PAT SCHEME
PERFORM, ACHIEVE, TRADE

NORMALIZATION DOCUMENT AND MONITORING & VERIFICATION GUIDELINES

Thermal Power Plant Sector

MINISTRY OF POWER
GOVERNMENT OF INDIA

PAT SCHEME
PERFORM, ACHIEVE, TRADE

NORMALIZATION DOCUMENT AND MONITORING & VERIFICATION GUIDELINES

Thermal Power Plant Sector

MINISTRY OF POWER
GOVERNMENT OF INDIA

Published by

Disclaimer

Contents

Part-II

MONITORING & VERIFICATION GUIDELINES

Tables

Figures

ÅtKzn{krkÇ;js
¼Hkjr ljdkj fo|q eaky; ½

BUREAU OF ENERGY EFFICIENCY
(Government of India, Ministry of Power)

vt; eBij ih,p-Mh
egkfuns'kd

Ajay Mathur, Ph.D.
Director General

Foreword

Perform Achieve and Trade (PAT), a flagship initiative under National Mission for Enhanced Energy Efficiency (NMEEE), is a regulatory intervention for reduction of specific energy consumption, with an associated market based mechanism through which additional energy savings can be quantified and traded as ECSerts.

Thermal Power Plant sector is one of the 8 notified energy intensive sectors under which a total of 144 plants are participating in this program. The targets are specified in terms of specific percentage of their present deviation of Net Operating Heat Rate from the Net Design Heat Rate. The total reported energy consumption of these Designated Consumers (DCs) is about 104 million toe. By the end of the first PAT cycle, the energy saving of 3.211 million toe /year is expected to be achieved, which is around 48% of total notional energy saving targets assessed under PAT.

The publication of **"Normalization Document and M&V Guidelines"** for **Thermal Power Plant Sector** is an effort to facilitate the DCs to comply with notified PAT rules to participate with the PAT scheme and contribute towards achieving national target of energy savings. This document will also be helpful to all empanelled Accredited Energy Auditors (EmAEAs) and State Designated Agencies (SDAs) in the monitoring and verification process of PAT.

I want to record my appreciation for members of the Technical Committee on Thermal Power Plant Sector, chaired by Shri. Alok, Deputy Director General (Technical), Bureau of Energy Efficiency (BEE), Shri A.K. Asthana, Senior Technical Expert, GIZ, Dr. Ashok Kumar, Energy Economist, BEE, and Shri Abhishek Kumar Yadav, Project Engineer, BEE, Shri Piyush Sharma, Technical Expert (GIZ) who worked tirelessly to put together the baseline data, normalization factors and M&V methodology for the sector. I especially want to record my appreciation for Shri S. Vikash Ranjan, Technical Expert (GIZ) who has put together the data and methodology associated with normalization.

I also compliment the efforts of all participating industrial units towards their endeavor in contributing to the national energy saving targets.

(Ajay Mathur)

ÅoÀtZ , oaÁkVZ eaÅtKcpk;   Save Energy for Benefit of Self and Nation

pEFkry] lsokHkou] vkj0 d0 iqje] ubZfnYyh&110 066
4th Floor, Sewa Bhawan, R.K. Puram, New Delhi - 110 066
VsyhQ Tel : 26178316 (lh/kh Direct) 26179699 (5 Lines) QSDl /Fax : 91 (11) 26178328
bZesy/E-mail : dg-bee@nic.in   oSclkbV/Web-Site : www.beeindia.in

Technical Committee on Thermal Power Plant Sector

S. No	Name of Member	Designation	Position
1	Shri Alok	Deputy Director General (Technical), BEE	Chairman
2	Shri L.D. Papney	Director (TE & TD), Central Electricity Authority	Member
3	Shri Chandrashekhar	Director (C&E), Central Electricity Authority	Member
4	Shri N. S. Mondal	Director (TR & M), Central Electricity Authority	Member
5	Shri S.C. Shrivastava	Joint Chief (Engg), Central Electricity Regulatory Commission	Member
6	Shri A.K. Gupta	Head of EEC, Excellence Enhancement Centre	Member
7	Shri Sankar Bandyopadhyay	General Manager, CenPEEP, NTPC Limited	Member
8	Shri Anil K. Mittal	Addl. Gen. Manager, CenPEEP, NTPC Limited	Member
9	Shri O.P. Khandelwal	Director (Technical), RRVUNL	Member
10	Shri Anil R Nandanwar	Executive Director (Gen O&M-II), MAHAGENCO)	Member
11	Shri Syamsundar Sen	Director (O&M and Projects), WBSEDCL)	Member
12	Shri N. Sankar	Director (Generation), TANGEDCO	Member

Special Thanks to Team NMEEE

S. No	Name of Member	Designation
1.	Shri Kapil Mohan, IAS	Ex. Deputy Director General, NMEEE
2.	Shri Alok, IAS	Ex Deputy Director General, NMEEE
3.	Shri K.K. Chakarvarti	Ex .Energy Economist
4.	Shri Ashok Kumar	Energy Economist
5.	Shri Sunil Khandare	Energy Economist
6.	Shri Saurabh Diddi	Energy Economist
7.	Shri Sameer Pandita	Assistant Energy Economist, BEE
8.	Shri Arijit Sengupta	Assistant Energy Economist, BEE
9.	Shri Girija Shankar	Assistant Energy Economist, BEE
10.	Smt. Vineeta Kanwal	Assistant Energy Economist, BEE
11.	Shri Ajay Tripathi	Media Manager
12.	Shri KK Nair	Finance and Accounts officer, BEE
13.	Shri A K Asthana	Senior Technical Expert, GIZ
14.	Shri Vikas Ranjan	Technical Expert, GIZ

1. Introduction

The National Action Plan on Climate Change (NAPCC) released by the Prime Minister on 30 June, 2008, recognises the need to maintain high economic growth to raise the living standards of India's vast majority of people and simultaneously reducing their vulnerability to the impacts of climate change.

The National Action Plan outlines eight national missions that represent multi-pronged, long-term, and integrated strategies for achieving key goals to mitigate the impact of climate change. These missions are listed below:

➢ National Solar Mission

➢ National Mission for Enhanced Energy Efficiency

➢ National Mission on Sustainable Habitat

➢ National Water Mission

➢ National Mission for Sustaining the Himalayan Ecosystem

➢ National Mission for a Green India

➢ National Mission for Sustainable Agriculture

➢ National Mission for Strategic Knowledge for Climate Change

1.1 National Mission for Enhanced Energy Efficiency

The National Mission for Enhanced Energy Efficiency (NMEEE) is one of the eight national missions with the objective of promoting innovative policy and regulatory regimes, financing mechanisms, and business models which not only create, but also sustain, markets for energy efficiency in a transparent manner with clear deliverables to be achieved in a time bound manner. It also has inbuilt provisions for monitoring and evaluation so as to ensure transparency, accountability, and responsiveness. The Ministry of Power (MoP) and Bureau of Energy Efficiency (BEE) were tasked to prepare the implementation plan for NMEEE.

NMEEE spelt out the following four new initiatives to enhance energy efficiency, in addition to the programmes on energy efficiency being pursued. These are:

➢ **Perform, Achieve and Trade (PAT)**, a market based mechanism to make improvements in energy efficiency in energy-intensive large industries and to make facilities more cost – effective by certification of energy saving that can be traded.

➢ **Market Transformation for Energy Efficiency (MTEE)** accelerates the shift to energy-efficient appliances in designated sectors through innovative measures that make the products more affordable.

➢ **Energy Efficiency Financing Platform (EEFP)**, a mechanism to finance demand side management programmes in all sectors by capturing future energy savings.

➢ **Framework for Energy Efficiency**

Perform, Achieve and Trade (PAT)	Market Transformation for Energy Efficiency (MTEE)
NMEEE	
Energy Efficiency Financing Platform (EEFP)	Framework for Energy Efficient Economic Development (FEEED)
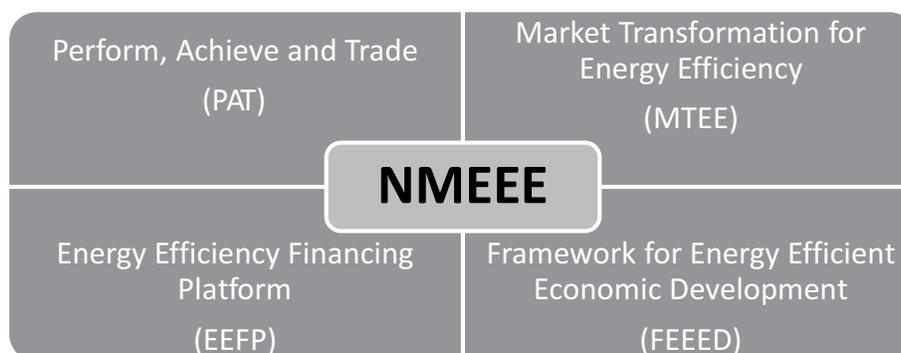
Economic Development (FEEED), for developing fiscal instruments to promote energy efficiency.

1.2 Perform, Achieve and Trade (PAT) Scheme

Under the National Mission on Enhanced Energy Efficiency (NMEEE), a market based mechanism known as Perform, Achieve and Trade (PAT) has been developed and launched to improve energy efficiency in the large energy intensive industries. It is envisaged that 6.686 million tonnes of oil equivalent will be reduced by 2014-15, which is about 4% of energy consumed by these industries. Under the PAT scheme, targets have been specified for all energy intensive industries notified as designated consumers (DCs) under the Energy Conservation Act, including thermal power stations.

National Energy Saving Targets under PAT (%)

- Chlor-Alkali
- Textile
- Pulp & Paper
- Aluminium
- Fertilizer
- Cement
- Iron & Steel
- Thermal Power Plants
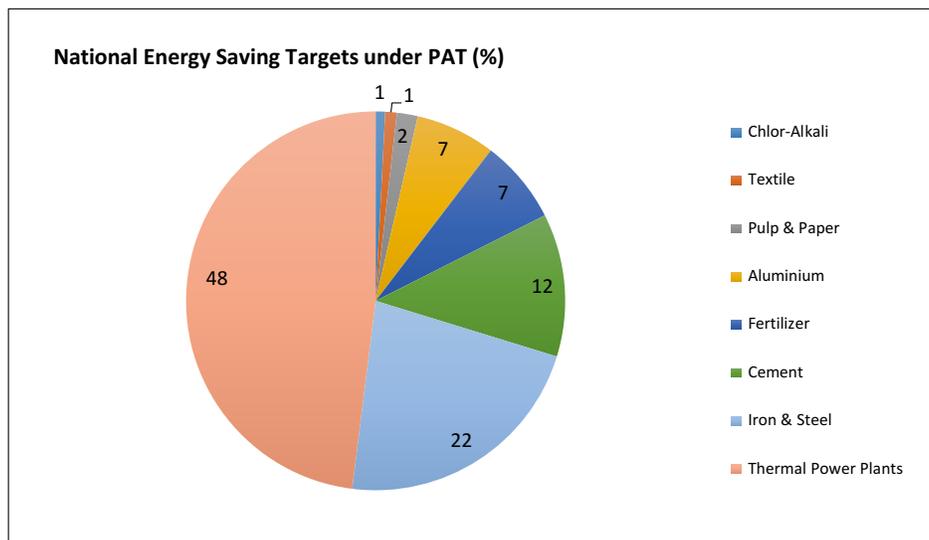
2 Background

The methodology of setting targets for designated consumers is transparent, simple and easy to use. It is based on reduction of specific energy consumption (SEC) on a gate-to-gate (GtG) basis to achieve targeted savings in the first commitment period of 3 years (2012-2015); the reduction in this phase is of 4.1% which is estimated to 6.686 million tonnes of oil equivalent (mtoe). Out of the 23 mtoe set as target from NMEEE, the PAT scheme is focussed on achieving 6.686 mtoe by 2015.

With the threshold limit of 30,000 toe energy consumption for a power station to become a designated consumer, 144 thermal power stations, with Coal/Lignite/Gas/Diesel as primary energy consumption, have been identified in Cycle I of PAT. The categorisation

of plants based on fuel such as coal, gas and diesel made the setting of target simple. The total reported energy consumption of these designated consumers is about 104 million tonne of oil equivalent. By the end of the first PAT cycle, energy savings of 3.211 million tonne of oil equivalent/year is expected to be achieved, which is around 48% of the total national energy saving targets assessed under PAT.

3 Categorisation and Distribution

The Thermal Power Plants can be categorised into coal, gas, and oil/diesel based. The categorisation of the DCs under PAT cycle has been shown below. Apart from the type of fuel source, the plants are also categorised into State, Central and Private. However, the target and normalisation methodology for all are same.

Fuel based Power Plant	State			Central			Private			Total		
	Total No.	Capacity (MW)	%	Total No.	Capacity (MW)	%	Total No.	Capacity (MW)	%	Total No.	Capacity (MW)	%
Coal	56	41534	46	23	30095	33	18	7231	8	97	78860	87
Gas	20	3823	4	9	4392	5	11	3122	3	40	11337	12
Diesel	4	385	0	0	0	0	3	412	0	7	797	1
Total	80	45742	50	32	34487	38	32	10765	12	144	90994	100

It can be clearly observed from the table above that coal based thermal power plants occupy the major chunk in all the sectors, i.e., state, central and private, followed by gas and diesel, respectively. Coal based plants contribute to more than 75 per cent of the total target.

4. Baseline value establishment

Section 4.01 **Definition**

(a) Baseline Year

Baseline year is declared as 2009-10.

(b) Baseline Generation (P base)

The arithmetic average of gross generation figures in MUs of 2007-08, 2008-09 and 2009-10.

(c) Baseline Specific Energy Consumption (SECbase)

The arithmetic average of Net Design Heat Rate (Kcal/kWh), Net Operative Heat Rate (kcal/kWh), Auxiliary Power Consumption (APC %) and Plant Load Factor (PLF %) figures of 2007-08, 2008-09 and 2009-10

(d) Baseline Capacity Utilization in % (CUbase)

Arithmetic average of PLF figures of 2007-08, 2008-09 and 2009-10 is taken as the baseline capacity utilization

5. Methodology for establishing the target

The methodology adopted for target setting is based on arithmetic average of Gross Design Heat Rate (kcal/kWh), Gross Operating Heat Rate (kcal/kWh) and Auxiliary Power consumption (%) figures of 2007-08, 2008-09 and 2009-10.

Section 5.01 **Relationship**

Based on the arithmetic average figure of three years, the Net Design Heat Rate (kcal/kWh) and Net Operating Heat Rate (kcal/kWh) has been calculated using the following formulae
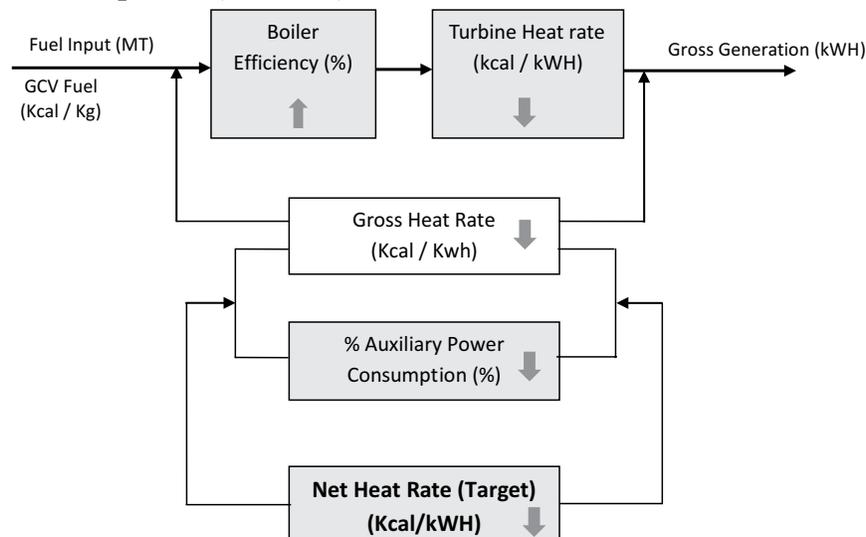
> **Net Operating Heat Rate = Gross operating Heat Rate / (1-APC %)**
>
> **Net Design Heat Rate = Gross Design Heat Rate / (1- APC %)**
>
> **Actual Deviation of net operating Heat Rate from net Design Heat Rate = Net Operating Heat Rate – Net Design Heat Rate**
>
> **% Deviation = Actual deviation from net design heat rate x 100/ net design heat rate**

The targets are specified in terms of specific percentage of their present deviation of Net Operating Heat Rate from the Net Design Heat Rate. The stations are classified in to various bands according to their present deviations of operating heat rate from design heat rate and stations with higher deviations has given higher targets. The indicative classification and targets for various bands for the generating stations are as under:-

Section 5.02 **Percentage Reduction Target methodology**

The energy consumption norms and standards for power stations shall be specified in terms of specific percentage of their present deviation of net operating heat rate, based on the average of previous three years, namely, 2007-08,2008-09 &2009-10 for the first cycle ,and for cycles thereafter in accordance with the provision of Rule 14 from the net design heat rate. The power stations shall be grouped into various bands according to their present deviations, of operating heat rate from design heat rate and for power stations with higher deviations the energy consumption norms and standards shall be established at lower level and shall be grouped taking into account percentage deviation as under
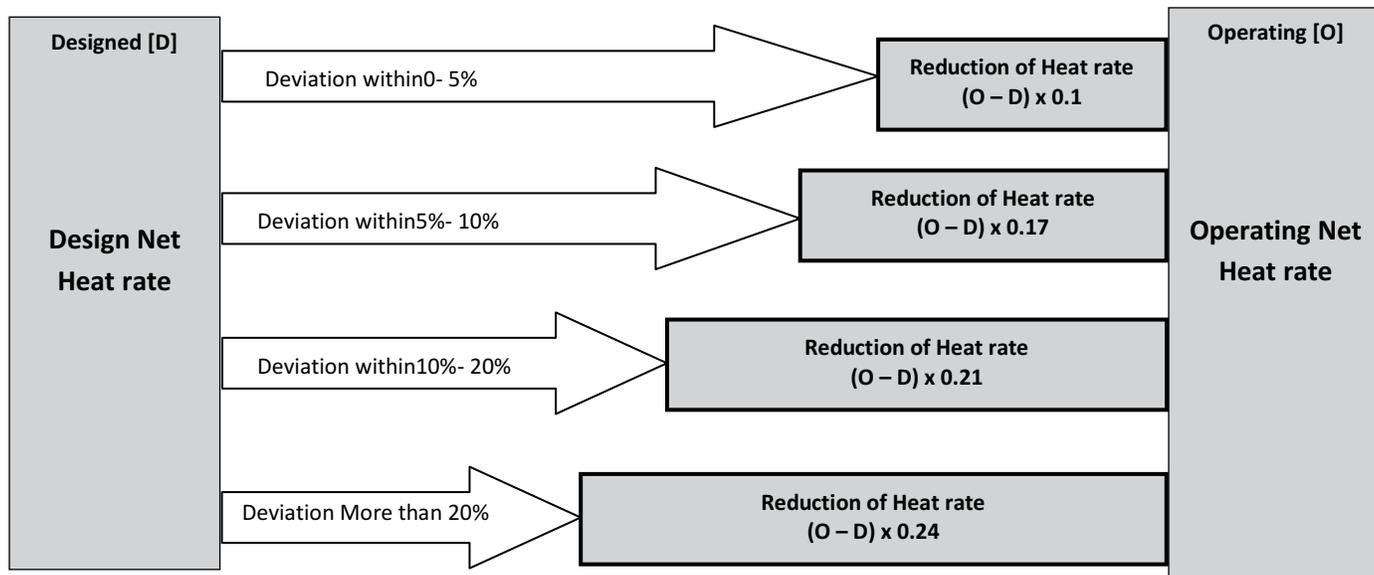
Category	Variation in Net Station Heat Rate from Design Net Heat Rate	Reduction Target for % deviation in the Net Station Heat Rate
I	Up to 5%	10%
II	More than 5% and up to 10%	17%
III	More than 10% and up to 20%	21%
IV	More than 20%	24%

6. Formula for Target Setting

Section 6.01   **Formula for target setting for Coal based Thermal Power Plant**

(a)   Design Net Heat Rate

Station Installed Capacity (MW)

= [U#1 Capacity (MW) + U#2 Capacity (MW) + … … … …]

Station Design Boiler Efficiency

=([{U#1 Installed Capacity (MW) X U#1 Boiler Efficiency(%)} + {U# 2 Installed Capacity (MW) XU# 2 Boiler Efficiency(%)} +⋯ … … …])/(Station Installed Capacity (MW))

Station THR (kcal/kWh)

=([{U# 1 THR X U#1 Installed Capacity (MW)} + {U#2 THR X U#2 Installed Capacity (MW)} + … … … …])/ (Station Installed Capacity (MW))

Unit DGHR (kcal/kWh)

=   Unit   THR   (kcal/kWh)/Boiler Efficiency (%)

Station DGHR(kcal/kWh)

=([{U# 1 DGHR X U# 1 Installed Capacity (MW)}+ U# 2 DGHR X U# 2 Installed Capacity (MW)} +⋯ … … …])/ (Station Installed Capacity (MW))

$$\text{Station Design Net Heat Rate (kcal/kWh)} = \frac{\text{(Station DGHR (kcal/kWh)}}{\text{(1-\%Operating APC))}}$$

Where

DGHR   =   *Design Gross Heat Rate (kcal/kWh)*

THR   =   *Turbine Heat Rate (kcal/kWh)*

DNHR   =   *Design Net Heat Rate (kcal/kWh)*

APC= Auxiliary Power Consumption (%) [Operating APC in Baseline Year]

(b)   Operating Net Heat Rate

Station Operating Load (MW)

=   U#1 Operating Load (MW) + U#2 Operating Load (MW) + … …

Operating Load (MW)

= Unit Gross Generation (MWh)/Unit Operating hours

Station Loading Factor (%)

=([{U# 1 loading factor (%) X U# 1 Gross Generation (MU)} +{ U#2 loading factor (%) X U# 2 Gross Generation (MU)} + … … …])/(Station Gross Generation (MU))

Station Gross Generation(MU)

=(U#1 Gross Generation (MU) + U#2 Gross Generation (MU) + … … …)

Station Net Generation (MU)

= Station Gross Generation (MU)x[1– APC (%)/100]

Station OGHR (kcal/kWh)

=([{U#1 OGHR (kcal/kWh) X U#1 Gross Generation (MU)} +{ U#2 OGHR (kcal/kWh) X U#2 Gross Generation (MU) }+⋯ … … …])/(Station Gross Generation (MU))

$$\text{Station ONHR (kcal/kWh)} = \frac{\text{Station ONHR (kcal/kWh)}}{1\text{-\%Operating APC}}$$

Where

OGHR   =   *Operating Gross Heat Rate*

ONHR   =   *Operating Net Heat Rate*

APC=*Auxiliary Power Consumption [Operating APC in Baseline Year]*

(c)   Heat Hate Reduction Target

The target in Thermal Power Sector under PAT Scheme is set by taking the deviation of NHR of Baseline year and design NHR. Based on the deviation percentage (to design), the target values for Heat Rate reduction are set in the slab.

Let the deviation percentage be "X", then

If X is <= 5(five), then the HR reduction target is 10% of the deviation.

If X is >5, but <=10, then the HR reduction target is 17% of the deviation.

If X is >10, but <=20, then the HR reduction target is 21% of the deviation.

If X is >20, then the HR reduction target is 24% of the deviation.

(d)   Coal based thermal Power Plant Station Target Net Operating Heat Rate without Normalization

The Station Net Operating Heat Rate without Normalization is the ONHR of baseline year minus the heat rate reduction target given to it.

Target Sation ONHR (kcal/kWh)

= Station Operating NHR for BY- Heat Rate Reduction Target

Where

OGHR   =   *Operating Gross Heat Rate*

ONHR   =   *Operating Net Heat Rate*

APC= *Auxiliary Power Consumption*

This Heat Rate has to be attained by the Station. If the station fails to meet its target, i.e., operates on a Heat Rate higher than the target, penalty will be levied on the Station. On the other hand, if the station over achieves its target, i.e., operates at a Heat Rate lesser than the target , it will be granted E-Certs, which can be traded in open market.

Section 6.02   **Formula for target setting for Gas based Thermal Power Plant**

(a)   Design Parameters

Station Installed Capacity (MW)

= [U#1 Capacity (MW) + U#2 Capacity (MW) + … … … …]

Station Design Module Efficiency

=([{U#1 Installed Capacity (MW) X U#1 Module Efficiency} + {U# 2 Installed Capacity (MW) XU# 2 Module Efficiency} +… … … …])/(Station Installed Capacity (MW))

Station Module Heat Rate (Gross Heat Rate) (kcal/kWh)

=([{U#1 THR X U#1 Installed Capacity (MW)} + {U#2 THR X U#2 Installed Capacity (MW)}+])/(Station Installed Capacity (MW))

Station Design Net Heat Rate (kcal/kWh)

$$= \frac{(Station\ DGHR\ (kcal/kWh)}{(1-\%Operating\ APC)}$$

(b)   Operating Parameters

Station Operating Load (MW)=U#1 Operating Load (MW)+U# 2 Operating Load (MW)+...

Station Gross Generation(MU)=

(U#1 Gross Generation (MU)+U#2 Gross Generation (MU) + …)

Station OGHR (kcal/kWh)

=([{U#1 OGHR (kcal/kWh) X U#1 Gross Generation (MU)} +{U#2 OGHR (kcal/kWh) X U#2 Gross Generation (MU) }+…

… … …])/(Station Gross Generation (MU))

Station Operating Net Heat Rate

$$\text{Station ONHR (kcal/kWh)} = \frac{\text{(Station OGHR (kcal/kWh))}}{1 - \% \text{ Operating APC}}$$

Where

OGHR = Operating Gross Heat Rate

ONHR = Operating Net Heat Rate

APC = Auxiliary Power Consumption

(c) Heat Hate Reduction Target

The target in Thermal Power Sector under PAT Scheme is set by taking the deviation of NHR of Baseline year and design NHR. Based on the deviation percentage (to design), the target values for Heat Rate reduction are set in the slab.

Let the deviation percentage be "X", then

If X is <= 5(five), then the HR reduction target is 10% of the deviation.

If X is >5, but <=10, then the HR reduction target is 17% of the deviation.

If X is >10, but <=20, then the HR reduction target is 21% of the deviation.

If X is >20, then the HR reduction target is 24% of the deviation.

(d) Target Station Net Operating Heat Rate without Normalization for AY

The Station Net Operating Heat Rate without Normalization is the ONHR of baseline year minus the heat rate reduction target given to it.

Target Sation ONHR (kcal/kWh)

= Station Operating NHR for BY- Heat Rate Reduction Target

Where

OGHR = Operating Gross Heat Rate

ONHR = Operating Net Heat Rate

APC = Auxiliary Power Consumption

This Heat Rate has to be attained by the Station. If the station fails to meet its target, i.e., operates on a Heat Rate higher than the target, penalty will be levied on the Station. On the other hand, if the station over achieves its target, i.e., operates at a Heat Rate lesser than the target , it will be granted E-Certs, which can be traded in open market.

7.   Examples for target setting

Section 7.01   **Sample Calculation for Target Setting for Coal based Thermal Power Station**

Coal based thermal power plants are plants having single primary fuel, which is coal. Oil is also used in these plants, but usually during the start-ups/shut-downs. These plants may be designed on a variety of grade of coal. Some plants are even designed for lignite. The normalization given caters to all the variety of coal and lignite used. Coal/Lignite Based Thermal Power plants operated on Rankine Cycle. For understanding the calculations and normalizations, we assume a Coal Based Thermal Power Station having 3(three) units of 210MW each.

Units	Design Capacity	As Provided by Original Equipment Manufacturer (OEM)			As established during Performance Guarantee Test (PG Test) **		
		Boiler Efficiency	Turbine Heat Rate	Unit Heat Rate	Boiler Efficiency	Turbine Heat Rate	Unit Heat Rate
	MW	%	kcal/kWh	kcal/kWh	%	kcal/kWh	kcal/kWh
U#1	210	87.3	2045	2342.50	87.3	2100.00	2406.88
U#2	210	87.3	2045	2342.50	87.3	2045.00	2343.84
U#3	210	87.3	2045	2342.50	87.3	2045.00	2343.84

** Parameters established during Performance Guarantee Test shall only be considered if OEM data parameters are not available.

The entire examples shall be worked out on the above mentioned table. Calculations based on the above mentioned Plant shall be:

(a) Design Parameters

Station Installed Capacity (MW)

= [U#1 Capacity (MW) + U#2 Capacity (MW) + … … … …]

= 210 +210+210

= 630 MW

If the configuration of unit is complex, like 2X210MW +3X500 MW, the same formula holds good. The station Installed capacity in this case shall become

= 210+210+500+500+500

=1920 MW

Station Design Boiler Efficiency

=([{U#1 Installed Capacity (MW) X U#1 Boiler Efficiency} + {U# 2 Installed Capacity (MW) XU#2 Boiler Efficiency} +⋯ … … …])/(Station Installed Capacity (MW))

= [210X87.3 + 210X 87.3 + 210X87.3]/630

= 87.3 %

Station THR (kcal/kWh)

=([{U#1 THR X U#1 Installed Capacity (MW)} + {U#2 THR X U#2 Installed Capacity (MW)} + … … … …])/ (Station Installed Capacity (MW))

= (2045 X 210 + 2045X 210 + 2045 X210) /

(210 + 210 + 210)

= 2045 kcal/ kWh

Unit DGHR (kcal/kWh)= (Unit THR (kcal/ kWh)/ Boiler Efficiency %)

U#1 DGHR = 2045/ 87.3 = 2342.5 kcal/kWh

U#2 DGHR = 2045/ 87.3 = 2342.5 kcal/kWh

U#3 DGHR = 2045/ 87.3 = 2342.5 kcal/kWh

Station DGHR(kcal/kWh)

=([{U# 1 DGHR X U# 1 Installed Capacity (MW)}+ U# 2 DGHR X U# 2 Installed Capacity (MW)}+⋯ … … …])/ (Station Installed Capacity (MW))

= (2342.5 X 210 + 2342.5 X 210 + 2342.5 X 210)/ (210 + 210 + 210)

= 2342.5 kcal/kWh

Station Design Net Heat Rate (kcal/kWh)

=(Station DGHR (kcal/kWh))/((1-% Operating APC))

= 2342.5 / (1 - 0.0757*)

= 2534.35 kcal/Kwh

* The Designed Auxiliary Power Consumption (APC) is considered as 7.57%

(b) Operating parameters

Now let us assume that the same Thermal Power Plant was operating with some parameters in the baseline year and assessment year. Table below represents the data of the plant

Units	Capacity (MW)	Current/ Assessment/ Target Year (20.... 20....)				Baseline Year (20.... 20....)			
		Operating Load	Loading Factor	Gross Generation	Unit Gross Heat Rate##	Operating Load	Loading Factor	Gross Generation	Unit Gross Heat Rate ##
		MW	%	MU	kcal/kWh	MW	%	MU	kcal/kWh
U#1	210	165	70	1445	2636	150	60	1314	2635
U#2	210	166	72	1454	2637	130	58	800	2636
U#3	210	150	60	1456	2800	120	55	714	2584

Station Operating Load (MW)

=U#1 Operating Load (MW)+U#2 Operating Load (MW)+...

Station Operating load in Baseline Year = 150+130+120
= 400 MW

Station Operating load in Assessment Year = 165+166+150
= 481 MW

Station Loading Factor (%)

=([{U# 1 loading factor (%) X U# 1 Gross Generation (MU)} +{ U#2 loading factor (%) X U# 2 Gross Generation (MU)} + … … …])/(Station Gross Generation (MU))

Station loading factor in Baseline Year
= {60*1314+58*800 +55*700} / (1314+800+714)
= 57.89 %

Station loading factor in Assessment Year
= {70*1445+72*1454+60*1456} / (1445+1454+1456)
= 67.32%

Station Gross Generation(MU)=

U# 1 Gross Generation (MU)+U#2 Gross Generation (MU) + …

Station gross Generation in Baseline Year
= 1314 +800 +714
= 2828 (MU)

Station gross Generation in Assessment Year
= 1445 +1454 +1456
= 4355 (MU)

Station OGHR (kcal/kWh)

=([{U#1 OGHR (kcal/kWh) X U#1 Gross Generation (MU)} +{ U#2 OGHR (kcal/kWh) X U#2 Gross Generation (MU) }+… … … …])/(Station Gross Generation (MU))

Station Operation GHR for Baseline Year
= (2635*1314 +2636*800 +2584*714) / 2828
= 2622.40 kcal/kWh

Station Operation GHR for Assessment Year=

(2636*1445 +2637*1454 +2800*1456) / 4355
= 2691.2 kcal/kWh

Station Operating Net Heat Rate

The Station Operating Gross Heat rate of Assessment and Baseline year has been calculated above. Now, considering the Auxiliary Power Consumption to be 6.89% and 7.57% for Assessment Year and baseline Year respectively, we can calculate the Net Operating Heat Rate.

$$\text{Station ONHR (kcal/kWh)} = \frac{\text{Station OGHR (kcal/kWh)}}{1 - \text{\% Operating APC}}$$

Where

OGHR = Operating Gross Heat Rate

ONHR = Operating Net Heat Rate

APC = Auxiliary Power Consumption

Station Operating Net Heat Rate for Baseline Year
= 2622.4 / (1-0.0757)
= 2837.17 kcal/kWh

Station Operating Net Heat Rate for Assessment Year
= 2691.2/ (1-0.0689)
= 2890.3 kcal/kWh

(c)   Heat Hate Reduction Target

The target in Thermal Power Sector under PAT Scheme is set by taking the deviation of NHR of Baseline year and design NHR. Based on the deviation percentage (to design), the target values for Heat Rate reduction are set in the slab.

Let the deviation percentage be "X", then

If X is <= 5(five), then the HR reduction target is 10% of the deviation.

If X is >5, but <=10, then the HR reduction target is 17% of the deviation.

If X is >10, but <=20, then the HR reduction target is 21% of the deviation.

If X is >20, then the HR reduction target is 24% of the deviation.

Accordingly, the target for the above mentioned Thermal Power Station has been calculated as below:

From Sections 1.6 and 2.5, we have-

Design Net Heat Rate (DNHR)

$$=2534.35 \text{ kcal/KWh}$$

Station Operating Net Heat Rate for Baseline Year (ONHR) $=2837.17 \text{ kcal/kWh}$

Difference between Design and Operating NHR

$$= ONHR-DNHR$$

$$= 2837.17 -2535.35$$

$$= 301.82 \text{ kcal/kWh}$$

Difference/ Deviation Percentage from design
$$=Difference/DNHR*100$$
$$=301.81/2534.35 *100$$
$$= 11.91\%$$

As the deviation percentage is greater than 10, but less than 20, it qualifies for 21% slab.
i.e.,   301.82*21% = 63.38 kcal/kWh

Heat Rate Reduction Target = 63.38 kcal/kWh

(d)   Target Station Net Operating Heat Rate without Normalization for AY

The Heat Rate Reduction Target is given on the basis of Baseline year and design parameters.

Section 3 depicts the Target Heat Rate that needs to be reduced, i.e., The station has to operate at a Net Heat Rate which is 63.38 kcal/kWh lesser than its baseline year. Hence,

The Station Net Operating Heat Rate without Normalization is ONHR for baseline year minus the HR reduction target

Target Heat Rate Reduction   = 63.38 kcal/kWh

Target Operating Net Heat Rate in baseline Year
$$= 2837.17-63.38$$
$$= 2773.79 \text{ kcal/kWh}$$

This Heat Rate has to be attained by the Station. If the station fails to meet its target, i.e., operates on a Heat Rate higher than 2773.79 kcal/kWh, penalty will be levied on the Station. On the other hand, if the station over achieves its target, i.e., operates at a Heat Rate lesser than 2773.79 kcal/kWh, it will be granted E-Certs, which can be traded in open market.

Section 7.02   **Sample Calculation for Target Setting for Gas based Thermal Power Station**

Gas based Thermal Power plants are basically based on combined cycle. These plants may use gas as primary source of fuel or a mixture of gas and other fuels such as Naptha. These may be further divided into open and closed cycle depending upon the type/ load of operation. For understanding the calculations, let us take the example of a Station having three units of 210MW capacity each.

Table below, represents the capacity, THR with module efficiency is given in the table below.

Design Capacity	As Provided by Original Equipment Manufacturer (OEM)		As established during Performance Guarantee Test (PG Test) **	
	Module Efficiency	Module Heat Rate@	Module Efficiency	Module Heat Rate
MW	%	kcal/kWh	%	kcal/kWh
210	45.0	1911.11	45.0	1911.11
210	45.0	1911.11	45.0	1911.11
210	46.0	1869.57	47.0	1829.79

** Parameters established during Performance Guarantee Test shall only be considered if OEM data parameters are not available.

THERMAL POWER PLANT - Under Perform, Achieve and Trade

The entire examples shall be worked out on the above mentioned table. Calculations based on the above mentioned Station shall be:

(a) Design Parameters

Station Installed Capacity (MW)

= [U#1 Capacity (MW) + U#2 Capacity (MW) + … … … …]

= 210 +210+210

= 630 MW

If the configuration of unit is complex, like 2X210MW +3X500 MW, the same formula holds good. The station Installed capacity in this case shall become

= 210+210+500+500+500

=1920 MW

Station Design Module Efficiency

=([{U#1 Installed Capacity (MW) X U#1 Module Efficiency} + {U#2 Installed Capacity (MW) XU# 2 Module Efficiency} +… … … …])/(Station Installed Capacity (MW))

=(210*45+210*45+210*46)/ (210+210+210)

= 45.33 %

Station Module Heat Rate (Gross Heat Rate) (kcal/kWh)

=([{U#1 THR X U#1 Installed Capacity (MW)} + {U#2 THR X U#2 Installed Capacity (MW)} + … … … …])/(Station Installed Capacity (MW))

=(1911.11*210+1911.11X210+1869.57X210) /(210 + 210 + 210)

= 1897.26 kcal/ kWh

Station Design Net Heat Rate (kcal/kWh)=

$$\frac{\text{Station DGHR (kcal/kWh))}}{\text{(1-\%Operating APC)}}$$

= 1897.26/(1-0.0566)

=2011.08 kcal/kWh

* The Designed Auxiliary Power Consumption (APC) is considered as 5.66%

(b) Operating parameters

Now let us assume that the same Thermal Power Plant was operating with some parameters in the baseline year and assessment year. Table below represents the data of the plant

Units	Capacity (MW)	Current/ Assessment/ Target Year (20.... 20....)			Baseline Year (20.... 20....)		
		Operating Load	Gross Generation	Unit Gross Heat Rate##	Operating Load	Gross Generation	Unit Gross Heat Rate ##
		MW	MU	kcal/kWh	MW	MU	kcal/kWh
U#1	210	165	1445	2636	150	1314	2635
U#2	210	166	1454	2637	130	800	2636
U#3	210	150	1456	2800	120	714	2384

Station Operating Load (MW)=U#1 Operating Load (MW)+U# 2 Operating Load (MW)+...

Station Operating load in Baseline Year

= 150+130+120

= 400 MW

Station Operating load in Assessment Year

= 165+166+150

= 481 MW

Station Gross Generation(MU)=
U#1 Gross Generation (MU)+U#2 Gross Generation (MU) + …

Station gross Generation in Baseline Year

$$= 1314 + 800 + 714$$

$$= 2828 \text{ (MU)}$$

Station gross Generation in Assessment Year

$$= 1445 + 1454 + 1456$$

$$= 4355 \text{ (MU)}$$

Station OGHR (kcal/kWh)

$$=([\{U\# 1 \text{ OGHR (kcal/kWh)} \times U\# 1 \text{ Gross Generation (MU)}\} + \{ U\#2 \text{ OGHR (kcal/kWh)} \times U\#2 \text{ Gross Generation (MU)} \} + \dots \dots]/ \text{ Generation (MU)})$$

Station Operation GHR for Baseline Year
$$= (2635*1314+2636*800+2384*714)/2828$$
$$= 2571.91 \text{ kcal/kWh}$$

Station Operation GHR for Assessment Year

$$= (2636*1445 +2637*1454 +2800*1456)/4355$$

$$= 2691.2 \text{ kcal/kWh}$$

Station Operating Net Heat Rate

The Station Operating Gross Heat rate of Assessment and Baseline year has been calculated above. Now, considering the Auxiliary Power Consumption to be 6.89% and 5.66% for Assessment Year and baseline Year respectively, we can calculate the Net Operating Heat Rate.

$$\text{Station ONHR (kcal/kWh)} = \frac{\text{Station OGHR (kcal/kWh)}}{1- \% \text{ Operating APC}}$$

Where

OGHR = Operating Gross Heat Rate

ONHR = Operating Net Heat Rate

APC = Auxiliary Power Consumption

Station Operating Net Heat Rate for Baseline Year
$$= 2571.91/(1-0.0566)$$
$$= 2726.21 \text{ kcal/kWh}$$

Station Operating Net Heat Rate for Assessment Year

$$= 2691.2/ (1-0.0689)$$

$$= 2890.3 \text{ kcal/kWh}$$

(c)   Heat Hate Reduction Target

The target in Thermal Power Sector under PAT Scheme is set by taking the deviation of NHR of Baseline year and design NHR. Based on the deviation percentage (to design), the target values for Heat Rate reduction are set in the slab.

Let the deviation percentage be "X", then

If X is <= 5(five), then the HR reduction target is 10% of the deviation.

If X is >5, but <=10, then the HR reduction target is 17% of the deviation.

If X is >10, but <=20, then the HR reduction target is 21% of the deviation.

If X is >20, then the HR reduction target is 24% of the deviation.

Accordingly, the target for the above mentioned Thermal Power Station has been calculated as below:

From Sections 1.6 and 2.5, we have-

Design Net Heat Rate (DNHR)
$$=2011.08 \text{ kcal/KWh}$$

Station Operating Net Heat Rate for Baseline Year (ONHR) =2726.21 kcal/kWh

Difference between Design and Operating NHR

$$= \text{ONHR-DNHR}$$

$$= 2726.21-2011.08$$

$$= 715.13 \text{ kcal/kWh}$$

Difference/ Deviation Percentage from design

$$=\text{Difference/DNHR}*100$$

$$=715.13/2011.08 *100$$
$$= 35.56\%$$

As the deviation percentage is greater than 20, it

qualifies for 24% slab.

i.e., 715.13*24% = 171.63kcal/kWh

Heat Rate Reduction Target = 171.63 kcal/kWh

(d)   Target Station Net Operating Heat Rate without Normalization for AY

The Heat Rate Reduction Target is given on the basis of Baseline year and design parameters.

Section 3 depicts the Target Heat Rate that needs to be reduced, i.e., The station has to operate at a Net Heat Rate which is 66.01 kcal/kWh lesser than its baseline year. Hence,

The Station Net Operating Heat Rate without Normalization is the ONHR for baseline year minus the HR reduction target

Where

Target Heat Rate Reduction
                              = 171.63 kcal/kWh

Target Operating Net Heat Rate in Assessment

Year   = 2726.21–171.63

                              = 2554.58 kcal/kWh

This Heat Rate has to be attained by the Station. If the station fails to meet its target, i.e., operates on a Heat Rate higher than 2554.58kcal/kWh, penalty will be levied on the Station. On the other hand, if the station over achieves its target, i.e., operates at a Heat Rate lesser than 2554.58kcal/kWh, it will be granted E-Certs, which can be traded in open market.

