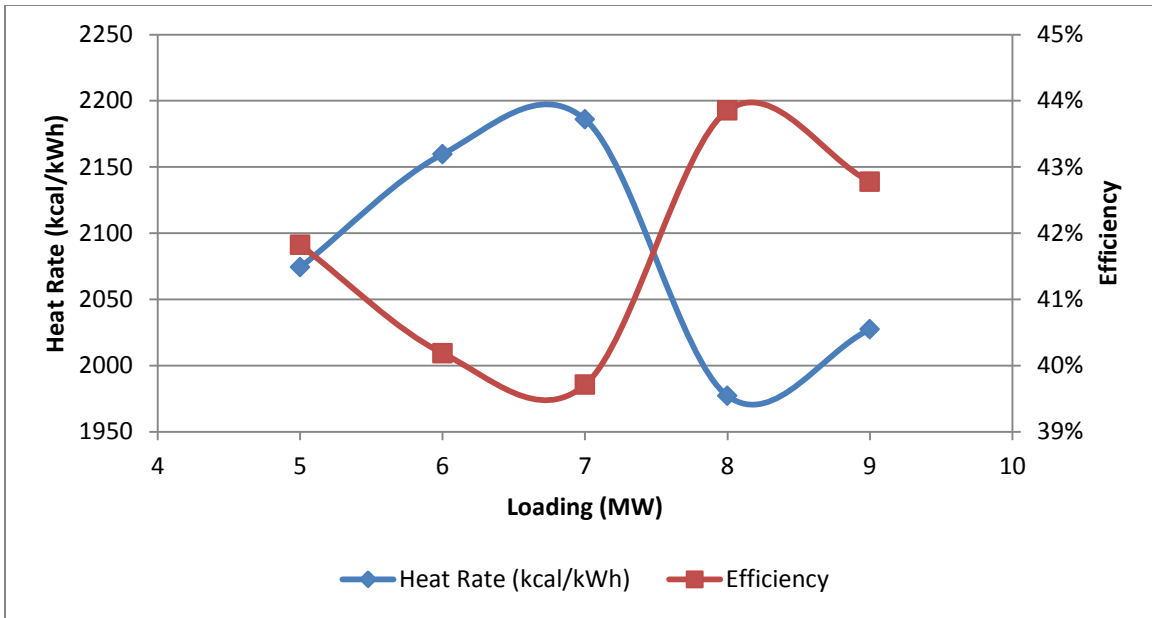
**Figure 6: Results – Generator 03, Sapugaskanda**

### 2.2.2 Generator 07

Table 7 shows the results of Generator 07 and the Figure 7 depicts the results in graphical form.

<b>Loading (MW) (Full load - 10 MW)</b>	<b>Heat Rate (kcal/kWh)</b>	<b>Efficiency</b>
5	2074.22	41.32%
6	2159.73	39.69%
7	2185.92	39.21%
8	1977.14	43.35%
9	2027.39	42.28%

**Table 7: Results – Generator 07, Sapugaskanda**



**Figure 7: Results – Generator 07, Sapugaskanda**

### 2.2.3 Generator 08

Table 8 shows the results of Generator 08 and the Figure 8 depicts the results in graphical form.

<b>Loading (MW) (Full load - 10 MW)</b>	<b>Heat Rate (kcal/kWh)</b>	<b>Efficiency</b>
5	2077.98	41.25%
6	2071.71	41.37%
7	1976.55	43.37%
8	1992.64	43.02%
9	2026.18	42.30%