8.   Normalization/ Correction factor to be considered for target setting:

There are several factors that need to be taken into consideration on capacity utilization of DCs for Normalization of a product under PAT rules, so that the undue advantage or disadvantage could not be imposed on DC. There are many factors, which can influence the SEC of a DC are listed below

Section 8.01   **Input Primary Energy**

Sr No	Sub-Group	Elements	Reason/ Requirement	Impact	Documents
1	Coal Quality in Boiler IPP	%H, % Moisture, %Ash, GCV	Poor quality of Fuel effects the Power Station Performance	Boiler Efficiency / Gas Turbine	Ref Calculation provided for Boiler Efficiency (Coal Linkage with Coal Field leads to poor quality of Coal contains impurities like stone, Ash, high moisture etc because of poor performance of washeries)
	Non Availability of fuel [External Factor]	Loss of Generation	Beyond DC's control	Plant Load Factor	i. Documents from Coal Supplying company. ii. Characteristics curve of Load Vs Design Turbine Heat Rate from OEM

Section 8.02 **Plant Load Factor**

Sr No	Sub-Group	Elements	Reason/ Requirement	Impact	Documents
2	Scheduling [External factor] or Backing down	PLF and Station heat rate	• Plant Load backing down due to lower power demand from the grid • Variations in demand from the estimated or forecasted values, which cannot be absorbed by the grid.	Boiler Efficiency / Gas Turbine	i. Scheduling Documents ii. Reference documents are required for deterioration in Plant Load Factor iii. Characteristics curve [Load Vs Heat Rate]
	Unscheduled Power and Outage [External Factor]	PLF and Station heat rate	Transmission outages resulting in reduced power availability.	Plant Load Factor	Characteristics curve-Heat Rate Vs Load

Section 8.03 **Fuel Mix**

Sr No	Sub-Group	Elements	Reason/ Requirement	Impact	Documents
3	Fuel	Use of different Fuel in same unit	Separate NHR for different fuel used in the unit	Boiler Efficiency	Fuel Quality and Quantity documentation

Section 8.04 **Fuel Quality**

Sr No	Sub-Group	Elements	Reason/ Requirement	Impact	Documents
3	Coal	Use of coal with different calorific value in AY and BY	Coal quality is beyond the control of plant	Boiler Efficiency, Auxiliary Power Consumption	Fuel Quality and Quantity documentation, Energy consumption of mills in AY and BY
	Gas	Use of Gas with different calorific value in AY and BY	Gas quality may be compromised due to limited availability	Net Heat Rate	Fuel Quality and Quantity documentation

Section 8.05 **Environmental Standards**

Sr No	Sub-Group	Elements	Reason/ Requirement	Impact	Documents
4	Additional Equipment Installation due to Environmental law	Auxilliary Power Consumption	The Energy will be normalized for additional Energy consumption. This is to be excluded from APC	APC	The DC has to maintain the documents for additional installation of Environmental Equipment
5	Flood, Earthquake etc		Proper weightage could be given in SEC in terms of capacity utilisation, energy used for re-establishment	Plant Load Factor	The DC has to maintain the authentic documents for natural disaster

9. Formulas of Normalization

Section 9.01 **Common Calculations for Normalization**

The target for Heat Rate Reduction is based on Baseline Year and Design parameters. However, there are factors which may have changed beyond control during the Assessment Year which may lead to higher Operating Net Heat Rate. These factors may be variation in coal quality, Plant Load Factor (PLF), Auxiliary Power Consumption (APC), number of start-ups, etc. We cannot bring the station on a platform with similar operating conditions as the baseline year. However, we have given relaxations on these factors which are beyond the control of any Station. These relaxations are known as normalization.

In normalization, the deviation due to each external factor is calculated in terms of Heat Rate and is subtracted from the Station Operating Net Heat rate for Assessment Year.

Station Average Operating Hour (Hr) Caused by low ULF/MLF due to Fuel Unavailability

$$= \frac{([U\# 1 \ AOHr \ X \ U\# 1 \ AOL \ (MW)\} + U\# 2 \ AOHr \ X \ U\# 2 \ AOL \ (MW) + \ \ldots \ldots \ldots \ldots \ ])/}{Station \ AOL \ (MW) \ due \ to \ Fuel \ Unavailability}$$

Where:

ULF   = Unit Load Factor

MLF   = Module Load Factor

AOHr = Average Operating Hour

AOL   = Average Operating Load

Station Average Operating Hour (Hr.)Caused by low ULF/MLF due to Scheduling

$$= \frac{([\{U\# 1 \ AOHr \ X \ U\# 1 \ AOL \ (MW)\} +\{ U\# 2 \ AOHr + U\# 2 \ AOL \ (MW)\} + \ldots \ldots \ldots \ldots])}{Station \ AOL \ (MW) \ due \ to \ Scheduling}$$

Where

ULF   = Unit Load Factor

MLF   = Module Load Factor

AOHr = Average Operating Hour
AOL   = Average Operating Load

**Station Average Operating Hour (Hr.)Caused by low ULF/
MLF due to Backing down**

$$= \frac{[\{U\# 1 \text{ AOHr X } U\# 1 \text{ AOL (MW)}\}+ \{U\# 2 \text{ AOHr} + U\# 2 \text{ AOL (MW)}\}+ \dots \dots \dots \dots]}{\text{Station AOL (MW)due to backing down}}$$

Where
ULF   = Unit Load Factor

MLF   = Module Load Factor

AOHr = Average Operating Hour

AOL   = Average Operating Load

Station Average Operating Hours (Hr.) caused by ULF/MLF due to any other external Factor

$$= \frac{([\{U\# 1 \text{ AOHr X } U\# 1 \text{ AOL (MW)}\} + \{U\# 2 \text{ AOHr}+ U\# 2 \text{ AOL (MW)}\} + \dots \dots \dots \dots])}{\text{Station AOL (MW) due to backing down}}$$

Where
ULF   = Unit Load Factor

MLF   = Module Load Factor

AOHr = Average Operating Hour
AOL   = Average Operating Load

External factors = Fuel Unavailability/ Scheduling/ backing down/ any other external factor etc.

Unit Average Operating Load (MW) Caused by low ULF/MLF due to External factors

= Total Generation (MWHr) / Total Operating Hour (Hr)

Where

Total Generation   = (Unit AOL (MW) X Unit AOHr) due to Fuel Unavailability + (Unit AOL (MW) X Unit AOHr) due to Scheduling + (Unit AOL (MW) X Unit AOHr) due to Backing Down + (Unit AOL (MW) X Unit AOHr) due to any other external factor]

Total Operating Hour   = [Unit AOHr due to Fuel Unavailability + Unit AOHr due to Scheduling + Unit AOHr due to Backing Down + Unit AOHr due to any other external factor]

ULF   = Unit Load Factor

MLF   = Module Load Factor

AOHr = Average Operating Hour

AOL   = Average Operating Load

External factors = Fuel Unavailability/ Scheduling/ backing down/ any other external factor etc.

Station Average Operating Load (MW) caused by low ULF/MLF due to Fuel Unavailability/ Scheduling/ Backing down/ any other external factor

= [*U# 1 AOL (MW) + U# 2 AOL (MW) + … … … …*]

Where:

ULF   = Unit Load Factor

MLF   = Module Load Factor

AOL   = Average Operating Load

Unit Average Operating Hours at Low ULF/MLF due to external Factors

= Total Generation (MWHr)/ Total Average Operating load (MW)

Where

Total Generation	= (Unit AOL (MW) X U# AOHr) due to Fuel Unavailability + (Unit AOL (MW) X Unit AOHr) due to Scheduling + (Unit AOL (MW) X Unit AOHr) due to Backing Down + (Unit AOL (MW) X Unit AOHr) due to any other external factor]
Total Average Operating Load	= [{Unit AOL (MW) to Fuel Unavailability + Unit AOL (MW)} due to Scheduling + Unit AOL (MW) to Backing Down + Unit AOL (MW) due to any other external factor]

ULF   = Unit Load Factor

MLF   = Module Load Factor

AOHr = Average Operating Hour

AOL   = Average Operating Load

External factors = Fuel Unavailability/ Scheduling/ backing down/ any other external factor etc.

Station Average Operating Hours at Low ULF/MLF due to external factors

= ([{(U# 1 AOL (MW) X U# 1 AOHr) at Low ULF/MLF due to external factor} + {(U# 2 AOL (MW) X U# 2 AOHr) at Low ULF//MLF due to external factor} + … … … …])/(Station AOL (MW) caused by low ULF/MLF due to external factors)

Where

ULF = Unit Load Factor

MLF = Module Load Factor

AOHr = Average Operating Hour

AOL = Average Operating Load

External factors = Fuel Unavailability/ Scheduling/ backing down/ any other external factor etc.

Unit Availability Factor={Hours in a Year – [RSHr + FO or Unavailability hour + PMO or Planned Unavailability]}/ Hours in a Year]

Where

RSHr = Reserve Shutdown Hour

FO = Forced Outage

PMO = Planned Maintenance Outage

Station RSHr

$$= \frac{([\{U\#1 \text{ RSHr X U\#1 Capacity (MW)}\} + \{U\#2 \text{ RSHr X U\#2 Capacity(MW)}\} + \ldots\ldots\ldots\ldots)}{\text{Total Station capacity X Hours in a Year}}$$

Station FO or Unavailability Hour

$$= \frac{([\{U\#1 \text{ FO X U\#1 Capacity (MW)}\} + \{U\#2 \text{ FO X U\#2 Capacity(MW)}\} + \ldots\ldots\ldots\ldots])}{((\text{Total Station capacity X Hours in a Year}))}$$

Station PMO or Planned

$$\text{Unavailability} = \frac{[\{U\#1 \text{ PMO X U\#1 Capacity (MW)}\} + \{U\#2 \text{ PMO X U\#2 Capacity (MW)}\} + \ldots\ldots\ldots.])}{\text{Total Station capacity X Hours in a Year})}$$

Station Availability Factor= 1- [Station RSHr + Station FO or Unavailability hour + Station PMO or Planned Unavailability]

Where

RSHr = Reserve Shutdown Hour

FO = Forced Outage

PMO = Planned Maintenance Outage

These formulas constitute the general working formulas which will find reference in all the calculations. These formulas are also used in day to day reporting to the plant management. The definition of terms mentioned above in sections shall be assumed only on above calculations in Sector specific Pro-forma (Form Sh)

Section 9.02 Normalization for Coal/ Lignite base Thermal Power Plant

(a) Coal/Lignite Quality in Boiler IPP

Coal is extremely heterogeneous, varying widely in their content and properties from country to country, mine to mine and even from seam to seam. The principle impurities are ash-forming minerals and sulphur. Some are interspersed through the coal seam; some are introduced by the mining process, and some principally organic sulphur, nitrogen and some minerals salts.

These impurities affect the properties of the coal and the combustion process, therefore the plant's boiler efficiency & Turbine Efficiency. The generating companies have no control over the quality of coal supplied. The raw coal mainly being supplied to the power stations could have variation in coal quality. Further, imported coal is also being used and blended with Indian coal by large number of stations, which could also lead to variations in coal quality.

The methodology should have provisions to take care of the impact of variations in coal quality. Therefore, average "Ash, Moisture, Hydrogen and GCV" contents in the coal during the baseline period as well as for Design Coal could be considered for Normalization and the correction factor has to be worked out based on the following boiler efficiency formula:

$$\text{Boiler Efficiency} = 92.5 - \frac{[50 * A + 630 (M + 9 H)]}{G.C.V}$$

Where:
A= Ash percentage in coal
M= Moisture percentage in coal
H= Hydrogen percentage in coal
G.C.V= Gross calorific value in kcal/kg
Station heat rate (Kcal/kWh) = Turbine heat rate/ Boiler efficiency

(i) Sample Calculation: Coal Quality- Designed Vs Actual

The quality of coal analyzed w.r.t. Proximate and Ultimate analysis. The ultimate analysis determines all coal component elements, solid or gaseous and the proximate analysis determines only the fixed carbon, volatile matter, and moisture and ash percentages. Coals of different ranks vary in chemical composition, lower ranks contains relatively lower carbon but higher oxygen, whereas for higher rank it will be reverse.

Proximate Analysis					
		Unit A		Unit B	
Item	Unit	Design	Operating	Design	Operating
Fixed Carbon	%	22			
Volatile matter	%	21	23.4		
Moisture	%	15	17.4	12	16
Ash	%	42	37.4	42	35.45
Grindability Index	HGI	55			
Higher Heating Value (GCV)	kcal/ kg	3300	3137	2824	2776
Size of Coal to Mill	mm	50			

The table represents proximate and ultimate analysis of coal for a particular plant. The plant has been designed for a particular coal and any deviation from the designed could result in lower or higher efficiencies of Boiler.

Ultimate Analysis					
		Unit A		Unit B	
Item	Unit	Design	Operating	Design	Operating
Carbon	%	33.73	33.8	31.9	33.75
Hydrogen	%	2.35	2.69	2.44	2.47
Sulphur	%	0.37		0.5	0.5
Nitrogen	%	0.75	1.82	0.69	1.82
Oxygen	%	5.48	6.8	11.08	10.01
Carbonates	%	0.27			
Phosphorous	%	0.05			
Moisture	%	15		12	16
Ash	%	42	37.4	42	35.45

The main constituent of Proximate and Ultimate analysis such as Ash, Moisture and hydrogen needs to be analysed w.r.t. the efficiency of Boiler.

(ii)   Non Availability of fuel (Coal/Gas/Lignite) [External Factor]

Due to fuel non- availability, plant may opt to reduce the load on turbine leading to low efficiency of units and Station. Due to decreased loading, the Plant load Factor will be worsened and affects the unit heat rate. The comparison between baseline year and assessment year will be carried out through characteristics curve of Load Vs Heat rate for correction factor and will be covered under Scheduling chapter in Section 9.02.

Similar approach could be followed in case of gas/liquid fuel based generating stations. However the average plant load factor of these stations is much lower than the coal based stations perhaps due to low availability of Gas/ Liquid fuel. Also the heat rate of the gas turbines is very sensitive to the unit loading and ambient air conditions. However, quality of gas supply does not vary widely and so correction for fuel quality would not be required.

(iii)   Sample Calculation: Coal Quality-Effect of fuel quality on Boiler efficiency & Turbine Heat Rate

Coal Proximate and Ultimate Analysis

Item	Unit	Design	Operating
Ash	%	28	41.17
H	%	2.5	2.5
Moisture	%	8	10.35
GCV	kcal/kg	4440	3632.7

Boiler Efficiency by calculation

Item	Unit	Formulae	Design	Operating
% Boiler Efficiency	%	[92.5-{50*A +630* (M+9*H)}/GCV]	87.86	86.25
Difference of Boiler Efficiency from Design to Operating	%		1.62	

In the above calculation for Unit A, Boiler was designed with specific coal having GCV of 4440 kcal/kg and certain Moisture, Ash, Hydrogen content. With the passage of time, the quality of coal deteriorates and reached lower level of GCV, Moisture and hydrogen. The plant has no option but to burn additional fuel and operate at lower efficiencies. The coal linked plant has to plug their fuel demand from the linkage mines only, hence without any alternative the plant needs to stay with their mines only. The poor quality coal not only deteriorates the efficiency of the plant, it also decreases the heat rate of station. As seen in the table, there is no major effect of Ash content in the efficiency of the boiler; however, the H&M factor determines the efficiency of the Boiler.

The efficiency of Unit A has come down from 87.86 to 86.25% with the use of low quality fuel, a decrease in 1.61% of Boiler Efficiency has been observed.

(iv)   Normalization formula for Plant A due to coal quality

Any change in Coal Quality directly affects Boiler Efficiency. The composition of coal largely varies depending upon its source. Based on these consents, coal is graded and is used accordingly in power and other sector. However, while the boiler is recommended and designed for a certain quality of coal, it has to be run on alternate quality due to a number of reasons. These reasons could be in control sometimes, but most of times beyond the control of plant operator. In India, the coal

availability has become a crisis and hence the plant management is most of the times forced to use any quality of coal that is available. Under such situations, where the coal quality cannot be controlled, and the boiler efficiency is affected, a normalization factor has been introduced. This normalization factor will take care of coal quality and give relief in Heat Rate, calculated from boiler efficiency as a result of deferred coal quality. Boiler Efficiency has been calculated using the formula considering all the aspects of coal.

Unit's Boiler Efficiency (For design, BY and AY Coal)

$$= 92.5 - \frac{\{50*A + 630*(M+9*H\}}{GCV \text{ of Coal}}$$

Where

BY = Baseline Year
AY = Assessment Year
GCV = Gross Calorific value (Kcal/ Kg)
M = Moisture (in %)
H = Hydrogen (in %)
A = Ash (in %)

Percentage Decrease in Efficiency from calculated Boiler Operating Efficiency to calculated Boiler Design Efficiency in BY

$$= \frac{\{\text{Calculated Boiler Design Efficiency - Calculated Boiler operating Efficiency in BY}\} \times 100)}{(\text{Calculated Boiler Design Efficiency})}$$

Percentage Decrease in Efficiency from calculated Boiler Operating Efficiency to calculated Boiler Design Efficiency in AY

$$= \frac{\{\text{Calculated Boiler Design Efficiency - Calculated Boiler operating Efficiency in AY}\} \times 100}{\text{Calculated Boiler Design Efficiency}}$$

Degradation/ Upgradation of Actual Boiler Design Efficiency in BY

$$= \frac{\{\text{Actual Design Boiler η of Unit (As per OEM) X \% Decrease in η in BY}\}}{100}$$

Where

BY = Baseline Year
OEM = Original Equipment Manufacturer

Degradation/Upgradation of Actual Boiler Design Efficiency in AY

$$= \frac{\{\text{Actual Design Boiler η of U\# (As per OEM) X \% Decrease in η in AY}\}}{100}$$

Where

AY = Assessment Year
OEM = Original Equipment Manufacturer

Normalized Boiler Efficiency Design for Unit in BY

= (Actual Design Boiler Efficiency of Unit (As per OEM)

— Degradation or Upgradation of Actual Boiler Design in BY)

Where

BY = Baseline Year

OEM = Original Equipment Manufacturer

Normalized Boiler Efficiency Design for Unit in AY

= Actual Design Boiler Efficiency of Unit (As per OEM) - Degradation or Upgradation of Actual Boiler Design in AY

Where

AY = Assessment Year

OEM = Original Equipment Manufacturer

Difference in Normalized Boiler Efficiency between BY and AY

= Normalized Boiler Design Efficiency in BY – Normalized Boiler Design Efficiency in AY

Where

AY = Assessment Year

BY = Baseline Year

Normalized Boiler Efficiency Design for Unit for the AY as compared to the BY

If the difference in Normalized Boiler Efficiency between BY and AY is less than or equal to zero, then No Normalization

If the difference in Normalized Boiler Efficiency between BY and AY is greater than zero, then the normalization is as below:

= Actual Design Boiler Efficiency of Unit (as per OEM) – Difference in Normalized Boiler Efficiency between BY and AY

Where

BY = Baseline Year

AY = Assessment Year

OEM = Original Equipment Manufacturer

Normalized Boiler Efficiency Design for Station:

= [{U# 1 Capacity (MW) X Normalized Boiler Efficiency Design for U# 1 for the AY as compared to the BY} + {U# 2 Capacity (MW) X Normalized Boiler Efficiency Design for U# 2 for the AY as compared to the BY} + …………] / Station total installed Capacity (MW)

Where

BY   = Baseline Year

AY   = Assessment Year

Normalized Unit THR

$$= \frac{\text{(Design THR X Normalized Boiler Efficiency Design for Unit in BY)}}{\text{Normalized Boiler Efficiency Design for Unit in AY}}$$

Where

THR   = Turbine Heat Rate

AY   = Assessment Year

BY   = Baseline Year

Heat Rate to be normalized in the Unit Operating Heat Rate:

If the difference in Normalized Boiler Efficiency between BY and AY is less than or equal to zero, Then No Normalization.

If the difference in Normalized Boiler efficiency between BY and AY is greater than zero, then the Normalization is as below:

Turbine Heat Rate to be normalized = Normalized Unit Turbine Heat Rate – Unit Design Turbine Heat Rate

Turbine Heat Rate to be normalized in the station operating Turbine Heat Rate

=([{HR to be normalized in U# 1 THR X U# 1 Gross Generation (MU)}

        +{ HR to be normalized in U# 2 THR X U# 2 Gross Generation (MU)

        + ………..])/[U# 1 Gross Generation (MU)

        + U# 2 Gross Generation (MU)+ …………])

(b)   Plant Load Factor [Scheduling]

Coal/ Lignite based plants continued to have major contribution towards electricity generation with a major share of 86.4% of the total thermal generation. Plant load factor (PLF) of thermal power stations at the national level, during 2011-12, reduced to 73.32% from 75.08% achieved during previous year. The Lower PLF was due to increased generation loss due to coal supply problem and transmission constraints and Reserve Shut down/Low system demand

PLF will also have an effect on the Auxiliary Power Consumption of the Station. Due to low PLF, the percentage APC will increase.This factor may be beyond the control of station, such as during low schedule, grid restriction, etc. However this shall be considered in different sub-section of APC normalization.

(i)   Method of Normalization
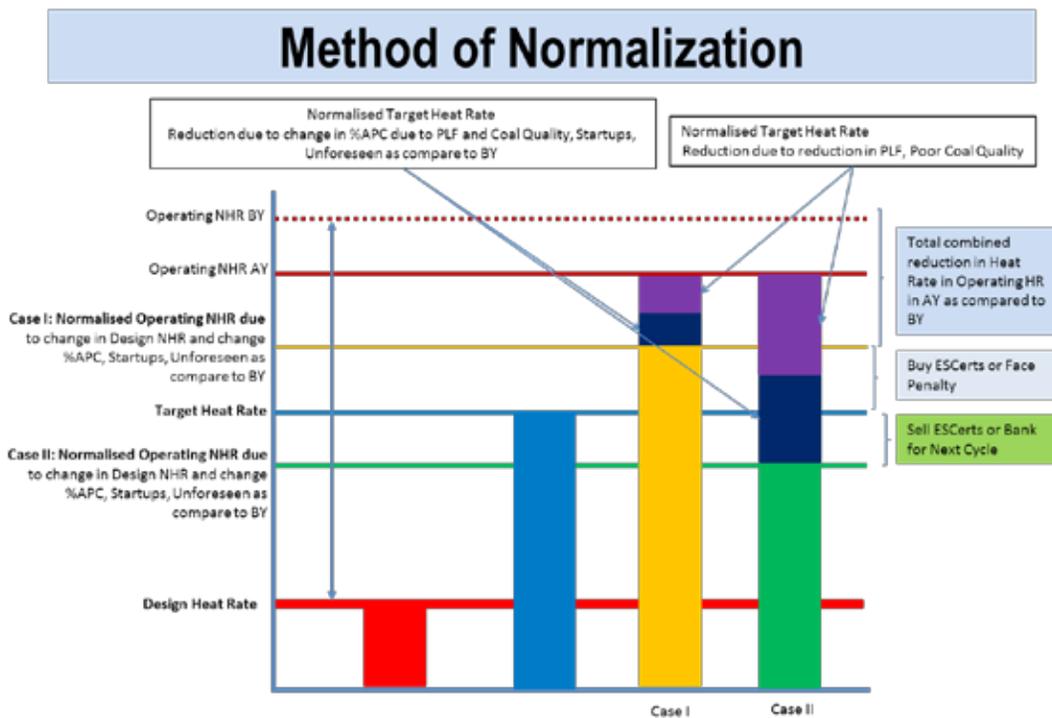
(ii)   Normalisation Example: Coal Based Thermal Power Plant (210 MW): Change in Plant Load Factor (PLF)

210 MW Characteristics Curve
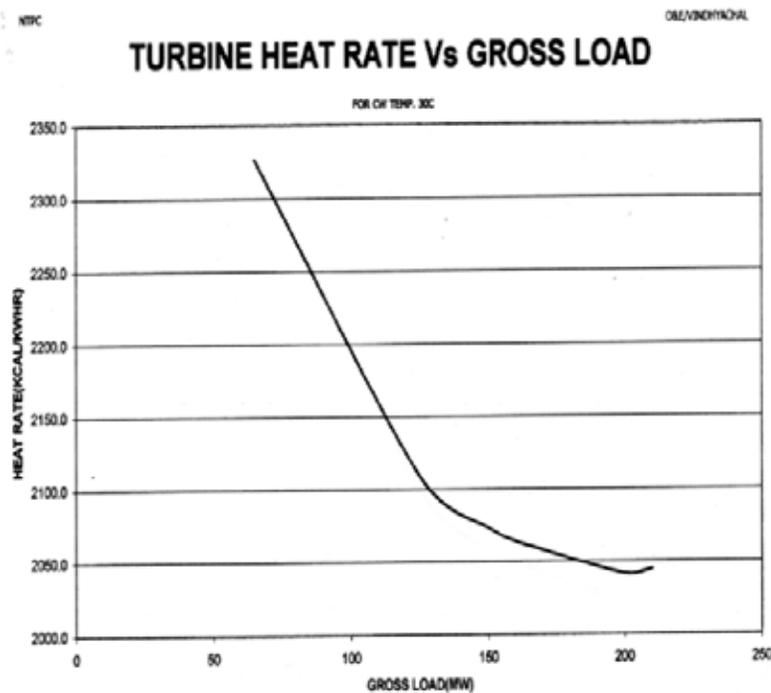
Excel topology 210 MW Characteristics Curve

Load (MW) Vs Turbine Heat Rate (kcal/kWh)

$y = 0.017x^2 - 6.5974x + 2684.1$
$R^2 = 0.9974$

(y-axis: kcal/kWh, values from 2000 to 2350; x-axis: Load (MW), values from 0 to 250)
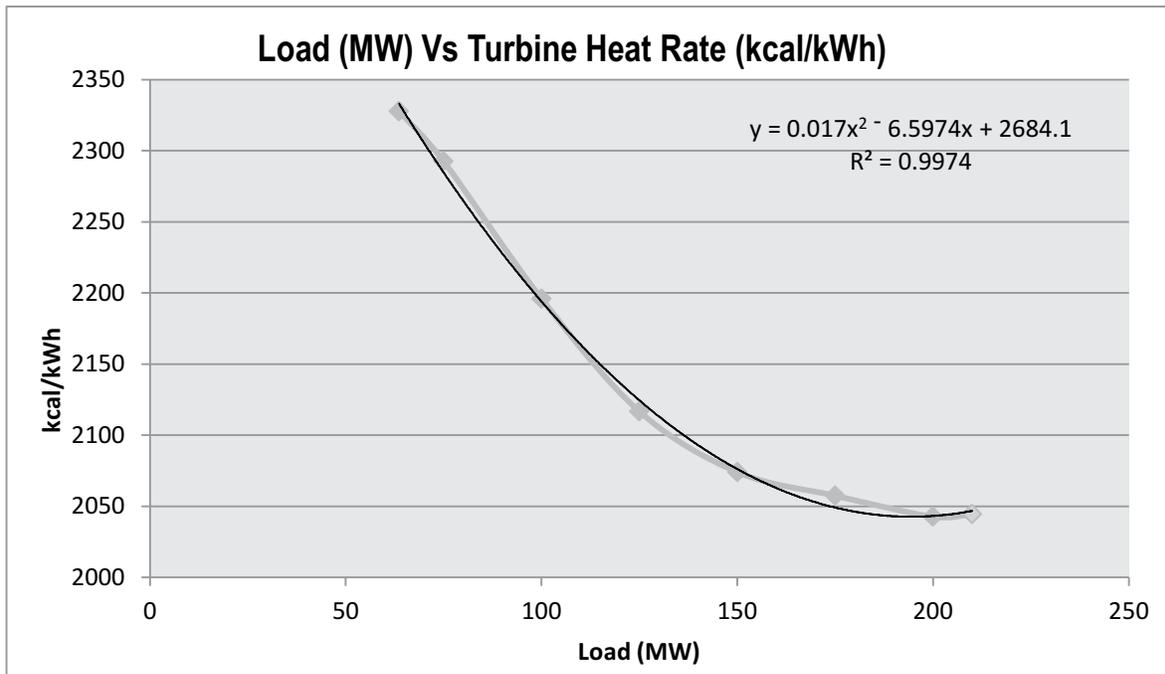
(iii) Normalisation Example for Plant A due to PLF

Change in Plant Load Factor (PLF) do affects the plant efficiency and the heat rate. PLF depends on a number of factors. These factors are sometimes under the control of plant operators and sometimes not. Moreover, at different period of times during a year, a plant may not run on a consistent PLF. All such factors which affects the generation, ultimately affects the PLF. It is understood that the plant may not be operating on the same PLF in the Assessment Year as in Baseline Year for internal as well as external reasons. Hence, in PLF normalization, all such factors which were beyond the control of the plant management, has been taken care off and due advantage has been given. In PLF normalization, like other normalizations, the benefit has been calculated and given in terms of Heat rate which will directly be subtracted from the Net Operating Heat Rate.

Percentage Difference between Design Turbine Heat Rate and Design Curve or HBD Turbine Heat Rate

$$= \frac{(\text{Design THR @ 100\% Load (OEM)} - \text{Design THR @ 100\% Load (Curve or HBD)} \times 100)}{\text{Design THR @ 100\% Load (OEM)}}$$

Where

THR = Turbine Heat Rate (kcal/kWh)

OEM = Original Equipment Manufacturer

HBD = Heat Balance Diagram

Total Operating hours in year as per Unit Availability factor (hrs/annum)

= Total hour in a year X Plant Availability Factor

Operating hours at full load (hrs/annum)

=Total Operating hours in year as per Unit Availability factor - AOHrs at Low ULF/ MLF

Where

AOHr = Average Operating Hours (hr)

ULF = Unit Load Factor

MLF = Module Load Factor

Loading Vs Heat Rate Equation given as y = ax2 - bx + c will be used to calculate the Turbine Heat Rate as per Load Vs Heat Rate Equation due to external factor.

$$y = ax2 - bx + c \quad (kcal/kWh)$$

Where

X = Operating Load (MW)

A = Equation Constant 1 =0.0171

b = Equation Constant 2 = 6.6159
c = Equation Constant 3 = 2684.8

Turbine Heat Rate as per Load Vs Heat Rate Equation due to external factor (kcal/kWh)

=Equation Constant 1

*(Average Operating Load (MW)caused by low ULF, MLF due to external factor)^2

Equation Constant 2

* Average Operating Load (MW)caused by low ULF,MLF due to external factor

+Equation Constant 3

Design Turbine Heat Rate after Curve correction and difference correction

= THR as per Load Vs HR Equation due to external factor X [1 + {% Difference between Design Turbine or Module HR and Design Curve or HBD Turbine or Module HR/ 100}]

Where

THR = Turbine Heat Rate (kcal/kWh)

L Vs HR = Load Vs Heat Rate

HBD = Heat balance Diagram

Normalized Design Turbine Heat rate due to external factor (kcal/kWh)

= [Design THR @ 100% Load (OEM) X Operating hours at full load + Design THR after Curve correction and difference correction X AOHrs at Low ULF/MLF] / Total Operating hours in year as per UAF

Where

THR = Turbine Heat Rate (kcal/kWh)

OEM= Original Equipment Manufacturer

AOHr = Average Operating Hours

UAF = Unit Availability Factor

Difference of Turbine Heat Rate due to external factor between AY and BY (kcal/kWh)

= Normalized Design THR due to external factor in AY - Normalized Design THR due to external factor in BY

Where

THR = Turbine Heat Rate (kcal/kWh)

AY = Assessment Year

BY = Baseline Year

Normalized Design Turbine Heat rate due to external factor as compared to BY

= Design THR @ 100% Load (OEM) + Difference of THR due to external factor between AY and BY

Where

THR = Turbine Heat Rate (kcal/kWh)

AY = Assessment Year

BY = Baseline Year

OEM= Original Equipment Manufacturer

Normalized Designed Station Turbine Heat Rate due to ULF as compared to BY

=[Normalized U# 1 Design THR due to external factor as compared to BY X U# 1 Capacity + Normalized U# 2 Design THR due to external factor as compared to BY X U# 2 Capacity + ……………] / Station installed Total Capacity (MW)

Where

THR = Turbine Heat Rate (kcal/kWh)

BY = Baseline Year

Weighted Design Turbine Heat Rate of Station

=[U# 1 Capacity X U# 1 Design THR @ 100% Load (OEM) + U# 2 Capacity X U# 2 Design THR @ 100% Load (OEM) + …………..] / Station installed Total Capacity (MW)

Where

THR = Turbine Heat Rate (kcal/kWh)

OEM= Original Equipment Manufacturer

Difference of THR between Normalized Design Heat Rate and Design Heat Rate

=Normalized Design Station THR due to ULF as compared to BY – Station Weighted Design THR

ULF = Unit Load Factor

THR = Turbine Heat Rate (kcal/kWh)

BY = Baseline Year

PLF Normalization = Difference of THR between NDHR and DHR

(c) Auxiliary Power Consumption (APC) Normalization

Auxiliary Power Consumption (APC) has a significant contribution in determining the Net Heat Rate of any Station. As other factors in a Power Plant, APC is also subject to change at different period of time. It primarily depends on the unit loading ultimately affecting the drives. It also depends on the ambient conditions at times. It is hence, very important to study the characteristics of APC during Assessment year and Baseline year. The APC in baseline Year and Assessment Year may not be same and therefore normalization for APC was needed to be introduced. Accordingly, The normalization has been worked out and, again as others,It gives the benefit in heat rate due to effect of APC.

PLF will also have an effect on the Auxiliary Power Consumption of the Station. Due to low PLF, the percentage APC will increase. This factor may be beyond the control of station, such as during low schedule, grid restriction, etc. However this shall be considered in different sub-section of APC normalization.

The normalization of APC can be subdivided into three categories

i) APC normalization due to external factors

ii) APC normalization for PA Fan loading due to change in coal quality

iii) APC normalization for Coal Grinding Mill, ID Fans and Ash Handling Plantloading due to change in coal quality

(i) APC normalization due to external factors

The APC of Thermal Power Plant is not fully dependent on the loading of plant. Due to decrease in PLF, the APC will not decrease with same ratio. Hence, a trend line equation could be generated from the normal operating condition of the Plant taking the data of APC and Plant loading for a station. The Excell topology of the Trendline equation is shown below

The chart shows: $y = -0.0001x^2 - 0.0304x + 9.6...$, $R^2 = 0.9031$ with legend entries Series1 and Poly. (Series1).

Auxiliary Power Consumption Trendline Equation

$y = ax2 - bx + c$ will be used to calculate the Turbine Heat Rate as per Load Vs Heat Rate Equation due to external factor.

$y = ax2 - bx + c$

Where

X = Operating Load (MW)

A = Equation Constant 1

b = Equation Constant 2

c = Equation Constant 3

Operating Hours at full load

=(Total hours in a year X PAF) — Weighted AOHr at Low loading due to external factor

— Weighted AOHr at Low loading due to internal factor)

Where

PAF = Plant Availability Factor

AOHr = Average Operating Hours

Weighted Operating Station Load

=[{Station Capacity X Operating Hours at Full Load} + {Station AOL (MW) caused by low loading due to external factor X Weighted AOHr at Low loading due to external factor} + {Station AOL (MW) caused by low loading due to internal factor X Weighted AOHr at Low loading due to internal factor}] / [Weighted AOHr at Low loading due to external factor + Weighted AOHr at Low loading due to internal factor+ Operating Hours at full load]

Where

AOHr = Average Operating Hours (Hrs)

AOL = Average Operating Load (MW)

Actual Loading Factor (%)

$$= \frac{(\text{Weighted Operating Station Load X 100})}{\text{Station Capacity}}$$

Actual Loading Factor for BY
= (461.92*100)/630 = 73.321 %

Actual Loading Factor for AY
= (377.55*100)/630 = 59.929 %

Weighted Station Load without external factor (MW)

= [{Station Capacity X Weighted AOHr at Low

loading due to external factor} + {Station Capacity X Operating hours at full Load} + {AOL (MW) caused by low loading due to Internal factor X Weighted AOHr at Low loading due to internal factor}] / [Weighted AOHr at Low loading due to external factor+Weighted AOHr at Low loading due to internal factor +Operating hours at full Load]

Where

AOHr = Average Operating Hours (Hrs)

AOL = Average Operating Load (MW)

Normalized Loading Factor

$$= \frac{\text{(Weighted Station Load without external factor (MW)X 100}}{\text{Station Capacity (MW)}}$$

Percentage APC as per Trend Line for AY and BY

This shall be calculated by the % APC Trend Line equation mentioned above for Assessment Year and baseline year individually.

=Constant 1 *(Normalized Loading Factor) ^2-Constant 2*Normalized Loading Factor + Constant 3

Where

APC =Auxiliary Power Consumption

BY = Baseline Year

AY = Assessment Year

Difference in APC of AY From BY= % APC as per trend line in AY -% APC as per trend line in BY

Where

APC =Auxiliary Power Consumption

BY = Baseline Year

AY = Assessment Year

Normalized APC

If the difference in APC of AY From BY is less than or equal to zero, then Normalized APC will be same as operating station APC.

If the difference in APC of AY From BY is greater than zero, then normalized APC is as below:

Normalized APC = Station Operating APC - Difference in APC of AY From BY

Where

APC =Auxiliary Power Consumption

BY = Baseline Year

AY = Assessment Year

APC Normalization in terms of Heat Rate

APC Normalization for external factors (kcal/kWh)

$$= \frac{\text{Operating GHR in AY}}{\text{(Operating GHR in AY)}} - \frac{\text{1-\% APC of AY}}{\text{(1- \% normalized APC)}}$$

Where

GHR =Gross Heat Rate (kcal/kWh)

AY =Assessment Year

APC =Auxiliary Power Consumption

(ii) APC normalization for PA Fan loading due to change in coal quality

Due to change in coal quality, there may be a marginal/ significant impact on the energy consumption of PA fans. This is primarily due to the reason that poor coal quality will increase the coal consumption and increased coal consumption will need more Primary air. To calculate this we arrive to a Trendline equation of specific PA consumption per tonne of coal by comparing the design Specific PA consumption of different sized units.

By the GCV of coal, Generation and GHR of Baseline and Assessment year, we can calculate the actual coal consumption of BY and AY. By comparing the GCV of BY with AY and

multiplying it with the total coal flow of BY, we can obtain the normalized coal consumption of the unit. The excel topology of Trendline equation for specific PA calculation is shown below.
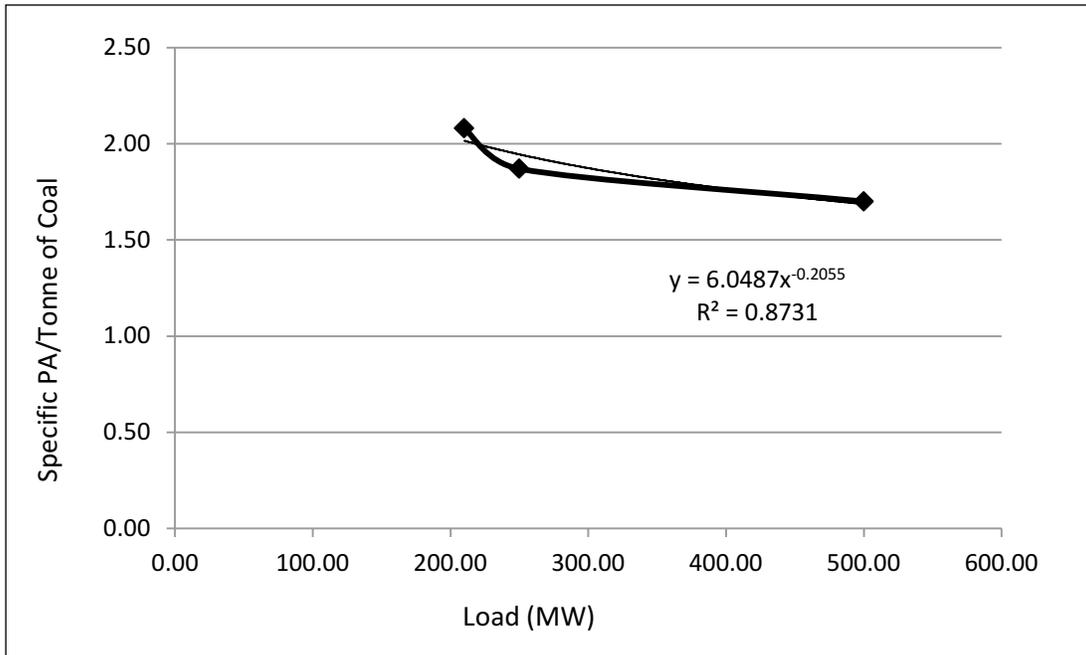
From the above Trendline equation, we will calculate the total PA requirement with normalized coal consumption and that of BY. Now by calculating the volume of PA and ultimately the power consumption of PA, we can calculate the increase in Power consumption of PA as a result of change in Coal GCV. It shall be described with examples in the chapters ahead.

The formula for calculation of increase in energy consumption of PA as a result of change in coal quality is mentioned below.

Total Coal Consumption per unit (AY and BY) (Tonnes/Hr)

= (GHR X Operating Load)/ Coal GCV

Where

GHR = Gross Heat Rate (kcal/kWh)

GCV = Gross Calorific Value (kcal/kg)

Normalized Total Coal Consumption per unit(Tonnes/Hr) =

Total Coal Consumption X Coal GCV for BY/ Coal GCV for AY

Where

GHR = Gross Heat Rate (kcal/kWh)

GCV = Gross Calorific Value (kcal/kg)

Increase in coal consumption due to change in GCV of coal in AY (Tonnes/Hr)

=*Normalised Coal Consumption (tonne/hr)-Total consumption of BY (tonnes/hr)*

Total Primary Air requirement per tonne of coal Trendline equation

$y=6.048x^{-0.2055}$

Where

Y= total PA requirement /tonne of coal (Tonnes)

x= operating load (MW)

Total Primary Air requirement (Tonnes/hr)

=Normalised coal consumption (TPH) X PA requirement per tonne of coal as per Trendline equation(tonne)

Where

TPH   =Tonnes per hour

PA   =Primary Air

Volume of Primary Air (m³/hr)

=Total PA requirement (TPH) X 1000 / 1.233

Where

TPH   =Tonnes per hour

PA   =Primary Air

Power Consumption from PA Fans (kW) for AY and BY

=2.725 X Volume of PA X 1000/ (0.95 X 0.8 X10⁶)

Where

AY   =Assessment Year

BY   =Basement Year

PA   = Primary Air

Increase in energy consumption due to change in GCV of coal in AY (kW/hr)

= Power Consumption from PA fans in AY with normalised coal consumption –Power Consumption from PA fans in BY

Where

AY   =Assessment Year

BY   =Basement Year

PA   = Primary Air

Normalized Thermal Energy due to change in GCV of coal per unit (million kcal)

= Increase in energy consumption due to change in GCV of coal in AY (kW/hr)

 X GHR of AY X Operating Hours of AY/10^6

Where

AY   = Assessment Year

GHR   =Gross Heat Rate (kcal/kWh)

GCV   =Gross Calorific Value (kcal/kg)

Normalized Thermal Energy due to change in GCV of coal for station (million kcal)

= NTE U#1 + NTE U#2 + NTE U#3 +…….

Where

NTE= Normalized Thermal Energy due to change in GCV of coal per unit (million kcal)

GCV=Gross Calorific Value (kcal/kg)

(iii)   APC normalization for Coal Grinding Mill, ID Fan and Ash Handling Plantloading due to change in coal quality

The change in coal quality directly affects the coal consumption of the unit. Coal quality also affects boiler efficiency which has been covered in earlier sections. A coal with higher GCV means less coal flow and vice-versa. More coal flow means more volume of air to be handled by the ID Fan, which ultimately affects the power consumption from the ID Fans. Due to change in coal quality there may rise a need of starting or stopping a mill. This affects the percentage APC significantly. Again, the quality of coal also implies percentage of Ash. More ash generation means more work done by the Ash handling plant, and in turn increased auxiliary consumption. Moreover, as the coal quality is something which cannot be controlled by the plant authorities, there comes the need of normalization for same.

Here, we try to normalize the %APC due to coal quality. Total coal consumption of AY and BY can be calculated by the GCV, GHR and generation. By comparing the GCV of AY and BY and multiplying it with the BY coal consumption, we can get the normalized coal consumption. Now by calculating the specific energy consumption of mill per tonne of coal for BY and multiplying it with the difference between normalized coal consumption and coal consumption in BY, we get the increase in energy consumption. It shall be described with examples in the chapters ahead.

The formula for calculation of increase in energy consumption of Mills as a result of change in coal quality is mentioned below.

Operating Hours (hrs) = Gross Generation (Million Units)X 1000/Operating load (MW)

Total Coal Consumption per unit (AY and BY) (Tonnes/Hr)

= (GHR X Operating Load)/ Coal GCV

Where

GHR = Gross Heat Rate (kcal/kWh)

GCV = Gross Calorific Value (kcal/kg)

Normalized Total Coal Consumption per unit(Tonnes/Hr) =

Total Coal Consumption X Coal GCV for BY/ Coal GCV for AY

Where

GHR = Gross Heat Rate (kcal/kWh)

GCV = Gross Calorific Value (kcal/kg)

Increase in coal consumption due to change in GCV of coal in AY (Tonnes/Hr)

=*Normalised Coal Consumption(tonne/hr) - Total consumption of BY (tonnes/hr)*

Total Electrical Energy consumption for Coal Grinding mills (VRM/Ball), ID Fan and Ash Handling Plant per hour (kW/hr)

=TEEC for Coal Grinding mills (VRM/Ball), ID Fan and Ash Handling Plant (Million Units) X 10^6/Operating Hours (hrs)

Where

TEEC = Total Electrical Energy Consumption

Specific energy consumption per tonne of coal (kWh/Tonne)

=TEEC for Coal Grinding mills (VRM/Ball),ID Fan and Ash Handling Plant per hour (kW/hr)/ Total Coal Consumption

Where

TEEC = Total Electrical Energy Consumption

Increase in energy consumption due to change in GCV of coal in AY (kW/hr)

=Increase in coal consumption due to change in GCV of coal in AY (Tonnes/hr)

X Specific energy consumption per tonne of coal in BY (kWh/Tonne)

Normalization due to change in GCV of coal per unit (Million kcal)

=Increase in energy consumption due to change in GCV of coal in AY (kW/hr)

X GHR of AY X Operating Hours of AY/10^6

Where

AY   = Assessment Year

BY   = Basement Year

GHR   = Gross Heat rate (kcal/kWh)
GCV   = Gross Calorific Value (kcal/kg)

Normalization for station due to change in GCV of coal for Station (Million kcal)

=NMC U#1 +NMC U#2 +NMC U#3 +…………

Where

NMC = Normalization due to change in GCV of coal (Million Units)

Now, we have the effect of coal quality on PA Fan and Mill, ID Fan and Ash Handling Plant loading/ energy Consumption

APC normalization for PA Fan + Coal Grinding Mill , ID Fan and Ash Handling Plant loading due to change in coal quality

={Normalized Thermal Energy due to change in GCV of coal for station due to PA Fans (million kcal) +Normalization for station due to change in GCV of coal for Station due to Mills, ID Fans and Ash Handling Plant (Million kcal)} / Gross Generation of AY

Final APC Normalization for the station

APC Normalization (kcal/kWh)

= APC Normalization due to external factors (kcal/kWh) + APC normalization for PA Fan, Coal Grinding Mill, ID Fan and Ash Handling Plant loading due to change in coal quality (kcal/kWh)

(d)   Other Normalization

Apart from the deviation in operating condition in PLA, coal quality and APC between baseline and assessment year, there still remains something which needs to be addressed. This is the energy consumption in start-up. A plant may be shut-down due to various reasons and on every start-up, there is a certain amount of energy which increases the heat rate. This energy varies for type of start-up, i.e., cold, warm or hot start-up. The number of start-up in the baseline year and assessment year may not be same, and this may be due to external reasons as well. Hence, normalization was considered for this aspect also and accordingly the benefit was given in terms of Heat Rate. Also, There are factors such as environmental concerns, unforeseen circumstances, shutdown etc., which may affect the Heat Rate. Such factors are also to be considered.

Based on the type of start-up, the energy consumption varies. The energy consumption also varies depending on the capacity of the unit. A detailed summary of energy consumptions in various capacity units under different types of start-ups in mentioned below.

Oil Consumption under various start-ups

For Cold Start-up

If capacity <= 250 MW, Oil Consumption is 50 KL

If capacity>250 MW, but<=500 MW, Oil Consumption is 90 KL

If capacity>500 MW,<=660MW, Oil Consumption is 110 KL

For Warm Start-up

If capacity <= 250 MW, Oil Consumption is 30 KL

If capacity>250 MW, but <=500 MW, Oil Consumption is 50 KL

If capacity>500 MW,<=660MW, Oil Consumption is 60 KL

For Hot Start-up

If capacity <= 250 MW, Oil Consumption is 20 KL

If capacity > 250 MW, but <= 500 MW, Oil Consumption is 30 KL

If capacity>500 MW,<=660MW, Oil Consumption is 40 KL

Based on these parameters, we will calculate the normalization for the station.

KL Oil Consumption = (Difference between number of start-ups in AY and BY) X (Oil Consumption as per above)

Thermal Energy to be subtracted due to Cold/ Warm/Hot Start up due to External Factor (Million kcal)

= [KL oil Consumption in cold Start up + KL oil Consumption in warm start up + KL oil Consumption in Hot Start up] X 10

Total Electrical Energy in Assessment Year (Million kcal)

= [Electrical Energy to be subtracted due to Shutdown (External Factor) in AY (MU)+Electrical Energy to be subtracted due to Environmental concern (External Factor) in AY (MU)+Electrical Energy to be subtracted due to Unforeseen Circumstances (External Factor) in AY(MU)] X GHR of Station in AY

Where

GHR = Gross Heat rate (kcal/kWh)

AY   = Assessment Year

Total Electrical Energy in Baseline Year (Million kcal)

= [Electrical Energy to be subtracted due to Shutdown (External Factor) in BY (MU)+Electrical Energy to be subtracted due to Unforeseen Circumstances (External Factor) in BY(MU)] X GHR of Station in BY

Where

GHR = Gross Heat rate (kcal/kWh)

BY = Baseline Year

Total Thermal Energy (Million kcal) in AY

=Thermal Energy to be subtracted due to Environmental concern (External Factor) in AY +Thermal Energy to be subtracted due to Unforeseen Circumstances (External Factor) in AY+Thermal Energy to be subtracted due to Cold/Warm/Hot Start up (External Factor) in AY

Where

AY = Assessment Year

Total Thermal Energy (Million kcal) in BY

= Thermal Energy to be subtracted due to Unforeseen Circumstances (External Factor) in BY

Where

BY= Baseline Year

Total Energy to be Subtracted or normalized (Million kcal)= [Total Electrical Energy forAY (Million kcal) + Total Thermal Energy for AY (million kcal)] – [(Total Electrical Energy for BY(Million kcal)+ Total Thermal Energy for BY (Million kcal)]

Where

AY = Assessment Year

BY = Baseline Year

Other Normalization (kcal/kWh)

$$= \frac{\text{Total Energy to be subtracted or normalized in AY (MU)}}{\text{Gross Generation in AY}}$$

Where

AY = Assessment Year

MU = Million Unit

(e) Final Normalization Calculation for Coal Based Thermal Power plant

From the sections above we know that there may have been a lot of change in operating conditions that the baseline year due to reasons beyond the control of plant management. Accordingly, normalizations were given for coal quality, PLF, APC and Other factors .i.e.,

Operating Station NHR of this station with Normalization

= Actual Operating Station NHR of this station without Normalization – Coal Quality Normalization – PLF normalization – APC Normalization – Other Normalization

Section 9.03 **Normalisation for Gas Based Thermal Power Plant**

(a) Gas Fuel Mix Normalization

A Gas based Power Plant may run on a mixture of fuels depending upon the availability and need. The ratio of fuel mix in generation may not be same in baseline year and assessment year due to a number of factors. Hence, normalizations are given on the Fuel mixture used in the module.

Gross Generation from Fuel Mix (Million Unit)

= Actual Gross Generation from Gas+ Actual Gross Generation from Naptha + Actual Gross Generation from Oil/Other Fuel

Module Heat Rate with Fuel Mix (kcal/kWh)

= [(Design Module HR @ 100% Load (OEM) for Gas X Actual Gross Generation from Gas) + (Design Module HR @ 100% Load for Naphtha X Actual Gross Generation

from Naphtha) + (Design Module HR @ 100% Load (OEM) for Oil/Other Fuel X Actual Gross Generation from Oil/Other Fuel)] / [Actual Gross Generation from Gas (MU) + Actual Gross Generation from Naphtha (MU) + Actual Gross Generation from Oil/Other Fuel (MU)]

Where
HR = Heat Rate (kcal/kWh)

Difference of Module Heat Rate with Fuel Mix in AY w.r.t. BY (kcal/kWh)

= Module HR with Fuel Mix in AY - Module HR with Fuel Mix in BY

Where

HR   = Heat rate (kcal/kWh)

AY   = Assessment Year
BY   = Baseline Year

Notion energy for Fuel Mix to be Normalized for Module (Million kcal)

=Difference of Module Heat Rate with Fuel Mix in AY w.r.t. BY X Gross Generation from Fuel Mix in AY

Where

AY   = Assessment Year

BY   = Baseline Year

Notion energy for Fuel Mix to be Normalized for station (Million kcal)

=   [Notion energy for Fuel Mix to be Normalized for Module 1 + Notion energy for Fuel Mix to be Normalized for Module 2 + Notion energy for Fuel Mix to be Normalized for Module 3 + …………]

Gas Fuel Mix Normalization (kcal/kWh)

$$= \frac{\text{(Notion energy for Fuel Mix to be Normalized for station (Million kcal)}}{\text{Gross Generation (Million Units)}}$$

(b)   Gas OC cycle Normalization

The Heat Rate of a module differs when run in open cycle and closed cycle. This may be due to various reasons. The duration of open and closed cycle in baseline year and assessment year may not be same. As a result the Net Heat rate of module and station will deviate. Hence, normalization has been given on Open/ closed cycle as well.

Gross Generation during Open Cycle (External Factor) and Closed Cycle Operation (MU)

= Actual Gross Generation during Closed Cycle (MU)+ Actual Gross Generation during Open Cycle due to external factor(MU)

Module Heat Rate for Open and Closed cycle operation (kcal/kWh)

= [(Design Module HR @ 100% Load (OEM) for Closed Cycle X Actual Gross Generation during Closed Cycle) + (Design Module HR @ 100% Load for Open Cycle X Actual Gross Generation during Open Cycle due to external factor) / [Actual Gross Generation during Closed Cycle (MU) + Actual Gross Generation during Open Cycle due to external factor (MU))]

Where

HR= Heat Rate (kcal/kWh)

Difference in Module Heat Rate with Open and Closed cycle operation in AY w.r.t. BY (kcal/kWh)

= Module HR for Open and Closed cycle operation in AY - Module HR for Open and Closed cycle operation in BY

Where

HR   = Heat Rate (kcal/kWh)

AY   = Assessment Year

BY   = Baseline Year

Notion energy for Gas OC Cycle to be Normalized for Module (Million kcal)

=Difference in Module HR with Open and

Closed cycle operation in AY w.r.t. BY (kcal/kWh) X Gross Generation from Open and Closed cycle operation (MU)

Where

HR = Heat Rate (kcal/kWh)

AY = Assessment Year

BY = Baseline Year

Notion energy for Gas OC Cycle to be Normalized for station (Million kcal)

= [Notion energy for Fuel Mix to be Normalized for Module 1 + Notion energy for Fuel Mix to be Normalized for Module 2 + Notion energy for Fuel Mix to be Normalized for Module 3 + … … … …]

Gas OC Cycle Normalization (kcal/kWh)

$$= \frac{\text{Notion energy for Gas OC Cycle to be Normalized for station (Million kcal)}}{\text{Gross Generation (MU)}}$$

(c) Auxiliary Power Consumption (APC) Normalization

Auxiliary Power Consumption (APC) has a significant contribution in determining the Net Heat Rate of any Station. As other factors in a Power Plant, APC is also subject to change at different period of time. It primarily depends on the unit loading ultimately affecting the drives. It also depends on the ambient conditions at times. It is hence, very important to study the characteristics of APC during Assessment year and Baseline year. The APC in baseline Year and Assessment Year may not be same and therefore normalization for APC was needed to be introduced. Accordingly, The normalization has been worked out and, again as others,It gives the benefit in heat rate due to effect of APC.

The APC of Thermal Power Plant is not fully dependent on the loading of plant. Due to decrease in PLF, the APC will not decrease with same ratio. Hence, a trend line equation could be generated from the normal operating condition of the Plant taking the data of APC and Plant loading for a station. The Excell topology of the Trendline equation is shown above

Auxiliary Power Consumption Trendline Equation

$y = ax^2 - bx + c$ will be used to calculate the Turbine Heat Rate as per Load Vs Heat Rate Equation due to external factor.

$y = ax^2 - bx + c$

Where

X = Operating Load (MW)

A = Equation Constant 1

b = Equation Constant 2

c = Equation Constant 3

Operating Hours at full load

= (Total hours in a year X PAF)

— Weighted AOHr at Low loading due to external factor

— Weighted AOHr at Low loading due to internal factor)

Where

PAF = Plant Availability Factor

AOHr = Average Operating Hours

Weighted Operating Station Load

=[{Station Capacity X Operating Hours at Full Load} + {Station AOL (MW) caused by low loading due to external factor X Weighted AOHr at Low loading due to external factor} + {Station AOL (MW) caused by low loading due to internal factor X Weighted AOHr at Low loading due to internal factor}] / [Weighted AOHr at Low loading due to external factor + Weighted AOHr at Low loading due to internal factor+ Operating Hours at full load]

Where

AOHr = Average Operating Hours (Hrs)

AOL = Average Operating Load (MW)

$$\text{Actual Loading Factor (\%)} = \frac{(\text{Weighted Operating Station Load X 100})}{(\text{Station Capacity})}$$

Weighted Station Load without external factor (MW)

= [{Station Capacity X Weighted AOHr at Low loading due to external factor} + {Station Capacity X Operating hours at full Load} + {AOL (MW) caused by low loading due to Internal factor X Weighted AOHr at Low loading due to internal factor}] / [Weighted AOHr at Low loading due to external factor+Weighted AOHr at Low loading due to internal factor +Operating hours at full Load]

Where

AOHr = Average Operating Hours (Hrs)

AOL = Average Operating Load (MW)

Normalized Loading Factor

$$= \frac{\text{Weighted Station Load without external factor (MW)X 100}}{\text{Station Capacity (MW)}}$$

Percentage APC as per Trend Line for AY and BY

This shall be calculated by the % APC Trend Line equation mentioned above for Assessment Year and baseline year individually.

=Constant 1 *(Normalized Loading Factor)^2- Constant 2*Normalized Loading Factor + Constant 3

Where

APC =Auxiliary Power Consumption

BY = Baseline Year
AY = Assessment Year

Difference in APC of AY From BY= % APC as per trend line in AY -% APC as per trend line in BY

Where

APC =Auxiliary Power Consumption

BY = Baseline Year
AY = Assessment Year

Normalized APC

If the difference in APC of AY From BY is less than or equal to zero, then Normalized APC will be same as operating station APC.

If the difference in APC of AY From BY is greater than zero, then normalized APC is as below:

Normalized APC = Station Operating APC - Difference in APC of AY From BY

Where

APC = Auxiliary Power Consumption

BY = Baseline Year

AY = Assessment Year

APC Normalization in terms of Heat Rate

APC Normalization (kcal/kWh) =

$$\frac{\text{Operating GHR in AY}}{\text{(1-\% APC of AY)}} - \frac{\text{Operating GHR in AY}}{\text{(1- \% normalized APC)}}$$

Where

GHR = Gross Heat Rate (kcal/kWh)

AY = Assessment Year

APC = Auxiliary Power Consumption

(d) PLF Normalization

The PLF of any station keeps on varying. The PLF of Baseline year and assessment year may not be same due to many reasons. Low loading adversely affects the heat rate of the station. .Low schedules for gas based generation coupled with the problem of gas supply shortages to various gas based stations, the gas based generation is having a negative growth. Hence, normalizations has been given for low PLF due to all external factors.

Percentage Difference between Design Module Heat Rate and Design Curve or HBD Module Heat Rate

$$= \frac{\text{(Design MHR @ 100\% Load (OEM) - Design mHR @ 100\% Load (Curve or HBD) X 100)/}}{\text{(Design MHR @ 100\% Load (OEM))}}$$

Where

MDR = Module Heat Rate (kcal/kWh)

OEM = Original Equipment Manufacturer

HBD = Heat Balance Diagram

Total Operating hours in year as per Unit Availability factor (hrs/annum)

= Total hour in a year X Plant Availability Factor

Operating hours at full load (hrs/annum)

=Total Operating hours in year as per Unit Availability factor - AOHrs at Low ULF/MLF

Where

AOHr = Average Operating Hours (hr)

ULF = Unit Load Factor

MLF = Module Load Factor

Loading Vs Heat Rate Equation given as $y = ax2 - bx + c$ will be used to calculate the Turbine Heat Rate as per Load Vs Heat Rate Equation due to external factor.

$y = ax2 - bx + c$ (kcal/kWh)

Where

X = Operating Load (MW)

A = Equation Constant 1 =0.0171

b = Equation Constant 2 = 6.6159

c = Equation Constant 3 = 2684.8

Module Heat Rate as per Load Vs Heat Rate Equation due to external factor (kcal/kWh)

=Equation Constant 1*(Average Operating Load (MW)caused by low ULF,MLF due to external factor)^^ 2-Equation Constant 2* Average Operating Load (MW)caused by low ULF,MLF due to external factor+Equation Constant 3

Design Module Heat Rate after Curve correction and difference correction

= MHR as per Load Vs HR Equation due to external factor X [1 + {% Difference between Design Turbine or Module HR and Design Curve or HBD Turbine or Module HR/ 100}]

Where

MHR   = Module Heat Rate (kcal/kWh)

L Vs HR   = Load Vs Heat Rate

HBD   = Heat balance Diagram

Normalized Design Module Heat rate due to external factor (kcal/kWh)

=   [Design MHR @ 100% Load (OEM) X Operating hours at full load + Design MHR after Curve correction and difference correction X AOHrs at Low ULF/MLF] / Total Operating hours in year as per UAF

Where

MHR   = Module Heat Rate (kcal/kWh)

OEM   = Original Equipment Manufacturer

AOHr = Average Operating Hours
UAF   = Unit Availability Factor

Difference of Module Heat Rate due to external factor between AY and BY (kcal/kWh)

=   Normalized Design MHR due to external factor in AY - Normalized Design MHR due to external factor in BY

Where

MHR   = ModuleHeat Rate (kcal/kWh)

AY   = Assessment Year

BY   = Baseline Year

Normalized Design ModuleHeat rate due to external factor as compared to BY

=   Design MHR @ 100% Load (OEM) + Difference of MHR due to external factor between AY and BY

Where

MHR   = ModuleHeat Rate (kcal/kWh)

AY   = Assessment Year

BY   = Baseline Year

OEM   = Original Equipment Manufacturer

Normalized Designed Station ModuleHeat Rate due to ULF as compared to BY

=[Normalized U# 1 Design MHR due to external factor as compared to BY X U# 1 Capacity + Normalized U# 2 Design MHR due to external factor as compared to BY X U# 2 Capacity + ……………] / Station installed Total Capacity (MW)

Where

MHR = ModuleHeat Rate (kcal/kWh)

BY   = Baseline Year

Weighted Design ModuleHeat Rate of Station

=[U# 1 Capacity X U# 1 Design MHR @ 100% Load (OEM) + U# 2 Capacity X U# 2 Design MHR @ 100% Load (OEM) + …………..] / Station installed Total Capacity (MW)

Where

MHR   = ModuleHeat Rate (kcal/kWh)

OEM   = Original Equipment Manufacturer

Difference of MHR between Normalized Design Heat Rate and Design Heat Rate

=Normalized Design Station MHR due to ULF as compared to BY – Station Weighted Design MHR

ULF   = Unit Load Factor

MHR   = ModuleHeat Rate (kcal/kWh)

BY   = Baseline Year

PLF Normalization = Difference of MHR between NDHR and DHR

(e)   Gas Quality Normalization

The Gas quality plays an important role in the Net Heat Rate of a gas fired station. Variation in Gas quality directly affects the Net Heat Rate. The effect of various Net Calorific Values (NCV) of Net Heat Rate plotted on excel gave the Trendline equation for NHR. The excel topology of the Trendline equation is shown below.
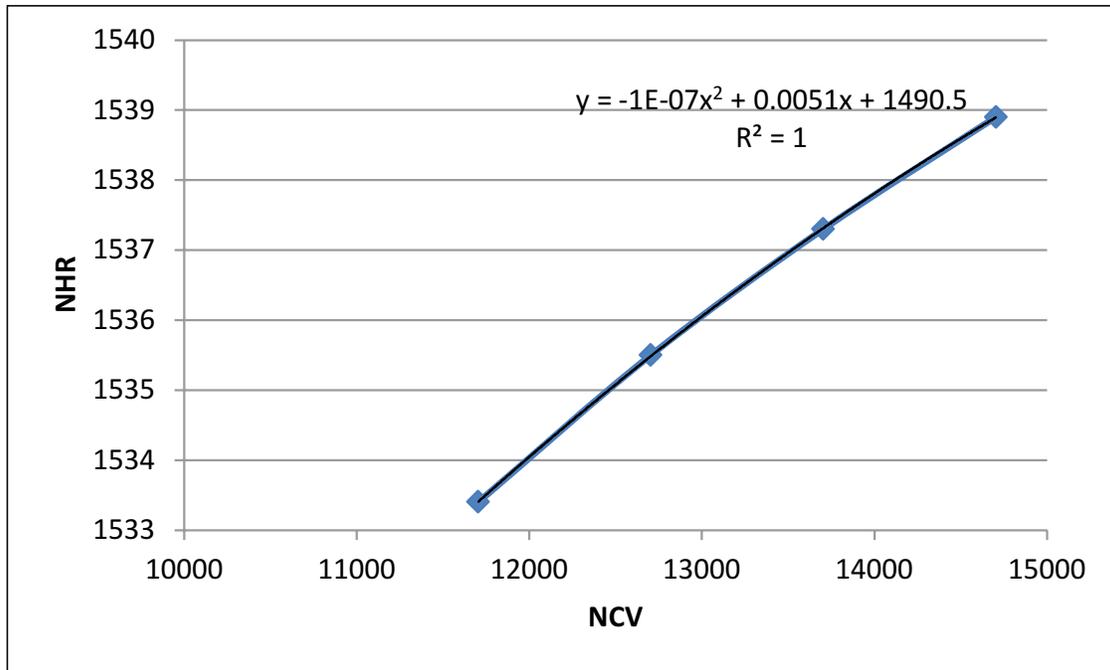
From the above Trendline equation, the NHR has been calculated depending on the NCV of Gas and accordingly the normalization has been given.

NHR Trendline equation (kcal/kWh)

$y = -10^{-7}x^2 + 0.0051x + 1490.5$

Where

Y= Net Heat Rate (kcal/kWh)
X=Net Calorific Value (kcal/kg)

Difference in NHR as per Trendline Equation between AY and BY (kcal/kWh)

=NHR as Per Trendline Equation for AY – NHR as per Trendline Equation for BY

Where

NHR = Net Heat Rate (kcal/kWh)

AY   =Assessment Year

BY   =Baseline year

Normalization due to change in Gas Quality (Million kcal)

= Difference in NHR as per Trendline Equation between AY and BY (kcal/kWh) X Gross Generation in AY

Where

NHR = Net Heat Rate (kcal/kWh)

AY   =Assessment Year

BY   =Baseline year

Normalization due to Change in Gas Quality for Station (kcal/kWh)

= Normalization due to change in Gas Quality (Million kcal) / OGHR in AY (kcal/kWh)

Where

OGHR=Gross Operating Heat Rate (kcal/kWh)

(f)   Other Normalization

Apart from the deviation in operating condition in PLA, coal quality and APC between baseline and assessment year, there still remains something which needs to be addressed. This is the energy consumption in start-up. A plant may be shut-down due to various reasons and on every start-up, there is a certain amount of energy which increases the heat rate. This energy varies for type of start-up, i.e., cold,

warm or hot start-up. The number of start-up in the baseline year and assessment year may not be same, and this may be due to external reasons as well. Hence, normalization was considered for this aspect also and accordingly the benefit was given in terms of Heat Rate. Also, There are factors such as environmental concerns, unforeseen circumstances, shutdown etc., which may affect the Heat Rate. Such factors are also to be considered.

Based on the type of start-up, the energy consumption varies. The energy consumption also varies depending on the capacity of the unit. A detailed summary of energy consumptions in various capacity units under different types of start-ups in mentioned below.

Oil Consumption under various start-ups

For Cold Start-up

If capacity <= 250 MW, Oil Consumption is 50 KL

If capacity > 250 MW, but <= 500 MW, Oil Consumption is 90 KL

If capacity >500 MW, <=660MW, Oil Consumption is 110 KL

For Warm Start-up

If capacity <= 250 MW, Oil Consumption is 30 KL

If capacity > 250 MW, but <= 500 MW, Oil Consumption is 50 KL

If capacity >500 MW, <=660MW, Oil Consumption is 60 KL

For Hot Start-up

If capacity <= 250 MW, Oil Consumption is 20 KL

If capacity > 250 MW, but <= 500 MW, Oil Consumption is 30 KL

If capacity >500 MW, <=660MW, Oil Consumption is 40 KL

Based on these parameters, we will calculate the normalization for the station.

KL Oil Consumption = (Difference between number of start-ups in AY and BY) X (Oil Consumption as per above)

Thermal Energy to be subtracted due to Cold/Warm/Hot Start up due to External Factor (Million kcal)

= [KL oil Consumption in cold Start up + KL oil Consumption in warm start up + KL oil Consumption in Hot Start up] X 10

Total Electrical Energy in Assessment Year (Million kcal)

= [Electrical Energy to be subtracted due to Shutdown (External Factor) in AY (MU)+Electrical Energy to be subtracted due to Environmental concern (External Factor) in AY (MU)+Electrical Energy to be subtracted due to Unforeseen Circumstances (External Factor) in AY(MU)] X GHR of Station in AY

Where

GHR = Gross Heat rate (kcal/kWh)

AY = Assessment Year

Total Electrical Energy in Baseline Year (Million kcal)

= [Electrical Energy to be subtracted due to Shutdown (External Factor) in BY (MU)+Electrical Energy to be subtracted due to Unforeseen Circumstances (External Factor) in BY(MU)] X GHR of Station in BY

Where

GHR = Gross Heat rate (kcal/kWh)

BY = Baseline Year

Total Thermal Energy (Million kcal) in AY

=Thermal Energy to be subtracted due to Environmental concern (External Factor) in AY +Thermal Energy to be subtracted due to Unforeseen Circumstances (External Factor) in AY+Thermal Energy to be subtracted due to Cold/Warm/Hot Start up (External Factor) in AY

Where

AY = Assessment Year

Total Thermal Energy (Million kcal) in BY

= Thermal Energy to be subtracted due to Unforeseen Circumstances (External Factor) in BY

Where

BY = Baseline Year

Total Energy to be Subtracted or normalized (Million kcal)= [Total Electrical Energy for AY (Million kcal) + Total Thermal Energy for AY (million kcal)] – [(Total Electrical Energy for BY(Million kcal)+ Total Thermal Energy for BY (Million kcal)]

Where

AY = Assessment Year

BY = Baseline Year

Other Normalization (kcal/kWh)

$$= \frac{\text{Total Energy to be subtracted or normalized in AY (MU)}}{\text{(Gross Generation in AY)}}$$

Where

AY = Assessment Year

MU = Million Unit

(g) Final Normalization Calculation for Gas based Thermal Power plant

From the sections above we know that there has been a lot of change in operating conditions than the baseline year due to reasons beyond the control of plant management. Hence, normalizations have been given for Fuel mix, OC Cycle, APC, PLF, Gas Quality and Other factors .i.e.,

Operating Station NHR of this station with Normalization

= Actual Operating Station NHR of this station without Normalization – Fuel mix Normalization – OC Cycle Normalization – APC Normalization- PLF Normalization- gas Quality Normalization – Other Normalization

10. Examples of Normalization

Section 10.01 **Common Calculations for Normalization**

We have seen in the chapters above, the calculation of each factors for which normalizations have been given.In normalization, the deviation due to each external factor is calculated in terms of Heat Rate and is subtracted from the Station Operating Net Heat rate for Assessment Year.

Now let us understand each normalization factor in detail, with examples.

Current/Assessment/Target Year (20... 20...)								Baseline Year (BY) Average (20.... 20....)							
Average Operating Load (MW) caused by low ULF/MLF due to Fuel Unavailability		Average Operating Load (MW) caused by low ULF/ MLF due to Scheduling		Average Operating Load (MW) caused by low ULF/MLF due to backing down@		Average Operating Load (MW) caused by low ULF/MLF due to any other external factor@		Average Operating Load (MW) caused by low ULF/MLF due to Fuel Unavailability		Average Operating Load (MW) caused by low ULF/ MLF due to Scheduling		Average Operating Load (MW) caused by low ULF/ MLF due to backing down		Average Operating Load (MW) caused by low ULF/ MLF due to any other external factor	
MW	Oper-ating Hours	MW	Oper-ating Hours	MW	Oper-ating Hours	MW	Oper-ating Hours	MW	Oper-ating Hours	MW	Oper-ating Hours	MW	Oper-ating Hours	MW	Oper-ating Hours
120	3000	160	1200	150	4000			140	3000	190	1200	170	4000		
150	3000	200	500	205	3000			180	3000	200	500	210	3000		
110	5000	0	0	0	0			180	3000	200	500	210	3000		

For understanding this, let us consider the table above. This table represents the loading and running hours of the station due to Fuel unavailability, Scheduling, backing down and other external factors for both Assessment and Baseline Year.

Station Average Operating Hour (Hr) Caused by low ULF/MLF due to Fuel Unavailability

$$= \frac{[U\# 1\ AOHr \times U\# 1\ AOL\ (MW)\} + U\# 2\ AOHr \times U\# 2\ AOL\ (MW) + \ldots\ldots\ldots\ldots\ ]}{Station\ AOL\ (MW)\ due\ to\ Fuel\ Unavailability}$$

Where:

ULF = Unit Load Factor

MLF = Module Load Factor

AOHr = Average Operating Hour

AOL = Average Operating Load

Station AOH due to Fuel Unavailability   for Baseline Year

= ((3000*140)+(3000*180)+(3000*180))/ (140+180+180)

= 3000 hrs.

Station AOH due to Fuel Unavailability   for Assessment Year

= ((3000*120)+(3000*150)+(5000*110))/ (120+150+110)

= 3578.947 hrs

Station Average Operating Hour (Hr.)Caused by low ULF/MLF due to Scheduling

$$= \frac{[\{U\# 1\ AOHr \times U\# 1\ AOL\ (MW)\} + \{ U\# 2\ AOHr + U\# 2\ AOL\ (MW)\} + \ldots\ldots\ldots\ ]}{Station\ AOL\ (MW)\ due\ to\ Scheduling}$$

Where

ULF = Unit Load Factor

MLF = Module Load Factor

AOHr = Average Operating Hour

AOL = Average Operating Load

Station AOH due to Scheduling   for Baseline Year

= ((1200*190)+(500*200)+(500*200))/ (190+200+200)

= 725.42 hrs.

Station AOH due to Scheduling   for Assessment Year

= ((1200*160)+(500*200)+(0))/ (160+200+0)

= 811.11 hrs

Station Average Operating Hour (Hr.)Caused by low ULF/ MLF due to Backing down

$$= \frac{[\{U\# 1\ AOHr \times U\# 1\ AOL\ (MW)\} + \{U\# 2\ AOHr + U\# 2\ AOL\ (MW)\} + \ldots\ldots\ldots]}{Station\ AOL\ (MW) due\ to\ backing\ down}$$

Where

ULF = Unit Load Factor

MLF = Module Load Factor

AOHr = Average Operating Hour

AOL = Average Operating Load

Station AOH due to backing Down for Baseline Year

= ((4000*170)+(3000*210)+(3000*210))/ (170+210+210) = 3288.13 MW

Station AOH due to Backing down for Assessment Year

= ((4000*150)+(3000*205)+(0))/ (150+105+0)

= 4764.70 hrs

Station Average Operating Hours (Hr.) caused by ULF/MLF due to any other external Factor

$$= \frac{[\{U\# 1\ AOHr \times U\# 1\ AOL\ (MW)\} + \{U\# 2\ AOHr + U\# 2\ AOL\ (MW)\} + \ldots\ldots\ldots]}{Station\ AOL\ (MW)\ due\ to\ backing\ down}$$

Where

ULF = Unit Load Factor

MLF = Module Load Factor

AOHr = Average Operating Hour

AOL = Average Operating Load

External factors = Fuel Unavailability/ Scheduling/ backing down/ any other external factor etc.

In the example of this station, nothing has been mentioned for other external factors. Hence,

Station AOH due to any other external factors = 0

This holds good for Baseline as well as Assessment Year as nothing has been mentioned for both years.

However, if a station has any other external factors it could be included in this section. Even if the baseline year had no other external factors and assessment year has, and vice-versa, it could be accounted here.

Unit Average Operating Load (MW) Caused by low ULF/MLF due to External factors

= Total Generation (MWHr) / Total Operating Hour (Hr)

Where

Total Generation = (Unit AOL (MW) X Unit AOHr) due to Fuel Unavailability + (Unit AOL (MW) X Unit AOHr) due to Scheduling + (Unit AOL (MW) X Unit AOHr) due to Backing Down + (Unit AOL (MW) X Unit AOHr) due to any other external factor]

Total Operating Hour = [Unit AOHr due to Fuel Unavailability + Unit AOHr due to Scheduling + Unit AOHr due to Backing Down + Unit AOHr due to any other external factor]

ULF = Unit Load Factor

MLF = Module Load Factor

AOHr = Average Operating Hour

AOL = Average Operating Load

External factors = Fuel Unavailability/ Scheduling/ backing down/ any other external factor etc.

Baseline Year

Unit # 1 Average Operating load = Total Generation/ Total Operating hours
= ((140*3000) + (190*1200) + (170*4000))/ (3000+1200+4000)
= 161.95 MW

Unit # 2 Average Operating load = Total Generation/ Total Operating hours
= ((180*3000) + (200*500) + (210*3000))/ (3000+500+3000)
= 195.38 MW

Unit # 3 Average Operating load = Total Generation/ Total Operating hours
= ((180*3000) + (200*500) + (210*3000))/ (3000+500+3000)
= 195.38 MW

Assessment Year

Unit # 1 Average Operating load = Total Generation/ Total Operating hours
= ((120*3000) + (160*1200) + (150*4000))/ (3000+1200+4000)
= 140.48 MW

Unit # 2 Average Operating load = Total Generation/ Total Operating hours
= ((150*3000) + (200*500) + (205*3000))/ (3000+500+3000)
= 179.23 MW

Unit # 3 Average Operating load = Total Generation/ Total Operating hours
= ((110*5000) + (0) + (0))/ (5000+0+0)
= 110 MW

Station Average Operating Load (MW) caused by low ULF/MLF due to Fuel Unavailability/ Scheduling/ Backing down/ any other external factor
= [U# 1 AOL (MW) + U# 2 AOL (MW) + … … … …]

Where:

ULF   = Unit Load Factor

MLF   = Module Load Factor

AOL   = Average Operating Load

Station Average Operating Load for Baseline Year   = 161.95+195.38+195.38
(Due to external factors)
= 552.72 MW

Station Average Operating Load for Assessment Year   = 140.48+179.23+110
(Due to external factors)
= 429.71 MW

Unit Average Operating Hours at Low ULF/ MLF due to external Factors
= Total Generation (MWHr)/ Total Average Operating load (MW)

Where

Total Generation	= (Unit AOL (MW) X U# AOHr) due to Fuel Unavailability + (Unit AOL (MW) X Unit AOHr) due to Scheduling + (Unit AOL (MW) X Unit AOHr) due to Backing Down + (Unit AOL (MW) X Unit AOHr) due to any other external factor]
Total Average Operating Load	= [{Unit AOL (MW) to Fuel Unavailability + Unit AOL (MW)} due to Scheduling + Unit AOL (MW) to Backing Down + Unit AOL (MW) due to any other external factor]

ULF   = Unit Load Factor

MLF   = Module Load Factor

AOHr = Average Operating Hour

AOL   = Average Operating Load

External factors = Fuel Unavailability/ Scheduling/ backing down/ any other external factor etc.

Baseline Year
Unit # 1 Average Operating Hour = Total Generation/ Total Operating hours

=((140*3000)+(190*1200)+(170*4000))/ (140+190+170)

= 2656 hrs

Unit # 2 Average Operating Hour = Total Generation/ Total Operating hours

=((180*3000)+(200*500)+(210*3000))/ (180+200+210)

= 2152.54 hrs

Unit # 3 Average Operating Hour = Total Generation/ Total Operating hours

=((180*3000)+(200*500)+(210*3000))/ (180+200+210)

= 2152.54 hrs

Assessment Year
Unit # 1 Average Operating Hour = Total Generation/ Total Operating hours

=((120*3000)+(160*1200)+(150*4000))/ (120+160+150)

= 2679.07 hrs.

Unit # 2 Average Operating Hour = Total Generation/ Total Operating hours

=((150*3000)+(200*500)+(205*3000))/ (150+200+205)

= 2099.09 hrs.

Unit # 3 Average Operating Hour = Total

Generation/ Total Operating hours

= ((110*5000) + (0) + (0))/ (110)

= 5000 hrs.

Station Average Operating Hours at Low ULF/ MLF due to external factors

= ([{(U# 1 AOL (MW) X U# 1 AOHr) at Low ULF/MLF due to external factor}

+ {(U# 2 AOL (MW) X U# 2 AOHr) at Low ULF//MLF due to external factor}

+ … … … …])/(Station AOL (MW) caused by low ULF/MLF due to external factors)

Where

ULF = Unit Load Factor

MLF = Module Load Factor

AOHr = Average Operating Hour

AOL = Average Operating Load

External factors = Fuel Unavailability/ Scheduling/ backing down/ any other external factor etc.

Station AOH due to external Factors for Baseline Year

= ((161.95*2656) + (195.38*2152.54) + (195.38*2152.54))/(161.95+195.38+195.38)

=2300.059 hrs

Station AOH due to external Factors for Assessment Year

= ((140.48*2679.07)+(179.23*2099.09)+(110*5000))/(140.48+179.23+110)

= 3031.29 hrs

From the above calculations, Station AOH and AOL for baseline and assessment year were derived. For the calculation of Unit availability factor and station availability factor, let us further assume the data of our station in the below mentioned two tables.

Units	Capacity	Baseline Year (20... 20...)							
		Reserve Shut-down	Forced Outage/ Unavail-ability	Planned Maintenance Outage / Planned Una-vailability	Unit Avail-ability Factor	Average Operat-ing Load (MW) caused by low ULF/MLF due to Internal factor	Operating hours	Average Operat-ing Load (MW) caused by low ULF/MLF due to external factor	Average Operating hours at Low ULF/ MLF
	MW	Hrs	Hrs	Hrs		MW	Hrs/ Annum	MW	Hrs/ Annum
1	210	500	500	300	0.85	170	3000	161.95	2656.00
2	210	600	600	400	0.82	200	5000	195.38	2152.54
3	210	300	300	400	0.85	200	5000	195.38	2152.54

The table above shows the Baseline Year condition of the station in terms of Generation and Running hours due to reserve shutdown, Forced Outage/ fuel unavailability, planned outage, etc. The factors shown here will help in the calculation of unit and station availability factor.

Units	Capacity	Current/Assessment/Target Year (20... 20...)							
		Reserve Shut-down	Forced Outage/ Unavail-ability	Planned Maintenance Outage / Planned Una-vailability	Unit Avail-ability Factor	Average Operat-ing Load (MW) caused by low ULF/MLF due to Internal factor	Operating hours	Average Operat-ing Load (MW) caused by low ULF/MLF due to external factor	Average Operating hours at Low ULF/ MLF
	MW	Hrs	Hrs	Hrs		MW	Hrs/ Annum	MW	Hrs/ Annum
1	210	400	500	300	0.863	170	3000	140.488	2679.07
2	210	300	300	400	0.886	120	5000	179.231	2099.10
3	210	300	600	500	0.840	120	5000	110.000	5000.00

The table above shows the Assessment Year condition of the station in terms of Generation and Running hours due to reserve shutdown, Forced Outage/ fuel unavailability, planned outage, etc. The factors shown here will help in the calculation of unit and station availability factor.

Based on these tables, we will calculate the followings:

Unit Availability Factor={Hours in a Year – [RSHr + FO or Unavailability hour + PMO or Planned Unavailability]}/ Hours in a Year]

Where

RSHr = Reserve Shutdown Hour

FO = Forced Outage

PMO = Planned Maintenance Outage

Baseline Year

| Unit #1 Availability Factor | = (8760-(500+500+300))/8760 |
| | = 0.8515 |

| Unit #2 Availability Factor | = (8760-(600+600+400))/8760 |
| | = 0.8173 |

| Unit #3 Availability Factor | = (8760-(300+300+400))/8760 |
| | = 0.8858 |

Assessment Year

| Unit #1 Availability factor | = (8760 – (400+500+300))/8760 |
| | = 0.8630 |

| Unit #2 Availability factor | = (8760-(300+300+400))/8760 |
| | = 0.8858 |

Unit #3 Availability factor = (8760-(300+600+500))/8760

= 0.8401

Station RSHr

$$= \frac{[\{U\#1\ RSHr \times U\#1\ Capacity\ (MW)\} + \{U\#2\ RSHr \times U\#2\ Capacity(MW)\} + \ldots\ldots\ldots\ldots}{Total\ Station\ capacity \times Hours\ in\ a\ Year}$$

Station RSHr for Baseline Year

= ((500*210)+(600*210)+(300*210))/ ((210+210+210)*8760)

= 0.0532

Station RSHr for Assessment Year

= ((400*210)+(300*210)+(300*210))/ ((210+210+210)*8760)

= 0.0380

Station FO or Unavailability Hour

$$= \frac{[\{U\#1\ FO \times U\#1\ Capacity\ (MW)\} + \{U\#2\ FO \times U\#2\ Capacity(MW)\} + \ldots\ldots\ldots]}{Total\ Station\ capacity \times Hours\ in\ a\ Year}$$

Station FO or Unavailability Hour for Baseline Year

= ((500*210)+(600*210)+(300*210))/ ((210+210+210)*8760)

= 0.0532

Station FO or Unavailability Hour for Assessment Year

= ((500*210)+(300*210)+(600*210))/ ((210+210+210)*8760)

= 0.0532

Station PMO or Planned

$$Unavailability = \frac{[\{U\#1\ PMO \times U\#1\ Capacity\ (MW)\} + \{U\#2\ PMO \times U\#2\ Capacity\ (MW)\} + \ldots\ldots\ldots\ldots]}{Total\ Station\ capacity \times Hours\ in\ a\ Year}$$

Station PMO or Planned Unavailability for Baseline Year

= ((300*210) + (400*210) + (400*210)) / ((210+210+210)*8760)

= 0.0418

Station PMO or Planned Unavailability for Assessment Year

= ((300*210) + (400*210) + (500*210)) / ((210+210+210)*8760)

= 0.0456

Station Availability Factor= 1- [Station RSHr + Station FO or Unavailability hour + Station PMO or Planned Unavailability]

Where

RSHr = Reserve Shutdown Hour

FO = Forced Outage

PMO = Planned Maintenance Outage

Station Availability factor for Baseline Year
= 1-(0.0532+0.0532+0.0418)
= 0.8518

Station Availability factor for Assessment Year
= 1-(0.0380+0.0532+0.0456)
= 0.8632

These formulas constitute the general working formulas which will find reference in all the calculations. These formulas are also used in day to day reporting to the plant management. The definition of terms mentioned above in section 5.1 to 5.13 shall be assumed only on above calculations in 'Form 1'. Now, let us see the working formulas and calculations of the normalizations.

Section 10.02 **Normalization for Coal/ Lignite base Thermal Power Plant**

(a) Coal/Lignite Quality in Boiler IPP
We know that change in coal quality affects the boiler efficiency directly. Also, the % APC varies with change in Coal Quality. The effect of coal quality on APC shall be calculated in sections ahead. Here, we will calculate the effect of coal quality on boiler efficiency and the normalization for it. Let us understand this with the help of the table below

Item	Unit 1			Unit 2			Unit 3		
	Current AY	Baseline Year [BY]	Design [D] for AY	Current Year [AY]	Baseline Year [BY]	Design [D] for AY	Current Year [AY]	Baseline Year [BY]	Design [D] for AY
Unit Capacity (MW)	210	210	210	210	210	210	210	210	210
Design Turbine Heat Rate (Kcal/kWh)	2045	2045	2045	2045	2045	2045	2045	2045	2045
Generation (MU)	1445			1454			1456		
Total Moisture (%)	10.35	9	8	10.35	15	12	10.35	9	8
Ash(%)	41.17	35	28	41.17	45	42	41.17	30	28
GCV (%)	3632.7	4000	4440	3632.7	3800	3700	3632.7	4200	4440
Hydrogen(%)	2.5	2.5	2.5	2.5	2.3	2.33	2.5	2.5	2.5
% Boiler Efficiency (As per Formulae) (%)	86.24	87.10	87.86	86.24	85.99	86.32	86.24	87.42	87.86
Actual Design Boiler Efficiency of Unit (As per OEM) (%)	87.3	87.3	87.3	87.3	87.3	87.3	87.3	87.3	87.3

Table above shows the unit wise coal analysis of the station, with its Design THR and Generation. With the help of this table, we will normalize the station on the basis of coal quality.