**Table 8: Results – Generator 08, Sapugaskanda**

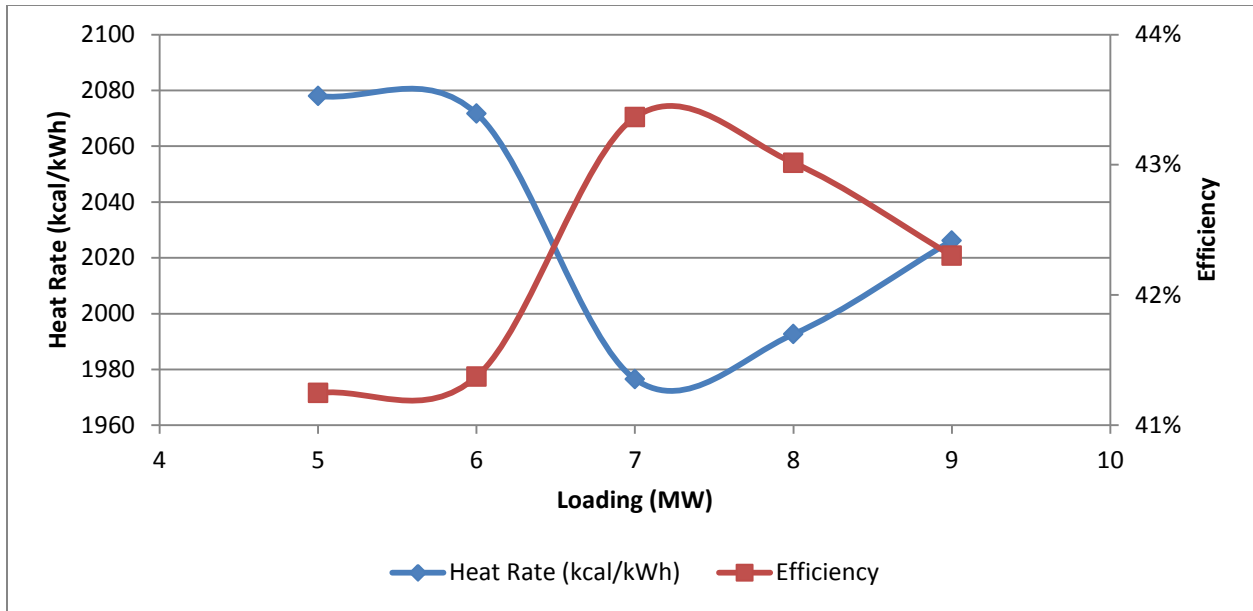


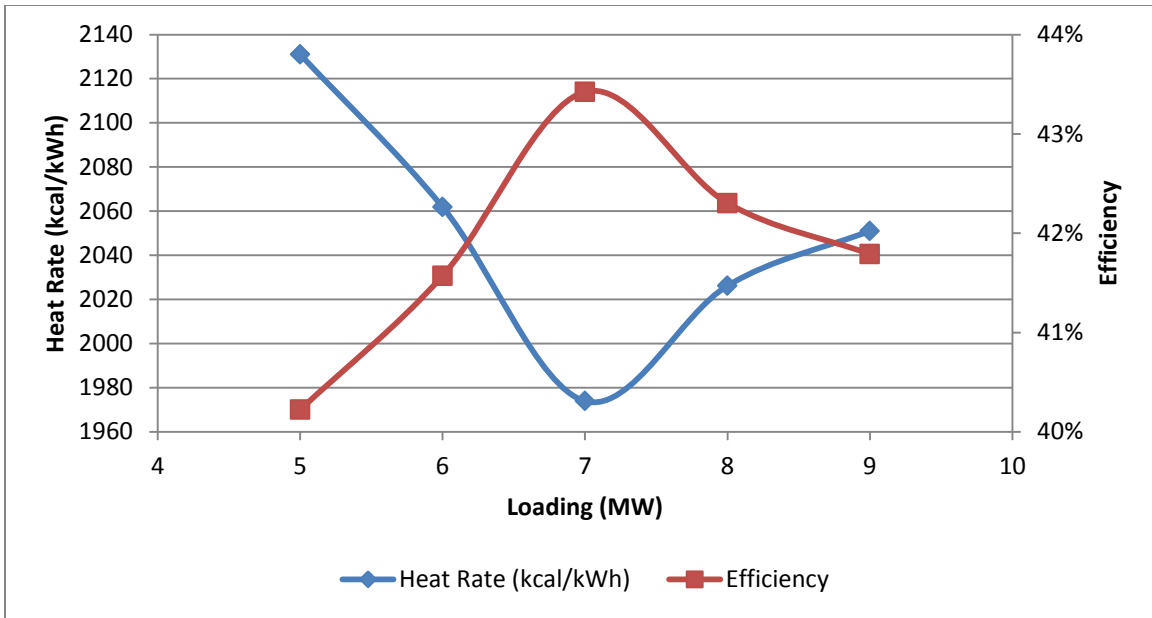
Figure 8: Results – Generator 08, Sapugaskanda

## 2.2.4 Generator 11

Table 9 shows the results of Generator 11 and the Figure 9 depicts the results in graphical form.