Unit's Boiler Efficiency (For design, BY and AY Coal)

$$=92.5 - \frac{\{50*A +630*(M+9*H\}}{(GCV \ of \ Coal)}$$

Where

BY = Baseline Year

AY = Assessment Year

GCV = Gross Calorific value (Kcal/ Kg)

M = Moisture (in %)

H = Hydrogen (in %)

A = Ash (in %)

We have from table above, different composition of coal during baseline and assessment year as well as design. From the above mentioned formula, we have;

Unit #1
Design Boiler Efficiency as per formula = 92.5-(50*28+630*(8+9*2.5))/4440 = 87.86%
Boiler efficiency for BY = 92.5-(5*35+630*(9+9*2.5))/4000 = 87.10%
Boiler efficiency for AY =92.5-(5*41.17+630*(10.35+9*2.5))/3632.7 = 86.24%
Actual Boiler Effciency (as per OEM) = 87.3%

Unit #2
Design Boiler Efficiency as per formula = 92.5-(50*42+630*(12+9*2.33))/3700 = 86.32%
Boiler efficiency for BY = 92.5-(5*45+630*(15+9*2.3))/3800 = 85.99%
Boiler efficiency for AY =92.5-(5*41.17+630*(10.35+9*2.5))/3632.7 = 86.24%
Actual Boiler Effciency (as per OEM) = 87.3%

Unit #3
Design Boiler Efficiency as per formula = 92.5-(50*28+630*(8+9*2.5))/4440 = 87.86%
Boiler efficiency for BY = 92.5-(5*30+630*(9+9*2.5))/4200 = 87.42%
Boiler efficiency for AY =92.5-(5*41.17+630*(10.35+9*2.5))/3632.7 = 86.24%
Actual Boiler Efficiency (as per OEM) = 87.3%

Percentage Decrease in Efficiency from calculated Boiler Operating Efficiency to calculated Boiler Design Efficiency in BY

$$= \frac{\{Calculated \ Boiler \ Design \ Efficiency - Calculated \ Boiler \ operating \ Efficiency \ in \ BY\} \ X \ 100}{Calculated \ Boiler \ Design \ Efficiency}$$

%Decrease in Boiler η in BY for Unit #1 = (87.86-87.10)*100/87.86 = 0.86

% Decrease in Boiler η in BY for Unit #2 = (86.32-85.99)*100/86.32 = 0.38

% Decrease in Boiler η in BY for Unit #3 = (87.86-87.42)*100/87.86 = 0.50

Percentage Decrease in Efficiency from calculated Boiler Operating Efficiency to calculated Boiler Design Efficiency in AY

$$= \frac{\{Calculated \ Boiler \ Design \ Efficiency - Calculated \ Boiler \ operating \ Efficiency \ in \ AY\} \ X \ 100}{Calculated \ Boiler \ Design \ Efficiency)}$$

% Decrease in Boiler η in AY for Unit #1 = (87.86-86.24)*100/87.86 = 1.84

% Decrease in Boiler η in AY for Unit #2 = (86.32-86.24)*100/86.32 = 0.0926

% Decrease in Boiler η in AY for Unit #3 = (87.86-86.24)*100/87.86 = 1.84

Degradation/Upgradation of Actual Boiler Design Efficiency in BY

$$= \frac{\{Actual \ Design \ Boiler \ \eta \ of \ Unit \ (As \ per \ OEM) \ X \ \% \ Decrease \ in \ \eta \ in \ BY\}}{100}$$

Where

BY = Baseline Year

OEM = Original Equipment Manufacturer

From the above mentioned formula, we can calculate the degradation/ Upgradation for individual units of this station.

Degradation/ Upgradation of Actual boiler Design η in BY for Unit #1
= (87.3*0.86)/100= 0.75

Degradation/ Upgradation of Actual boiler Design η in BY for Unit #2
= (87.3*0.38)/100= 0.331

Degradation/ Upgradation of Actual boiler Design η in BY for Unit #3
= (87.3*0.50)/100= 0.436

Degradation/Upgradation of Actual Boiler Design Efficiency in AY

$$\frac{\{\text{Actual Design Boiler } \eta \text{ of U\# (As per OEM)} \times \% \text{ Decrease in } \eta \text{ in AY}\}}{100}$$

Where

AY = Assessment Year

OEM = Original Equipment Manufacturer

Degradation/ Upgradation of Actual boiler Design η in AY for Unit #1

= (87.3*1.84)/100= 1.606

Degradation/ Upgradation of Actual boiler Design η in AY for Unit #2

= (87.3*0.0926)/100= 0.08

Degradation/ Upgradation of Actual boiler Design η in AY for Unit #3
= (87.3*1.84)/100= 1.606

Normalized Boiler Efficiency Design for Unit in BY

= (Actual Design Boiler Efficiency of Unit (As per OEM)

- Degradation or Upgradation of Actual Boiler Design in BY)

Where

BY = Baseline Year

OEM = Original Equipment Manufacturer

Normalized Boiler η Design for Unit#1 in BY = 87.3-0.75 = 86.55%

Normalized Boiler η Design for Unit#2 in BY = 87.3-0.311 = 86.989%

Normalized Boiler η Design for Unit#3 in BY = 87.3-0.436 = 86.864%

Normalized Boiler Efficiency Design for Unit in AY

= Actual Design Boiler Efficiency of Unit (As per OEM) - Degradation or Upgradation of Actual Boiler Design in AY

Where

AY = Assessment Year

OEM = Original Equipment Manufacturer

Normalized Boiler η Design for Unit#1 in AY = 87.3-1.606 = 85.694%

Normalized Boiler η Design for Unit#2 in AY = 87.3-0.08 = 87.22%

Normalized Boiler η Design for Unit#3 in AY = 87.3-1.606 = 85.694%

Difference in Normalized Boiler Efficiency between BY and AY

= Normalized Boiler Design Efficiency in BY – Normalized Boiler Design Efficiency in AY

Where

AY = Assessment Year

BY = Baseline Year

Difference between Normalized Boiler η between BY and AY for Unit #1
=86.55-85.694 = 0.856

Difference between Normalized Boiler η between BY and AY for Unit #2
=86.989-87.22 = -0.231

Difference between Normalized Boiler η between BY and AY for Unit #3
=86.864-85.694 = 1.17

Normalized Boiler Efficiency Design for Unit for the AY as compared to the BY

If the difference in Normalized Boiler Efficiency between BY and AY is less than or equal to zero, then No Normalization

If the difference in Normalized Boiler Efficiency between BY and AY is greater than zero, then the normalization is as below:

= Actual Design Boiler Efficiency of Unit (as per OEM) – Difference in Normalized Boiler Efficiency between BY and AY

Where
BY   = Baseline Year
AY   = Assessment Year
OEM = Original Equipment Manufacturer

Normalized Boiler Efficiency Design for Unit for the AY as compared to the BY for Unit#1
=87.3-0.856 = 86.444%

Normalized Boiler Efficiency Design for Unit for the AY as compared to the BY for Unit#2
=87.3 - 0 = 87.3%

If the difference in Normalized Boiler Efficiency between BY and AY is less than or equal to zero, then No Normalization

Normalized Boiler Efficiency Design for Unit for the AY as compared to the BY for Unit#3
=87.3-1.17 = 86.13%

Normalized Boiler Efficiency Design for Station:

= [{U# 1 Capacity (MW) X Normalized Boiler Efficiency Design for U# 1 for the AY as compared to the BY} + {U# 2 Capacity (MW) X Normalized Boiler Efficiency Design for U# 2 for the AY as compared to the BY} + …………] / Station total installed Capacity (MW)

Where

BY   = Baseline Year

AY   = Assessment Year

Normalizes Boiler η Design for Station

= (210*86.444 + 210*87.3 + 210* 86.13)/ (210+210+210)

= 86.623%

Normalized Unit THR

$$= \frac{\text{Design THR X Normalized Boiler Efficiency Design for Unit in BY}}{\text{Normalized Boiler Efficiency Design for Unit in AY}}$$

Where

THR   = Turbine Heat Rate

AY   = Assessment Year

BY   = Baseline Year

Normalized THR for Unit#1 = (2045*86.55)/ 85.694 = 2065.428 kcal/kWh

Normalized THR for Unit#2 = (2045*86.989)/ 87.22 = 2039.584 kcal/kWh

Normalized THR for Unit#3 = (2045*86.864)/ 85.694 = 2072.921 kcal/kWh

Heat Rate to be normalized in the Unit Operating Heat Rate:

If the difference in Normalized Boiler Efficiency between BY and AY is less than or equal to zero, Then No Normalization.

If the difference in Normalized Boiler efficiency between BY and AY is greater than zero, then the Normalization is as below:

Turbine Heat Rate to be normalized = Normalized Unit Turbine Heat Rate – Unit Design Turbine Heat Rate

Heat Rate to be normalized in the Unit Operating Heat Rate for Unit #1

=2065.428 -2045 = 20.428 kcal/kWh

Heat Rate to be normalized in the Unit Operating Heat Rate for Unit #2

=2039.585 -2045 = -5.41 kcal/kWh, If the difference in Normalized Boiler Efficiency between BY and AY is less than or equal to

zero, Then No Normalization. Hence, No normalization for Unit#2

Heat Rate to be normalized in the Unit Operating Heat Rate for Unit #3

=2072.921 -2045 = 27.921 kcal/kWh

Turbine Heat Rate to be normalized in the station operating Turbine Heat Rate
=([{HR to be normalized in U# 1 THR X U# 1 Gross Generation (MU)}

+{ HR to be normalized in U# 2 THR X U# 2 Gross Generation (MU)

+ ………..])/[U# 1 Gross Generation (MU) + U# 2 Gross Generation (MU)+ …………])

= (20.428*1445 + 0*1454 +27.921*1456)/ (1445+1454+1456)

= 16.11 kcal/kWh
Coal Quality Normalization = 16.11 kcal/kWh

Table below represents the final table that will appear in the form.

Item	Unit	AY	Unit 1 Baseline Year [BY]	Design [D] for AY	Current Year [AY]	Unit 2 Baseline Year [BY]	Design [D] for AY	Current Year [AY]	Unit 3 Baseline Year [BY]	Design [D] for AY
% Decrease in Efficiency from calculated Boiler operating Efficiency to calculated Boiler Design Efficiency	%	1.84	0.86		0.09	0.38		1.84	0.50	
Degradation/Upgradation of Actual Boiler Design Efficiency	%	1.61	0.75		0.08	0.33		1.61	0.44	
Normalised Design Boiler Efficiency for Unit	%	**85.69**	**86.55**		**87.22**	**86.97**		**85.69**	**86.86**	
Difference in Normalised Boiler Efficiency between BY and AY	%		**0.86**			**-0.25**			**1.17**	
Normalised Turbine Heat Rate	kcal/kwh		**2065.42**			**2039.12**			**2072.92**	
Heat Rate to be normalised in the Unit operating Heat Rate	kcal/kwh		**20.42**	*Final Normalization*		**0.00**			**27.92**	
Heat Rate to be normalised in the station operating Heat Rate	***kcal/kwh***	***16.11***								
Normalised Boiler Efficiency Design for Unit for the AY as compared to the BY	%		**86.44**			**87.30**			**86.13**	
Normalised Boiler Efficiency Design for Station	***%***	***86.62***								

In this table all the figures shown has been individually calculated in the sections above.

(b)   Plant Load Factor [Scheduling]

To understand the PLF normalization, let us consider the example of the same plant which we considered earlier. Table below represents some of the parameters of this plant. Apart from the design parameters, other parameters are taken from the calculations done in other sections mentioned above and in this section itself. Here we will see the calculation of PLF Normalization to be given to this station.

Item	Unit	Unit-1		Unit-2		Unit-3	
		AY	BY	AY	BY	AY	BY
Unit Capacity	MW	210	210	210	210	210	210
Design Turbine Heat Rate @ 100% Load (OEM)	kcal/kwh	2045.00	2045.00	2045.00	2045.00	2045.00	2045.00
Boiler Design Efficiency	%	87.3	87.3	87.3	87.3	87.3	87.3
Design Turbine Heat Rate @ 100% Load (Curve or HBD)	kcal/kwh	2044.44	2044.44	2044.44	2044.44	2044.44	2044.44
% Difference between Design Turbine/Module Heat Rate and Design Curve or HBD Turbine/Module Heat rate	%	0.0274	0.0274	0.0274	0.0274	0.027	0.027
Plant Availability Factor	Factor	0.8630	0.8515	0.8858	0.8173	0.8401	0.8858
Average Operating Load (MW) caused by low ULF/MLF due to external factor	MW	140.49	161.95	179.23	195.38	110.00	195.38
Average Operating hours at Low ULF/MLF	Hrs/Annum	2679.07	2656.00	2099.10	2152.54	5000.00	2152.54

Percentage Difference between Design Turbine Heat Rate and Design Curve or HBD Turbine Heat Rate

$$= \frac{\text{Design THR @ 100\% Load (OEM) - Design THR @ 100\% Load (Curve or HBD) X 100}}{\text{Design THR @ 100\% Load (OEM)}}$$

Where

THR = Turbine Heat Rate (kcal/kWh)

OEM = Original Equipment Manufacturer

HBD = Heat Balance Diagram

Unit#1
% Difference between DTHR and Design Curve

or HBD THR for BY

= (2045-2044.44)*100/ 2045 = 0.0274

% Difference between DTHR and Design Curve or HBD THR for AY

= (2045-2044.44)*100/ 2045 = 0.0274

Unit#2

% Difference between DTHR and Design Curve or HBD THR for BY

= (2045-2044.44)*100/ 2045 = 0.0274

% Difference between DTHR and Design Curve or HBD THR for AY

= (2045-2044.44)*100/ 2045 = 0.0274

Unit#3

% Difference between DTHR and Design Curve or HBD THR for BY

= (2045-2044.44)*100/ 2045 = 0.0274

% Difference between DTHR and Design Curve or HBD THR for AY

= (2045-2044.44)*100/ 2045 = 0.0274

Total Operating hours in year as per Unit Availability factor (hrs/annum)

= Total hour in a year X Plant Availability Factor

Unit # 1

Total Operating hours in year as per Unit Availability factor for BY

= 8760* 0.85 = 7459.14 hrs/annum

Total Operating hours in year as per Unit Availability factor for AY

= 8760* 0.86 = 7559.88 hrs/annum

Unit # 2

Total Operating hours in year as per Unit Availability factor for BY

= 8760* 0.82 = 7159.54 hrs/annum

Total Operating hours in year as per Unit Availability factor for AY

= 8760* 0.89 = 7759.60 hrs/annum

Unit # 3

Total Operating hours in year as per Unit Availability factor for BY

= 8760* 0.88 = 7759.60 hrs/annum

Total Operating hours in year as per Unit Availability factor for AY

= 8760* 0.84 = 7359.27 hrs/annum

Operating hours at full load (hrs/annum)

=Total Operating hours in year as per Unit Availability factor - AOHrs at Low ULF/MLF

Where

AOHr = Average Operating Hours (hr)

ULF   = Unit Load Factor

MLF   = Module Load Factor

Unit#1
Operating hours at full load (hrs/annum) for BY = 7459.14-2656 = 4803.14

Operating hours at full load (hrs/annum) for AY = 7559.88-2679.07 = 4880.81

Unit#2
Operating hours at full load (hrs/annum) for BY = 7159.54-2152.54 = 5007

Operating hours at full load (hrs/annum) for AY = 7759.60-2099.10 = 5660.5

Unit#3
Operating hours at full load (hrs/annum) for BY = 7759.60-2152.54 = 5607.06

Operating hours at full load (hrs/annum) for AY = 7359.27-5000 = 2359.27

Loading Vs Heat Rate Equation given as $y = ax2 - bx + c$ will be used to calculate the Turbine Heat Rate as per Load Vs Heat Rate Equation due to external factor.

y = ax2 - bx + c   (kcal/kWh)

Where

X   = Operating Load (MW)

A   = Equation Constant 1 =0.0171

b   = Equation Constant 2 = 6.6159

c   = Equation Constant 3 = 2684.8

Turbine Heat Rate as per Load Vs Heat Rate Equation due to external factor (kcal/kWh)

=   Equation Constant 1

*   (Average Operating Load (MW)caused by low ULF,MLF due to external factor)^2

-   Equation Constant 2

*   Average Operating Load (MW)caused by low ULF,MLF due to external factor

+   Equation Constant 3

Unit #1
THR as per Load Vs HR Equation due to external factor (kcal/kWh) for BY

= 0.0171* 161.95 2 – 6.6159* 161.95 + 2684.8

= 2061.85 kcal/kWh

THR as per Load Vs HR Equation due to external factor (kcal/kWh) for BY

= 0.0171* 140.49 2 – 6.6159* 140.49+ 2684.8

= 2092.85 kcal/kWh

Unit #2
THR as per Load Vs HR Equation due to external factor (kcal/kWh) for BY

= 0.0171* 195.38 2 – 6.6159* 195.38 + 2684.8

= 2044.95 kcal/kWh

THR as per Load Vs HR Equation due to external factor (kcal/kWh) for BY

= 0.0171* 179.23 2 – 6.6159* 179.23 + 2684.8

= 2048.34 kcal/kWh

Unit #3
THR as per Load Vs HR Equation due to external factor (kcal/kWh) for BY

= 0.0171* 195.38 2 – 6.6159* 195.38 + 2684.8

= 2044.95 kcal/kWh

THR as per Load Vs HR Equation due to external factor (kcal/kWh) for BY

= 0.0171* 110 2 – 6.6159* 110 + 2684.8

= 2163.96 kcal/kWh

Design Turbine Heat Rate after Curve correction and difference correction

=   THR as per Load Vs HR Equation due to external factor X [1 + {% Difference between Design Turbine or Module HR and Design Curve or HBD Turbine or Module HR/ 100}]

Where
THR   =   Turbine Heat Rate (kcal/kWh)
L Vs HR   =   Load Vs Heat Rate
HBD   =   Heat balance Diagram

Unit#1
DTHR after Curve Correction and difference correction for BY

= 2061.85*(1+(0.027/100))

= 2062.41 kcal/kWh

DTHR after Curve Correction and difference correction for AY

= 2092.85*(1+(0.027/100))

= 2093.42 kcal/kWh

Unit#2
DTHR after Curve Correction and difference correction for BY

=2044.95 *(1+(0.027/100))

= 2045.51 kcal/kWh

DTHR after Curve Correction and difference correction for AY

= 2048.34*(1+(0.027/100))

= 2048.90 kcal/kWh

Unit#3

DTHR after Curve Correction and difference correction for BY

= 2044.95*(1+(0.027/100))

= 2045.51 kcal/kWh

DTHR after Curve Correction and difference correction for AY

= 2163.95*(1+(0.027/100))

= 2164.55 kcal/kWh

Normalized Design Turbine Heat rate due to external factor (kcal/kWh)

= [Design THR @ 100% Load (OEM) X Operating hours at full load + Design THR after Curve correction and difference correction X AOHrs at Low ULF/MLF] / Total Operating hours in year as per UAF

Where

THR = Turbine Heat Rate (kcal/kWh)

OEM = Original Equipment Manufacturer

AOHr = Average Operating Hours

UAF = Unit Availability Factor

Unit#1

Normalized DTHR due to external factor for BY
= ((2045*4803.14)+(2062.41*2656))/7459.14 = 2051.20 kcal/kWh

Normalized DTHR due to external factor for AY
= ((2045*4880.81)+(2093.42*2679.07))/7559.88 = 2062.16 kcal/kWh

Unit#2

Normalized DTHR due to external factor for BY
= ((2045*5007)+(2045.51*2152.54))/7159.54 = 2045.15 kcal/kWh

Normalized DTHR due to external factor for AY
= ((2045*5660.5)+(2048.90*2099.10))/7759.60 = 2062.16 kcal/kWh

Unit#3

Normalized DTHR due to external factor for BY
= ((2045*5607.06)+(2045.51*2152.54))/7759.60 = 2045.14 kcal/kWh

Normalized DTHR due to external factor for AY
= ((2045*2359.27)+(2164.55*5000))/7359.27 = 2126.22 kcal/kWh

Difference of Turbine Heat Rate due to external factor between AY and BY (kcal/kWh)

= Normalized Design THR due to external factor in AY - Normalized Design THR due to external factor in BY

Where

THR = Turbine Heat Rate (kcal/kWh)

AY = Assessment Year

BY = Baseline Year

Difference of THR due to external factor between AY and BY for Unit#1

= 2062.16-2051.20 = 10.96 kcal/kWh

Difference of THR due to external factor between AY and BY for Unit#2

= 2046.05-2045.15 = 0.90 kcal/kWh

Difference of THR due to external factor between AY and BY for Unit#3

= 2126.22-2045.14 = 81.08 kcal/kWh

Normalized Design Turbine Heat rate due to external factor as compared to BY

= Design THR @ 100% Load (OEM) + Difference of THR due to external factor between AY and BY

Where

THR = Turbine Heat Rate (kcal/kWh)

AY = Assessment Year

BY = Baseline Year

OEM = Original Equipment Manufacturer

Normalized DTHR due to external factor as compared to BY for Unit#1

=2045+10.96 = 2055.96 kcal/kWh

Normalized DTHR due to external factor as compared to BY for Unit#2

=2045+0.90 = 2045.90 kcal/kWh

Normalized DTHR due to external factor as compared to BY for Unit#3

=2045+81.08 = 2126.08 kcal/kWh

Normalized Designed Station Turbine Heat Rate due to ULF as compared to BY

=[Normalized U# 1 Design THR due to external factor as compared to BY X U# 1 Capacity + Normalized U# 2 Design THR due to external factor as compared to BY X U# 2 Capacity + ……………] / Station installed Total Capacity (MW)

Where

THR = Turbine Heat Rate (kcal/kWh)

BY = Baseline Year

Normalized DSTHR due to ULF as compared to BY

=((2055.96*210) + (2045.90*210) + (2126.08*210))/ (210+210+210)

=2075.98 kcal/kWh

Weighted Design Turbine Heat Rate of Station

=[U# 1 Capacity X U# 1 Design THR @ 100% Load (OEM) + U# 2 Capacity X U# 2 Design THR @ 100% Load (OEM) + …………..] / Station installed Total Capacity (MW)

Where

THR = Turbine Heat Rate (kcal/kWh)

OEM = Original Equipment Manufacturer

Weighted Design THR of Station

=((2045*210)+(2025*210)+(2045*210))/ (210+210+210)

=2045 kcal/kWh

Difference of THR between Normalized Design Heat Rate and Design Heat Rate

=Normalized Design Station THR due to ULF as compared to BY – Station Weighted Design THR

ULF = Unit Load Factor

THR = Turbine Heat Rate (kcal/kWh)

BY = Baseline Year

Difference of THR between NDHR and DHR = 2075.98-2045 = 30.98kcal.kWh

PLF Normalization = Difference of THR between NDHR and DHR

PLF Normalization =30.98kcal/kWh

Table below represents the final table that will appear in the form.

Item	Unit	Unit-1		Unit-2		Unit-3	
		AY	BY	AY	BY	AY	BY
Total Operating hours in year as per Unit Availability factor	Hrs/Annum	7560.00	7460.00	7760.00	7160.00	7360.00	7460.00
Operating hours at full load	Hrs/Annum	4880.93	4804.00	5660.90	5007.46	2360.00	5307.46
Turbine Heat Rate as per Load Vs Heat Rate Equation due to external factor	kcal/kwh	*2092.85*	*2061.85*	*2048.34*	*2044.95*	*2163.96*	*2044.95*
Design Turbine Heat Rate after Curve correction and difference correction	kcal/kwh	2093.42	2062.41	2048.90	2045.51	2164.55	2045.51
Normalised Design Turbine Heat rate due to external factor	kcal/kwh	2062.16	2051.20	2046.06	2045.15	2126.22	2045.15
Difference of Turbine Heat Rate due to external factor between AY and BY	kcal/kwh	10.96		0.90		81.07	
Normalised Design Turbine Heat rate due to external factor as compared to BY	kcal/kwh	2055.96		2045.90		2126.07	
Weighted Design Turbine Heat Rate of Station	kcal/kwh	2045.00	2045.00				
Normalised Design Station Turbine Heat Rate due to ULF as compared to BY	kcal/kwh	2075.98					
Differnce of Turbine Heat rate between Normalised Design Heat Rate and Design Heat Rate	**kcal/kwh**	**30.98**					

> This is the final Normalization

In this table all the figures shown has been individually calculated in the sections above.

(c) Auxiliary Power Consumption (APC) Normalization

APC has a significant contribution in determining the NHR of a Station. The APC may differ in BY and AY due to many reasons. The normalization has been worked out for Low PLF, and change in coal quality.

(i) APC normalization due to external factors

The normalization has been worked out for low PLF due to external/ internal factors. For understanding, let us consider the below mentioned table.

Item	Unit	Assessment Year (AY)	Baseline Year (BY)
Station Capacity	MW	630	630
APC	%	6.89	5.9
APC Trend line Equation		y = -0.0001x2 - 0.0304x + 9.6114	y = -0.0001x2 - 0.0304x + 9.6114
Constant 1	a	0.00010	0.00010
Constant 2	b	0.03040	0.03040
Constant 3	c	9.61500	9.61500
Plant Availability Factor		0.863	0.840
Station Average Operating Load (MW) caused by low loading due to external factor	MW	429.72	552.72
Weighted Average Operating hours at Low loading due to external factor	hrs	3031.29	2300.06
Average Operating Load (MW) caused by low loading due to Internal factor	MW	290.00	370.00
Weighted Average Operating hours at Low loading due to internal factor	hrs	3827.59	4081.08

Table 8: APC related parameters

Table above shows the parameters related to APC. The AOL and AOH have been taken from the calculations in above sections. From these parameters we will calculate the normalization for APC.

Auxiliary Power Consumption Trendline Equation

$y = ax2 - bx + c$ will be used to calculate the Turbine Heat Rate as per Load Vs Heat Rate Equation due to external factor.

$$y = ax2 - bx + c$$

Where

X = Operating Load (MW)

A = Equation Constant 1

b = Equation Constant 2

c = Equation Constant 3

Operating Hours at full load

=(Total hours in a year X PAF)

— Weighted AOHr at Low loading due to external factor

— Weighted AOHr at Low loading due to internal factor)

Where
PAF = Plant Availability Factor
AOHr = Average Operating Hours

Operating Hours at Full Load for BY
=(8760*0.8401)-2300.06-4081.08
=978.13 hrs.

Operating Hours at Full Load for AY
=(8760*0.863)-3031.29-3827.59
=701.00 hrs.

Weighted Operating Station Load
=[{Station Capacity X Operating Hours at Full Load} + {Station AOL (MW) caused by low loading due to external factor X Weighted AOHr at Low loading due to external factor} + {Station AOL (MW) caused by low loading due to internal factor X Weighted AOHr at Low loading due to internal factor}] / [Weighted AOHr at Low loading due to external factor + Weighted AOHr at Low loading due to internal factor+ Operating Hours at full load]

Where
AOHr = Average Operating Hours (Hrs)
AOL = Average Operating Load (MW)

Weighted Operating Station load for BY

= ((630*987.78)+(552.72*2300.06)+(370*4081.08))/(2300.06+4081.08+987.13)

= 461.92 MW

Weighted Operating Station load for AY

= ((630*701)+(429.72*3031.29)+(290*3827.59))/(3031.29+3827.59+701)

= 377.55 MW

Actual Loading Factor (%)

= (Weighted Operating Station Load X 100)/ (Station Capacity)

Actual Loading Factor for BY = (461.92*100)/630 = 73.321 %

Actual Loading Factor for AY = (377.55*100)/630 = 59.929 %

Weighted Station Load without external factor (MW)
= [{Station Capacity X Weighted AOHr at Low loading due to external factor} + {Station Capacity X Operating hours at full Load} + {AOL (MW) caused by low loading due to Internal factor X Weighted AOHr at Low loading due to internal factor}] / [Weighted AOHr at Low loading due to external factor+Weighted AOHr at Low loading due to internal factor +Operating hours at full Load]

Where

AOHr = Average Operating Hours (Hrs)

AOL = Average Operating Load (MW)

Weighted Station Load without external factor for BY

=((630*2300.06)+(630*987.13)+(370*4081.08))/ (2300.06+4081.08+987.13)

= 485.99 MW

Weighted Station Load without external factor for AY

=((630*3031.29)+(630*701)+(290*3827.59))/ (3031.29+3827.59+701)

= 457.86 MW

Normalized Loading Factor

$$= \frac{\text{Weighted Station Load without external factor (MW)} \times 100}{\text{Station Capacity (MW)}}$$

Normalized Loading factor for AY =457.86*100/630 = 72.676

Percentage APC as per Trend Line for AY and BY

This shall be calculated by the % APC Trend Line equation mentioned above for Assessment Year and baseline year individually.

=Constant 1 *(Normalized Loading Factor) ^2-Constant 2*Normalized Loading Factor + Constant 3

Where

APC = Auxiliary Power Consumption

BY = Baseline Year

AY = Assessment Year

Percentage APC as per Trend Line for BY

= 0.00010*73.3212 – 0.03040*73.321 + 9.61500
= 6.85%

Percentage APC as per Trend Line for AY

= 0.00010*72.7672 – 0.03040*72.676 + 9.61500

= 6.88%

Difference in APC of AY From BY= % APC as per trend line in AY -% APC as per trend line in BY

Where

APC = Auxiliary Power Consumption

BY = Baseline Year

AY = Assessment Year

Difference in APC of AY From BY = 6.88 – 6.85 = 0.03%

Normalized APC

If the difference in APC of AY From BY is less than or equal to zero, then Normalized APC will be same as operating station APC.

If the difference in APC of AY From BY is greater than zero, then normalized APC is as below:

Normalized APC = Station Operating APC - Difference in APC of AY From BY

Where

APC = Auxiliary Power Consumption

BY = Baseline Year

AY = Assessment Year

Normalized APC = 6.89 – 0.03 = 6.86%

Table below represents the final table that will appear in the form.

Item	Unit	Assessment Year (AY)	Baseline Year (BY)
Operating hours at full Load	hrs	701.00	987.13
Weighted Operating Station Load	MW	377.55	461.92
Actual Loading Factor	*%*	*59.929*	*73.321*
Weighted Station Load without external factor	MW	457.86	485.99
Normalised Loading Factor		*72.676*	
% APC as per trend line	%	6.88	6.85
Difference in APC	%	0.03	
Normalised APC	*%*	*6.86*	

This is the final APC

In this table all the figures shown has been individually calculated in the sections above.

APC Normalization in terms of Heat Rate

APC Normalization (kcal/kWh)

$$= \frac{\text{Operating GHR in AY}}{(1 - \% \text{ APC of AY})} - \frac{\text{Operating GHR in AY}}{(1 - \% \text{ normalized APC})}$$

Where

GHR = Gross Heat Rate (kcal/kWh)

AY = Assessment Year

APC = Auxiliary Power Consumption

APC Normalization = (2691.16/(1-0.0689)) – (2691.16/(1-0.0686)) = 0.930 kcal/kWh

APC Normalization = 0.930 kcal/kWh

(ii) APC normalization for PA Fan loading due to change in coal quality

Let us consider the station with different coal GCV in BY and AY. Accordingly, the total coal consumption will change and hence, the primary air requirement will also change. This change will increase/ decrease the energy consumption of PA fans. We have to normalize that part of energy consumption from PA fans which attributes to change in GCV of coal. For understanding, let us assume the table below

Item	Unit	Unit-1		Unit-2		Unit-3	
		AY	BY	AY	BY	AY	BY
Gross Heat Rate	kcal/kWh	2636.00	2635.00	2637.00	2636.00	2800.00	2384.00
Operating Load	MW	165.00	150.00	166.00	130.00	150.00	120.00
Gross Generation	Million Units	1445.00	1314.00	1454.00	800.00	1200.00	1000.00
Operating Hours	hrs	8757.58	8760.00	8759.04	6153.85	8000.00	8333.33
Coal GCV	kcal/kg	3632.70	4000.00	3632.70	3800.00	3632.70	4200.00

Table above shows the station with different operating load, Generation and GCV of coal for BY and AY. We will now calculate the normalization.

Total Coal Consumption per unit (AY and BY) (Tonnes/Hr)

= (GHR X Operating Load)/ Coal GCV

Where

GHR = Gross Heat Rate (kcal/kWh)

GCV = Gross Calorific Value (kcal/kg)

Unit#1

Total Coal Consumption in BY= 2635*150/4000 = 98.81 Tonnes/ hr

Total Coal Consumption in AY= 2636*165/3632.70 = 119.73 Tonnes/hr

Unit#2

Total Coal Consumption in BY= 2635*130/3800 =90.18 Tonnes/ hr

Total Coal Consumption in AY= 2636*166/3632.70 = 120.50 Tonnes/hr

Unit#3

Total Coal Consumption in BY= 2635*120/4200 = 68.11 Tonnes/ hr

Total Coal Consumption in AY= 2636*150/3632.70 = 115.62 Tonnes/hr

Normalized Total Coal Consumption per unit(Tonnes/Hr) =

Total Coal Consumption X Coal GCV for BY/Coal GCV for AY

> Where
>
> GHR = Gross Heat Rate (kcal/kWh)
>
> GCV = Gross Calorific Value (kcal/kg)

Normalized Coal Consumption for U#1=98.11 *4000/3632.70 = 108.80 Tonnes/hr

Normalized Coal Consumption for U#2=90.18 *3800/3632.70 = 94.33 Tonnes/hr

Normalized Coal Consumption for U#3=68.11 *4200/3632.70 = 78.75 Tonnes/hr

Increase in coal consumption due to change in GCV of coal in AY (Tonnes/Hr)

=*Normalised Coal Consumption(tonne/hr)-Total consumption of BY (tonnes/hr)*

Increase in coal consumption due to change in GCV in AY for U#1=108.80-98.81=9.99 TPH

Increase in coal consumption due to change in GCV in AY for U#2=94.33-90.18=4.15 TPH

Increase in coal consumption due to change in GCV in AY for U#3=78.75-68.11=10.64TPH

Total Primary Air requirement per tonne of coal Trendline equation

$y=6.048x^{-0.2055}$

Where

Y= total PA requirement /tonne of coal (Tonnes)

x= operating load (MW)

Unit #1
Total Primary Air requirement per tonne of coal Trendline equation for AY/BY

=6.046*150-0.2055=2.16 tonnes

Unit #2
Total Primary Air requirement per tonne of coal Trendline equation for AY/BY

=6.046*130-0.2055=2.22 tonnes

Unit #3
Total Primary Air requirement per tonne of coal Trendline equation for AY/BY

=6.046*120-0.2055=2.26 tonnes

Total Primary Air requirement (Tonnes/hr)
=Normalised coal consumption (TPH) X PA requirement per tonne of coal as per Trendline equation(tonne)

Where

TPH =Tonnes per hour

PA =Primary Air

Unit #1
Total PA Requirement for BY = 98.81*2.16 =213.45 TPH

Total PA Requirement for AY = 108.80*2.16 =235.03 TPH

Unit #2
Total PA Requirement for BY = 90.18*2.22 =200.61 TPH

THERMAL POWER PLANT - Under Perform, Achieve and Trade

Total PA Requirement for AY = 94.33*2.22 =209.85 TPH

Unit #3
Total PA Requirement for BY = 68.11*2.26 =154.04 TPH

Total PA Requirement for AY = 78.75*2.26 =178.09 TPH

Volume of Primary Air (m³/hr)
=Total PA requirement (TPH) X 1000 / 1.233

Where

TPH   =Tonnes per hour

PA   =Primary Air

Unit#1
Volume of Primary Air on BY=213.45 *1000/1.2333=173068.67 m3/hr

Volume of Primary Air on AY=235.03 *1000/1.2333=190567.53 m3/hr

Unit#2
Volume of Primary Air on BY=200.61 *1000/1.2333=162660.88 m3/hr

Volume of Primary Air on AY=209.85 *1000/1.2333=170152.53 m3/hr

Unit#3
Volume of Primary Air on BY=154.04*1000/1.2333=124899.23 m3/hr

Volume of Primary Air on AY=178.09*1000/1.2333=144404.10 m3/hr

Power Consumption from PA Fans (kW) for AY and BY

=2.725 X Volume of PA X 1000/ (0.95 X 0.8 X106)

Where

AY   =Assessment Year

BY   =Basement Year

PA   = Primary Air

Unit #1
Power Consumption from PA Fans for BY =2.725*173068.67*1000/(0.95*0.80*10^6) =620.654 kW

Power Consumption from PA Fans for AY =2.725*190567.53*1000/(0.95*0.80*10^6) =683.28kW

Unit #2
Power Consumption from PA Fans for BY =2.725*162660.88*1000/(0.95*0.80*10^6) =583.22kW

Power Consumption from PA Fans for AY =2.725*170152.05*1000/(0.95*0.80*10^6) =610.08kW

Unit #3
Power Consumption from PA Fans for BY =2.725*124899.23*1000/(0.95*0.80*10^6) =447.83kW

Power Consumption from PA Fans for AY =2.725*144404.10*1000/(0.95*0.80*10^6) =517.76kW

Increase in energy consumption due to change in GCV of coal in AY (kW/hr)

= Power Consumption from PA fans in AY with normalised coal consumption –Power Consumption from PA fans in BY

Where

AY   =Assessment Year

BY   =Basement Year

PA   = Primary Air

Increase in energy consumption due to change in GCV of coal in AY for U#1

=683.28-620.54=62.74 kW/hr

Increase in energy consumption due to change in GCV of coal in AY for U#2

=610.08-583.22=26.86 kW/hr

Increase in energy consumption due to change in GCV of coal in AY for U#3

=517.76-447.83=69.94 kW/hr

Normalized Thermal Energy due to change in GCV of coal per unit (million kcal)

= Increase in energy consumption due to change in GCV of coal in AY (kW/hr)

X GHR of AY X Operating Hours of AY/10^6

Where

AY   = Assessment Year

GHR   =Gross Heat Rate (kcal/kWh)

GCV   =Gross Calorific Value (kcal/kg)

Normalized Thermal Energy due to change in GCV of coal per unit (million kcal) for U#1

=62.74*2636*8757.58/10^6 = 1448.41 Million kcal

Normalized Thermal Energy due to change in

GCV of coal per unit (million kcal) for U#2

=26.86*2637*8759.04/10^6=620.40 Million kcal

Normalized Thermal Energy due to change in GCV of coal per unit (million kcal) for U#3

=69.94*2800*8000/10^6 = 1566.55 Million kcal

Normalized Thermal Energy due to change in GCV of coal for station (million kcal)

= NTE U#1 + NTE U#2 + NTE U#3 +…….

Where

NTE= Normalized Thermal Energy due to change in GCV of coal per unit (million kcal)

GCV=Gross Calorific Value (kcal/kg)

Normalized Thermal Energy due to change in GCV of coal for station (million kcal)

=1448.41+620.40+1566.55 =3635.36 Million Kcal

Table below represents the final table that will appear in the form.

Item	Unit	Unit-1		Unit-2		Unit-3	
		AY	BY	AY	BY	AY	BY
Total Coal Consumption	Tonnes/hr	119.73	98.81	120.50	90.18	115.62	68.11
Normalised Total Coal Consumption	Tonnes/hr	108.80		94.33		78.75	
Increase in coal consumption due to change in GCV of coal in AY	Tonnes/hr	9.99		4.15		10.64	
Total Primary Air requirement per tonne of coal trendline equation	Tonnes		$y = 6.0487x^{-0.2055}$		$y = 6.0487x^{-0.2055}$		$y = 6.0487x^{-0.2055}$
Total Primary Air requirement per tonne of coal trendline equation for BY and AY	Tonnes	2.16	2.16	2.22	2.22	2.26	2.26
Total Primary Air requirement	Tonnes/hr	235.03	213.45	209.85	200.61	178.09	154.04
Volume of Primary Air	m³/ hr	190567.53	173068.67	170152.05	162660.88	144404.10	124899.23
Power Consumption from PA fans	kW	683.28	620.54	610.08	583.22	517.76	447.83
Increase in energy consumption due to change in GCV of coal in AY	kW/Hr	62.74		26.86		69.94	
Normalized Thermal Energy due to change in GCV of coal	Million kcal	1448.41		620.40		1566.55	
Normalization for station due to change in GCV of coal	Million kcal	3635.36		*Final Energy Normalization*			

In this table all the figures shown has been individually calculated in the sections above.

(iii) APC normalization for Coal Grinding Mill, ID Fan and Ash Handling Plant loading due to change in coal quality

Let us consider the station with different coal GCV in BY and AY. Accordingly, the total coal consumption will change due to change in coal quality. This change will increase/ decrease the energy consumption of coal grinding mills, ID Fans and Ash handling Plants. We have to normalize that part of energy consumption from these equipment which attributes to change in GCV of coal. For understanding, let us assume the table below

Item	Unit	Unit-1		Unit-2		Unit-3	
		AY	BY	AY	BY	AY	BY
Gross Heat Rate	kcal/kWh	2636.00	2635.00	2637.00	2636.00	2800.00	2384.00
Operating Load	MW	165.00	150.00	166.00	130.00	150.00	120.00
Gross Generation	Million Units	1445.00	1314.00	1454.00	800.00	1200.00	1000.00
Operating Hours	hrs	8757.58	8760.00	8759.04	6153.85	8000.00	8333.33
Coal GCV	kcal/kg	3632.70	4000.00	3632.70	3800.00	3632.70	4200.00
Total Energy Consumption for Coal Grinding Mills (VRM/Ball), ID Fans and Ash Handling Plant	Million Units	250	200	150	100	250	200

Table above shows the station with different operating load, Generation and GCV of coal for BY and AY. We will now calculate the normalization.

Total Coal Consumption per unit (AY and BY) (Tonnes/Hr)

= (GHR X Operating Load)/ Coal GCV

Where

GHR = Gross Heat Rate (kcal/kWh)

GCV = Gross Calorific Value (kcal/kg)

Unit#1
Total Coal Consumption in BY= 2635*150/4000 = 98.81 Tonnes/ hr

Total Coal Consumption in AY= 2636*165/ 3632.70 = 119.73 Tonnes/hr

Unit#2
Total Coal Consumption in BY= 2635*130/3800 =90.18 Tonnes/ hr

Total Coal Consumption in AY= 2636*166/ 3632.70 = 120.50 Tonnes/hr

Unit#3
Total Coal Consumption in BY= 2635*120/4200 = 68.11 Tonnes/ hr

Total Coal Consumption in AY= 2636*150/ 3632.70 = 115.62 Tonnes/hr

Normalized Total Coal Consumption per unit(Tonnes/Hr) =

Total Coal Consumption X Coal GCV for BY/ Coal GCV for AY

Where

GHR = Gross Heat Rate (kcal/kWh)

GCV = Gross Calorific Value (kcal/kg)

Normalized Coal Consumption for U#1=98.11* 4000/3632.70 = 108.80 Tonnes/hr

Normalized Coal Consumption for U#2=90.18* 3800/3632.70 = 94.33 Tonnes/hr

Normalized Coal Consumption for U#3=68.11* 4200/3632.70 = 78.75 Tonnes/hr

Increase in coal consumption due to change in GCV of coal in AY (Tonnes/Hr)

=Normalised Coal Consumption(tonne/hr)-Total consumption of BY (tonnes/hr)

Increase in coal consumption due to change in GCV in AY for U#1=108.80-98.81=9.99 TPH

Increase in coal consumption due to change in GCV in AY for U#2=94.33-90.18=4.15 TPH

Increase in coal consumption due to change in GCV in AY for U#3=78.75-68.11=10.64TPH

Operating Hours (hrs) = Gross Generation (Million Units)X 1000/Operating load (MW)

Unit#1
Operating hours for BY= 1314*1000/150 =8760 hrs

Operating hours for AY= 1445*1000/165 =8757.58 hrs

Unit#2
Operating hours for BY= 800*1000/130 =6153.85 hrs

Operating hours for AY= 1454*1000/166 =8759.04 hrs

Unit#3
Operating hours for BY= 1000*1000/120 =8333.33 hrs

Operating hours for AY= 1200*1000/150 =8000 hrs

Total Electrical Energy consumption for Coal Grinding mills (VRM/Ball), ID Fans and Ash handling Plant per hour (kW/hr)

=TEEC for Coal Grinding mills (VRM/Ball), ID Fans and Ash handling Plant (Million Units) X 10^6/Operating Hours (hrs)

Where

TEEC = Total Electrical Energy Consumption

Unit#1
Total Electrical Energy consumption for Coal Grinding mills (VRM/Ball), ID Fans and Ash handling Plantper hour for BY

=200*10^6/8760 =22831.05 kW/hr

Total Electrical Energy consumption for Coal Grinding mills (VRM/Ball), ID Fans and Ash handling Plant per hour for AY

=250*10^6/8757.58 =28546.71 kW/hr

Unit#2
Total Electrical Energy consumption for Coal Grinding mills (VRM/Ball), ID Fans and Ash handling Plant per hour for BY

=100*10^6/6153.85 =16250 kW/hr

Total Electrical Energy consumption for Coal Grinding mills (VRM/Ball), ID Fans and Ash handling Plant per hour for AY

=150*10^6/8759.04 =17125.17 kW/hr

Unit#3
Total Electrical Energy consumption for Coal Grinding mills (VRM/Ball), ID Fans and Ash handling Plant per hour for BY

=200*10^6/8333.33 =24000 kW/hr

Total Electrical Energy consumption for Coal Grinding mills (VRM/Ball), ID Fans and Ash handling Plant per hour for AY

=250*10^6/8000=31250 kW/hr

Specific energy consumption per tonne of coal (kWh/Tonne)

=TEEC for Coal Grinding mills (VRM/Ball), ID Fans and Ash handling Plant per hour (kW/hr)/ Total Coal Consumption
Where

TEEC = Total Electrical Energy Consumption

Unit#1
Specific energy consumption per tonne of coal (kWh/Tonne) in BY

=22831.05/98.81=231.05 kW/Tonne

Specific energy consumption per tonne of coal (kWh/Tonne) in AY

=28546.71/119.73=238.43 kW/Tonne

Unit#2

Specific energy consumption per tonne of coal (kWh/Tonne) in BY

=16250/90.18=180.20 kW/Tonne

Specific energy consumption per tonne of coal (kWh/Tonne) in AY

=17125.17/120.50=142.12 kW/Tonne

Unit#3

Specific energy consumption per tonne of coal (kWh/Tonne) in BY

=24000/68.11=352.35 kW/Tonne

Specific energy consumption per tonne of coal (kWh/Tonne) in AY

=31250/115.62=270.29 kW/Tonne

Increase in energy consumption due to change in GCV of coal in AY (kW/hr)

=Increase in coal consumption due to change in GCV of coal in AY (Tonnes/hr)

X Specific energy consumption of mill per tonne of coal in BY (kWh/Tonne)

Increase in energy consumption due to change in GCV of coal in AY for U#1

=9.99*231.05=2308.43 kW/hr

Increase in energy consumption due to change in GCV of coal in AY for U#2
=4.15*180.20=748.38 kW/hr

Increase in energy consumption due to change in GCV of coal in AY for U#3
=10.64*352.35=3747.96 kW/hr

Normalization due to change in GCV of coal per unit (Million kcal)

=Increase in energy consumption due to change in GCV of coal in AY (kW/hr)

X GHR of AY X Operating Hours of AY/10^6

Where

AY = Assessment Year

BY = Basement Year

GHR = Gross Heat rate (kcal/kWh)

GCV = Gross Calorific Value (kcal/kg)

Normalization due to change in GCV of coal per unit (Million kcal) for U#1

=2308.43*2636*8757.58/10^6=53290.11 Million kcal

Normalization due to change in GCV of coal per unit (Million kcal) for U#2

=748.38*2637*8759.04/10^6=17285.67 Million kcal

Normalization due to change in GCV of coal per unit (Million kcal) for U#3

=3747.96*2800*8000/10^6=83954.22 Million kcal

Normalization for station due to change in GCV of coal for Station (Million Units)

=NMC U#1 +NMC U#2 +NMC U#3 +…………

Where

NMC = Normalization due to change in GCV of coal (Million Units)

Normalization for station due to change in GCV of coal for Station (Million Units)

=53290.11+17285.67+83954.22 = 154529.99 Million kcal

Table below represents the final table that will appear in the form.

Item	Unit	Unit-1		Unit-2		Unit-3	
		AY	BY	AY	BY	AY	BY
Total Coal Consumption	Tonnes/hr	119.73	98.81	120.50	90.18	115.62	68.11
Total Electrical Energy consumption for Coal Grinding mills (VRM/Ball), ID Fan and Ash Handling Plant	Million Units	250.00	200.00	150.00	100.00	250.00	200.00
Normalised Coal Consumption	Tonnes/hr	108.80		94.33		78.75	
Increase in coal consumption due to change in GCV of coal in AY	Tonnes/hr	9.99		4.15		10.64	
Total Electrical Energy consumption for Coal Grinding mills (VRM/Ball) per hour	kW/hr	28546.71	22831.05	17125.17	16250.00	31250.00	24000.00
Specific energy consumption per tonne of coal	kWh/Tonne	238.43	231.05	142.12	180.20	270.29	352.35
Increase in energy consumption due to change in GCV of coal in AY	kW/hr	2308.43		748.38		3747.96	
Normalization due to change in GCV of coal	Million kcal	53290.11		17285.67		83954.22	
Normalization for station due to change in GCV of coal	Million kcal	154529.99					

Final Energy Normalization

In this table all the figures shown has been individually calculated in the sections above.

Now, we have the effect of coal quality on PA Fan + Mill, ID Fans and Ash handling Plant loading/ energy Consumption

APC normalization for PA Fan & Coal Grinding Mill , ID Fans and Ash handling Plantloading due to change in coal quality

={Normalized Thermal Energy due to change in GCV of coal for station (million kcal)

+Normalization for station due to change in GCV of coal for Station (Million Units)}
 / Gross Generation of AY

=(3635.36+154529.99)/4099=38.59 kcal/kWh

Final APC Normalization for the station
APC Normalization (kcal/kWh)

= APC Normalization due to external factors (kcal/kWh) + APC normalization for PA Fan,Coal Grinding Mill, ID Fans and Ash handling Plant loading due to change in coal quality (kcal/kWh)

=0.930+38.59 =39.520 kcal/kWh

APC Normalization =39.520 kcal/kWh

(d)   Other Normalization

In this station, PLF, coal quality, APC has been normalized, but there was some energy consumption due to start-ups and environmental factors also, which needs to be addressed. Let us assume the table below for calculating the same.

Unit	MW	Baseline Year (BY)			Assessment Year (AY)			Difference (AY)-(BY)			kL Oil consumption		
		Cold Start	Warm Start	Hot Start	Cold Start	Warm Start	Hot Start	Cold Start	Warm Start	Hot Start	Cold Start	Warm Start	Hot Start
1	210	1.00	1.00	2.67	3.00	3.00	5.00	2.00	2.00	2.33	100.00	60.00	46.67
2	210	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	210	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
										TOTAL	100.00	60.00	46.67

Table above shows the details of start-ups in the station. Based on the type of start-up, the energy consumption varies. The energy consumption also varies depending on the capacity of the unit. A detailed summary of energy consumptions in various capacity units under different types of start-ups in mentioned below.

Oil Consumption under various start-ups
For Cold Start-up
If capacity <= 250 MW, Oil Consumption is 50 KL

If capacity > 250 MW, but <= 500 MW, Oil Consumption is 90 KL

If capacity >500 MW, <=660MW, Oil Consumption is 110 KL

For Warm Start-up
If capacity <= 250 MW, Oil Consumption is 30 KL
If capacity > 250 MW, but <= 500 MW, Oil Consumption is 50 KL
If capacity >500 MW, <=660MW, Oil Consumption is 60 KL

For Hot Start-up
If capacity <= 250 MW, Oil Consumption is 20 KL
If capacity > 250 MW, but <= 500 MW, Oil Consumption is 30 KL
If capacity >500 MW, <=660MW, Oil Consumption is 40 KL

Based on these parameters, we will calculate the normalization for the station.

KL Oil Consumption = (Difference between number of start-ups in AY and BY) X (Oil Consumption as per above)

Oil Consumption for Cold Start-up = 2*50 = 100 KL

Oil Consumption for Warm Start-up = 2*30 = 60 KL

Oil Consumption for Hot Start-up = 2.33*20 = 46.60 KL

Thermal Energy to be subtracted due to Cold/Warm/Hot Start up due to External Factor (Million kcal)

= [KL oil Consumption in cold Start up + KL oil Consumption in warm start up + KL oil Consumption in Hot Start up] X 10

Thermal Energy to be subtracted due to Cold/Warm/Hot Start up due to External Factor

= (100+60+46.60)*10 = 2066 Million kcal

For further calculations, let us take the parameters from table 10 below. This table represents the electrical energy used in the station due to external factors.

Item	Unit	Assessment Year (AY)	Baseline Year (BY)
Thermal Energy to be subtracted due to Cold/Warm/Hot Start up (External Factor)	Million kcal	2066.00	
Electrical Energy to be subtracted due to Shutdown (External Factor)	MU	3	0
Electrical Energy to be subtracted due to Environmental concern (External Factor)	MU	4.0	
Thermal Energy to be subtracted due to Environmental concern (External Factor)	Million kcal	0.0	
Electrical Energy to be subtracted due to Unforeseen Circumstances (External Factor)	MU	0.0	0
Thermal Energy to be subtracted due to Unforeseen Circumstances (External Factor)	Million kcal	0.0	0
Gross Heat Rate of Station	kcal/kWh	2691	2635
Gross Generation	MU	4355	

Total Electrical Energy in Assessment Year (Million kcal)

= [Electrical Energy to be subtracted due to Shutdown (External Factor) in AY (MU)+Electrical Energy to be subtracted due to Environmental concern (External Factor) in AY (MU)+Electrical Energy to be subtracted due to Unforeseen Circumstances (External Factor) in AY(MU)] X GHR of Station in AY

Where

GHR = Gross Heat rate (kcal/kWh)

AY = Assessment Year

Total Electrical energy in AY= (3+4+0)*2691 = 18837 Million kcal

Total Electrical Energy in Baseline Year (Million kcal)

= [Electrical Energy to be subtracted due to Shutdown (External Factor) in BY (MU)+Electrical Energy to be subtracted due to Unforeseen Circumstances (External Factor) in BY(MU)] X GHR of Station in BY

Where

GHR = Gross Heat rate (kcal/kWh)

BY = Baseline Year

Total Electrical energy in BY= (0+0+0)*2635 = 0

Total Thermal Energy (Million kcal) in AY
=Thermal Energy to be subtracted due to Environmental concern (External Factor) in AY +Thermal Energy to be subtracted due to Unforeseen Circumstances (External Factor) in AY+Thermal Energy to be subtracted due to Cold/Warm/Hot Start up (External Factor) in AY

Where

AY = Assessment Year

Total Thermal Energy in AY = (0+0+2066) = 2066 Million kcal

Total Thermal Energy (Million kcal) in BY

= Thermal Energy to be subtracted due to Unforeseen Circumstances (External Factor) in BY

Where

BY = Baseline Year

Total Thermal Energy in BY = 0

Total Energy to be Subtracted or normalized (Million kcal)= [Total Electrical Energy forAY (Million kcal) + Total Thermal Energy for AY (million kcal)] – [(Total Electrical Energy for BY(Million kcal)+ Total Thermal Energy for BY (Million kcal)]

Where

AY = Assessment Year

BY = Baseline Year

Total Energy to be Subtracted or normalized
= (18837+2066)-(0+0)
= 20903 Million kcal

Table below represents the final table that will appear in the form.

Item	Unit	Assessment Year (AY)	Baseline Year (BY)
Total Electrical Energy	Million kcal	18837	0
Total Thermal Energy	Million kcal	2066	0
Total Energy to be subtracted	**Million kcal**	**20903**	

Final Energy Normalization

In this table all the figures shown has been individually calculated in the sections above.

Other Normalization (kcal/kWh)

$$= \frac{\text{(Total Energy to be subtracted or normalized in AY (MU)}}{\text{Gross Generation in AY}}$$

Where

AY = Assessment Year

MU = Million Unit

Other Normalization = 20903/ 4355 = 4.7999 kcal/kWh

Other Normalization = 4.8 kcal/kWh

(e) Final Normalization Calculation for Coal Based Thermal Power plant

From the sections above we know the followings

Operating Station Net Heat Rate in Baseline Year = 2837.17 kcal/kWh

Heat Rate Reduction Target = 63.38 kcal/kWh

Target Operating Station Net Heat Rate in Assessment Year

= 2837.17-63.38=2773.79kcal/kWh

Also, from the calculations in sections above, we know

Actual Operating Station NHR of this station without Normalization is 2890.3 kcal/kWh

It means, this station failed to achieve its target of 63.38 kcal/kWh Heat Rate reduction in Assessment Year. The Station failed short of 2890.3-2773.79 = 116.51 kcal/kWh.

The station will now have to pay penalty for 116.51 kcal/kWh or can buy E-Certs worth 116.51kcal/kWh from other Stations/ industries. However, we know that there has been a lot of change in operating conditions that the baseline year due to reasons beyond the control of plant

management. Hence, we gave normalizations for coal quality, PLF, APC and Other factors .i.e.,

Operating Station NHR of this station with Normalization

= Actual Operating Station NHR of this station without Normalization – Coal Quality Normalization – PLF normalization – APC Normalization – Other Normalization

=2890.3-16.11-30.98-39.52-4.8

=2798.89 kcal/kWh

This is the normalized Heat rate. However this station still fails to meet the target even after the normalization by 2798.89-2773.79 =25.1kcal/ kWh.

Therefore, this station has to pay a penalty for 25.1 kcal/kWh or purchase E-Certs worth 25.1skcal/kWh from other Stations/ industries.

Section 10.03 Normalisation for Gas Based Thermal Power Plant

(a) Gas Fuel Mix Normalization

A Gas based Power Plant may run on a mixture of fuels depending upon the availability and need. The ratio of fuel mix in generation may not be same in baseline year and assessment year due to a number of factors. Hence, normalizations are given on the Fuel mixture used in the module. For understanding the calculations, let us assume the table belows for a station.

Item	Unit	Module-1		Module-2		Module-3	
		AY	BY	AY	BY	AY	BY
Module Capacity	MW	210	210	210	210	210	210
Design Module Heat Rate @ 100% Load (OEM) for Gas	kcal/kwh	1911.11	1911.11	1911.11	1911.11	1869.57	1869.57
Design Module Heat Rate @ 100% Load for Naphtha	kcal/kwh	1915	1915	1915	1915	1915	1915
Design Module Heat Rate @ 100% Load (OEM) for Oil/Other Fuel	kcal/kwh	0	0	0	0	0	0
Actual Gross Generation from Gas	MU	1200.00	1200.00	0.00	900.00	600.00	0.000
Actual Gross Generation from Naphtha	MU	320.00	300.00	0.00	200.00	100.00	0.00
Actual Gross Generation from Oil/Other Fuel	MU	0.00	0.00	0.00	0.00	0.00	0.00

It can be observed from table above that the Module 2 was not running in Assessment year. However, it was running in baseline year. Similarly, Module 3 was not running in baseline year, but it was running in assessment year. Accordingly we will have the normalizations.

Gross Generation from Fuel Mix (Million Unit)
= Actual Gross Generation from Gas+ Actual Gross Generation from Naptha + Actual Gross Generation from Oil/Other Fuel

Module#1
Gross Generation for BY = 1200+300+0 = 1500 MU
Gross Generation for AY = 1200+320+0 = 1520 MU

Module#2
Gross Generation for BY = 900+100+0 = 1100 MU
Gross Generation for AY = 00+00+00 = 0

Module#3
Gross Generation for BY = 0+0+0 = 0
Gross Generation for AY = 600+100+0 = 700 MU

Module Heat Rate with Fuel Mix (kcal/kWh)

= [(Design Module HR @ 100% Load (OEM) for Gas X Actual Gross Generation from Gas) + (Design Module HR @ 100% Load for Naphtha X Actual Gross Generation from Naphtha) + (Design Module HR @ 100% Load (OEM) for Oil/Other Fuel X Actual Gross Generation from Oil/Other Fuel)] / [Actual Gross Generation from Gas (MU) + Actual Gross Generation from Naphtha (MU) + Actual Gross Generation from Oil/Other Fuel (MU)]

Where

HR = Heat Rate (kcal/kWh)

Module #1
Module HR with Fuel mix for BY

= ((1911.11*1200)+(1915*300)+0)/(1200+300)= 1911.89 kcal/kWh

Module HR with Fuel mix for AY

= ((1911.11*1200)+(1915*320)+0)/(1200+320)= 1911.93 kcal/kWh

Module #2

Module HR with Fuel mix for BY

=((1911.11*900)+(1915*200)+0)/(900+200)= 1911.81 kcal/kWh

Module HR with Fuel mix for AY
= ((1911.11*0)+(1915*0)+0)/(0+0)= 0

Module #3
Module HR with Fuel mix for BY
= ((1911.11*0)+(1915*0)+0)/(0+0)=0

Module HR with Fuel mix for AY
=((1869.57*600)+(1915*100)+0)/(600+100)= 1876.06 kcal/kWh

Difference of Module Heat Rate with Fuel Mix in AY w.r.t. BY (kcal/kWh)

= Module HR with Fuel Mix in AY - Module HR with Fuel Mix in BY

Where

HR = Heat rate (kcal/kWh)

AY = Assessment Year

BY = Baseline Year

Difference of MHR with Fuel Mix in AY w.r.t. BY for Module#1

=1911.93-1911.89 = 0.041 kcal/kWh

Difference of MHR with Fuel Mix in AY w.r.t. BY for Module#2

=0-1911.8 = -1911.8 kcal/kWh

Difference of MHR with Fuel Mix in AY w.r.t. BY for Module#3

=1876.1-0 = 1876.1 kcal/kWh

Notion energy for Fuel Mix to be Normalized for Module (Million kcal)

=Difference of Module Heat Rate with Fuel Mix in AY w.r.t. BY X Gross Generation from Fuel Mix in AY

Where

AY = Assessment Year

BY = Baseline Year

Notion energy for Fuel Mix to be normalized for Module#1

=0.041*1520 = 62.32 Million kcal

Notion energy for Fuel Mix to be normalized for Module#2

= -1911.8*0 = 0

Notion energy for Fuel Mix to be normalized for Module#3

= 1876.1*700 = 1313270 Million kcal

Notion energy for Fuel Mix to be Normalized for station (Million kcal)

= [Notion energy for Fuel Mix to be Normalized for Module 1 + Notion energy for Fuel Mix to be Normalized for Module 2 + Notion energy for Fuel Mix to be Normalized for Module 3 + …………]

=62.32+0+1313270

=1313332.32 Million kcal

Table below represents the final table that will appear in the form.

Item	Unit	Module-1		Module-2		Module-3	
		AY	BY	AY	BY	AY	BY
Gross Generation from Fuel Mix	MU	1520.00	1500.00	0.00	1100.00	700.00	0.00
Module Heat Rate with Fuel Mix	kcal/kwh	1911.93	1911.89	0.0	1911.8	1876.1	0.0
Difference in Assessment year w.r.t. Baseline Year	kcal/kwh	0.041		-1911.8		1876.1	
Notional energy for Fuel Mix to be Normalised for Module	Million kcal	62.3		0.0		1313270.0	
Notional energy for Fuel Mix to be Normalised for station	*Million kcal*	**1313332.32**			Final Energy Normalization		

In this table all the figures shown has been individually calculated in the sections above.

Gas Fuel Mix Normalization (kcal/kWh)

$$= \frac{\text{Notion energy for Fuel Mix to be Normalized for station (Million kcal)}}{\text{Gross Generation (Million Units)}}$$

=1313332.32/ 4355*

=301.56 kcal/kWh

Gas Fuel Mix Normalization = 301.56 kcal/ kWh

(b) Gas OC cycle Normalization

The Heat Rate of a module differs when run in open cycle and closed cycle. This may be due to various reasons. The duration of open and closed cycle in baseline year and assessment year may not be same. As a result the Net Heat rate of module and station will deviate. Hence, normalization has been given on Open/ closed cycle as well.For understanding the calculations, let us assume the table below for a station.

Item	Unit	Module-1		Module-2		Module-3	
		AY	BY	AY	BY	AY	BY
Module Capacity	MW	210	210	210	210	210	210
Design Module Heat Rate @ 100% Load (OEM) for Closed Cycle	kcal/kwh	1911.11	1911.11	1911.11	1911.11	1869.57	1869.57
Design Module Heat Rate @ 100% Load for Open Cycle	kcal/kwh	2900	2900	2900	2900	2900	2900
Design Module Heat Rate @ 100% Load (OEM) for Oil/Other Fuel	kcal/kwh	0	0	0	0	0	0
Actual Gross Generation during Closed Cycle	MU	1400.00	1200.00	200.00	0	0	600.00
Actual Gross Generation during Open Cycle due to external factor	MU	120.00	300.00	100.00	0.00	0.00	100.00
Actual Gross Generation during Open Cycle due to internal factor	MU	0.00	0.00	0.00	0.00	0.00	0.00

Table above represents the Heat Rate and generation from open cycle and closed cycle. Based on these parameters, the onward calculations shall be done.

Gross Generation during Open Cycle (External Factor) and Closed Cycle Operation (MU)

= Actual Gross Generation during Closed Cycle (MU)+ Actual Gross Generation during Open Cycle due to external factor(MU)

Module#1
Gross Generation during Open Cycle and closed cycle for BY
=1200+300 = 1500 MU
Gross Generation during Open Cycle and closed cycle for AY
=1400+120 = 1520 MU

Module#2
Gross Generation during Open Cycle and closed cycle for BY
=0+0 = 0
Gross Generation during Open Cycle and closed cycle for AY
=200+100 = 300 MU

Module#3
Gross Generation during Open Cycle and closed cycle for BY
=600+100 =700 MU
Gross Generation during Open Cycle and closed cycle for AY
=0+0 = 0

Module Heat Rate for Open and Closed cycle operation (kcal/kWh)

= [(Design Module HR @ 100% Load (OEM) for Closed Cycle X Actual Gross Generation during Closed Cycle) + (Design Module HR @ 100% Load for Open Cycle X Actual Gross Generation during Open Cycle due to external factor) / [Actual Gross Generation during Closed Cycle (MU) + Actual Gross Generation during Open Cycle due to external factor (MU))]

Where

HR= Heat Rate (kcal/kWh)

Module#1
Module Heat Rate for Open and Closed cycle operation for BY
=((1911.11*120)+(2900*300))/(120+300) = 2108.9 kcal/kWh

Module Heat Rate for Open and Closed cycle operation for AY
=((1911.11*1400)+(2900*120))/(1400+120)= 1989.2 kcal/kWh

Module#2
Module Heat Rate for Open and Closed cycle operation for BY
=((1911.11*0)+(2900*0))/(0+0) =0

Module Heat Rate for Open and Closed cycle operation for AY
=((1911.11*200)+(2900*100))/(200+100) = 2240.7 kcal/kWh

Module#3
Module Heat Rate for Open and Closed cycle operation for BY
=((1869.57*600)+(2900*100))/(600+100) = 2016.8 kcal/kWh

Module Heat Rate for Open and Closed cycle operation for AY
=((1869.57*0)+(2900*0))/(0+0) = 0

Difference in Module Heat Rate with Open and Closed cycle operation in AY w.r.t. BY (kcal/kWh)
= Module HR for Open and Closed cycle operation in AY - Module HR for Open and Closed cycle operation in BY

Where

HR = Heat Rate (kcal/kWh)

AY = Assessment Year

BY = Baseline Year

Difference in MHR with Open and Closed cycle operation in AY w.r.t. BY for Module#1
=1989.2-2108.9 = -119.7 kcal/kWh

Difference in MHR with Open and Closed cycle operation in AY w.r.t. BY for Module#2
=2240.7-0 = 2240.7 kcal/kWh

Difference in MHR with Open and Closed cycle operation in AY w.r.t. BY for Module#3
=0-2016.8 = -2016.8

Notion energy for Gas OC Cycle to be Normalized for Module (Million kcal)
=Difference in Module HR with Open and Closed cycle operation in AY w.r.t. BY (kcal/kWh) X Gross Generation from Open and Closed cycle operation (MU)

Where

HR = Heat Rate (kcal/kWh)

AY = Assessment Year

BY = Baseline Year

Notion energy for Gas OC Cycle to be normalized for Module #1

= -119.7*1520 = -181944 Million kcal

Notion energy for Gas OC Cycle to be normalized for Module #2
= 2240.7*300= 672210 Million kcal

Notion energy for Gas OC Cycle to be normalized for Module #3
= -2016.8*0 = 0 Million kcal

Notion energy for Gas OC Cycle to be Normalized for station (Million kcal)

= [Notion energy for Fuel Mix to be Normalized for Module 1 + Notion energy for Fuel Mix to be Normalized for Module 2 + Notion energy for Fuel Mix to be Normalized for Module 3 + …………]

Notion energy for Gas OC Cycle to be normalized for station
=-181944 +672210+0
= 490266 Million kcal

Table below represents the final table that will appear in the form.

Item	Unit	Module-1		Module-2		Module-3	
		AY	BY	AY	BY	AY	BY
Gross Generation during Open Cycle (External Factor) and Closed Cycle operation	MU	1520.00	1500.00	300.00	0.00	0.00	700.00
Module Heat Rate for Open and Closed Cycle Operation	kcal/kwh	1989.2	2108.9	2240.7	0.0	0.0	2016.8
Difference in Assessment year w.r.t. Baseline Year	kcal/kwh	-119.7		2240.7		-2016.8	
Notion energy for Gas OC Cycle to be Normalised for Module	Million kcal	-181955.8		672222.0		0.0	
Notion energy for Gas OC Cycle to be Normalised for station	Million kcal	*490266.24*		*Final Energy Normalization*			

In this table all the figures shown has been individually calculated in the sections above.

Gas OC Cycle Normalization (kcal/kWh)

$$= \frac{\text{(Notion energy for Gas OC Cycle to be Normalized for station (Million kcal))}}{\text{(Gross Generation (MU))}}$$

Gas OC Cycle Normalization = 490266/4355 = 112.58 kcal/kWh

Gas OC Cycle Normalization =112.58 kcal/kWh

(c)   Gas Quality Normalization
Due to change in gas quality, the Net Heat Rate deviates significantly. This can be understood by the Trendline equation and excel topology mentioned in earlier sections. Accordingly, let us calculate the normalization for gas quality for this station. For calculation, let us assume the table below.

Sr No	Item	Unit	AY	BY
1	Station Net Heat Rate	kcal/kWh	2896.35	2693.02
2	Net Calorific Value of Gas	kcal/kg	12000	10995.66667
3	NHR Trendline equation	kcal/kWh	y = -10^-7x^2 + 0.0051x + 1490.5	y = -10^-7x^2 + 0.0051x + 1490.5
6	Gross Generation in AY	Million Units	4099	

NHR Trendline equation (kcal/kWh)
$y = -10^{-7}x^2 + 0.0051x + 1490.5$
Where
Y= Net Heat Rate (kcal/kWh)
X=Net Calorific Value (kcal/kg)

NHR as per Trendline equation in BY
$=-10^{(-7)}*10995.67^2+0.0051*10995.69+1490.5$
=1534.49 kcal/kWh

NHR as per Trendline equation in AY
$=-10^{(-7)}*12000^2+0.0051*12000+1490.5$
=1537.3kcal/kWh

Difference in NHR as per Trendline Equation between AY and BY (kcal/kWh)
=NHR as Per Trendline Equation for AY – NHR as per Trendline Equation for BY

Where
NHR = Net Heat Rate (kcal/kWh)
AY   =Assessment Year
BY   =Baseline year

Difference in NHR as per Trendline Equation between AY and BY (kcal/kWh)

=1537.3-1534.49 = 2.81 kcal/kWh

Normalization due to change in Gas Quality (Million kcal)

= Difference in NHR as per Trendline Equation between AY and BY (kcal/kWh) X Gross Generation in AY

Where

NHR = Net Heat Rate (kcal/kWh)

AY   =Assessment Year

BY   =Baseline year

Normalization due to change in Gas Quality (Million kcal)

=2.81*4099 =11528.718 Million kcal

Table below represents the final table that will appear in the form.

Item	Unit	AY	BY
Station Net Heat Rate	kcal/kWh	2896.35	2693.02
Net Calorific Value of Gas	kcal/kg	12000	10995.66667
NHR trendline equation	kcal/kWh	$y = -10^{-7}x^2 + 0.0051x + 1490.5$	$y = -10^{-7}x^2 + 0.0051x + 1490.5$
NHR as per trendline equation	kcal/kWh	1537.3	1534.487431
Difference in NHR as per trendlne Equation between AY and BY	kcal/kWh	2.812568544	
Gross Generation in AY	Million Units	4099	
Normalization due to change in Gas Quality	Million Kcal	11528.71846	

Final Energy Normalization

In this table all the figures shown has been individually calculated in the sections above.

Normalization due to Change in Gas Quality for Station (kcal/kWh)

= Normalization due to change in Gas Quality (Million kcal) / OGHR in AY (kcal/kWh)

Where

OGHR=Gross Operating Heat Rate (kcal/kWh)

Normalization due to Change in Gas Quality for Station (kcal/kWh)

=11528.718/2684.4 =4.29 kcal/kWh

(d) Auxiliary Power Consumption (APC) Normalization

Auxiliary Power Consumption (APC), as in all plants, has a significant contribution in determining the Net Heat Rate Gas based stations as well. APC is subject to change at different period of time. It primarily depends on the unit loading ultimately affecting the drives. It also depends on the ambient conditions at times. For understanding, let us assume the table below, where APC differs in AY and BY.

Item	Unit	Assessment Year (AY)	Baseline Year (BY)
Station Capacity	MW	630	630
APC	%	6.89	5.9
APC Trend line Equation		$y = -0.0001x2 - 0.0304x + 9.6114$	$y = -0.0001x2 - 0.0304x + 9.6114$
Constant 1	a	0.00010	0.00010
Constant 2	b	0.03040	0.03040
Constant 3	c	9.61500	9.61500
Plant Availability Factor		0.863	0.840
Station Average Operating Load (MW) caused by low loading due to external factor	MW	429.72	552.72
Weighted Average Operating hours at Low loading due to external factor	hrs	3031.29	2300.06
Average Operating Load (MW) caused by low loading due to Internal factor	MW	290.00	370.00
Weighted Average Operating hours at Low loading due to internal factor	hrs	3827.59	4081.08

THERMAL POWER PLANT - Under Perform, Achieve and Trade

Table above shows the parameters related to APC. The AOL and AOH have been taken from the calculations in above sections. From these parameters we will calculate the normalization for APC.

Auxiliary Power Consumption Trendline Equation

$y = ax2 - bx + c$ will be used to calculate the Turbine Heat Rate as per Load Vs Heat Rate Equation due to external factor.

$y = ax2 - bx + c$

Where
X   = Operating Load (MW)
A   = Equation Constant 1
b   = Equation Constant 2
c   = Equation Constant 3

Operating Hours at full load

  =(Total hours in a year X PAF)

    — Weighted AOHr at Low loading due to external factor

    — Weighted AOHr at Low loading due to internal factor)

Where

PAF   = Plant Availability Factor

AOHr = Average Operating Hours

Operating Hours at Full Load for BY
=(8760*0.8401)-2300.06-4081.08
=978.13 hrs.

Operating Hours at Full Load for AY
=(8760*0.863)-3031.29-3827.59
=701.00 hrs.

Weighted Operating Station Load

=[{Station Capacity X Operating Hours at Full Load} + {Station AOL (MW) caused by low loading due to external factor X Weighted AOHr at Low loading due to external factor} + {Station AOL (MW) caused by low loading due to internal factor X Weighted AOHr at Low loading due to internal factor}] / [Weighted AOHr at Low loading due to external factor + Weighted AOHr at Low loading due to internal factor+ Operating Hours at full load]

Where

AOHr = Average Operating Hours (Hrs)

AOL   = Average Operating Load (MW)

Weighted Operating Station load for BY
= ((630*987.78)+(552.72*2300.06)+(370*4081.08))/(2300.06+4081.08+987.13)
= 461.92 MW

Weighted Operating Station load for AY
= ((630*701)+(429.72*3031.29)+(290*3827.59))/(3031.29+3827.59+701)
= 377.55 MW

Actual Loading Factor (%)

$$= \frac{(\text{Weighted Operating Station Load X 100})/}{(\text{Station Capacity})}$$

Actual Loading Factor for BY = (461.92*100)/630 = 73.321 %

Actual Loading Factor for AY = (377.55*100)/630 = 59.929 %

Weighted Station Load without external factor (MW)

= [{Station Capacity X Weighted AOHr at Low loading due to external factor} + {Station Capacity X Operating   hours at full Load} + {AOL (MW) caused by low loading due to Internal factor X Weighted AOHr at Low loading due to internal factor}] / [Weighted AOHr at Low loading due to external factor+Weighted AOHr at Low loading due to internal factor +Operating hours at full Load]

Where

AOHr = Average Operating Hours (Hrs)

AOL = Average Operating Load (MW)

Weighted Station Load without external factor for BY

=((630*2300.06)+(630*987.13)+(370*4081.08))/(2300.06+4081.08+987.13)

= 485.99 MW

Weighted Station Load without external factor for AY

=((630*3031.29)+(630*701)+(290*3827.59))/(3031.29+3827.59+701)

= 457.86 MW

Normalized Loading Factor

$$= \frac{\text{Weighted Station Load without external factor (MW)} \times 100}{\text{Station Capacity (MW)}}$$

Normalized Loading factor for AY =457.86*100/630 = 72.676

Percentage APC as per Trend Line for AY and BY

This shall be calculated by the % APC Trend Line equation mentioned above for Assessment Year and baseline year individually.

=Constant 1 *(Normalized Loading Factor)^2-Constant 2*Normalized Loading Factor + Constant 3

Where

APC =Auxiliary Power Consumption

BY = Baseline Year

AY = Assessment Year

Percentage APC as per Trend Line for BY
= 0.00010*73.3212 – 0.03040*73.321 + 9.61500
= 6.85%

Percentage APC as per Trend Line for AY
= 0.00010*72.7672 – 0.03040*72.676 + 9.61500
= 6.88%

Difference in APC of AY From BY= % APC as per trend line in AY -% APC as per trend line in BY

Where

APC =Auxiliary Power Consumption

BY = Baseline Year

AY = Assessment Year

Difference in APC of AY From BY = 6.88 – 6.85 = 0.03%

Normalized APC
If the difference in APC of AY From BY is less than or equal to zero, then Normalized APC will be same as operating station APC.

If the difference in APC of AY From BY is greater than zero, then normalized APC is as below:

Normalized APC = Station Operating APC - Difference in APC of AY From BY

Where

APC =Auxiliary Power Consumption

BY = Baseline Year

AY = Assessment Year

Normalized APC = 6.89 – 0.03 = 6.86%

APC Normalization in terms of Heat Rate

APC Normalization (kcal/kWh)

$$= \frac{\text{Operating GHR in AY}}{(1\text{-}\% \text{ APC of AY})} - \frac{\text{Operating GHR in AY}}{(1\text{- } \% \text{ normalized APC})}$$

Where

GHR =Gross Heat Rate (kcal/kWh)

AY =Assessment Year

APC   =Auxiliary Power Consumption

APC Normalization = (2691.16/(1-0.0689)) – (2691.16/(1-0.0686)) = 0.930 kcal/kWh

APC Normalization = 0.930 kcal/kWh

Table below represents the final table that will appear in the form.

Item	Unit	Assessment Year (AY)	Baseline Year (BY)
Operating hours at full Load	hrs	701.00	987.13
Weighted Operating Station Load	MW	377.55	461.92
Actual Loading Factor	*%*	*59.929*	*73.321*
Weighted Station Load without external factor	MW	457.86	485.99
Normalised Loading Factor		*72.676*	
% APC as per trend line	%	6.88	6.85
Difference in APC	%	0.03	
Normalised APC	*%*	*6.86*	

This is the final APC

In this table all the figures shown has been individually calculated in the sections above.

(e)   Plant Load Factor [Scheduling]

To understand the PLF normalization, let us consider the example of the same plant which we considered earlier. Table below represents some of the parameters of this plant. Apart from the design parameters, other parameters are taken from the calculations done in other sections mentioned above and in this section itself. Here we will see the calculation of PLF Normalization to be given to this station.

Item	Unit	Unit-1 AY	Unit-1 BY	Unit-2 AY	Unit-2 BY	Unit-3 AY	Unit-3 BY
Unit Capacity	MW	210	210	210	210	210	210
Design Module Heat Rate @ 100% Load (OEM)	kcal/kwh	2045.00	2045.00	2045.00	2045.00	2045.00	2045.00
Design Module Heat Rate @ 100% Load (Curve or HBD)	kcal/kwh	2044.44	2044.44	2044.44	2044.44	2044.44	2044.44
% Difference between Design Turbine/Module Heat Rate and Design Curve or HBD Turbine/Module Heat rate	%	0.0274	0.0274	0.0274	0.0274	0.027	0.027
Plant Availability Factor	Factor	0.8630	0.8515	0.8858	0.8173	0.8401	0.8858
Average Operating Load (MW) caused by low ULF/MLF due to external factor	MW	140.49	161.95	179.23	195.38	110.00	195.38
Average Operating hours at Low ULF/MLF	Hrs/Annum	2679.07	2656.00	2099.10	2152.54	5000.00	2152.54

Percentage Difference between Design Module Heat Rate and Design Curve or HBD Module Heat Rate

$$= \frac{\text{Design MHR @ 100\% Load (OEM) - Design MHR @ 100\% Load (Curve or HBD) X 100}}{\text{Design MHR @ 100\% Load (OEM)}}$$

Where

MHR = Module Heat Rate (kcal/kWh)

OEM = Original Equipment Manufacturer

HBD = Heat Balance Diagram

Unit#1
% Difference between DMHR and Design Curve or HBD MHR for BY
= (2045-2044.44)*100/ 2045 = 0.0274

% Difference between DMHR and Design Curve or HBD MHR for AY
= (2045-2044.44)*100/ 2045 = 0.0274

Unit#2
% Difference between DMHR and Design Curve or HBD MHR for BY
= (2045-2044.44)*100/ 2045 = 0.0274

% Difference between DMHR and Design Curve or HBD MHR for AY
= (2045-2044.44)*100/ 2045 = 0.0274

Unit#3
% Difference between DMHR and Design Curve or HBD MHR for BY
= (2045-2044.44)*100/ 2045 = 0.0274

% Difference between DMHR and Design Curve or HBD MHR for AY
= (2045-2044.44)*100/ 2045 = 0.0274

Total Operating hours in year as per Unit Availability factor (hrs/annum)
= Total hour in a year X Plant Availability Factor

Unit # 1
Total Operating hours in year as per Unit Availability factor for BY

= 8760* 0.85 = 7459.14 hrs/annum

Total Operating hours in year as per Unit Availability factor for AY
= 8760* 0.86 = 7559.88 hrs/annum

Unit # 2
Total Operating hours in year as per Unit Availability factor for BY
= 8760* 0.82 = 7159.54 hrs/annum

Total Operating hours in year as per Unit Availability factor for AY
= 8760* 0.89 = 7759.60 hrs/annum

Unit # 3
Total Operating hours in year as per Unit Availability factor for BY
= 8760* 0.88 = 7759.60 hrs/annum

Total Operating hours in year as per Unit Availability factor for AY
= 8760* 0.84 = 7359.27 hrs/annum

Operating hours at full load (hrs/annum)
=Total Operating hours in year as per Unit Availability factor - AOHrs at Low ULF/MLF

Where

AOHr = Average Operating Hours (hr)

ULF = Unit Load Factor

MLF = Module Load Factor

Unit#1
Operating hours at full load (hrs/annum) for BY = 7459.14-2656 = 4803.14

Operating hours at full load (hrs/annum) for AY = 7559.88-2679.07 = 4880.81

Unit#2

Operating hours at full load (hrs/annum) for BY = 7159.54-2152.54 = 5007

Operating hours at full load (hrs/annum) for AY = 7759.60-2099.10 = 5660.5

Unit#3

Operating hours at full load (hrs/annum) for BY = 7759.60-2152.54 = 5607.06

Operating hours at full load (hrs/annum) for AY = 7359.27-5000 = 2359.27

Loading Vs Heat Rate Equation given as y = ax2 - bx + c will be used to calculate the Module Heat Rate as per Load Vs Heat Rate Equation due to external factor.

y = ax2 - bx + c   (kcal/kWh)

Where

X   = Operating Load (MW)

A   = Equation Constant 1 =0.0171

b   = Equation Constant 2 = 6.6159

c   = Equation Constant 3 = 2684.8

Turbine Heat Rate as per Load Vs Heat Rate Equation due to external factor (kcal/kWh)

= Equation Constant 1

* (Average Operating Load (MW) caused by low ULF, MLF due to external factor)^^ 2

— Equation Constant 2

* Average Operating Load (MW)caused by low ULF,MLF due to external factor

+ Equation Constant 3

Unit #1

THR as per Load Vs HR Equation due to external factor (kcal/kWh) for BY
= 0.0171* 161.95 2 – 6.6159* 161.95 + 2684.8
= 2061.85 kcal/kWh

THR as per Load Vs HR Equation due to external factor (kcal/kWh) for BY

= 0.0171* 140.49 2 – 6.6159* 140.49+ 2684.8
= 2092.85 kcal/kWh

Unit #2

THR as per Load Vs HR Equation due to external factor (kcal/kWh) for BY
= 0.0171* 195.38 2 – 6.6159* 195.38 + 2684.8
= 2044.95 kcal/kWh

THR as per Load Vs HR Equation due to external factor (kcal/kWh) for BY
= 0.0171* 179.23 2 – 6.6159* 179.23 + 2684.8
= 2048.34 kcal/kWh

Unit #3

THR as per Load Vs HR Equation due to external factor (kcal/kWh) for BY
= 0.0171* 195.38 2 – 6.6159* 195.38 + 2684.8
= 2044.95 kcal/kWh

THR as per Load Vs HR Equation due to external factor (kcal/kWh) for BY
= 0.0171* 110 2 – 6.6159* 110 + 2684.8
= 2163.96 kcal/kWh

Design Module Heat Rate after Curve correction and difference correction

=   MHR as per Load Vs HR Equation due to external factor X [1 + {% Difference between Design Turbine or Module HR and Design Curve or HBD Turbine or Module HR/ 100}]

Where

MHR = ModuleHeat Rate (kcal/kWh)

L Vs HR   = Load Vs Heat Rate

HBD   = Heat balance Diagram

Unit#1

DMHR after Curve Correction and difference correction for BY
= 2061.85*(1+(0.027/100))
= 2062.41 kcal/kWh

DMHR after Curve Correction and difference

correction for AY
= 2092.85*(1+(0.027/100))
= 2093.42 kcal/kWh

Unit#2

DMHR after Curve Correction and difference correction for BY
=2044.95 *(1+(0.027/100))
= 2045.51 kcal/kWh

DMHR after Curve Correction and difference correction for AY
= 2048.34*(1+(0.027/100))
= 2048.90 kcal/kWh

Unit#3

DMHR after Curve Correction and difference correction for BY
= 2044.95*(1+(0.027/100))
= 2045.51 kcal/kWh

DMHR after Curve Correction and difference correction for AY
= 2163.95*(1+(0.027/100))
= 2164.55 kcal/kWh

Normalized Design Module Heat rate due to external factor (kcal/kWh)

= [Design MHR @ 100% Load (OEM) X Operating hours at full load + Design MHR after Curve correction and difference correction X AOHrs at Low ULF/MLF] / Total Operating hours in year as per UAF

Where

MHR = ModuleHeat Rate (kcal/kWh)

OEM = Original Equipment Manufacturer

AOHr = Average Operating Hours

UAF = Unit Availability Factor

Unit#1
Normalized DMHR due to external factor for BY
= ((2045*4803.14)+(2062.41*2656))/7459.14 = 2051.20 kcal/kWh

Normalized DMHR due to external factor for AY
= ((2045*4880.81)+(2093.42*2679.07))/7559.88 = 2062.16 kcal/kWh

Unit#2
Normalized DMHR due to external factor for BY
= ((2045*5007)+(2045.51*2152.54))/7159.54 = 2045.15 kcal/kWh

Normalized DMHR due to external factor for AY
= ((2045*5660.5)+(2048.90*2099.10))/7759.60 = 2062.16 kcal/kWh

Unit#3
Normalized DMHR due to external factor for BY
= ((2045*5607.06)+(2045.51*2152.54))/7759.60 = 2045.14 kcal/kWh

Normalized DMHR due to external factor for AY
= ((2045*2359.27)+(2164.55*5000))/7359.27 = 2126.22 kcal/kWh

Difference of Module Heat Rate due to external factor between AY and BY (kcal/kWh)

= Normalized Design MHR due to external factor in AY - Normalized Design MHR due to external factor in BY

Where

MHR = Module Heat Rate (kcal/kWh)

AY = Assessment Year

BY = Baseline Year

Difference of MHR due to external factor between AY and BY for Unit#1
= 2062.16-2051.20 = 10.96 kcal/kWh

Difference of MHR due to external factor between AY and BY for Unit#2
= 2046.05-2045.15 = 0.90 kcal/kWh

Difference of MHR due to external factor between AY and BY for Unit#3
= 2126.22-2045.14 = 81.08 kcal/kWh

Normalized Design Module Heat rate due to external factor as compared to BY

= Design MHR @ 100% Load (OEM) + Difference of MHR due to external factor between AY and BY

Where

mHR = Module Heat Rate (kcal/kWh)

AY = Assessment Year

BY = Baseline Year

OEM = Original Equipment Manufacturer

Normalized DMHR due to external factor as compared to BY for Unit#1

=2045+10.96 = 2055.96 kcal/kWh

Normalized DMHR due to external factor as compared to BY for Unit#2

=2045+0.90 = 2045.90 kcal/kWh

Normalized DMHR due to external factor as compared to BY for Unit#3

=2045+81.08 = 2126.08 kcal/kWh

Normalized Designed Station Module Heat Rate due to ULF as compared to BY

= [Normalized U# 1 Design MHR due to external factor as compared to BY X U# 1 Capacity + Normalized U# 2 Design MHR due to external factor as compared to BY X U# 2 Capacity + ……………] / Station installed Total Capacity (MW)

Where

mHR = Module Heat Rate (kcal/kWh)

BY = Baseline Year

Normalized DSMHR due to ULF as compared to BY

=((2055.96*210)+(2045.90*210)+(2126.08*210))/(210+210+210)

=2075.98 kcal/kWh

Weighted Design Module Heat Rate of Station

= [U# 1 Capacity X U# 1 Design MHR @ 100% Load (OEM) + U# 2 Capacity X U# 2 Design MHR @ 100% Load (OEM) + …………..] / Station installed Total Capacity (MW)

Where

MHR = Module Heat Rate (kcal/kWh)

OEM = Original Equipment Manufacturer

Weighted Design MHR of Station

=((2045*210)+(2025*210)+(2045*210))/(210+210+210)

=2045 kcal/kWh

Difference of MHR between Normalized Design Heat Rate and Design Heat Rate

= Normalized Design Station MHR due to ULF as compared to BY – Station Weighted Design MHR

ULF = Unit Load Factor

MHR = Module Heat Rate (kcal/kWh)

BY = Baseline Year

Difference of MHR between NDHR and DHR = 2075.98-2045 = 30.98kcal.kWh

PLF Normalization = Difference of MHR between NDHR and DHR

PLF Normalization =30.98kcal/kWh

Table below represents the final table that will appear in the form.