Loading (MW) (Full load - 10 MW)	Heat Rate (kcal/kWh)	Efficiency
5	2131.03	40.22%
6	2061.86	41.57%
7	1973.90	43.42%
8	2026.20	42.30%
9	2051.04	41.79%

Table 9: Results – Generator 11, Sapugaskanda



**Figure 9: Results – Generator 11, Sapugaskanda**

### 2.2.5 Generator 12

Table 10 shows the results of Generator 12 and the Figure 10 depicts the results in graphical form.

<b>Loading (MW)</b> <b>(Full load - 10 MW)</b>	<b>Heat Rate</b> <b>(kcal/kWh)</b>	<b>Efficiency</b>
5	2063.23	41.54%
6	2011.83	42.61%
7	2014.81	42.54%
8	2077.47	41.26%
9	1962.96	43.67%

**Table 10: Results – Generator 12, Sapugaskanda**



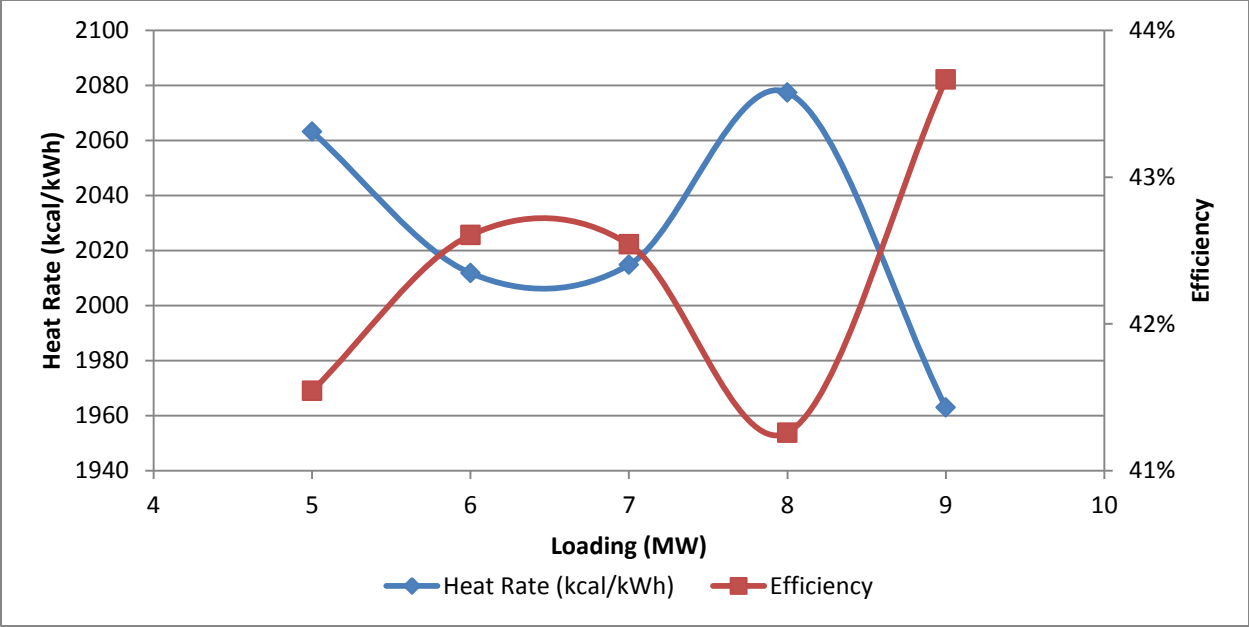


Figure 10: Results – Generator 12, Sapugaskanda

### 2.3 Lakvijaya Power Station

Lakvijaya power station has a 300 MW generator run on coal.

PUCSL received the Performance test general report prepared by The Commissioning and Test Institute of Sichuan Electric Power Industry. The report has been compiled in May 2012.

According to the report,

- Rated value of turbine Heat Rate = 7984 kJ/kWh
- Test Results for turbine Heat Rate = 7951.22 kJ/kWh (1900.34 kcal/kWh)

### 2.4 Jaffna Power Plant (heavy fuel)

Jaffna power station has 3 generators, 8 MW each run on heavy fuel.

PUCSL received the efficiency test report prepared by Lakdhanavi Limited, during commissioning of the plant. The report has been compiled on 22<sup>nd</sup> March 2013.