Item	Unit	Unit-1 AY	Unit-1 BY	Unit-2 AY	Unit-2 BY	Unit-3 AY	Unit-3 BY
Total Operating hours in year as per Unit Availability factor	Hrs/Annum	7560.00	7460.00	7760.00	7160.00	7360.00	7460.00
Operating hours at full load	Hrs/Annum	4880.93	4804.00	5660.90	5007.46	2360.00	5307.46
Module Heat Rate as per Load Vs Heat Rate Equation due to external factor	kcal/kwh	*2092.85*	*2061.85*	*2048.34*	*2044.95*	*2163.96*	*2044.95*
Design Module Heat Rate after Curve correction and difference correction	kcal/kwh	2093.42	2062.41	2048.90	2045.51	2164.55	2045.51
Normalised Design Module Heat rate due to external factor	kcal/kwh	2062.16	2051.20	2046.06	2045.15	2126.22	2045.15
Difference of Module Heat Rate due to external factor between AY and BY	kcal/kwh	10.96		0.90		81.07	
Normalised Design Module Heat rate due to external factor as compared to BY	kcal/kwh	2055.96		2045.90		2126.07	
Weighted Design Module Heat Rate of Station	kcal/kwh	2045.00	2045.00				
Normalised Design Station Module Heat Rate due to ULF as compared to BY	kcal/kwh	2075.98					
Differnce of Module Heat rate between Normalised Design Heat Rate and Design Heat Rate	**kcal/kwh**	**30.98**					

This is the final Normalization

In this table all the figures shown has been individually calculated in the sections above.

(f)   Other Normalization

In this station, PLF, coal quality, APC has been normalized, but there was some energy consumption due to start-ups and environmental factors also, which needs to be addressed. Let us assume the table below for calculating the same.

Unit	MW	Baseline Year (BY) Cold Start	Baseline Year (BY) Warm Start	Baseline Year (BY) Hot Start	Assessment Year (AY) Cold Start	Assessment Year (AY) Warm Start	Assessment Year (AY) Hot Start	Difference (AY)-(BY) Cold Start	Difference (AY)-(BY) Warm Start	Difference (AY)-(BY) Hot Start	kL Oil consumption Cold Start	kL Oil consumption Warm Start	kL Oil consumption Hot Start
1	210	1.00	1.00	2.67	3.00	3.00	5.00	2.00	2.00	2.33	100.00	60.00	46.67
2	210	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	210	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
										TOTAL	100.00	60.00	46.67

Table above shows the details of start-ups in the station. Based on the type of start-up, the energy consumption varies. The energy consumption also varies depending on the capacity of the unit. A detailed summary of energy consumptions in various capacity units under different types of start-ups in mentioned below.

Oil Consumption under various start-ups
For Cold Start-up
If capacity <=250 MW, Oil Consumption is 50 KL
If capacity > 250 MW, but <= 500 MW, Oil Consumption is 90 KL
If capacity >500 MW, <=660MW, Oil Consumption is 110 KL

For Warm Start-up
If capacity <=250 MW, Oil Consumption is 30 KL
If capacity > 250 MW, but <= 500 MW, Oil Consumption is 50 KL
If capacity >500 MW, <=660MW, Oil Consumption is 60 KL

For Hot Start-up
If capacity <=250 MW, Oil Consumption is 20 KL
If capacity > 250 MW, but <= 500 MW, Oil Consumption is 30 KL
If capacity >500 MW, <=660MW, Oil Consumption is 40 KL

Based on these parameters, we will calculate the normalization for the station.

KL Oil Consumption = (Difference between number of start-ups in AY and BY) X (Oil Consumption as per above)

Oil Consumption for Cold Start-up=2*50=100 KL
Oil Consumption for Warm Start-up=2*30=60 KL
Oil Consumption for Hot Start-up = 2.33*20 = 46.60 KL

Thermal Energy to be subtracted due to Cold/ Warm/Hot Start up due to External Factor (Million kcal)
= [KL oil Consumption in cold Start up + KL oil Consumption in warm start up

+ KL oil Consumption in Hot Start up] X 10

Thermal Energy to be subtracted due to Cold/ Warm/Hot Start up due to External Factor

= (100+60+46.60)*10 = 2066 Million kcal

For further calculations, let us take the parameters from table 17 below. This table represents the electrical energy used in the station due to external factors.

Item	Unit	Assessment Year (AY)	Baseline Year (BY)
Thermal Energy to be subtracted due to Cold/Warm/Hot Start up (External Factor)	Million kcal	2066.00	
Electrical Energy to be subtracted due to Shutdown (External Factor)	MU	3	0
Electrical Energy to be subtracted due to Environmental concern (External Factor)	MU	4.0	
Thermal Energy to be subtracted due to Environmental concern (External Factor)	Million kcal	0.0	
Electrical Energy to be subtracted due to Unforeseen Circumstances (External Factor)	MU	0.0	0
Thermal Energy to be subtracted due to Unforeseen Circumstances (External Factor)	Million kcal	0.0	0
Gross Heat Rate of Station	kcal/kWh	2691	2635
Gross Generation	MU	4355	

Total Electrical Energy in Assessment Year (Million kcal)
= [Electrical Energy to be subtracted due to Shutdown (External Factor) in AY (MU)+Electrical Energy to be subtracted due to Environmental concern (External Factor) in AY (MU)+Electrical Energy to be subtracted due to Unforeseen Circumstances (External Factor) in AY(MU)] X GHR of Station in AY

Where

GHR = Gross Heat rate (kcal/kWh)

AY = Assessment Year

Total Electrical energy in AY= (3+4+0)*2691 = 18837 Million kcal

Total Electrical Energy in Baseline Year (Million kcal)
= [Electrical Energy to be subtracted due to Shutdown (External Factor) in BY (MU)+Electrical Energy to be subtracted due to Unforeseen Circumstances (External Factor) in BY(MU)] X GHR of Station in BY

Where

GHR = Gross Heat rate (kcal/kWh)

BY = Baseline Year

Total Electrical energy in BY= (0+0+0)*2635 = 0

Total Thermal Energy (Million kcal) in AY
=Thermal Energy to be subtracted due to Environmental concern (External Factor) in AY +Thermal Energy to be subtracted due to Unforeseen Circumstances (External Factor) in AY+Thermal Energy to be subtracted due to Cold/Warm/Hot Start up (External Factor) in AY

Where

AY = Assessment Year

Total Thermal Energy in AY = (0+0+2066) = 2066 Million kcal

Total Thermal Energy (Million kcal) in BY
= Thermal Energy to be subtracted due to Unforeseen Circumstances (External Factor) in BY

Where

BY = Baseline Year

Total Thermal Energy in BY = 0

Total Energy to be Subtracted or normalized (Million kcal)= [Total Electrical Energy forAY (Million kcal) + Total Thermal Energy for AY (million kcal)] – [(Total Electrical Energy for BY(Million kcal)+ Total Thermal Energy for BY (Million kcal)]

Where

AY = Assessment Year

BY = Baseline Year

Total Energy to be Subtracted or normalized
= (18837+2066)-(0+0)
= 20903 Million kcal

Table below represents the final table that will appear in the form.

Item	Unit	Assessment Year (AY)	Baseline Year (BY)
Total Electrical Energy	Million kcal	18837	0
Total Thermal Energy	Million kcal	2066	0
Total Energy to be subtracted	**Million kcal**	**20903**	

Final Energy Normalization

In this table all the figures shown has been individually calculated in the sections above.

Other Normalization (kcal/kWh)

$$= \frac{\text{Total Energy to be subtracted or normalized in AY (MU)}}{\text{Gross Generation in AY}}$$

Where

AY   = Assessment Year

MU   = Million Unit

Other Normalization = 20903/ 4355 = 4.7999 kcal/kWh

Other Normalization = 4.8 kcal/kWh

(g)   Final Normalization Calculation for Gas based Thermal Power plant

From the sections above we know the followings

Operating Station Net Heat Rate in Baseline Year = 2726.11 kcal/kWh

Heat Rate Reduction Target = 171.63 kcal/kWh

Target Operating Station Net Heat Rate in Assessment Year
= 2726.11-171.63= 2554.58 kcal/kWh

Also, from the calculations in sections above, we know

Actual Operating Station NHR of this station without Normalization is 2890.3 kcal/kWh

It means, this station failed to achieve its target of 171.63kcal/kWh Heat Rate reduction in Assessment Year. The Station failed short of 2890.3-2554.58=335.72 kcal/kWh.

The station will now have to pay penalty for 335.72kcal/kWh or can buy E-Certs worth 335.72 kcal/kWh from other Stations/ industries.

However, we know that there has been a lot of change in operating conditions than the baseline year due to reasons beyond the control of plant management. Hence, we gave normalizations for Fuel mix, OC Cycle, APC and Other factors .i.e.,

Operating Station NHR of this station with Normalization

= Actual Operating Station NHR of this station without Normalization – Fuel mix Normalization – OC Cycle Normalization – Gas Quality Normalization– APC Normalization – PLF Normalization-Other Normalization

=2890.3-301.56-112.58-4.29--0.93-30.98-4.8

=2437.02 kcal/kWh

This is the normalized Heat rate. However this station has over achieved from its target value after the normalizations by 2437.02-2554.58= -117.56 kcal/kWh. Negative sign indicates that the plant has over achieved.

Therefore, this station is eligible for E-Certs worth 117.56 kcal/kWh, which can be traded in the open market with other stations/ industries.

11. Normalization for Fuel Mix (Gas + Oil) in Thermal Power Plant

In certain plants, the fuel fired in boiler is not coal. Due to various reasons, the plant has to fire alternate fuel. This results in a variation in boiler efficiency, ultimately leading to variation in heat rate. A plant may have fired 'X' ratio of Gas and Oil/others during Baseline Year and this ratio has significantly changed in the Assessment Year. The change in fuel ratio leads to a major change in heat rate.

Hence, this aspect has been taken care of, and normalized.

Section 11.01   Formulas

a.   Gross Generation from Fuel Mix (Million Unit)

= Actual Gross Generation from Gas+ Actual Gross Generation from Oil/Other Fuel

b. Gross Heat Rate with Fuel Mix (kcal/kWh)

= [(Design GHR @ 100% Load (OEM)for Gas X Actual Gross Generation from Gas)

+ (Design GHR @ 100% Load (OEM)for Oil Other Fuel X Actual Gross Generation from Oil Other Fuel)]

/ [Actual Gross Generation from Gas (MU)

+ Actual Gross Generation from Oil Other Fuel (MU)]

Where

GHR =Gross Heat Rate (kcal/kWh)

c. Difference of Gross Heat Rate with Fuel Mix in AY w.r.t. BY (kcal/kWh)

= GHR with Fuel Mix in AY - GHR with Fuel Mix in BY

Where

GHR = Gross Heat rate (kcal/kWh)

AY = Assessment Year

BY = Baseline Year

d. Notional energy for Fuel Mix to be Normalized for Unit (Million kcal)

=Difference of GHR with Fuel Mix in AY w.r.t.BY X Gross Generation from Fuel Mix

Where

AY = Assessment Year

BY = Baseline Year

GHR =Gross Heat Rate

e. Notion energy for Fuel Mix to be Normalized for station (Million kcal)

=Notion energy for Fuel Mix to be Normalized for Unit 1 + Notion energy for Fuel Mix to be Normalized for Unit 2 + Notion energy for Fuel Mix to be Normalized for Unit 3 + …………

Section 11.02   **Examples**

The plant shall enter the Gross Heat Rate at 100% load with Gas and Oil Others in the relevant section in Form-Sh sheet. Also, the generation from Gas and Oil/Others shall be entered in the respective column in Form-Sh sheet for Assessment and Baseline Year.

The plant might have other nomenclature for the units

The type of fuel fired shall be entered with corresponding Heat Rate. The 1st part of the table is considered for Fuel Type 1

Sr No	Unit	Nomenclature of Units as per Standard Practice of TPPs	COD Date	Design Capacity MW	As Provided by Original Equipment Manufacturer (OEM)			As established during Performance Guarantee Test (PG Test) **			Design Fuel Type (Coal/Lignite/Gas/Naptha/Oil/Other)	Source of Data
					Boiler Efficiency %	THR(Coal based TPP) kcal/kWh	Unit Heat Rate* kcal/kWh	Boiler Efficiency %	THR (Coal based TPP) kcal/kWh	UHR kcal/kWh		
i	Unit 1		30-09-2013	210	87.3	2045	2342.50	87.0	2100.00	2413.79	Gas	
ii	Unit 2		01-10-2013	210	87.3	2045	2342.50	87.0	2045.00	2350.57	Gas	
iii.	Unit 3		01-10-2013	210	87.3	2045	2342.50	87.3	2045.00	2343.84	Gas	
Unit /Module wise Design Data Details (For other fuel)												
i	Unit 1						2222.00		0.00		Oil	
ii	Unit 2						2345.00		0.00		Oil	
iii.	Unit 3						2222.00		0.00		Oil	

The plant might have other fuels and the corresponding Heat Rate shall be entered here as Fuel Type 2

Table above shows the details for fuel 1& 2, to be entered for various units with corresponding Heat Rates

THERMAL POWER PLANT - Under Perform, Achieve and Trade

Naptha not to be considered for TPPs.

Sr No	Item	Unit	Actual Gross Generation-Closed Cycle			Actual Gross Generation-Open Cycle due to Internal factor			Actual Gross Generation-Open Cycle due to External factor			Actual Gross Generation-Closed Cycle			Actual Gross Generation-Open Cycle due to Internal factor			Actual Gross Generation-Open Cycle due to External factor			Source of Data
			Current/ Assessment/ Target Year (20.... 20....)									Baseline Year (20.... 20....)									
			Gas	Naptha	Oil/ Other Fuel	Gas	Naptha	Oil/Other Fuel	Gas	Naptha	Oil/Other Fuel	Gas	Naptha	Oil/Other Fuel	Gas	Naptha	Oil/Other Fuel	Gas	Naptha	Oil/Other Fuel	
i	Unit1	MU	1100		100				100		50	1000		300				200		500	
ii	Unit2	MU	1000		250				50		50	500		200				100		100	
iii.	Unit3	MU	900		200				150		50	400		100				100		100	

Table above shows the total generation from various fuels due to various factors. Naptha shall not be entered by TPPs. Fuels other than gas shall be entered in the oil/other fuels column.

a. Gross Generation from Fuel Mix (Million Unit)

= Actual Gross Generation from Gas+ Actual Gross Generation from Oil/Other Fuel

Gross Generation from Fuel Mix (Million Unit) for AY
For U#1 = (1100+100) + (100+50) = 1350 MU
For U#2 = (1000+50) + (250+50)   = 1350 MU
For U#3 = (900+150)+ (200+50)   = 1300 MU

Gross Generation from Fuel Mix (Million Unit) for BY
For U#1 = (1000+200) + (300+500) = 2000 MU
For U#2 = (500+100) + (200+100)   = 900 MU
For U#3 = (400+100) + (100+100)   = 700 MU

b. Gross Heat Rate with Fuel Mix (kcal/kWh)

= [(Design GHR @ 100% Load (OEM)for Gas X Actual Gross Generation from Gas)

+ (Design GHR @ 100% Load (OEM)for Oil Other Fuel X Actual Gross Generation from Oil Other Fuel)]

/ [Actual Gross Generation from Gas (MU) + Actual Gross Generation from Oil Other Fuel (MU)]

Gross Heat Rate with Fuel Mix (kcal/kWh) for AY
ForU#1={(2342.5*1200)+(2222*150)}/(1200+ 150) =2329.11 kcal/kWh

For U#2 = {(2342.5*1050)+(2345*300)}/(1050+300) =2343.05 kcal/kWh

For U#3 = {(2342.5*1050)+(2222*250)}/(1050+250) =2319.32 kcal/kWh

Gross Heat Rate with Fuel Mix (kcal/kWh) for BY
For U#1 = {(2342.5*1200)+(2222*800)}/(1200+800) =2294.30 kcal/kWh

For U#2 = {(2342.5*600)+(2345*300)}/(600+300) =2343.33 kcal/kWh

For U#3 = {(2342.5*500)+(2222*200)}/(500+200) =2308.07 kcal/kWh

c. Difference of Gross Heat Rate with Fuel Mix in AY w.r.t. BY (kcal/kWh)

= GHR with Fuel Mix in AY - GHR with Fuel Mix in BY

Difference of Gross Heat Rate with Fuel Mix in AY w.r.t. BY (kcal/kWh)

For U#1 =2329.11-2294.30   =34.810 kcal/kWh
For U#2 =2343.05-2343.33   = -0.278 kcal/kWh
For U#3 =2319.32-2308.07   = 11.255 kcal/kWh

d.   Notional energy for Fuel Mix to be Normalized for Unit (Million kcal)

=Difference of GHR with Fuel Mix in AY w.r.t.BY X Gross Generation from Fuel Mix

Notional energy for Fuel Mix to be Normalized for Unit (Million kcal)

For U#1 =34.810*1350   =46993.9 Million kcal

For U#2 = -0.278*1350   = -375.4 Million kcal

For U#3 = 11.255 *1300   = 14631 Million kcal

e.   Notion energy for Fuel Mix to be Normalized for station (Million kcal)

=   Notion energy for Fuel Mix to be Normalized for Unit 1

+   Notion energy for Fuel Mix to be Normalized for Unit 2

+   Notion energy for Fuel Mix to be Normalized for Unit 3 + …………

Notion energy for Fuel Mix to be Normalized for station (Million kcal)
=46993.9 + (-375.4) +14631.8
=61250.25 Million kcal

12.   Condition for Normalisation

• The Boiler Efficiency calculation needs to be done separately for different units in a Power Station and weighted average should be taken to arrive net station heat rate

• The influence of external factor on the Plant Load Factor of each unit must be put into records and separate calculation is to be done for separate units [Scheduling of Station, Backing down of unit, unavailability of Fuel]

• Any claims of normalization shall be backed by relevant documents of baseline year and assessment year.

• All the manufacturer's/ OEM documents shall be made available.

Section 12.01   Documents to be maintained by plant

1.   Design documents of Coal Quality as per OEM (Proximate and Ultimate Analysis)

2.   Operating Coal Quality [Test Certificate for Coal Analysis include Proximate and Ultimate analysis of Coal (As FiredBasis)]- Monthly average of the lot (Test from Government Lab should be cross verified)

3.   Performance guarantee Test (PG Test) report for Original Equipment Manufacturer (OEM)

4.   Design Boiler Efficiency documents and Design Turbine Heat Rate documents

5.   Characteristics Curve of Unit Turbine Heat Rate Vs Load from Original Equipment Manufacturer (OEM)

6.   Design Boiler Efficiency Document from Original Equipment Manufacturer (OEM)

7.   Characteristics curve of Boiler Load Vs Efficiency from OEM

8.   Documents related to Scheduling/Outage due to external factor

9.   Documents related to non-availability of Fuel from Fuel Supplier

11.   OEM document for equipment ratings.

13. Conclusion

The target setting methodology elaborated the wide bandwidth of specific energy consumption among the plant. This itself depicts the potential of Energy saving opportunities. PAT could be instrumental in harnessing the saving potential exist in the plant by employing different management techniques, upgraded technologies, best available practices and technologies through economical viable projects.

Normalization of Plant parameters in the assessment year w.r.t. the baseline year is a process so as to avoid any favorable or negative impact on the specific energy consumption of the plant. This will also assist on evaluating the correct impact of the energy efficiency projects implemented by the plant. Once the Normalization factors are activated, it automatically brings all the plants under one platform. This will be another big step in terms of benchmarking the Plants as a whole.

Part-II
MONITORING & VERIFICATION GUIDELINES

1.   Introduction

1.1.   Background

Ministry of Power and Bureau of Energy Efficiency (BEE) have been implementing several programs for efficient use of energy and its conservation. Their effort are further supplemented by the National Mission for Enhanced Energy Efficiency (NMEEE), which is one of the missions under the National Action Plan on Climate Change (NAPCC), launched by Hon'ble Prime Minister on 30th June 2008 to ensure increase in the living standards of India's vast majority of people while addressing concerns regarding climate change.

The Perform Achieve and Trade (PAT) Scheme is one of the initiatives under NMEEE program,which was notified on 30th March 2012. PAT scheme is a market assisted compliance mechanism, designed to accelerate implementation of cost effective improvements in energy efficiency in large energy-intensive industries, through certification of energy savings that could be traded. PAT flows out Energy Conservation Act, 2001 (Amended in 2010).

The key goal of the PAT scheme is to mandate specific energy efficiency improvements for the most energy intensive industries. The scheme builds on the large variation in energy intensities of different units in almost each notified sector, ranging from amongst the best in the world and some of the most inefficient units. The scheme envisages improvements in the energy intensity of each unit. The energy intensity reduction target, mandated for each unit, depend on its current efficiency: more efficient units have a lower reduction target less efficient units have a higher target.

The Ministry of Power, in consultation with Bureau of Energy Efficiency has prescribed the energy consumption norms and standards,

in the exercise of the power conferred under clause (g) and (n) of section 14 of the Energy conservation Act 2001 (Amended in 2010) for the Designated Consumers-vide S.O. 687 (E) [Energy Conservation (Energy Consumption Norms and Standards for Designated Consumers, Form, Time within which, and Manner of Preparation and Implementation of Scheme, Procedure for Issue of Energy Savings Certificates and Value of per Metric Ton of Oil Equivalent of Energy Consumed) Rules, 2012] dated 30 March, 2012 (Containing Baseline Specific Energy Consumption, Product Output and Target Specific Energy consumption for the Designated Consumers).

The above notification is based on the Rules notified under G.S.R. 269 (E) [Energy Conservation (Energy Consumption Norms and Standards for Designated Consumers, Form, Time within which, and Manner of Preparation and Implementation of Scheme, Procedure for Issue of Energy Savings Certificates and Value of per Metric Ton of Oil Equivalent of Energy Consumed) Rules, 2012] dated 30th March, 2012, herein referred as PAT Rules, 2012

The scheme covers 478 designated consumers (DC) in 8 sectors (thermal power stations, iron and steel plants, cement, fertiliser, textile, pulp and paper, chlor alkali and aluminium) in the first phase. Together these designated consumers used about 36% of the fossil fuel consumed in India in 2010. Each designated consumer has been mandated to achieve a prescribed reduction in its specific energy consumption. The reduction targets were notified in March, 2012. Overall, all the plants together are to achieve a 4.05% reduction in the average energy consumption by 2014-15. This implies a reduction of about 6.686 million tonnes of oil equivalent (mtoe) in their annual energy consumption and a reduction of about 23 million tonnes of carbon dioxide emission, annually.

A robust monitoring, reporting and verification process will ensure effective and credible assessment of energy performance, achieved by industries covered under PAT.

1.2. Purpose

A reliable monitoring, reporting and verification (M&V) system forms the backbone of assessment process of the PAT scheme. The objective of the M&V system is to streamline the activities to be carried out for verifying the energy performanceachieved by the Designated Consumer in the target year.

> The documents sets out the requisite guidelines forM&V in the Monitoring and Verification phase under thePAT Rules. It provides practical guidance and proceduresto Designated Consumers (DCs) and Empanelled Accredited Energy Auditors (EmAEA) on verification requirements, and aims to establisha verification process consistent with relevant rules and regulation.

The Assessment of performance verification involves an independent evaluation of each activity undertaken by the DCs for compliance under PAT rules. Verification plays a crucial role in maintaining the integrity of the scheme and ensuring transparent validation.

The verification process will ensure that the information and data in Form 1and Pro-forma are free from material omissions, misrepresentations and errors.

The process requires EmAEA to verify the monitoring and verification of energy performance of DCsin accordance with PAT rules while taking into the consideration,Normalization factors and any other relevant conditions as defined PAT Rules

The verification must be completed between 1st April to 30th June of the year, following the assessment year.Submission of final verification report,verified annual Form1,SectorSpecificPro-forma, EmAEA's verification report along with authentic supporting documents shall be done by the DC to the concern State Designated Agency (SDA) and Bureau of Energy Efficiency before 30th June.

This document helps develop clarity on the verification process as it:

➢ Provides Designated Consumers and EmAEAaset of guidelines to establish methods for assessment ofspecific energy consumption.

➢ Defines broad techniques for assessing/ determining factors that effects the performance of establishment.

➢ Provides general terms, which are applicable to all sectors and also includes specific sector term.

➢ Will be guided as per the provisions conferred under Rule 3 of PAT Rules 2012.

➢ Provides support to the Designated Consumer to meet its obligation specified in Rule 7 and Rule 15 of the PAT Rules.

1.3. Definition of M&V

M&V is the process to verify the Specific Energy Consumption through verifiable means of each Designated Consumer in the baseline year and in the assessment year by an empanelled accredited energy auditor.

The underlying principles for Monitoring and Verification include:

► **Consistency:** By applying uniform criteria to meet the requirements of the sector specific methodology throughout the assessment period.

► **Transparency:** Information in the verification reports shall be presented in an open, clear, factual, neutral and coherent manner based on documentary evidence

► **Acceptability:** The Empanelled Accredited Energy Auditors shall base their findings

and conclusions upon objective evidence, conduct all activities in connection with the validation and verification processes in accordance with the rules and procedures laid down by BEE, and state their validation or verification activities, findings, and conclusions in their reports truthfully and accurately.

► **Measurability:** Measurement is a fundamental starting point for any kind of data captured for Energy Performance Index.

    i. Measurement in energy saving projects: The energy saving from any project is determined by comparing measured parameters before and after implementation of a project, making appropriate adjustments for changes in conditions.

    ii. Measurement of parameters for data captured in Pro-forma: The parameters entered in the pro-forma shall be taken from the measured logs with supporting documentation through Computational documentation from basic measurement at field

    iii. Measurement activities in the baseline and assessment year consist of the following:

- meter installation, calibration and maintenance
- data gathering and screening,
- development of a computation method and acceptable estimates from the basic measurement at field,
- computations with measured data, and
- reporting, quality assurance

A measurement boundary is a notional border drawn around equipment and/or systems that are relevant for determining the savings achieved through implementation of Energy saving projects.

► **Traceability:** The documents presented for substantiating the reduction in specific energy consumption or savings from ECM should be verifiable and visible.

► **Verifiability:** The validation of filled in data in the Pro-formaand savings from Energy Conservation Measures through proper authentic documentation are to be carried out by the EmAEA.

1.4. Empanelled Accredited Energy Auditor or Verifier

The accredited energy auditor firm empanelled with BEE will be the verifier of PAT. Given below are key exercises the verifier will carry out and their meaning.

Verification: A thorough and independent evaluation by the accredited energy auditor of the activities undertaken by the designated consumer for compliance with the energy consumption norms and standards in the target year compared to the energy consumption norms and standards in the baseline year and consequent entitlement to energy saving certificates.

Certification: It is the process of certifying the verification report or check-verification report by the accredited energy auditor to the effect that the entitlement of energy saving certificate is quantified accurately in relation to compliance of energy consumption norms and standards by the designated consumer during the target year.

Check-verification: This is an independent review and ex-post determination by the Bureau through the accredited energy auditor, of the energy consumption norms and standards achieved in any year of the three-year cycle which have resulted from activities undertaken by the designated consumer with regard to compliance of the energy consumption norms and standards.

1.4.1. Qualification of Empanelled Accredited Energy Auditor (EmAEA)for Verification and Check-Verification

A firm registered under the Indian Partnership Act, 1932 (9 of 1932) or a company incorporated under the Companies Act, 1956 (1 of 1956) or any other legal entity competent to sue or to be sued or enter into contracts shall be entitled to undertake verification and check-verification regarding compliance with the energy consumption norms and standards and issue or purchase of energy savings certificate if it,-

(a) has at least one accredited energy auditor whose name is included in the list of the accredited energy auditors maintained by the Bureau under regulation 7 of the Bureau of Energy Efficiency (Qualifications for Accredited Energy Auditors and Maintenance of their List) Regulations, 2010;

(b) has at least three energy auditors;

(c) has adequate expertise of field studies including observations, probing skills, collection and generation of data, depth of technical knowledge and analytical abilities for undertaking verification and check-verification;

(d) has a minimum turnover of ten lakhs rupees per annum in at least one of the previous three years or in case of a newly formed organisation, a net worth of ten lakhs rupees.

The application shall be accompanied by a certificate of registration or incorporationas the case may be.

1.4.2. Obligation of Empanelled Accreditor Energy Auditor

(1) For the work of verification or check verification, the accredited energy auditor shall constitute a team comprising of a team head and other members including

Process Experts:

Provided that a person who was in the employment of a designated consumer within the previous four years,shall not be eligible to perform the work of verification or check-verification for such designated consumer;

Provided further that any person or firm or company or other legal entity, who was involved in undertaking energy audit in any of the designated consumer within the previous four years,shall not be eligible to perform the work of verification or check-verification for such designated consumer.

(2) The accredited energy auditor shall ensure that persons selected as team head and team members must be independent, impartial and free of potential conflict of interest in relation to activities likely to be assigned to them for verification or check-verification.

(3) The accredited energy auditor shall have formal contractual conditions to ensure that each team member of verification and check-verification teams and technical experts act in an impartial and independent manner and free of potential conflict of interest.

(4) The accredited energy auditor shall ensure that the team head, team members and experts prior to accepting the assignment inform him about any known, existing, former or envisaged link to the activities likely to be undertaken by them regarding verification and check verification.

(5) The accredited energy auditor must have documented system for determining the technical or financial competence needed to carry out the functions of verification and check –verification and in determining the capability of the persons, the accredited energy auditor shall consider and record among other things the following aspects,namely:-

(a) complexity of the activities likely to be undertaken;

(b) risks associated with each project activity;

(c) technological and regulatory aspects;

(d) size and location of the designated consumer;

(e) type and amount of field work necessary for the verification or check-verification.

(6) The accredited energy auditor shall have documented system for preparing the plan for verification or check-verification functions and the said plan shall contain all the tasks required to be carried out in each type of activity, in terms of man days in respect of designated consumers for the purpose of verification and check – verification.

(7) The accredited energy auditor shall provide in advance the names of the verification or check-verification team members and their biodata to the designated consumer concerned.

(8) The accredited energy auditor shall provide the verification or check-verification team with the relevant working documents indicating their full responsibilities with intimation to the designated consumer.

(9) The accredited energy auditor shall have documented procedures for the following:

(i) to integrate all aspects of verification or check-verification functions;

(ii) for dealing with the situations in which an activity undertaken for the purpose of compliance with the energy consumption norms and standards or issue of energy savings certificate shall not be acceptable as an activity for the said purposes.

(10) The accredited energy auditor shall conduct independent review of the opinion of verification or check-verification team and shall form an independent opinion and give necessary directions to the said team if required.

(11) In preparing the verification and check-verification reports, the accredited energy auditor shall ensure transparency, independence and safeguard against conflict of interest.

(12) The accredited energy auditor shall ensure the confidentiality of all information and data obtained or created during the verification or check verification report.

(13) In assessing the compliance with the energy consumption norms and standards and issue of energy savings certificates, the accredited energy auditor shall follow the provisions of the Act, rules and regulations made thereunder.

(14) After completion of the verification or check-verification, the accredited energy auditor shall submit the verification (in Form- "B") or check-verification report, together with the certificate in Form-'C', to the Bureau.

1.5. Important Documents required for M&V process

I. Accepted Baseline Audit Report (Available with BEE and DC)[1]
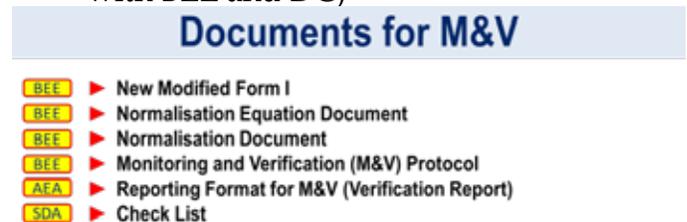
Figure 1: M&V Documents

---

[1]Baseline Report: Available with BEE and respective DCs. EmAEA to verify the consistency of Report

II.   Form 1& Sector Specific Pro-forma

III. Form A,B,C,D as covered in PAT rules

IV.   Normalisation Factors Document available with BEE

V.   Normalisation Guidelines Document available with BEE

VI.   Check List to be used by all stakeholders

VII. Reporting Format for EmAEA

1.6.   Stakeholders

I.   Ministry of Power, Government of India

II.   Bureau of Energy Efficiency

III.   Designated Consumers

IV.   State Designated Agencies

V.   Empanelled Accredited Energy Auditor

VI.   Adjudicator

VII.   Trading Regulator

VIII. ESCerts Management Registry

Figure 2: Stakeholders

Regulator	Administrator	Implementer	State Nodal Agency / Adjudicator	Verifier	Trading Regulator, Registry
MoP	Bureau of Energy Efficiency	Designated Consumer	State Designated Agency/ SERC	Empanelled Accredited Energy Auditor	CERC/ POSOCO
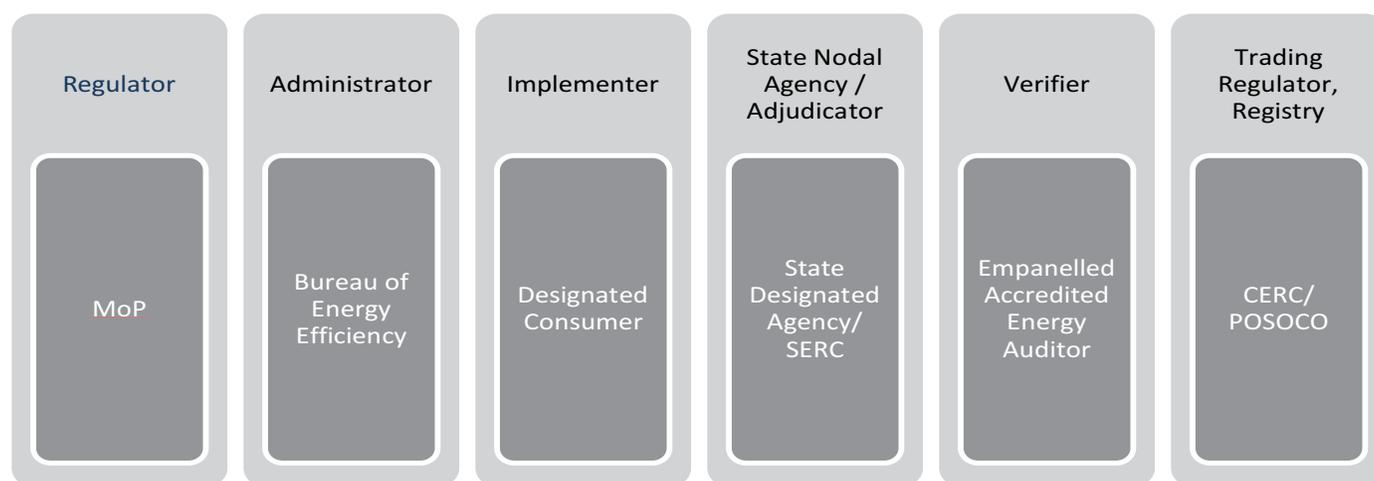
2.   Broad Roles and Responsibilities

The various roles to be assessed in the verification process include administration, regulation and services delivery. The key stakeholders are Ministry of Power, Bureau of Energy Efficiency, state designated agencies, adjudicator, designated consumers and empanelled accredited energy auditor.

2.1.   General

The roles and responsibilities of individuals and designated consumer are set out in Energy Conservation Rules 2012 [2]

The roles and responsibilities of the Designated Consumer (DC), Empanelled Accredited Energy Auditor (EmAEA), Bureau of Energy Efficiency (BEE), State Designated Agencies (SDA), Adjudicator and Ministry of Power (MoP) can be summed up as under

The designated consumer shall fill the data manually in Excel Sheet Pro-forma and in PATNET in the sector specific Pro-forma and Form 1 stating source of data, of its installation as per gate to gate boundary concept. The filled in forms with the authentic source of data in terms of hard copy document shall have to be kept ready by designated consumer for verification. The designated consumer in consultation with the EmAEA, shall put in place transparent, independent and credible monitoring and verification arrangement. The verifier shall

---

[2]Energy Conservation Rules 2012: Energy Consumption Norms and Standards for Designated Consumers, Form, Time within which, and Manner of Preparation and Implementation of Scheme,Procedure for Issue of Energy Savings Certificate and Value of Per Metric Ton of Oil Equivalent of Energy Consumed) as per Notification G.S.R.269 (E) dated 30th march 2012

ensure transparency, independence and safeguard against conflict of interest.

As part of the verification process, the EmAEA shall carry out a strategic and statistical analysis, checking of relevant and authentic documents, quarterly, yearly and end of cycle internal data audit reports, performance assessment documents (Form A), Form I and sector specific pro-forma from designated consumers; the EmAEA will also carry out the actual verification and produce an internal verification report, Form B. These verified Forms, documents and reports will then be submitted to the SDA with a copy to the Bureau. The SDA, in turn after proper verification of Form A sent by DC may send its comments to BEE for final verification based on the SDA Check List.

If the accredited energy auditor records a positive opinion in his verification report, the Bureau shall consider that all the requirements with regard to the compliance with energy consumption norms and standards, entitlement about issue or liability to purchase energy savings certificate have been met.

BEE on satisfying itself about the correctness of the verification and check-verification reports, wherever sought by it, will send its recommendations under clause (aa) of sub-section (2) of section 13 to the Central Government, based on the claim raised by the designated consumer in Form `A', within 10 working days from the last date of its submission, for issuance of energy saving certificates under section 14A.

2.2. Designated Consumer

The Designated Consumers have the following responsibilities with respect to EOC or mid cycle verification as per guidelines in Energy Conservation Rules 2012:

1. To monitor and report in accordance with the monitoring plan approved by the BEE.

2. Establish data and information management system as per Sector Specific Supporting Pro-forma for Form 1, Normalization formulae

3. M&V arrangements for energy consumption and production by Designated Consumer

4. Without prejudice to the monitoring plan approved by the BEE, DC must comply with on-going obligations imposed under PAT Rules 2012

5. The monitoring methodology or the Input Data Entry with Normalisation factors shall be changed if this improves the accuracy of the reported data and for taking out any errors reported by DC in the Sector Specific Pro-forma (Linking formulae, error formulae or wrong data entry)

6. The designated consumer in consultation with the accredited energy auditor, shall put in place transparent, independent and credible monitoring and verification arrangements for energy consumption and production based on the Bureau of Energy Efficiency (Manner and Intervals of Time for Conduct of Energy Audit) Regulations, 2010 for compliance with the energy consumption norms and standard, and the said arrangements shall include,-

i) Preparation and Maintenance of Quarterly Data Reports to be prepared by DCs from 2012 onwards up to assessment year
   a. On the performance of plant and production process
   b. Internal Field Audit Report on Energy and Process

ii) Preparation and Maintenance of Yearly Data Reports to be prepared by DCs from 2012 onwards up to assessment year
   a. On the performance of plant and production process

b. Outcome of Internal Field Audit

c. Measures to reduce energy consumption and improve energy efficiency

d. Measures taken to improve the efficiency of the production processes during each year

iii) Preparation and Maintenance of Yearly Data Reports to be prepared by DCs from 2012 onwards up to assessment year

a. Report on production achieved, energy consumed

b. specific energy consumption achieved, specific energy consumption

c. reduction achieved, measures adopted for energy conservation and quantity of energy saved;

iv) Preparation and Maintenance of Consolidated End of Cycle (EOC) Data Reports to be prepared by DCs from 2012 onwards up to assessment year

a. Report on production achieved, energy consumed

b. specific energy consumption achieved, specific energy consumption

c. reduction achieved, measures adopted for energy conservation and quantity of energy saved;

7. The DC has to maintain in set tabulated format and set reports template as per above guidelines for submission to EmAEA

8. The DC has to fill the data in the Sector Specific Pro-forma for the Normalization factors including M&V protocol for its facility in conformity with the Sectoral

Normalisation factor guidelines prepared by BEE

9. The data to be filled in the latest version of MS Office Excel sheet and PATNET

10. Designated Consumers shall facilitate verification and check-verification work by the EmAEA and SDA.

11. The designated consumers shall,-

(a) get their compliance with the energy consumption norms and standards assessed by accredited energy auditors;

(b) take all measures, including implementation of energy efficiency projects recommended by the accredited energy auditor and good practices prevalent or in use in the concerned industrial sector so as to achieve the optimum use of energy in their plant;

furnish the full and complete data, provide necessary documents and other facilities required by the accredited energy auditor for the purpose of performing the function of verification and check-verification.

12. The designated consumer for the purpose of compliance with the energy consumption norms and standards during the target year, in the relevant cycle shall take the following actions and furnish the status of compliance to the state designated agency with a copy to the Bureau in Form D by the end of five months from the last date of submission of Form `A'-

(a) practise energy conservation and carry out energy efficiency measures to comply with energy consumption norms, or

(b) where the energy efficiency measures implemented are found inadequate for achieving compliance with the energy consumption norms and standards,

the designated consumer shall purchase energy saving certificates to meet the compliance norms in terms of metric tonne of oil equivalent.

2.3. Empanelled Accredited Energy Auditor (EmAEA)

The EmAEA is responsible for verification of compliance with Energy Consumption Norms and Standards for Designated Consumers, Gate to Gate Specific Energy Consumption of baseline and assessment year as per guidelines of PAT Rules 2012 with subsequent attributes

13. To ensure that the verification is carried out by properly trained and competent staff as per Section 1.4.2 are essential

14. The EmAEA is responsible for ensuring that the systems and processes adopted by the DC for determination of GtG SEC from the data in Sector Specific Proforma along with Normalisation sheets and information protocol have been maintained in conformity with the various notifications and information provided by BEE/SDA from time to time

15. EmAEA is required to perform various roles such as technical review of manufacturing processes and energy consumption patterns, system variability and its impact on energy consumption; the EmAEA is also required to apply statistical methods of verification and also ensure integrity and authenticity of data.

16. The accredited energy auditor shall independently evaluate each activity undertaken by the designated consumer towards compliance with the energy consumption norms and standards, and entitlement to or requirement of energy saving certificates.

    (A) The accredited energy auditor, in order to assess the correctness of the information provided by the

designated consumer regarding the compliance with energy consumption norms and standards shall:

(a) Apply standard auditing techniques;

(b) Follow the rules and regulation framed under the Act;

(c) Integrate all aspects of verification, and certification functions;

(d) Make independent technical review of the opinion and decision of the verification team; also take into consideration, a situation where a particular activity may or may not form part of the activities related to the compliance with the energy consumption norms and standards, and the procedure for the assessment shall include:

Document review, involving

(i) Review of data and its source, and information to verify the correctness, credibility and interpretation of presented information;

(ii) Cross checks between information provided in the audit report and, if comparable information is available from sources other than those used in the audit report, the information from those other sources and independent background investigation;

Follow up action, involving-

(iii) Site visits, interviews with personnel responsible in the designated consumers' plant;

(iv) Cross-check of information provided by interviewed personnel to ensure that no relevant information has been omitted or, over or under valued;

(v) Review of the application of formulae and calculations, and reporting of the findings in the verification report.

(B) The accredited energy auditor shall report the results of his assessment in a verification report and the said report shall contain,

(a) The summary of the verification process, results of assessment and his/her opinion along with the supporting documents;

(b) The details of verification activities carried out in order to arrive at the conclusion and opinion, including the details captured during the verification process and conclusion relating to compliance with energy consumption norms and standards, increase or decrease in specific energy consumption with reference to the specific energy consumption in the baseline year;

(c) the record of interaction, if any, between the accredited energy auditor and the designated consumer as well as any change made in his/her assessment because of the clarifications, if any, given by the designated consumer.

17. EmAEA to prepare a verification report as per Reporting template to be provided by BEE

18. EmAEA to resolve errors, omissions or misrepresentations in the data/records/calculations in consultation with the Designated Consumers (DCs) prior to completing the verification report

19. EmAEA to resolve calculation errors in the Sector Specific Pro-forma in consultation

with the BEE prior to completing the verification

2.4. State Designated Agencies (SDA)

All the documents like verified Sector Specific Pro-forma, Form 1, Verification report of EmAEA and related documents will be routed to BEE via SDA.