All the machines were tested at 100% (maximum continuous rating) with Power Factor = 0.8. Table xxx gives the test results. The report gives Specific Fuel Consumption values. Those values were used to calculate the Heat Rate values assuming that the calorific value of the fuel to be 44217 kJ/kg.

Table 11 shows the results.

DG set	Specific Fuel Consumption (SFC) (kg/kWh) – Given in the Report	Heat Rate (kcal/kWh) (Calculated)
DG 01	0.2068	2185.43
DG 02	0.2052	2168.53
DG 03	0.2063	2180.15
<b>Total Plant</b>	<b>0.2061</b>	<b>2178.04</b>

Table 11: Details – Jaffna Power plant

### 3 Heat Rate Tests of Independent Power Producers (IPPs)

Heat Rate tests for IPPs were conducted under the supervision of PUCSL.

#### 3.1 Asia Power (Private) Limited

**General:**

There are 8 machines, each 6.35 MW. These Machines usually do not run on partial loads when dispatched. Therefore following plan was used for the test.

- a. Heat Rate Test was done individually for all 8 machines.
- b. Only the Heat Rates at full running capacity (6.35 MW) were examined.

**Date:**

31<sup>st</sup> October 2013

**The test results and other information:**

- Generator No.4 and Generator No.8 were not ready for the test.
- Table 12 shows the results.

<b>Generator</b>	<b>Heat Rate (kcal/kWh)</b>	<b>Remarks</b>
Generator 1	1944.67	
Generator 2	1934.76	
Generator 3	1944.78	
Generator 4	Not done	Due to a breakdown
Generator 5	654.05	Not Reliable
Generator 6	1927.61	
Generator 7	1894.57	
Generator 8	Not done	Due to a breakdown
<b>Total Plant</b>	<b>1929.24</b>	<b>(Excluding Gen 05)</b>
<b>Average</b>	<b>1929.28</b>	<b>(Excluding Gen 05)</b>
<b>Standard deviation</b>	<b>20.70</b>	<b>(Excluding Gen 05)</b>

Table 12: Results – Asia Power

### 3.2 Colombo Power (Private) Limited

**General:**

There are 4 machines, each 15 MW. These Machines usually do not run on partial loads when dispatched. Therefore following plan was used for the test.

- a. Heat Rate Test was done individually for all 4 machines.
- b. Only the Heat Rates at full running capacity (15 MW) were examined.

**Date:**

22<sup>nd</sup> October 2013

**The test results and other information:**

Table 13 shows the results.

<b>Generator</b>	<b>Heat Rate (kcal/kWh)</b>	<b>Remarks</b>
Generator 1	2048.66	
Generator 2	2030.71	
Generator 3	2047.02	
Generator 4	2038.04	
<b>Total Plant</b>	<b>2041.11</b>	

**Table 13: Results – Colombo power**

### 3.3 Ace Power Embilipitiya (Private) Limited

**General:**

There are 14 machines, each 7 MW. These Machines usually do not run on partial loads when dispatched. Therefore following plan was used for the test.

- a. Heat Rate Test was done individually for all 14 machines.
- b. Only the Heat Rates at full running capacity (7 MW) were examined.

**Date:**

23<sup>rd</sup> October 2013

**The test results and other information:**

- Generator No.11 was not ready for the test.
- A sample of fuel oil was sent to DNV to test for fuel parameters. The results of that report were used for the calculation.

Table 14 shows the results.

<b>Generator</b>	<b>Heat Rate (kcal/kWh)</b>	<b>Remarks</b>
Generator 1	2047.52	
Generator 2	2098.49	
Generator 3	2066.59	
Generator 4	2057.67	
Generator 5	2061.26	
Generator 6	2072.71	
Generator 7	2083.82	
Generator 8	2060.32	
Generator 9	2082.88	
Generator 10	2203.35	Comparatively High
Generator 11	Not Done	Due to a breakdown
Generator 12	2061.55	
Generator 13	2073.70	
Generator 14	2073.70	
<b>Total Plant</b>	<b>2073.54</b>	<b>Excluding Gen 10</b>
<b>Average</b>	<b>2070.29</b>	<b>Excluding Gen 10</b>
<b>Standard deviation</b>	<b>13.31</b>	<b>Excluding Gen 10</b>

**Table 14: Results – ACE power Embilipitiya**

### 3.4 AES Kelanitissa (Private) Limited

#### General:

The capacity of the plant is 163 MW, a combined cycle gas turbine power plant. Followings were the plan used for the test.