20. The technical role of SDA are

i. Inspection & enforcement for M&V related systems

ii. Assist BEE in information management process

iii. Review and validation of Sector Specific Pro-forma, Form 1, Verification report of EmAEA and related documents before sending it to BEE

iv. After submission of duly verified Form 'A' by designated consumer, SDA may convey its comments, if any, on Form 'A' to the Bureau within fifteen days of the last date of submission of Form 'A'.

v. BEE, in consultation with SDA may decide to undertake review on Check verification

vi. The EmAEA in-charge of check-verification shall submit the report with due certification Form C to the BEE and the concerned SDA

vii. The State designated agency may furnish its comments on the report within ten days from the receipt of the report from the EmAEA. In case no comments are received from the concerned state designed agency concerned, it shall be presumed that they have no comments to offer in the matter

viii. The State designated agency within two months from the date of the receipt of the report referred to in sub-rule (9) shall initiate-

(a) action to recover from the designated consumer the loss to the Central Government by way of unfair gain to the designated consumer;

(b) penalty proceedings against the persons mentioned in the said report,under intimation to the Bureau;

(c) register complaint for such fraudulent unfair gain if designated consumer does not pay penalty and loss to the exchequer in the specified time mentioned in the penalty proceedings.

21. The administrative role of SDA is given below

The designated agency may appoint, after 5 years from the date of commencement of this Act, as many inspecting officers as may be necessary for the purpose of ensuring compliance with energy consumption standard specified under clause (a) of section 14 or ensure display of particulars on the label of equipment or appliances specified under clause (b) of section 14 or for the purpose of performing such other functions as may be assigned to them.

Subject to any rules made under this Act, an inspecting officer shall have power to –

(a) inspect any operation carried on or in connection with the equipment or appliance specified under clause (b) of section 14 or in respect of which energy standards under clause (a) of section 14 have been specified;

(b) enter any place of designated consumer at which the energy is used for any activity

(c) inspect any equipment or appliance as may be required and which may be available at such places where energy is used for any activity;

(d) inspect any production process to ascertain the energy consumption norms and standards

2.5. Adjudicator

Section 27 and Section 28 of the Energy Conservation (EC) Act, 2001 shall be referred to for power to adjudicate.

2.6. Bureau of Energy Efficiency

BEE shall co-ordinate with the Designated Consumers, SDA, Sectoral technical committee and other agencies to administer and monitor the Scheme as per PAT Rules and EC Act 2001.

22. BEE shall recommend to the Central Government the norms for processes and energy consumption standards required to be notified under clause (a) of section 14 of Energy Conservation Act, 2001.

23. It will prepare and finalise sector specific Pro-forma for annual data entry in consultation with the technical committee set up by BEE.

24. BEE will prepare and finalise sector specific normalisation factors applicable in assessment year in consultation with the technical committee set up by BEE.

25. The Bureau will carry out empanelment of the accredited energy auditor firm as verifier

26. It will carry out capacity building of SDA, EmAEA, energy managers of designated consumers

27. The Bureau on satisfying itself about the

correctness of verification report, and check-verification report, wherever sought by it, send its recommendation under clause (aa) of sub-section (2) of section 13 to the Central Government, based on the claim raised by the designated consumer in Form `A', within ten working days from the last date of submission of said Form `A' by the concerned state designated agency, for issuance of energy savings certificates under section 14A

2.7. Ministry of Power

28. The roles and responsibilities of the Central Government have been covered under clause 14(chapter V) of EC Act, 2001 and notified under PAT Rules, 2012

2.8. Institutional Framework for PAT

Transparency, flexibility and engagement with industry players in programme design help ensure effective industrial energy efficiency policy, which even the facilities covered are likely to buy into. PAT's design phase involved extensive consultations with designated consumers; the consultations ensured the design phase was transparent and allowed industry to engage in the process.

Since PAT is largely a federal scheme, involvement of state designated agencies as an extended arm of enforcement ushers outcome in the right direction.

An institutional frame work consisting of State Designated Agencies, Designated Consumers, Accredited Energy Auditors, Trading Exchanges[3] and Financing facilities has been established to implement the scheme. Bureau of Energy Efficiency is leading the process with state level capacity supported by AEA and Sectoral Technical committee constituted for rationalizing the process.

Figure 3: Institutional Framework

---

[3] Trading Exchanges: IEX & PXIL

3. Process & Timelines

3.1. Activities and Responsibilities

The Energy Conservation Rules, 2012 clearly define the timeline of activities and responsibilities to be carried out for accomplishment of PAT scheme. From submitting the action plan to trading of ESCerts by designated consumers, the various steps under PAT need to be executed in a definite time frame.

Constant monitoring of the scheme, through parameters like total ESCerts issued and traded, complying sectors or participants, market liquidity, etc, will be carried out. Delays at any point of the process-chain will be identified and timely action taken by the administrator/ regulator.

Automation of processes, wherever feasible, will be carried out for seamless implementation of PAT.

Table 1: Activities and Responsibilities for PAT Cycle I

S. No	Name of Form	Submitted by	Time of Submission	Submission authorities
1.	Form A	DCs	Three months from conclusion of target year (end of first, second or third year of relevant cycle) **30th June, 2015**	SDA & BEE
2.	Form B (Certificate of verification by AEE)	DCs	Three months from conclusion of target year (end of first, second or third year of relevant cycle) **30th June, 2015**	SDA & BEE
3.	BEE's Recommendation to MoP for issuance of ESCerts	BEE	10 working days from receipt of forms A & B	Ministry of Power
4.	Issuance of ESCerts	Central Government (MoP)	Within 15 days from receipt of recommendations by BEE	BEE
5.	Form D (status of Compliance)	DC	End of 5 months from the last date of submission of Form A	SDA & BEE
6.	Form C (check verification report and certificate)	AEA (Accredited Energy Auditor)	Within 6 months after issuance of ESCerts or within 1 year of submission of compliance report	BEE

3.2. Process Interlinking

The complete process, from notifying the reduction targets to issuing Escerts, is interlinked among various stakeholders complying to a definite time frame as shown below:

Figure 4: Interlinking Stakeholders
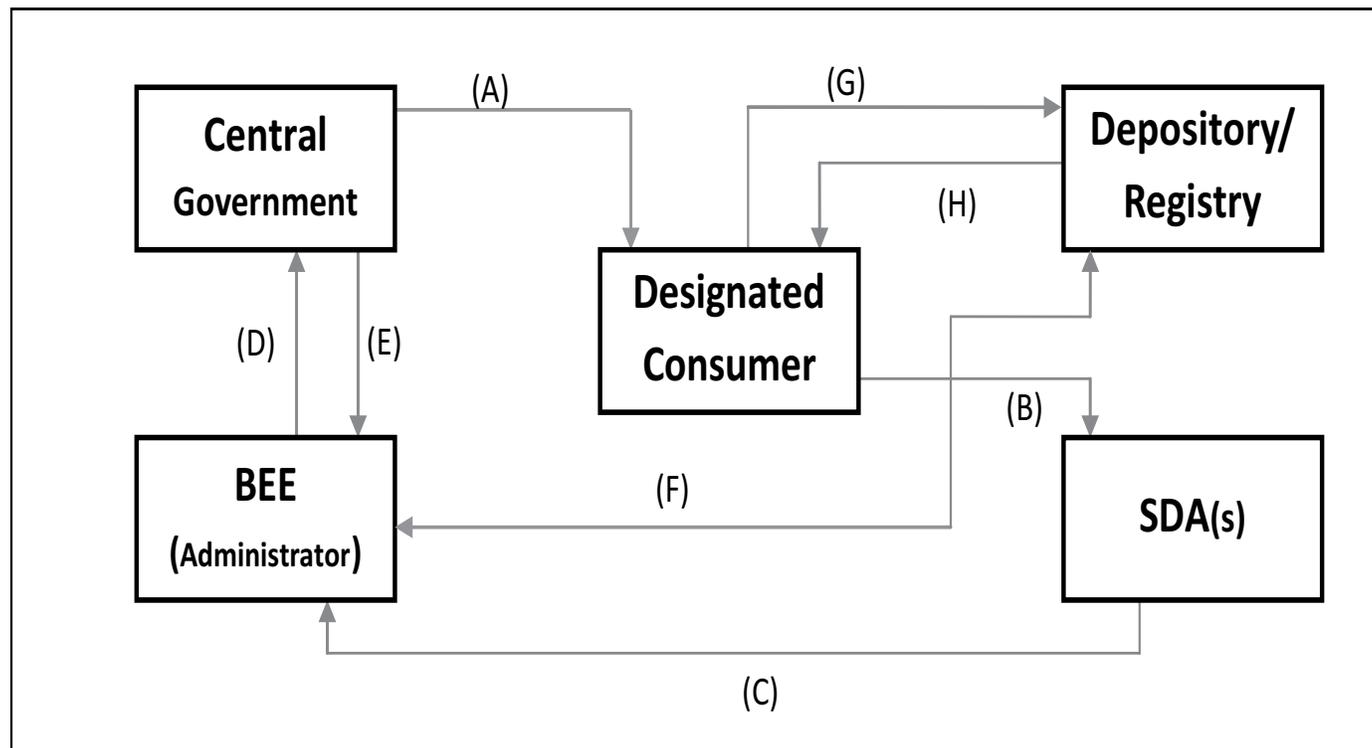
(A) Targets from Central Government to DCs

(B) Performance Assessment Document (Form A) from DC to SDA

(C) Performance Assessment Document (PAD) (Form-A) with recommendation for issuance, if overachieved, from SDA to BEE

(D) Recommendation of ESCerts Issuance by BEE to Central Government

(E) ESCerts Issuance Instruction from Central Government to BEE

(F) Electronic ESCerts Issuance Instruction from BEE to Depository

(G) DC Interaction with Depository account

(H) ESCerts credit to DC's account

3.2.1. Issuance of ESCerts

```
┌──────────────────────────────┐          ┌─────────────────────┐
│ Forms and Document [Form I,   │          │ FORM 1 filling in   │
│ Proforma, Form A, Form B]     │──────────│ PATNET by DC on     │
│ duly verified by EmAEA        │          │ achieved SEC in AY  │
│ Submission by DC to SDA with  │          └─────────────────────┘
│ a copy to BEE                 │
└──────────────────────────────┘
              │
              ▼
┌──────────────────────────────┐
│ Forms and Document submission │
│ by SDA to BEE                 │
└──────────────────────────────┘
              │
              ▼
┌──────────────────────────────┐
│ Verification of Forms and     │
│ Documents submitted by DC &   │
│ SDA by BEE                    │
└──────────────────────────────┘
              │
              ▼
┌────────────────┐      ◇ Change in SEC      Yes   ┌──────────────────────┐
│ SEC after Check-│─────◇ value after    ◇────────│ SEC value to be      │
│ Verification    │      ◇ assessment   ◇          │ rectified in PATNET  │
└────────────────┘           ◇     ◇               │ by BEE with          │
                              │ No                  │ information to DC     │
                              ▼                     └──────────────────────┘
                    ◇ Final SEC    Under achiever  ◇ Final SEC
                    ◇ of BY/ AY ◇─────────────────◇ of AY ◇
```

Change in SEC value after assessment → **Yes** → SEC value to be rectified in PATNET by BEE with information to DC → **Final SEC of AY**

No → **Final SEC of BY/ AY** — Under achiever — **Final SEC of AY**

Over achiever ... Under Achiever ... Over achiever

┌──────────────────────────────┐
│ DC to purchase the ESCerts   │
│ from Exchange - up to November│
└──────────────────────────────┘

┌──┐
│ Recommendation of EScerts by BEE to the Central Government if │
│ a DC overachieves the target   │
└──┘

┌──┐
│ **ISSUANCE OF ESCERTS BY CENTRAL GOVERNMENT (For Over   │
│ Achievers)**   │
└──┘

┌──┐
│ Trading of ESCerts at Trading Platform   │
└──┘

┌──┐
│ Submission of Form D by Designated Consumer   │
└──┘

┌──┐
│ Penalty Proceedings to start by SDA on recommendation of BEE   │
│ for the DCs not complying the Norms and Standards as per   │
│ Notification   │
└──┘

Figure 5: Flow Chart of ESCerts issuance

29. Penalty for Non-Achievement of Target

   i. Compliance as per Form D of Energy Conservation Rules 2012

      (a) Energy savings certificates: Enter +ve value if energy savings certificates issued to designated consumer or enter –ve value in case recommended for purchase of energy savings certificates

      (b) Energy savings certificates

submitted for compliance: If designated consumer is recommended for purchase of energy savings certificates, then enter value of energy savings certificates submitted by designated consumer for compliance of energy consumption norms and standards- saving target of designated consumer.

(c) Balance energy saving certificates: If the balance is ZERO then the designated consumer has complied with its energy saving target and if the balance is –ve then the consumer will be recommended for penalty.

ii. For Penalty and Power to adjudicate, refer section 26 and 27 of the EC Act 2001

iii. As per EC Act, 2001, section 26, the fixed penalty is a maximum 10 lakh rupees and variable penalty is the price of 1 tonne of oil equivalent as specified in Energy Conservation Rules, 2012. Any amount payable under this section, if not paid, will be recovered as if it were an arrear of land revenue.

3.3. Flow Chart showing verification process (Rules and Act required dates in ***bold Italics***)

Responsibility	Date	Action and Stages of verification process
DC	***By June 30 each Year***	Submission of Energy Return Form I and Sector Specific Supporting Pro-forma for Form 1
DC	***By June 30 [First Year of PAT Cycle]***	Submission of Action Plan
DC	***Before M&V phase of PAT Cycle***	Hiring of Empanelled Accredited energy Auditor
DC/EmAEA	***April 1-June 30 [After completion of relevant PAT cycle]***	Monitoring and Verification
DC	***By June 30 [M&V phase of PAT Cycle]***	Submission of Verified Form I and Sector Specific Pro-forma, Form A, Form B and Other Document to SDA & BEE
DC	***By June 30 [After end of 1ˢᵗ and 2ⁿᵈ Year PAT Cycle]For Advance ESCerts***	Submission of Verified Form I and Sector Specific Pro-forma, Form A, Form B and Other Document to SDA & BEE
SDA	**[15 days of the last date of sub. of Form A]**	Submission of Comments on Verified Form I and Sector Specific Pro-forma, Form A, Form B and Other Document to BEE
BEE	**[10 working days from last date of submission of Form A by SDA][M&V phase of PAT Cycle]**	Recommendation of Energy Saving Certificates to Central Government **[10 working days from last date of submission of Form A by SDA]**
Central Government	**[15 working days from date of receipt of recommendation by BEE][M&V phase of PAT Cycle]**	Issue of Energy Saving Certificates**[15 working days from date of receipt of recommendation by BEE]**
DC	**[5 months from date of submission of Form A by DC to SDA][M&V phase of PAT Cycle]**	Submission of Form D to SDA and BEE**[5 months from date of submission of Form A by DC to SDA]**
BEE/Power Exchange	**[M&V phase of PAT Cycle]**	ESCerts Trading period

Figure 6: Time Line Flow Chart

Monitoring & Verification Guidelines

4. Verification requirement

4.1. Guidelines for Selection Criteria of EmAEA by Designated Consumer

30. The EmAEA will be selected only from the List of EmAEA as available in the BEE official website

31. The procedure for selection of EmAEA should be followed from guidelines of PAT Rules 2012

32. The designated consumer may select EmAEA based on their experience in energy auditing and in the related sector as per information in Form III and Form IV (Register Containing List Of Accredited Energy Auditors) Submitted by the Accredited Energy Auditor (www.bee-india.nic.in)

33. The EmAEA has preferably attended at least one training programme on Monitoring and Verification Guidelines organised by the Bureau of Energy Efficiency.

34. The Designated Consumer needs to verify following during selection of AEA

    (a) Provided that a person who was in the employment of a designated consumer within the previous four years, shall not be eligible to perform the work of verification or check-verification for such designated consumer;

    (b) Provided further that any person or firm or company or other legal entity, who was involved in undertaking energy audit in any of the designated consumer within the previous four

years, shall not be eligible to perform the work of verification or check verification for such designated consumer.

35. EmAEA is required to submit the documentation on determining the capability of the team on Technical and financial competence after getting the formal order from Designated Consumer

36. EmAEA is required to submit the Name and detailed Bio-data on Energy Audit or Verification experiences of the team head, team members and experts to the DC prior to selection

37. The Designated Consumer to ensure that the EmAEA must have documented system on preparing plan for verification or check-verification along with activities chart defining task in man-days.

38. The selection process of EmAEA needs to be completed before 31st March of the end of PAT Cycle

39. The scope of work may cover the period up to check-verification.

4.2. Guidelines for Empanelled Accredited Energy Auditor

40. The EmAEA shall constitute a team in accordance with section 10 of Energy Conservation Rules, 2012.

41. Where ever necessary, EmAEA must state any discrepancies in their final verification reports and potential improvements to achieve more accurate reporting in line with the PAT Rules and EC Act.

Table 2: Team Details (Minimum Team Composition)

Sr No	Designation	Qualification	Experience
1	Team Head	Accredited Energy Auditor	In the Field of Energy Auditing of PAT Sectors [4]
2	Team Member [Expert]	Graduate Engineer	Process or Technical Expert related to the specific sector, where verification will take place having experience of more than 10 years
3	Team Member	Certified Energy Auditor	In the Field of Energy Auditing
4	Team Member	Graduate/ Diploma Engineer	

42. The EmAEA may constitute any number of verification or check-verification teams to carry out the verification of a number of designated consumers.

43. The EmAEA shall ensure that it has formal contracts with team members, including technical experts, for verification and check-verification so as to act in an impartial and independent manner and free of potential conflict of interest.

44. The EmAEA, has the sole responsibility and signing authority on Form B, Form C

45. The EmAEA should complete the verification for onward submission to SDA and BEE before 30 June in the year following the assessment year.

46. The EmAEA should furnish a time plan and activities chart to the designated consumer after receiving a valid work order.

47. The Designated Consumer shall inform Bureau of Energy Efficiency about the date of start of verification by EmAEA.

48. The verification shall not be carried out by two different EmAEA for the particular DC in a single PAT cycle.

49. The audit report shall be certified by the EmAEA and shall be counter signed by the DCs Energy Manager and Competent Authority

50. The EmAEA to submit an undertaking along with Form B indicating that there is no conflict of interest in the team assigned and PAT Rules 2012 and its amendments have been complied with.

4.3. Guidelines for Verification process

4.3.1. Sector Specific Pro-forma

The Sector Specific Pro-forma is made with the purpose of capturing the data for Production, Energy and Normalization factors under equivalent condition for the baseline and assessment year. The filled in Pro-forma is used to calculate the Notional Energy for Normalization. Once complete data is filled in the Pro-forma, the SEC after Normalization automatically comes out in the summary sheet enabling the DC to see the actual performance of the plant

51. The Energy Conservation (Form and Manner for submission of Report on the Status of Energy Consumption by the Designated Consumers) Rules, 2007 directs every designated consumers to submit the status of energy consumption in electronic form as well as hard copy, within three

---

[4] PAT Sectors: Thermal Power Stations, Steel, Cement, Aluminium, Fertiliser, Pulp & Paper, Textile, Chlor-Alkali

months, to the designated agency with a copy to Bureau of Energy Efficiency at the end of the previous financial year in Form-1.

52. The Sector Specific Pro-forma have many sections to cover all the aspects of GtG[5] methodology as follows:

► Instruction for Form 1 filling

► General Information Sheet

► Form 1

► Sector Specific Pro-forma

   o Production and Capacity Utilization Details

   o Section wise details of various products

   o Electricity and Renewable Energy Consumption

   o Power Generation (DG/GG/GT/STG/Co-Gen/WHR)

   o Fuel Consumption (Solid/Liquid/Gas/Biomass & Others)

   o Heat Rate of different power sources and Coal Quality

   o Miscellaneous Data for Normalisation

► Installation of additional equipment to protect the environment

► Project Activities details

► Summary Sheet

► Normalization calculation sheets

53. Form 1 will be generated automatically after filling in the Pro-forma, which is required to be filled in the PATNET as input for final assessment of gate-to-gate specific energy consumption (GtG SEC) for the baseline and assessment years.

54. Formulae cells in Pro-forma,Summary sheet and Normalisation calculation sheets are locked to ensure data security, reliability etc.

55. There are five columns in the Sector Specific Pro-forma. Three columns are used for Baseline years i.e., Year 1, Year 2 and Year 3, the fourth column will be used for computing the average data of the baseline years and the fifth one for entering the data in Year 4 i.e. Assessment year/Target year/Current year.

56. The Sector Specific Pro-forma will be used for mandatory submission of annual Energy return. The data will be filled in the year 3 column as previous year and year 4 as current year after making the others column cells empty.

57. Average of the three baseline years is taken as baseline data for Normalisation

58. For the purpose of taking the average of baseline year, other columns are not to be left blank. However, if a plant's data show only one or two years of operation, then the third year column should be left blank.59. Cells have been Colour coded and locked for data security purpose in the Pro-forma.

4.3.2. Reporting in Sector Specific Pro-forma

60. Baseline parameter and Plant boundary in Gate to Gate Concept means

► **Plant Boundary for Energy and Product**

   ▪ Input Raw material

   ▪ Output product

   ▪ Captive Power Plant (CPP) installed within premises or outside the plant demographic boundary

   ▪ Energy inputs and Outputs (Electricity/Gas/Steam etc)

---

[5] GtG: Gate to Gate

► **Defining Input Energy in Sector Specific Pro-forma**

- Fuel Input to the Captive Power Plants

- Fuel Input to the Process

- Bifurcation of Input Energy for Renewables/Alternate source/ Biomass etc in Captive Power Plants

- Not connected with Grid-The energy used from the Renewables/Alternate source/ Biomass will not be added in the total input energy

- Connected with Grid-The energy used from Renewables/Alternate source/Biomass will be added in the total input energy

- Waste Heat Recovery

- Co-generation

- Accounting of Energy generation and Energy used inside the plant boundary

► **Raw material input and Product output**

- Intermediary semi-finished Product output for market sale- the energy for making the intermediary product to be deducted from the total energy consumption

- Intermediary semi-finished Product input as raw material in between the process- the energy for making up to the semi-finished intermediate product to be added in the total energy consumption.

61. The baseline Production and Energy related data to be entered in Sector Specific Pro-forma as per Baseline Report by individual DCs. The same will be verified by EmAEA.

62. The DCs are required to fill the data as per instruction sheets in all the relevant

baseline and assessment year data field with source of data

63. The entered baseline data in the Excel Sheets will be locked for data security by BEE. The DC can enter data in all the fields other than locked Cells.

64. The Locked-in Sector Specific Pro-forma is to be sent to DCs for data entry.

65. The primary and secondary source of data should be kept ready in hard copies for verification by EmAEA as per guidelines in the instruction sheet.

66. DCs are advised to fill the data in Excel Sheets only and return the same in Excel form to SDAs with a copy to BEE along with hard copies of Form 1, Sector Specific Pro-forma, Summary and all Normalisation sheets duly signed.

4.3.3. Verification Process

As part of the verification process, the EmAEA shall carry out the following steps:

67. The EmAEA after receiving the work order is advised to get the final Baseline report (Accepted by BEE) from the DC.

68. The EmAEA shall conduct a site visit on mutually agreed dates with Designated Consumer, to inspect the monitoring systems, conduct interviews, and collect sufficient information and supporting documentary evidence (vide Sector Specific Pro-forma.)

69. Prior to visiting the site, the EmAEA is advised to study the Baseline reports, Sector Specific Pro-forma and Sector specific Normalisation document

70. 70. For computing gate-to-gate SEC the plant boundary is defined such that the total energy input and the defined product output is fully captured. Typically, it includes the entire plant – excluding

housing colony, residential complex and transportation systems. Similarly, mining operations in the case of iron & steel, aluminium and cement sectors do not fall under the plant boundary.

The same boundary should be considered for entire PATcycle as finalised for the baseline year in the final Baseline Energy Audit Report. Ideally, plant boundary should not change during the entire cycle. Any change in plant boundary limit or merger of two plants, division of operation should be duly reported. The definition of Plant boundary should be considered same as established in the baseline year

71. The EmAEA will assign the activities among team members for verifying the data through the Pro-forma, Documented Primary and secondary sources, Field reports, conducting interviews, site visits etc.

72. The filled in Baseline data for Production and Energy shall be verified through Baseline Report by EmAEA.

73. The additional Baseline data filled by DC needs to be verified based on authentic documentary evidence.

74. The baseline verified data shall be considered as final data to be filled in the sector specific pro-forma. In case of any typographical or factual error, the same shall be taken into account after taking into account corrected during verification process subject to all factual and authentic data source is available by DC. The EmAEA may take into account while preparing the verification form B.

75. The SEC calculation methodology as devised in the pro-forma shall be considered.

76. In case of any discrepancies observed in baseline data w.r.t. the Baseline reported data, the same should be reported to BEE with proper justification from EmAEA or DC for rectification in the existing Sector Specific Pro-forma. The rectified Pro-forma from BEE will be sent to the DC through e-mail.

77. Officials from Bureau of Energy Efficiency may visit Designated Consumers' Plant during the course of verification by EmAEA.

Figure 7: Stakeholders Output

BEE	Designated Consumer	Empanelled AEA [EmAEA]
☒ Verification of entered Baseline data in Pro-forma for Production and Energy as per Baseline Report	☒ Data entry in Pro-forma for Assessment year and Baseline years as per instruction sheet	☒ Team Building by Empaneled AEA including experts
☒ Locked-in Pro-forma to be sent to DCs for data entry in assessment year	☒ Source of Data from Primary and secondary source to be kept ready for verification as per guidelines	☒ Documents to carry ▶ Baseline report ▶ Sector specific Pro-forma ▶ Normalisation Document ▶ M&V Guidelines
☒ Preparation of Document ▶ Normalisation Document ▶ M&V Guidelines	☒ Performance Assessment Form (Form A)	☒ Work distribution among Team members at site
	☒ Selection and hiring of Empaneled AEA as per guidelines of PAT Rules	☒ Cross verification of Baseline data in the Pro-forma from the baseline report
	☒ Submission of Form A and Form B along with Form I and Pro-forma to SDA and BEE	☒ Review of Form I,Pro-forma data and its source
		☒ Review of application of formulae and calculation
		☒ Preparation of verification report
		☒ Form B signing
OUTPUT Form I & Sector Specific Pro-forma Normalisation Document M&V Guidelines	**OUTPUT** Filled-in Form I & Pro-forma Filled-in Form A,B Source of Data as Document	**OUTPUT** Verified Form I & Pro-forma EmAEA Signed Form B

78. Review of assessment year data and its authentic sources:

    i. The verifier shall ask the filled in Sector Specific Pro-forma with Form 1 from the Designated Consumer along with authentic documentary evidence

    ii. Incase DC reports some error; Interlinking or calculation error, these are to be reported back to BEE by the EmAEA with proper justification. BEE will send the rectified Pro-forma to DC through e-mail.

    iii. EmAEA shall start the verification of Pro-forma referring to the documents provided by DC

    iv. The guidelines as relevant to the data source are tabulated for different sections in Table 3 to 13 for Designated Consumers of sectors other than Thermal Power Plants. The instruction sheet of Thermal Power Plant sectormay be referred for detailed documentation requirement.

    v. EmAEA may seek other documents relevant to the process of M&V as well apart from the documents mentioned in the guidelines.

    vi. EmAEA should include a Fuel Analysis report, internally or externally, in the Verification Report

    vii. Data sampling method could be performed on sources of data, so that Operator's Log book/Log Sheet data/Shift Report (Basic data Entry Point particularly for Lab test/Production/External reasons etc) could be verified in a loop of verifying the source document. EmAEA is advised to verify random sampling of data up to the primary source for some of the

    major parameters, affecting SEC of the Plant, which will be included in the Verification Report

    viii. In case of discrepancies between authentic document provided by DC and the Pro-forma, the same to be recorded in the EmAEA's verification report with justification if any from DC's and EmAEA.

79. Review of Energy Savings Projects

    i. In terms of Rule 7 of PAT Rules 2012 on Quarterly, Yearly and EOC[6] internal data reports prepared by the Designated Consumer

    ii. In terms of Internal Audit reports prepared and maintained by the Designated Consumer

    iii. In terms of measures adopted for energy conservation and quantity of energy saved and investment made by the Designated Consumer covering the relevant cycle

    iv. Through Photographs, Screenshots in support of measures implemented in each year, if feasible

    v. Through Percentage improvement in energy savings achieved in every year following the baseline year until the target year

    vi. Verification & validation based on evaluation of implemented Energy efficiency projects through commissioning and procurement documents

    vii. Site visit to some of the implemented Energy efficiency projects for verification and validation

    viii. Establish linkage of expected results of projects on reduction of GtG SEC

---

[6] EOC: End of Cycle

ix. Identify SEC reduction reasons in the Verification Report

80. Review of Formulae and its application

i. EmAEA to review the formulae used in the Pro-forma with Normalisation factor sheets and its applications; Errors are to be reported immediately to BEE.

ii. EmAEA to review the formulae and calculation used to arrive certain data filled in the Pro-forma by Designated Consumer and documented properly in the Verification Report

81. Verification through interview of personnel, site visits and cross-checking with the filled in data in sector specific Pro-forma.

4.3.4. Primary and Secondary source of Documentation

82. The DC shall provide all the information necessary for the verification process, including supporting documents and access to the plant site. It will be the responsibility of the EmAEA to maintain the confidentiality of the data collected and not to use them for any purpose other than PAT.

83. The data submitted for verification and other figure for SEC calculation of any unit has to be in line with the units' declared production and consumption figures as per the statutory financial audit and declaration in their annual report.

84. EmAEA, while verifying the SEC calculation, should also cross-verify the input figures based on the procurement plans and physical receipts.

85. The transit and handling losses have to be within the standard norms allowable under financial audit.

86. Guidelines on sources of data for Designated Consumer and EmAEA:

a. The general guidelines for the sectors other than Thermal Power Plants sector are tabulated in Table 3 to 13 in subsequent pages.

b. For the thermal power plant sector, please refer to sector specific pro-forma

c. Designated Consumer and EmAEA may also refer the guidelines provided in the instruction sheet attached with the Sector Specific Pro-forma.

87. The general guidelines on sources of data are mentioned below. **In case of any discrepancies, EmAEA may seek additional field documents or equipment/ section log sheets for particular data verification**

Table 3: Production and Capacity Utilisation details

Sr No	Details	Unit	Frequency of record	Primary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor	Secondary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor
				Production and capacity utilization details	
1	Production Capacity of a Plant/section/ line/unit	Tonne	Annual	1) Original equipment manufacturer (OEM) Document of line/unit/ equipment capacity 2) Enviromental Consent to establish/operate document 3) DoF Communication	1) Equipment/Section wise capacity document from OEM 2) Capacity calculation document submitted for Enviromental Consent

Sr No	Details	Unit	Frequency of record	Primary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor	Secondary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor
2	Production of a Plant/ section/line/unit	Tonne	Continuous, Hourly, Daily, Monthly	1) Log Sheet 2) DCS/CCR/ SCADA Report/ Trends 3) DPR 4) MPR 5) SAP Entry in PP/SD module 6) Excise record (ER1) 7) Annual Report 8) TOP	1)Storage Level 2) Feeding Weigh feeders 3) Belt Weigher 4) Solid flow meter 5) Counters
3	Production of Intermediate/ Semifinished Product/Other product	Tonne	Continuous, Hourly, Daily, Monthly	1) Log Sheet 2) DCS/CCR/ SCADA Report/ Trends 3) DPR 4) MPR 5) SAP Entry in PP/SD module 6) Excise record (ER1) 7) Annual Report 8) TOP	1)Storage Level 2) Feeding Weigh-feeders 3) Belt Weigher 4) Solid flow meter 5) Counters
4	Opening stock of Intermediary product	Tonne	Daily, Monthly	1) Inventory Report 2) Excise Document (ER1)3) Stores Entry 4) SAP Entry in MM/ PP/SD module 5) Annual Financial report 6) TOP	1) Field Inventory 2) Storage Level
5	Closing Stock of intermediary product	Tonne	Daily, Monthly	1) Inventory Report 2) Excise Document (ER1)3) Stores Entry 4) SAP Entry in MM/ PP/SD module 5) TOP	1) Field Inventory
6	Export of Intermediary Product	Tonne	Daily, Monthly	1) Excise Document 2) Stores receipt 3) SAP Entry in FI/ SD Module 4) Annual Report 5) TOP	1) Internal material Transfer Records
7	Import of Intermediary Product	Tonne	Daily, Monthly	1) Excise Document 2) Stores receipt 3) SAP Entry in FI/ SD Module 4) Annual Report 5) TOP	1) Internal material Transfer Records
8	Raw material consumption if any	Tonne	Daily, Monthly	1)Lab Product Test Report 2) DPR 3) MPR 4) SAP Entry in MM/PP module 5) Raw material stock entry (Stores) 6) TOP	1) Lab Testing Register 2) Closing and opening stock
9	Thermal Energy Consumption of section/Unit/Product	Tonne	Daily, Monthly	1)Fuel Weigh-feeder 2) Fuel Flow Meter 3) DPR 4) MPR 5) SAP Entry in MM/PP module 6) TOP	1)Storage Level 2) Feeding Weigh feeders 3) Belt Weigher 4) Solid flow meter
10	Electrical Energy Consumption of section/Unit/Product	Tonne	Daily, Monthly	1) Energy Management System 2) Equipment List Major Eqp section 3) DPR 4) SAP Entry in MM/PP module 6) TOP	1)Storage Level 2) Feeding Weigh feeders 3) Belt Weigher 4) Solid flow meter

Table 4: Major Equipment capacity and Operating SEC

Sr No	Details	Unit	Frequency of record	Primary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor	Secondary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor
Major Eqp Capacity and Operating SEC					
1	Major Eqp wise production in Tonne.	Tonne	Continuous, Hourly, Daily, Monthly	1) Log Sheet 2) CCR SCADA Report/ Trends 3) DPR 4) MPR 5) SAP Entry in MM/ PP module	1)Storage Level 2) Feeding Weigh feeders 3) Belt Weigher 4) Solid flow meter
2	Operating Major Eqp thermal SEC (Total thermal energy consumed in Major Eqp/ total Major Eqp production) in kcal/ kg Intermediary Product.	Kcal/ kg or kcal/ Tonne	Continuous, Hourly, Daily, Monthly	1)Fuel Weigh-feeder 2) Fuel Flow Meter 3) DPR 4) MPR 5) SAP Entry in MM/PP module	1)Storage Level 2) Feeding Weigh feeders 3) Belt Weigher 4) Solid flow meter
3	Operating Major Eqp electrical SEC (Total electricity consumed in Major Eqp/ total Major Eqp production) in kWh/ kg Intermediary Product.	Kwh/ Tonne	Continuous, Hourly, Daily, Monthly	1) Energy Management System 2) Equipment List Major Eqp section 3) DPR 4) SAP Entry in MM/PP module	1)Electrical Meter Record for Major Eqp section
4	Major Eqp wise annual running hours.	Hrs	Continuous, Hourly, Daily, Monthly	1) Major Eqp Log sheet 2) DPR 3) MPR 4) DCS/CCR/ DCS Trends	1)Major Eqp Shift operator's Log Register 2) Breakdown report
5	Annual Hot-Hot start in Nos	Nos	Continuous, Hourly, Daily, Monthly	1) Major Eqp Log sheet 2) DPR 3) MPR 4) DCS/CCR/ DCS Trends	1)Major Eqp Shift operator's Log Register 2) Breakdown report
6	Total annual Hot-Cold Stoppage Hours for Major Eqp due to **external factor** [5]	Hrs	Continuous, Hourly, Daily, Monthly	1) Major Eqp Log sheet 2) DPR 3) MPR 4) DCS/CCR/ DCS Trends	1)Major Eqp Shift operator's Log Register 2) Breakdown report
7	Total annual Hot-Cold Stoppage Nos for Major Eqp due to external factor	Nos	Continuous, Hourly, Daily, Monthly	1) Major Eqp Log sheet 2) DPR 3) MPR 4) DCS/CCR/ DCS Trends	1)Major Eqp Shift operator's Log Register 2) Breakdown report

---

[5] External Factor: Market Demand, Grid Failure (Where CPP is not Sync with Grid), Raw material unavailability, Natural Disaster, Rioting or Social unrest, Major change in government policy hampering plant's process system, Any unforeseen circumstances not controlled by plant management

Sr No	Details	Unit	Frequency of record	Primary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor	Secondary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor
8	Total annual Electrical Energy Consumption for Hot-Cold Stoppage for Major Eqp due to external factor in Lakh kWh	Lakh kWh	Continuous, Hourly, Daily, Monthly	1) Energy Meter Reading for Major Eqp Section 2) Major Eqp Log sheet 3) DPR 4) MPR 5) CCR SCADA Trends	1)Major Eqp Shift operator's Log Register 2) Breakdown report
9	Total annual Cold-Hot Start Hours for Major Eqp due to external factor	Hrs	Continuous, Hourly, Daily, Monthly	1) Major Eqp Log sheet 2) Major Eqp Shift operator's Log Register 3) DPR 4) MPR 5) CCR SADA Trends	1)Major Eqp Shift operator's Log Register 2) Breakdown report
10	Total annual Cold-Hot Start Nos for Major Eqp due to external factor	Nos	Continuous, Hourly, Daily, Monthly	1) Major Eqp Log sheet 2) Major Eqp Shift operator's Log Register 3) DPR 4) MPR 5) DCS/CCR/DCS Trends	1)Major Eqp Shift operator's Log Register 2) Breakdown report
11	Total annual Electrical Energy Consumption for Cold-Hot Start for Major Eqp due to external factor in Lakh kWh	Lakh kWh	Continuous, Hourly, Daily, Monthly	1) Energy Meter Reading for Major Eqp Section 2) Major Eqp Log sheet 3) DPR 4) MPR 5) DCS/CCR/DCS Trends	1)Major Eqp Shift operator's Log Register 2) Breakdown report
12	Annual Cold-Hot Start in Nos due to internal factors	Nos	Continuous, Hourly, Daily, Monthly	1) Major Eqp Log sheet 2) Major Eqp Shift operator's Log Register 3) DPR 4) MPR 5) DCS/CCR/DCS Trends	1)Major Eqp Shift operator's Log Register 2) Breakdown report

Table 5: Boiler Details (Process and Co-Generation)

Sr No	Details	Unit	Frequency of record	Primary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor	Secondary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor
	Boiler Details (Process/Co-Gen)				
1	Type			1) OEM Document	
2	Rated Capacity	TPH	Annual	1) OEM document on Boiler Capacity 2) Predicted performance Data (PPD) for Boiler 3) Environmental Consent to Operate	1) Capacity calculation submitted for Environmental Consent
3	Total Steam Generation	Ton	Continuous, Hourly, Daily, Monthly	1) Log Sheet 2) DCS/ SCADA Trend 3) DGR 4)MGR 5) SAP Entry in PP/PM Module	1) Steam Flow Meter 2) Process steam Consumption report 3) Log Book

Sr No	Details	Unit	Frequency of record	Primary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor	Secondary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor
4	Running hours	Hrs	Continuous, Hourly, Daily, Monthly	1) Log Sheet 2) DCS/ SCADA Trend 3) DGR 4)MGR 5) SAP Entry in PP/PM Module	1) Hour Meter 2) Log book
5	Coal Consumption	Tonne	Continuous, Hourly, Daily, Monthly	1) Log Sheet 2) DCS/ SCADA Trend 3) DGR 4)MGR 5) SAP Entry in PP/PM Module	1) Weigh Feeder 2) Solid flow Meter 3) Coal Storage register 4) Storage Level
6	GCV of Coal	kcal/ kg	Daily, Monthly, Yearly	1) Daily Internal Report from Lab on Fuel Proximate Analysis performed on each lot. 2) Test Certificate from Government Accredited lab. (Plant to maintain minimum 1 sample test in a quarter for Proximate and Ultimate Analysis i.e. 4 test certificates in a year for each fuel in case of CPP/Cogen Fuel, for Process Fuel 1 sample test in a quarter for Proximate Analysis) 3) Purchase Order, where guaranteed GCV range is mentioned	1) Lab Register on Fuel Testing for Proximate Analysis 2) Calibration Record of instrument used for testing
7	Type of Fuel – 2 Name : Consumption	Tonne	Continuous, Hourly, Daily, Monthly	1) DGR 2) MGR 3) CPP/ Cogen Log Sheet 4) SAP Entry in MM/PP/FI module 5) Annual Report	1)Belt Weigher before Fuel Bunker
8	GCV of any Fuel -2	kcal/ kg	Daily, Monthly, Yearly	1) DGR 2) MGR 3) Lab Test Report	1) Lab Register on Fuel Testing for Proximate Analysis 2) Calibration Record of instrument used for testing
9	Type of Fuel – 3 Name : Consumption	Tonne	Continuous, Hourly, Daily, Monthly	1) DGR 2) MGR 3) CPP/ Cogen Log Sheet 4) SAP Entry in MM/PP/FI module 5) Annual Report	1)Belt Weigher before Fuel Bunker
10	GCV of any Fuel -3	kcal/ kg	Daily, Monthly, Yearly	1) DGR 2) MGR 3) Lab Test Report	1) Lab Register on Fuel Testing for Proximate Analysis 2) Calibration Record of instrument used for testing
11	Type of Fuel – 4 Name : Consumption	Tonne	Continuous, Hourly, Daily, Monthly	1) DGR 2) MGR 3) CPP/ Cogen Log Sheet 4) SAP Entry in MM/PP/FI module 5) Annual Report	1) Belt Weigher before Fuel Bunker

Sr No	Details	Unit	Frequency of record	Primary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor	Secondary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor
12	GCV of any Fuel -4	kcal/ kg	Daily, Monthly, Yearly	1) DGR 2) MGR 3) Lab Test Report	1) Lab Register on Fuel Testing for Proximate Analysis 2) Calibration Record of instrument used for testing
13	Feed water Temperature	°C	Continuous, Hourly, Daily, Monthly	1) DGR 2) DCS/SCADA Trends	
14	Operating Efficiency	%	Continuous, Hourly, Daily, Monthly	1) Indirect Method or Direct method calculation	
15	SH Steam outlet Pressure (Operating)	kg/ cm2	Continuous, Hourly, Daily, Monthly	1) DGR 2) DCS/SCADA Trends	1) Field Pressure Meter
16	SH Steam outlet Temperature (Operating)	°C	Continuous, Hourly, Daily, Monthly	1) DGR 2) DCS/SCADA Trends	1) Field Temperature Meter
17	SH Steam Enthalpy (Operating)	kcal/ kg	Continuous, Hourly, Daily, Monthly	1) Steam Table	
18	Design Efficiency	%	Yearly	1) OEM document on Boiler Efficiency 2) Predicted performance Data (PPD) for Boiler	1) Design Calculation

Table 6: Electricity from Grid/Others, Renewable Purchase Obligation, Notified Figures

Sr No	Details	Unit	Frequency of record	Primary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor	Secondary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor
Electricity from Grid / Other (Including Colony and Others) / Renewable Purchase obligation/Notified Figures					
1	Annual electricity purchase from the grid	Lakh kWh	Daily, Monthly	1) Monthly Electricity Bills from Grid 2) Internal Meter reading records for grid incomer	Energy Management System

Sr No	Details	Unit	Frequency of record	Primary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor	Secondary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor
2	Renewable electricity consumption through wheeling	Lakh kWh	Daily, Monthly	1) Open Access records 2) Electricity Bills for Renewable energy 3) Renewable Purchase Obligation document	Energy Management System
3	Electricity consumption from CPP located outside of the plant boundary though wheeling	Lakh kWh	Daily, Monthly	1) Open Access records 2) Electricity Bills (for Wheeling)	Energy Management System
4	Renewable Purchase obligation of plant for the current year in % (Solar and Non-Solar).	%	Yearly	1) Renewable Purchase Obligation document	
5	Renewable Purchase obligation of plant for the current year in Lakh kWh (Solar and Non-Solar).	Lakh kWh	Yearly	1) Renewable Purchase Obligation document	
6	Renewable Purchase obligation of plant for the current year in MW (Solar and Non-Solar).	MW	Yearly	1) Renewable Purchase Obligation document	
7	Renewable Energy Generator Capacity in MW as approved by MNRE	MW	Yearly	1)'Certificate for Registration' to the concerned Applicant as 'Eligible Entity' confirming its entitlement to receive Renewable Energy Certificates for the proposed RE Generation project	
8	Quantum of Renewable Energy Certificates (REC) obtained as a Renewable Energy Generator (Solar & Non-Solar) in terms of REC equivalent to 1 MWh	Nos	Yearly	1) Renewable Energy Certificates	
9	Quantum of Energy sold interms of preferential tariff under REC Mechanism in MWh	Nos	Lot, Yearly	1)Power Purchase Agreement (PPA) for the capacity related to such generation to sell electricity at preferential tariff determined by the Appropriate Commission	

Sr No	Details	Unit	Frequency of record	Primary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor	Secondary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor
10	Plant connected load	kW	Monthly	1) L-Form document 2) Electrical Inspectorate record	1) Total connected Load (TCL) of Plant 2) Equipment List
11	Plant contract demand with utility	kVA	Monthly	1) Monthly Electricity Bills from Utility	
12	DCs Notified Specific Energy Consumption in TOE/T for Baseline Year	TOE/T		1) Notification S.O.687 dated 31/03/2012	
13	DCs Target Specific Energy Consumption in TOE/T for Target year	TOE/T		1) Notification S.O.687 dated 31/03/2012	
14	Equivalent Major Product Output in tonne as per PAT scheme Notification	Tonne		1) Notification S.O.687 dated 31/03/2012	