- The plant, running at 65% of the full capacity.
- The plant, running at 75% of the full capacity.
- The plant, running at 85% of the full capacity.
- The plant, running at 100% of the full capacity.

#### Date:

8<sup>th</sup> November 2013

#### The test results and other information:

- A sample of fuel oil was sent to test for fuel parameters. The results of that report were used for the calculation.

Table 15 shows the results and the Figure 15 depicts the results in graphical form.

Loading (MW)	Heat Rate (kcal/kWh)	Efficiency
101(65%)	3038.36	28%
118(75%)	2739.81	31%
136(85%)	2502.18	34%
157(100%)	2027.57	42%

Table 15: Results – AES Kelanitissa

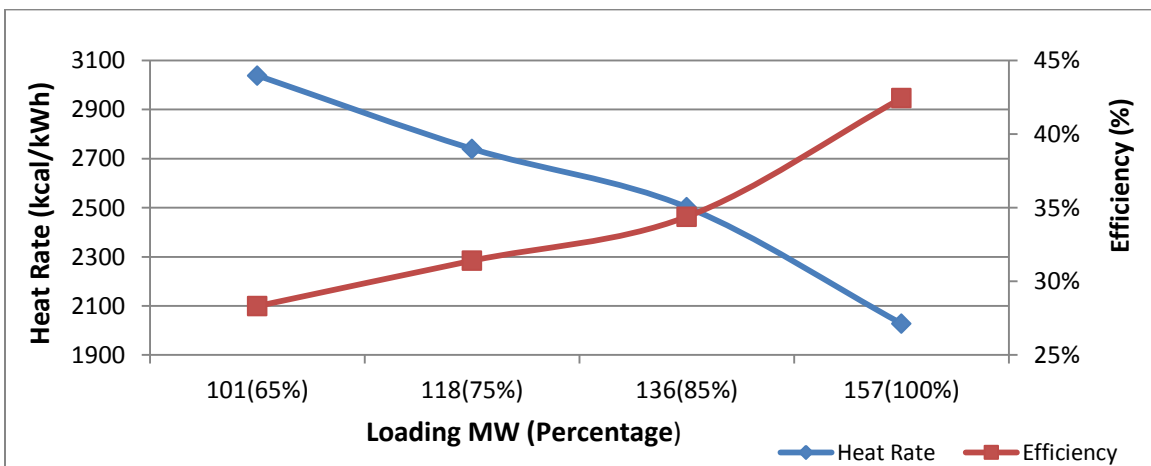


Figure 11: Results – AES Kelanitissa

### 3.5 West Coast Power (Private) Limited

**General:**

The capacity of the plant is 270 MW, a combined cycle gas turbine power plant. Followings were the plan used for the test. However only the first 2 steps of the test were done (40% and 50%)

- a. The plant, running at 40% of the full capacity.
- b. The plant, running at 50% of the full capacity.
- c. The plant, running at 100% of the full capacity.

**Dates:**

- 7<sup>th</sup> November 2013 – part (a.) and (b.)
- 13<sup>th</sup> January 2014 – part (c.)

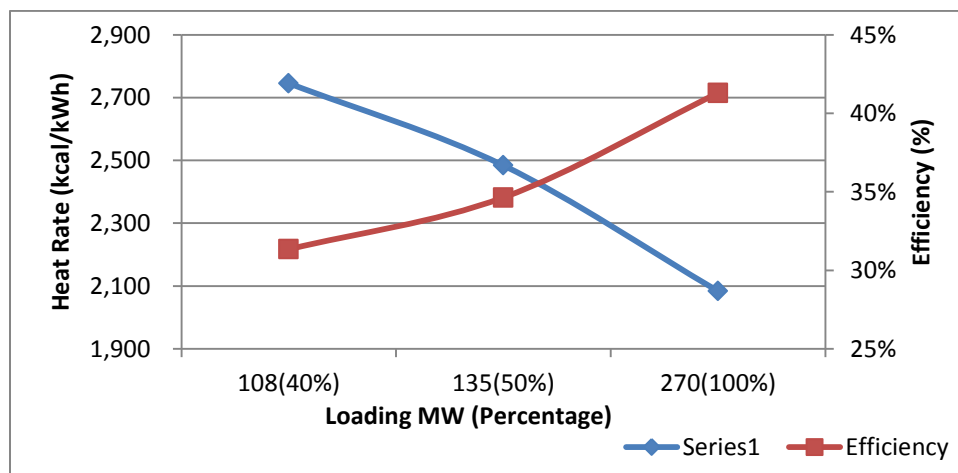
**The test results and other information:**

- A sample of fuel oil was sent to DNV to test for fuel parameters. The results of that report were used for the calculation.

Table 16 shows the results and the figure 12 depicts the results in graphical form.

Loading (MW)	Heat Rate (kcal/kWh)	Efficiency
108(40%)	2,745.70	31%
135(50%)	2,483.94	35%
270(100%)	2,083.46	41%

**Table 16: Results – West Coast**



**Figure 12: Results – West Coast**

### **3.6 Heladhanavi Diesel Power Plant**

In Heladhanavi power plant, there is not any facility to take individual readings for each and every generator. Therefore the Heat Rate for the total plant was taken into consideration.

- The Heat Rate for the plant = 2,088.73 kcal/kWh

### **3.7 Northern Power Diesel Power Plant**

A Heat Rate test for Northern Power could not be conducted due to the unavailability of fuel flow meters in the facility.



## 4 Summary

Table 17 and Table 18 shows a summary of the obtained results of each plant along with respective Heat Rate values as per the latest available Bulk Supply Tariff (BST) filing (January to June 2014, Forecast)

In the BST filing the respective Heat Rates are mentioned in different units other than kcal/kWh. Therefore to get them into a common basis calculations were done based on following assumptions. (The assumptions were plant specific since the information requirement for the calculation of each plant was different.)

For CEB Owned Plants:

1. For Kelanitissa Power Station:
  - a. Density of fuel =  $840 \text{ kgm}^{-3}$
  - b. Calorific value = 10500 kcal/kg
2. Sapugaskanda Power Station:
  - a. Density of fuel =  $962.2 \text{ kgm}^{-3}$
  - b. Calorific value = 10500 kcal/kg
3. Jaffna Power Plant:
  - a. Density of fuel =  $985 \text{ kgm}^{-3}$
  - b. Calorific value = 10568 kcal/kg

For IPPs:

1. For Colombo Power (Private) Limited:
  - a. Calorific value = 9808.56 kcal/kg
2. For Ace Power Embilipitiya (Private) Limited:
  - a. Calorific value = 9864.34 kcal/kg
3. For AES Kelanitissa (Private) Limited:
  - a. Density of fuel =  $840 \text{ kgm}^{-3}$
4. For West Coast Power (Private) Limited:
  - a. Density of fuel =  $968.8 \text{ kgm}^{-3}$
5. For Heladhanavi Diesel Power Plant:
  - a. Calorific value =  $10243.54 \text{ kgm}^{-3}$

<b>CEB Owned Plants</b>	<b>Heat Rate (kcal/kWh)</b>	
	<b>Measured Value (Total Plant)</b>	<b>BST Filing Value</b>
Kelanitissa Power Station (GTs)	4074.20	2751.84
Combined Cycle Power Plant, Kelanitissa	2020.37	1415.93
Sapugaskanda Power Station (10MW)	2016.44	2222.68
Sapugaskanda Power Station (20MW)	2245.89	2222.68
Lakvijaya Power Station, (Turbine Heat Rate)	1900.34*	2394.00
Jaffna Power Plant (heavy fuel)	2178.04	2383.74

**Table 17: Summary – CEB Owned Plants**

\* Since the given value is the “Turbine Heat Rate”, it does not reflect the true Heat Rate of the plant.

<b>Independent Power Producers</b>	<b>Heat Rate (kcal/kWh)</b>	
	<b>Measured Value (Total Plant)</b>	<b>BST Filing Value</b>
Asia Power	1929.24	2211.71
Colombo Power (Private) Limited	2041.11	2138.27
Ace Power Embilipitiya (Private) Limited	2073.54	2186.92
AES Kelanitissa (Private) Limited, (at Full load)	2027.57	1988.75
West Coast Power (Private) Limited (at Full load)	2083.46	2174.65
Heladhanavi Diesel Power Plant	2088.73	2110.17

**Table 18: Summary - IPPs**