Table 7: Own generation through Captive Power Plants

Sr No	Details	Unit	Frequency of record	Primary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor	Secondary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor
Own Generation through CPP (STG/GG/GT/WHRB/DG)					
1	Selection is required from the drop down list for grid connectivity with grid (Yes/No)	Yes/ No			
2	Installed capacity of all the Units in MW.	MW	Annual	1) OEM document for capacity 2) Rating plate of Generator	1) Capacity Enhancement document 2) R&M document
3	Gross unit generation of all the Units in Lakh kWh.	Lakh kWh	Continuous, Hourly, daily, Monthly	1) Daily Generation Report 2) Monthly Generation Report 3) CPP main energy meter reading record 4) Energy Management System data	1) Energy Meter
4	Auxiliary power consumption (APC) in %.	%	Continuous, Hourly, daily, Monthly	1) Daily Power Report 2) Monthly Power Report 3) CPP main energy meter reading record 4) Energy Management System data	1) Energy Meter 2) Equipment List

Sr No	Details	Unit	Frequency of record	Primary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor	Secondary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor
5	Design Heat Rate of all the Units in kcal/kWh.	Kcal/kWh	Annual	1) OEM document on designed heat rate	1) PG test document
6	Annual running hours of all the units.	Hrs	Continuous, Hourly, daily, Monthly	1) Daily Generation Report 2) Monthly Generation Report 3)Energy Management System data	1) Break down report 3) Operators Shift Register
7	Annual available hours of respective unit. Ex. If a unit commissions on 1st Oct, then available hour for the year will be 4380 hours	Hrs	Continuous, Hourly, daily, Monthly	1) Daily Generation Report 2) Monthly Generation Report 3) Energy Management System data	1) Break down report 3) Operators Shift Register
8	Break down hrs due to internal, Planned and external factor for calculating Plant Availability Factor	Hrs	Hourly, daily, Monthly	1) CPP Log Sheet 2) Operators log Register 3) Daily generation Report 4) Monthly Generation Report 5) Energy Management System data 6)Refer Sr. No: N	1) Operator's Shift Register 2) CPP Break down analysis Report
9	No of hrs per annum during which Plant run on low load due to Internal Factors/ Breakdown in Plant (Average weighted hours of all the units)	Hrs	Hourly, daily, Monthly	1) CPP Log Sheet 2) Operators log Register 3) Daily generation Report 4) Monthly Generation Report 5) Energy Management System data 6)Refer Sr. No: N	1) Operator's Shift Register 2) CPP Break down analysis Report
10	No of hrs per annum during which Plant runs on low load due to Fuel Unavailability/ Market demand/ External Condition (Average weighted hours of all the units)	Hrs	Hourly, daily, Monthly	1) CPP Log Sheet 2) Operators log Register 3) Daily generation Report 4) Monthly Generation Report 5) Energy Management System data 6)Refer Sr. No: N	1) Operator's Shift Register 2) CPP Break down analysis Report
Through Co-Generation					
1	Grid Connected	Yes/No			
2	Installed Capacity	MW	Annual	1) OEM document for capacity 2) Rating plate of Generator	1) Capacity Enhancement document 2) R&M document
3	Annual Gross Unit generation	Lakh kWh	Continuous, Hourly, daily, Monthly	1) Daily Generation Report 2) Monthly Generation Report 3) CPP main energy meter reading record 4) Energy Management System data	1) Energy Meter

Sr No	Details	Unit	Frequency of record	Primary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor	Secondary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor
4	Auxiliary Power Consumption	Lakh kWh	Continuous, Hourly, daily, Monthly	1) Daily Power Report 2) Monthly Power Report 3) CPP main energy meter reading record 4) Energy Management System data	1) Energy Meter 2) Equipment List
5	Design Heat Rate	kcal/ kWh	Annual	1) OEM document on designed heat rate	1) PG test document
6	Running Hours	Hrs	Continuous, Hourly, daily, Monthly	1) Daily Generation Report 2) Monthly Generation Report 3) Energy Management System data Inlet Steam	1) Break down report 3) Operators Shift Register
Inlet Steam					
7	Total Steam Flow	Ton	Continuous, Hourly, daily, Monthly	1) Daily Generation Report 2) Monthly Generation Report 3) DCS/SCADA Records	1) Makeup water Reading 2) Field Steam Flow meter reading
8	Avg. Steam Pressure	Kg/ cm2	Continuous, Hourly, daily, Monthly	1) Daily Generation Report 2) Monthly Generation Report 3) DCS/SCADA Records	1) Field Pressure Meter
9	Avg. Steam Temperature	°C	Continuous, Hourly, daily, Monthly	1) Daily Generation Report 2) Monthly Generation Report 3) DCS/SCADA Records	1) Field Temperature Meter
10	Avg. Steam Enthalpy	kcal/ kg	Continuous, Hourly, daily, Monthly	1) Steam Table	
Steam Extraction 1 (MP)					
11	Total Steam Flow (at the Header)	Ton	Continuous, Hourly, daily, Monthly	1) Daily Generation Report 2) Monthly Generation Report 3) DCS/SCADA Records	1) Makeup water Reading 2) Field Steam Flow meter reading
12	Avg. Steam Pressure (at the Header)	Kg/ cm2	Continuous, Hourly, daily, Monthly	1) Daily Generation Report 2) Monthly Generation Report 3) DCS/SCADA Records	1) Field Pressure Meter
13	Avg.Steam Temperature (at the Header)	°C	Continuous, Hourly, daily, Monthly	1) Daily Generation Report 2) Monthly Generation Report 3) DCS/SCADA Records	1) Field Temperature Meter
14	Avg. Steam Enthalpy (at the Header)	kcal/ kg	Continuous, Hourly, daily, Monthly	1) Steam Table	

Sr No	Details	Unit	Frequency of record	Primary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor	Secondary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor
Steam Extraction 2 (LP)					
15	Total Steam Flow (at the Header)	Ton	Continuous, Hourly, daily, Monthly	1) Daily Generation Report 2) Monthly Generation Report 3) DCS/SCADA Records	1) Makeup water Reading 2) Field Steam Flow meter reading
16	Avg. Steam Pressure (at the Header)	Kg/cm2	Continuous, Hourly, daily, Monthly	1) Daily Generation Report 2) Monthly Generation Report 3) DCS/SCADA Records	1) Field Pressure Meter
17	Avg. Steam Temperature (at the Header)	°C	Continuous, Hourly, daily, Monthly	1) Daily Generation Report 2) Monthly Generation Report 3) DCS/SCADA Records	1) Field Temperature Meter
18	Avg. Steam Enthalpy (at the Header)	kcal/kg	Continuous, Hourly, daily, Monthly	1) Steam Table	
Steam Condensing					
18	Total Exhaust Steam Flow	Ton	Continuous, Hourly, daily, Monthly	1) Daily Generation Report 2) Monthly Generation Report 3) DCS/SCADA Records	1) Makeup water Reading 2) Field Steam Flow meter reading
20	Exhaust Steam Vacuum	Kg/cm2 (a)	Continuous, Hourly, daily, Monthly	1) Daily Generation Report 2) Monthly Generation Report 3) DCS/SCADA Records	1) Field Pressure Meter
Power from dedicated line					
1	Power wheeled through dedicated line in MW (average for the year)	MW	Hourly, daily, monthly	1) Energy Meter reading for nos of hours, 2) Daily Power Report	Energy Meter
2	Electricity wheeled in a year in lakh kWh	Lakh kWh		1) Separate Energy Meter Reading 2) Daily and Monthly Power Report	
3	Heat Rate of wheeled imported Electricity in kcal/kWh	kcal/kWh	daily, Monthly	1) Power Purchase Agreement 2) DGR of Sister concerned from where the power is wheeled 3)	1) Primary document from the sister concern 2) Excise document of purchase electricity
Power Export and Colony/Others consumption					

Monitoring & Verification Guidelines

Sr No	Details	Unit	Frequency of record	Primary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor	Secondary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor
1	Quantity of electricity sold to the grid in Lakh kWh.	Lakh kWh	Continuous, Hourly, daily, Monthly	1) Daily Power Report 2) Monthly Power Report 3) Export main energy meter reading record 4) Energy Management System data 5) Monthly Export bill receipt sent to utility	Export Energy Meter
2	Quantity of electricity consumed in colony / other in Lakh kWh.	Lakh kWh	Continuous, Hourly, daily, Monthly	1) Daily Power Report 2) Monthly Power Report 3) Colony/other main energy meter reading record 4) Energy Management System data	1) colony/Others meter

Table 8: Solid Fuel Consumption

Sr No	Details	Unit	Frequency of record	Primary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor	Secondary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor
Solid Fuel Consumption					
A. Coal (Indian) / Petcoke/ Coal (Imported) / Coal (Lignite)/Coal 1/Coal 2/Coal 3/ Coal 4 (Other Solid Fuel)/ Dolachar/Coal fines/Met Coke/Coke Breeze /Nut coke/Lump Coke (Imported)					
1	Landed cost of Solid Fuel i.e. Basic Cost+All Taxes + Freight. The landed cost of last purchase order in the financial year	Rs./ MT	Annual	1) Purchase Order for basic rates and taxes 2) Freight document for rates	
2	Gross calorific value (As Fired Basis[6]) of solid fuel consumed for power generation	kcal/ kg	Lot, Daily, Monthly, Quarterly	1) Daily Internal Report from Lab on Fuel Proximate Analysis performed on each lot. 2) Test Certificate from Government Accredited lab. (Plant to maintain minimum 1 sample test in a quarter for Proximate and Ultimate Analysis i.e. 4 test certificates in a year for each fuel in case of CPP/Cogen/WHRB Fuel, for Process Fuel 1 sample test in a quarter for Proximate Analysis) 3) Purchase Order, where guaranteed GCV range is mentioned	1) Lab Register on Fuel Testing for Proximate Analysis 2) Calibration Record of instrument used for testing

---

[6] Location of sampling: As fired Fuel after the Grinding Mill

Sr No	Details	Unit	Frequency of record	Primary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor	Secondary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor
3	Gross calorific value (As Fired Basis [7]) of solid fuel consumed in the process	kcal/kg	Lot, Daily, Monthly, Quarterly	1) Daily Internal Report from Lab on Fuel Proximate Analysis performed on each lot. 2) Test Certificate from Government Accredited lab. (Plant to maintain minimum 1 sample test in a quarter for Proximate and Ultimate Analysis i.e. 4 test certificates in a year for each fuel in case of CPP/Cogen/WHRB Fuel, for Process Fuel 1 sample test in a quarter for Proximate Analysis) 3) Purchase Order, where guaranteed GCV range is mentioned	1) Lab Register on Fuel Testing for Proximate Analysis 2) Calibration Record of instrument used for testing
4	Annual solid fuel quantity purchased	Tonne	Lot, Daily, Monthly, Yearly	1) Purchase Order 2) Stores Receipt 3) SAP Entry in MM/PP/FI module 4) Annual Report	1) Stores Receipt Register
5	Annual solid fuel moisture % (As Received Basis)	%	Lot, Daily, Monthly, Yearly	1) Daily Internal Report from Lab on Fuel Proximate Analysis performed on each lot. 2) Purchase Order, where guaranteed % moisture range is mentioned	1) Lab Register on Fuel Testing for Proximate Analysis 2) Calibration Record of instrument used for testing
6	Annual solid fuel quantity consumed in power generation	Tonne	Hourly, Daily and Monthly	1) DPR 2) MPR 3) CPP/Cogen/WHRB Log Sheet 4) SAP Entry in MM/PP/FI module 5) Annual Report	1)Belt Weigher before Coal Bunker
7	Annual solid fuel quantity consumed in process	Tonne	Hourly, Daily and Monthly	1) DPR 2) MPR 3) Major Eqp Log Sheet 4) SAP Entry in MM/PP/FI module 5) Annual Report	1) Belt Weigh Feeder 2) Solid Flow Meter
B. Biomass and other renewable solid fuel / Solid waste					
1	Landed cost of Solid Fuel i.e. Basic Cost+All Taxes + Freight. The landed cost of last purchase order in the financial year	Rs./Tonne	Yearly	1) Purchase Order for basic rates and taxes 2) Freight document for rates	

---

[7] Location of sampling: As fired Fuel after the Grinding Mill

---

Sr No	Details	Unit	Frequency of record	Primary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor	Secondary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor
2	Gross calorific value of biomass / solid waste	kcal/kg	Lot, Daily, Monthly, Quarterly	1) Daily Internal Report from Lab on Fuel Proximate Analysis performed on each lot. 2) Test Certificate from Government Accredited lab (NABL). (Plant to maintain minimum 1 sample test in a quarter for Proximate and Ultimate Analysis i.e. 4 test certificates in a year for each fuel in case of CPP Fuel, for Process Fuel 1 sample test in a quarter for Proximate Analysis) 3) Purchase Order, where guaranteed GCV range is mentioned	1) Lab Register on Fuel Testing for Proximate Analysis 2) Calibration Record of instrument used for testing
3	Annual biomass/ solid waste quantity purchased	Tonne	Lot, Daily, Monthly, Yearly	1) Purchase Order 2) Stores Receipt 3) SAP Entry in MM/PP/FI module 4) Annual Report	1) Stores Receipt Register
4	Annual solid fuel moisture % (As Received Basis)	%	Lot, Daily, Monthly, Yearly	1) Daily Internal Report from Lab on Fuel Proximate Analysis performed on each lot. 2) Purchase Order, where guaranteed % moisture range is mentioned	1) Lab Register on Fuel Testing for Proximate Analysis 2) Calibration Record of instrument used for testing
5	Annual biomass/ solid waste Consumed in power generation	Tonne	Hourly, Daily and Monthly	1) DPR 2) MPR 3) CPP Log Sheet 4) SAP Entry in MM/PP/FI module 5) Annual Report	1)Belt Weigher before Coal Bunker
6	Annual biomass/ solid waste consumed in processing	Tonne	Hourly, Daily and Monthly	1) DPR 2) MPR 3) Major Eqp Log Sheet 4) SAP Entry in MM/PP/FI module 5) Annual Report	1) Belt Weigh Feeder 2) Solid Flow Meter

Table 9: Liquid Fuel Consumption

Sr No	Details	Unit	Frequency of record	Primary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor	Secondary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor
	Liquid Fuel Consumption				
A	**Furnace Oil**				
1	Landed cost of Solid Fuel i.e. Basic Cost+All Taxes + Freight. The landed cost of last purchase order in the financial year	Rs/ Tonne	Annual	1) Purchase Order for basic rates and taxes 2) Freight document for rates	
2	Gross calorific value of furnace oil	kcal/ kg	Lot, Monthly, Yearly	1) Test report from Supplier 2) Internal Test Report from lab 3) Test report from Government Accredited (NABL) Lab[8] 4) Standard Value as per Notification	Lab Register
3	Annual furnace oil quantity purchase	kL	Lot, Monthly, Yearly	1) Purchase Order 2) Stores Receipt 3) SAP Entry in MM/ PP/FI module 4) Annual Report	Stores Receipt
4	Density of furnace oil	kg/Ltr	Lot, Montly, Yearly	1) Test report from Supplier 2) Internal Test Report from lab 3) Test report from Government Accredited (NABL) Lab 4) Standard Value as per Notification	Lab Register
5	Furnace oil quantity consumed in DG set for power generation	kL	Daily, Monthly, Yearly	1) Daily Generation Report 2) Monthly Generation Report 3) DG Log Sheet 4) SAP Entry in MM/PP/FI module 5) Annual Report	Flow Meter, Dip measurement in day tank
6	Furnace oil quantity consumed in CPP for power generation in kilo liters.	kL	Daily, Monthly, Yearly	1) Daily Generation Report 2) Monthly Generation Report 3) CPP Log Sheet 4) SAP Entry in MM/PP/FI module 5) Annual Report	Flow Meter, Dip measurement in day tank
7	Furnace oil quantity used in process heating (including Pyro-processing and Product mill Hot Air Generator) in kilo litres.	kL	Daily, Monthly, Yearly	1) DPR 2) MPR 3) Major Eqp Log Sheet 4) Product Mill Log Sheet 5) SAP Entry in MM/PP/FI module 6) Annual Report	Flow Meter, Dip measurement in day tank

[8] Government Accredited Lab: National Accreditation Board for Testing and Calibration Laboratories(NABL Labs)

Sr No	Details	Unit	Frequency of record	Primary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor	Secondary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor
B	**LSHS/HSHS**				
1	Landed cost of Solid Fuel i.e. Basic Cost+All Taxes + Freight. The landed cost of last purchase order in the financial year	Rs/ Tonne	Annual	1) Purchase Order for basic rates and taxes 2) Freight document for rates	
2	Gross calorific value of LSHS/HSHS	kcal/ kg	Lot, Monthly, Yearly	1) Test report from Supplier 2) Internal Test Report from lab 3) Test report from Government Accredited Lab 4) Standard Value as per Notification	Lab Register
3	Annual LSHS/HSHS quantity purchase	Tonne	Lot, Monthly, Yearly	1) Purchase Order 2) Stores Receipt 3) SAP Entry in MM/ PP/FI module 4) Annual Report	Stores Receipt
4	LSHS/HSHS quantity consumed in DG set for power generation	Tonne	Daily, Monthly, Yearly	1) Daily Generation Report 2) Monthly Generation Report 3) DG Log Sheet 4) SAP Entry in MM/PP/FI module 5) Annual Report	Flow Meter, Dip measurement in day tank
5	LSHS/HSHS quantity consumed in CPP for power generation	Tonne	Daily, Monthly, Yearly	1) Daily Generation Report 2) Monthly Generation Report 3) CPP Log Sheet 4) SAP Entry in MM/PP/FI module 5) Annual Report	Flow Meter, Dip measurement in day tank
6	LSHS/HSHS quantity consumed in process heating.	Tonne	Daily, Monthly, Yearly	1) DPR 2) MPR 3) Major Eqp Log Sheet 4) Product Mill Log Sheet 5) SAP Entry in MM/PP/FI module 6) Annual Report	Flow Meter, Dip measurement in day tank
C	**HSD/LDO**				
1	Landed cost of Solid Fuel i.e. Basic Cost+All Taxes + Freight. The landed cost of last purchase order in the financial year	Rs./ Tonne	Annual	1) Purchase Order for basic rates and taxes 2) Freight document for rates	
2	the gross calorific value of HSD/LDO	kcal/ kg	Lot, Monthly, Yearly	1) Test report from Supplier 2) Internal Test Report from lab 3) Test report from Government Accredited Lab 4) Standard Value as per Notification	Lab Register

Sr No	Details	Unit	Frequency of record	Primary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor	Secondary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor
3	Annual HSD/LDO quantity purchase	kL	Lot, Monthly, Yearly	1) Purchase Order 2) Stores Receipt 3) SAP Entry in MM/PP/FI module 4) Annual Report	Stores Receipt
4	Density of HSD/LDO	kg/Ltr	Lot, Monthly, Yearly	1) Test report from Supplier 2) Internal Test Report from lab 3) Test report from Government Accredited Lab 4) Standard Value as per Notification	Lab Register
5	HSD/LDO quantity used in DG set for power generation	kL	Daily, Monthly, Yearly	1) Daily Generation Report 2) Monthly Generation Report 3) DG Log Sheet 4) SAP Entry in MM/PP/FI module 5) Annual Report	Flow Meter, Dip measurement in day tank
6	HSD/LDO quantity used in CPP for power generation	kL	Daily, Monthly, Yearly	1) Daily Generation Report 2) Monthly Generation Report 3) CPP Log Sheet 4) SAP Entry in MM/PP/FI module 5) Annual Report	Flow Meter, Dip measurement in day tank
7	HSD/LDO quantity used in Transportation, if any	kL	Daily, Monthly, Yearly	1)Vehicle Log book 2) Stores Receipt 3) Fuel Dispenser meter reading 3) Work Order for Internal Transportation	
8	HSD/LDO quantity used in process heating	kL	Daily, Monthly, Yearly	1) DPR 2) MPR 3) Major Eqp Log Sheet 4) Product Mill Log Sheet 5) SAP Entry in MM/PP/FI module 6) Annual Report	Flow Meter, Dip measurement in day tank
D	**Liquid Waste**				
1	Landed cost of Solid Fuel i.e. Basic Cost+All Taxes + Freight. The landed cost of last purchase order in the financial year	Rs/ Tonne	Annual	1) Purchase Order for basic rates and taxes 2) Freight document for rates	
2	Gross calorific value of liquid waste	kcal/ kg	Lot, Monthly, Yearly	1) Test report from Supplier 2) Internal Test Report from lab 3) Test report from Government Accredited Lab 4) Standard Value as per Notification	Lab Register
3	Annual liquid waste quantity purchase	kL	Lot, Monthly, Yearly	1) Purchase Order 2) Stores Receipt 3) SAP Entry in MM/PP/FI module 4) Annual Report	Stores Receipt

Sr No	Details	Unit	Frequency of record	Primary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor	Secondary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor
4	Density of liquid waste	kg/Ltr	Lot, Monthly, Yearly	1) Test report from Supplier 2) Internal Test Report from lab 3) Test report from Government Accredited Lab 4) Standard Value as per Notification	Lab Register
5	Liquid waste quantity consumed in DG set for power generation	kL	Daily, Monthly, Yearly	1) Daily Generation Report 2) Monthly Generation Report 3) DG Log Sheet 4) SAP Entry in MM/PP/FI module 5) Annual Report	Flow Meter, Dip measurement in day tank
6	Liquid waste quantity consumed in CPP for power generation	kL	Daily, Monthly, Yearly	1) Daily Generation Report 2) Monthly Generation Report 3) CPP Log Sheet 4) SAP Entry in MM/PP/FI module 5) Annual Report	Flow Meter, Dip measurement in day tank
7	Liquid waste quantity consumed in process heating	kL	Daily, Monthly, Yearly	1) DPR 2) MPR 3) Major Eqp Log Sheet 4) Product Mill Log Sheet 5) SAP Entry in MM/PP/FI module 6) Annual Report	Flow Meter, Dip measurement in day tank

Table 10: Gaseous Fuel Consumption

Sr No	Details	Unit	Frequency of record	Primary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor	Secondary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor
				Gaseous Fuel Consumption	
A	Natural Gas (CNG/NG/PNG/LNG)				
1	Landed cost of Solid Fuel i.e. Basic Cost+All Taxes + Freight. The landed cost of last purchase order in the financial year	Rs./ Tonne	Annual	1) Purchase Order for basic rates and taxes 2) Freight document for rates	
2	Gross calorific value of NG	kcal/ SCM	Lot, Monthly, Yearly	1) Test report from Supplier 2) Test report from Government Accredited Lab 3) Standard Value as per Notification	
3	Annual NG quantity purchase	Million SCM	Lot, Daily, Monthly, Yearly	1) Purchase Order 2) Stores Receipt 3) SAP Entry in MM/ PP/FI module 4) Annual Report	Gas Meter Reading, Bullet Pressure Reading

Sr No	Details	Unit	Frequency of record	Primary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor	Secondary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor
4	NG quantity consumed in power generation	Million SCM	Continuous, Daily, Monthly, Yearly	1) Daily Generation Report 2) Monthly Generation Report 3) GG Log Sheet 4) SAP Entry in MM/PP/FI module 5) Annual Report	Gas Meter Reading, Bullet Pressure Reading
5	NG quantity consumed in transportation	Million SCM	Daily, Monthly, Yearly	1)Vehicle Log book 2) Stores Receipt 3) Fuel Dispenser meter reading 3) Work Order for Internal Transportation	Gas Meter Reading, Bullet Pressure Reading
6	NG quantity consumed in process heating	Million SCM	Daily, Monthly, Yearly	1) DPR 2) MPR 3) Major Eqp Log Sheet 4) Product Mill Log Sheet 5) SAP Entry in MM/PP/FI module 6) Annual Report	Gas Meter Reading, Bullet Pressure Reading
B	**Liquefied Petroleum Gas (LPG)**				
1	Landed cost of Solid Fuel i.e. Basic Cost+All Taxes + Freight. The landed cost of last purchase order in the financial year	Rs./ Tonne	Annual	1) Purchase Order for basic rates and taxes 2) Freight document for rates	
2	Gross calorific value of LPG in kcal/kg.	kcal/ kg	Lot, Daily, Monthly, Yearly	1) Test report from Supplier 2) Test report from Government Accredited Lab 3) Standard Value as per Notification	
3	Annual LPG quantity purchase	Million kg	Lot, Daily, Monthly, Yearly	1) Purchase Order 2) Stores Receipt 3) SAP Entry in MM/ PP/FI module 4) Annual Report	Gas Meter Reading, Bullet Pressure Reading
4	LPG quantity consumed in power generation	Million kg	Daily, Monthly, Yearly	1) DPR 2) MPR 3) GG Log Sheet 4) SAP Entry in MM/ PP/FI module 5) Annual Report	Gas Meter Reading, Bullet Pressure Reading
5	LPG quantity consumed in process heating	Million kg	Daily, Monthly, Yearly	1) DPR 2) MPR 3) Major Eqp Log Sheet 4) Product Mill Log Sheet 5) SAP Entry in MM/PP/FI module 6) Annual Report	Gas Meter Reading, Bullet Pressure Reading

Table 11: Documents for Quality Parameter

Sr No	Details	Unit	Frequency of record	Primary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor	Secondary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor
Quality Parameters					
A	**Raw Material Quality**				
1	Raw Material Quality (Sector Specific Raw Material Quality testing)	%	Lot, Monthly	1) Internal Test Certificate 2) External Test Certificate from related Sector Govt Accredited Lab	1) Lab Test Report Register
B	**Coal Quality in CPP (As Fired Basis)**				
1	the Ash % in coal used in CPP/Cogen/WHRB	%	Lot, Daily, Monthly, Quarterly	1) Daily Internal Report from Lab on Fuel Proximate Analysis performed on each lot. 2) Test Certificate from Government Accredited lab. (Plant to maintain minimum 1 sample test in a quarter for Proximate and Ultimate Analysis i.e. 4 test certificates in a year for each fuel in case of CPP/Cogen/WHRB Fuel, for Process Fuel 1 sample test in a quarter for Proximate Analysis) 3) Purchase Order, where guaranteed GCV range is mentioned	1) Lab Register on Fuel Testing for Proximate Analysis 2) Calibration Record of instrument used for testing
2	the Moisture % in coal used in CPP/Cogen/WHRB				
3	the Hydrogen % in coal used in CPP/Cogen/WHRB				
4	the GCV value of coal used in CPP/Cogen/WHRB				

Table 12: Documents related to Environmental Concern, Biomass/Alternate Fuel availability, Project Activities, New Line commissioning, Unforeseen Circumstances

Sr No	Details	Unit	Requirement	Frequency of record	Primary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor	Secondary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor
				Miscellaneous Data		
A	**Additional Equipment installation after baseline year due to Environmental Concern**					
(i)	Electrical Energy Consumption with list of additional Equipment installed due to Environmental Concern after baseline year in Sheet! Addl Eqp List-Env.	Lakh kWH	List of Equipment to be filled up	Daily, Monthly, Annual	Energy Meter Readings and Power consumption details of each additional equipment installed from 1st Apr to 31st March	1) EMS 2) Energy Meter 3) Addition Equipment List with capacity and running load 4) Purchase Order document 5) SAP Data in MM module
(ii)	Thermal Energy Consumption with list of additional Equipment installed due to Environmental Concern after baseline year in Sheet! Addl Eqp List-Env.	Million kcal	List of Equipment to be filled up	Daily, Monthly, Annual	Solid/Liquid/Gaseous Fuel consumption of each additional equipment installed from 1st Apr to 31st March	1) Fuel Flow Meter 2) Weigh Feeder 3) Purchase Order document 4) SAP Data in MM module
B	**Biomass/ Alternate Fuel availability**					
(i)	Details of replacement of Bio-mass with fossil fuel due to un-availability. This is required in fossil fuel tonnage in terms of equivalent GCV of Bio-mass (Used in Process)	Tonne	Fossil Fuel: Coal/ Lignite/Fuel Oil	Monthly	1) Authentic Document in relation to Bio-Mass/Alternate Solid Fuel/Alternate Liquid Fuel availability in the region. 2) Test Certificate of Bio-mass from Government Accredited Lab for GCV in Baseline and assessment year 3) Test Certificate of replaced Fossil Fuel GCV	
(ii)	Details of replacement of Alternate Solid Fuel with fossil fuel due to un-availability. This is required in fossil fuel tonnage in terms of equivalent GCV of Alternate Solid Fuel (Used in Process)	Tonne		Monthly		

Sr No	Details	Unit	Requirement	Frequency of record	Primary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor	Secondary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor
(iii)	Details of replacement of Alternate Liquid Fuel with fossil fuel due to un-availability. This is required in fossil fuel tonnage in terms of equivalent GCV of Alternate Liquid Fuel (Used in Process)	Tonne		Monthly		
C	**Project Activities (Construction Phase)**					
(i)	Electrical Energy[9] Consumption with list of Project Activities and energy consumed during project activities treated as Construction phase in Lakh kwh Ref: Sheet Project Activity List	Lakh kWH	List of Equipment to be filled up	Daily, Monthly	Energy Meter Readings of each project activity with list of equipment installed under each activity from 1st Apr to 31st March	1) EMS 2) Energy Meter 3) Addition Equipment List with capacity and running load 3) Purchase Order document 4) SAP Data in MM module
(ii)	Thermal Energy Consumption with list of Project Activities and energy consumed during project activities treated as Construction phase in Million kcal converted from different fuel Ref: Sheet Project Activity List	Million kcal	List of Equipment to be filled up	Daily, Monthly	Solid/Liquid/Gaseous Fuel consumption of each project activity with list of equipment under each activity installed from 1st Apr to 31st March	1) Fuel Flow Meter 2) Weigh Feeder 3) Purchase Order document 4) SAP Data in MM module
D	**New Line/Unit Commissioning**					
(i)	Electrical energy consumed in Lakh kWh during its commissioning till it attains 70% of the new line capacity utilisation	Lakh kWH		Daily, Monthly	1) Rated Capacity of new Process/line from OEM 2) Energy Meter Readings and Power Consumption record of process/line with list of equipment installed from 1st Apr to 31st March	1) EMS 2) Energy Meter 3) Addition Equipment List with capacity and running load

---

[9] The Electrical Energy which is not included in colony/others

Sr No	Details	Unit	Requirement	Frequency of record	Primary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor	Secondary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor
(ii)	Thermal energy consumed in Million kcal during its commissioning till it attains 70% of the new line capacity utilisation. The energy is calculated after converting from the different fuel GCV used in the new process/line	Million kcal		Daily, Monthly	1) Rated Capacity of new Process/line from OEM 2) Thermal Energy Consumption record with list of equipment from DPR/ Log book/SAP Entry in PP module	1) Fuel Flow Meter 2) Weigh Feeder
(iii)	Final/Intermediary Product production during its commissioning up to 70% of new line/ process capacity utilisation in Tonne	Tonne		Daily, Monthly	1) Rated Capacity of new Process/line from OEM 2) Production record from DPR/Log book/SAP Entry in PP module	1) Weigh Feeder
(iv)	Date of achieving 70% capacity utilisation of new process/line	Dates			1) Record/Document from SAP Entry/Log Book Entry/DPR/ MPR	Operator's Shift Register
(v)	Electrical Energy consumed in Lakh kWh from external source during its commissioning till it attains 70% of the new unit capacity utilisation in Power generation	Lakh kWH		Daily, Monthly	1) Rated Capacity of new unit from OEM 2) Energy Meter Readings and Power Consumption record of unit from external source with list of equipment installed from 1st Apr to 31st March	1) EMS 2) Energy Meter 3) Addition Equipment List with capacity and running load
(vi)	Thermal energy consumed in Million kcal during its commissioning till it attains 70% of the new unit capacity utilisation. The energy is calculated after converting from the different fuel GCV used in the new unit in Power generation	Million kcal		Daily, Monthly	1) Rated Capacity of new unit from OEM 2) Thermal Energy Consumption record with list of equipment from DPR/Log book/ SAP Entry	1) Fuel Flow Meter 2) Weigh Feeder

Sr No	Details	Unit	Requirement	Frequency of record	Primary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor	Secondary Documents from where the information can be sourced and to be kept ready for verification by Accredited Energy Auditor
(vii)	Net generation in Lakh kwh from the new unit in power generation, used in the Product Plant till the new unit achieved 70% of Capacity Utilisation	Lakh kWH		Daily, Monthly	1) Record/Document from SAP Entry/Log Book Entry/DPR/MPR	1) EMS 2) Energy Meter
(viii)	Date of achieving 70% capacity utilisation of new unit in Power generation	Dates			1) Record/Document from SAP Entry/Log Book Entry/DPR/MPR	
E	**Unforeseen Circumstances**					
(i)	Electrical Energy Consumption with list of unforeseen circumstances consumed in Lakh kWh claimed for Normalisation	Lakh kWH	Unforeseen Circumstances: Situation not under direct or in-direct control of plant management		1) Relevant document on Unforeseen Circumstances beyond the control of plant 2) Energy Meter Readings and Power Consumption during the said period of unforeseen circumstances	1) EMS 2) Energy Meter 3) Addition Equipment List with capacity and running load
(ii)	Thermal Energy Consumption with list of unforeseen circumstances consumed in Million kcal claimed for Normalisation	Million kcal			1) Relevant document on Unforeseen Circumstances beyond the control of plant 2) Thermal Energy Consumption record during the said period of unforeseen circumstances from DPR/Log book/SAP Entry	1) Fuel Flow Meter 2) Weigh Feeder

Sr No	Details
	Document related to external factor
(i)	**Market Demand**
	1)Product Storage Full record from Product Mill Log book 2)SAP entry in SD and FI module 3) SAP entry in PP module 4) Document related to sales impact of market
(ii)	**Grid Failure**
	1) SLDC Reference No. for planned Stoppages from respective Substation 2) Log book record of Main Electrical Substation of Plant 3) DPR 4) MPR 5) SAP entry in PM module of Electrical department
(iii)	**Raw Material un-availability**
	1) Material Order copy and denial document from Mines owner 2) SAP entry in MM/FI module on raw material order 3) DPR 4) MPR
(iv)	**Natural Disaster**
	1) Supporting Authentic document from Local district Administration 2) Major Eqp Log Sheet 3) Major Eqp operators Report book 4) DPR 5) MPR
(v)	**Major change in government policy hampering plant's process system**
	1)Government Notification or Statutory order 2) Authentic document from plant on effect of Major Eqp production due to policy change 3) DPR 4) MPR 5) SAP Entry on production change
(vi)	**Unforeseen circumstances/Labour Strike/Lockouts/Social Unrest/Riots**
	1) Relevant document on Unforeseen Circumstances beyond the control of plant 2) Energy Meter Readings and Power Consumption during the said period of unforeseen circumstances 3) Thermal Energy Consumption record during the said period of unforeseen circumstances from DPR/Log book/SAP Entry
(vii)	**Note**
	The hard copy/Printouts is to be signed by Authorised signatory, if SAP data is used as documents
(viii)	**Availability of documentation**
	1) For Normalisation factors, which became applicable due to external factors, authentic documents to be produced by DC for the baseline as well for the assessment year. In absence of these authentic documents, no Normalisation Factor will be applied/Considered. 2) While selecting "No" from the drop down list, the inbuilt calculation automatic treat the Normalisation for particular factor as zero. However, DC needs to submit an undertaking from the Authorized Signatory on non-availability of document

5. Understanding Conditions

"Normalisation" means a process of rationalization of Energy and Production data of Designated Consumer to take into account changes in quantifiable terms that impact energy performance under equivalent conditions.

There are several factors that need to be taken into consideration in the assessment year, such as change in product mix, capacity utilisation, change in fuel quality, import/export of power, etc influenced by externalities i.e., factors beyond the plant's control, while assessing the specific energy consumption of the plant.

In order to incorporate and address the changes occurring from baseline year to assessment year, the Bureau has formulated sub-technical committees under the technical committee for each sector. The sub-technical committees include representatives from DCs, research associations, ministries concerned, expert bodies from the government and the private sector, among others. The sub-committee identified and prepared the normalisation factors with the consent of DCs.

The operating parameters in the assessment year have to be normalised with reference to the baseline year so as to avoid any favourable or adverse impact on the specific energy consumption of the plant. This will also assist in quantifying and establishing the benefits of the energy efficiency projects the plant implemented.

5.1. Specific Issues

88. The complete Normalisation Process with equations and calculations have been dealt separately in sector specific Normalisation documents. EmAEA needs to study the document to carry out the verification process.

89. The details of data furnished in Form 1 shall be drawn from the sector-specific Pro-forma, referred to in the guidelines, relevant to every designated consumer and the said sector-specific Pro-forma, duly filled in, shall also be annexed to Form 1

90. The Sector Specific Pro-forma have built-in calculations of Normalisation with specific Energy Calculation in the summary sheet. The notified Form 1 will be generated automatically from the Pro-forma, once filled in all respect.

91. The normalization will be given to DCs only upon submission of valid/authentic supporting documents, failing which, the DC will not be eligible for normalizations.

92. The DC should submit valid reasons for operating parameters for which normalisation has been provided but not claimed.

93. For the new DCs, which are not covered under PAT scheme shall also fill up the Sector Specific Pro-forma for the verification of their total energy consumption.

94. Notional/Normalized Energy will not to be considered in Total Energy Consumption, while deciding whether a plant falls under the designated consumer category or not. Normalization energy is considered only in the calculation of Gate to Gate Specific Energy Consumption.

95. **Definition of External Factors:** The factors over which an individual DC does not have any control but that can impact the SEC are classified as external factors.

   i. External Factors should be scrutinized carefully for Normalisation applicability

   ii. The defined external factors in the document are to be supported by external authentic documentary evidences

   iii. The EmAEA should bring in any other undefined external factor, which may affect production or energy of a DC, in the verification report with authentic documentary evidences

   iv. The external factors identified are as follows:

   a. Market Demand

   b. Grid Failure/Breakdown (Grid not Synchronized with CPP)

   c. Raw Material Unavailability

   d. Natural Disaster (Flood, Earthquake etc)

   e. Major change in Government policy (affect plant's process)

   f. Unforeseen Circumstances (Labour Strike/Lockouts/Social Unrest/Riots/Others)

96. **Boundary Limit:**

   a. Establishment of plant GtG boundary is required with clear understanding of raw material input, Energy input, Power Import/Export, Intermediary product Import/Export, housing Colony Power, Construction/Others

Power, Power supplied to other Ancillary unit outside the plant boundary

b. Inclusion and exclusion from the plant boundary is maintained as established in the baseline year

c. Section-wise screen-shot of SCADA (supervisory control and data acquisition) system from the central control room (CCR)/distributed control systems (DCS) is to be included in the verification report

d. Raw material input in the Plant boundary to be recorded for inclusion in the verification report

5.2. Fuel

97. **Fuel Testing**

    a. Validation of Fuel quality testing from external and internal labs for same sample for each solid fuel used

    b. Test Certificate from Government Accredited Lab (NABL):

       i. **CPP Fuel:** Plant to maintain minimum 1 sample test certificate in a quarter for Proximate and Ultimate Analysis i.e. 4 test certificates in a year for each fuel

       ii. **Process Fuel:** 1 sample test certificate in a quarter for Proximate Analysisi.e. 4 test certificates in a year for each fuel

    c. Liquid /Gaseous Fuel Testing: As per Table 9

    d. Reproducibility Limit of same sample

       i. The means of the result of duplicate determinations carried out in each of two laboratories on representative portions taken from the same sample at the last stage of sample preparation, should

not differ by more than 71.7 kcal/kg as per ISO 1928: 1995 (E)

       ii. If the difference is greater than 71.7 kcal/kg, the difference will be added to the gross calorific value (GCV) value of the test result obtained in DC's Lab for that particular quarter

    e. Daily Proximate analysis record of all types of Coal to be maintained at Lab for ongoing submission as document related to fuel analysis

98. Note on Proximate and Ultimate Analysis of Coal

    If the ultimate analysis has not been carried out in the baseline year for getting H% result, following conversion formulae from Proximate to Ultimate analysis of coal could be used for getting elemental chemical constituents like %H.

Relationship between Ultimate and Proximate analysis

$$\%C = 0.97C + 0.7(VM+0.1A) – M(0.6-0.01M)$$
$$\%H2 = 0.036C + 0.086 (VM -0.1xA) – 0.0035M2(1-0.02M)$$
$$\%N2 = 2.10 -0.020 VM$$

Where
C = % of fixed carbon
A = % of ash
VM = % of volatile matter
M = % of moisture

99. The basis of Fuel sample testing i.e., As Received Basis (ARB), As Fired Basis (AFB), As Dried Basis (ADB) for calculating or measuring GCV in assessment year will be same as made during baseline year. However, the location of Fuel sample testing and weight measurement should remain identical. This will be identified in the Pro-forma under Remarks column, if the basis is other than As Fired.

100. The status quo to be maintained in the assessment year for the basis of measuring

GCV of Fuel (For Ex. As Received Basis, As Fired Basis, As Dried Basis etc.) as followed in the baseline year i.e., if DC has submitted GCV value on "as received basis", the basis will be same in the assessment year as well. The DC has to write in the remarks/source of data field on basis of GCV taken in the assessment year. However, the EmAEA is requested to report the Fuel GCV "As fired basis" in the verification report, which may become baseline for subsequent PAT cycles.

101. Standard applicable IS Norms should be followed for Fuel (Solid, Liquid, Gas) sampling for internal or external lab from different location

102. Internal Coal Testing method to be elaborated as per IS Norms and to be included as document in the EmAEA report.

103. Gross Calorific Value or High Heat Value:

   a. It is advised to measure the GCV of coal with the help of Bomb Calorimeter only in the assessment year and record the value daily in the LAB register for ongoing submission as document related to Fuel analysis.

   b. The method for calculating GCV/ NCV from Proximate and Ultimate Analysis in the assessment year will remain same as that made during the baseline year.

   c. In the absence of formulae for calculating GCV, the following Dulong's formulae may be used for Gross Calorific Value (GCV) or High Heat Value (HHV) calculation

   Dulong's Formulae (Value from Ultimate Analysis) for GCV covers basic principle, that there are only 3 components in a fuel which generate heat i.e., Carbon, Hydrogen and Sulphur as per following expression

$Q = 81 \times C + 342.5 \times [H - O/8] + 22.5 \times S$

Where
Q is GCV in kcal/kg
C = % of Carbon by weight
H=% of Hydrogen by weight
O=% of Oxygen by weight
S=% of Sulphur by weight

104. **Net Calorific Value (NCV) or Low Heat Value (LHV):**

   a. The NCV includes the Steam-condensing latent heat, the NCV is defined as the gross calorific value minus the latent heat of condensation of water (at the initial temperature of the fuel), formed by the combustion of hydrogen in the fuel. The latent heat of steam at ordinary temperature may be taken as 587kcal/kg. The NCV could be calculated by the following expression

$NCV = GCV - 5.87 \times (9 \times H + M)$

Where
NCV = Net Calorific Value (kcal/kg)
GCV = Gross Calorific Value (kcal/kg)
H= % of Hydrogen by weight
M= % of Moisture by weight

5.3. Normalization Condition and calculation

105. Plant should maintain the records of the number of outages during the baseline and assessment year.

106. Plant needs to maintain proper Energy Meter Reading/Records due to external factors for baseline as well as for assessment year.

107. Section wise Energy metering (Electrical and Thermal) is required for making Equivalent Product in Textile sub-sectors. Proper calculation document should be maintained, if energy figures are arrived by calculation method.

108. The Plant is to maintain Frequency of calibration and records of Energy monitoring equipment.

109. Calibration records of all weighing and measurement system with frequency of calibration to be included in the verification report.

110. The documents maintained by DCs should clearly show the direct reasons of the shutdown along with time and duration in hours and Energy consumed with quantity of Feed to reach the pre-shutdown production level for each such break-down or shutdown.

111. Details of Additional Equipment in Pro-forma:

    a. **Additional Product/Section detail:** The Designated Consumer may furnish additional Product/Section details as per sectional format in a separate Excel Sheet for insertion in the existing Pro-forma if sectional input data format is full. Otherwise, Total energy of additional section or product could be converted into the last product or section through SEC of both the product/section and feed the same in the last product/section format for baseline as well as for assessment year.

    b. **Additional Line for Start/Stop Normalization:** If the numbers of line/unit exceeds from the existing numbers, the DCs are advised to insert separate excel sheet of same format for finalization and BEE should insert additional line with normalization calculation.

    c. Additional Boiler detail (Process/Co-gen): Additional numbers of Process or Co-gen boiler will be annexed in a separate Excel sheet as per the format provided in the Pro-forma for Boilers.

112. Lump CPPs: Information for all parameters of CPP [10] to be provided for all CPPs in Weighted Average terms w.r.t Gross Unit Generation in the CPP section, except for Design Heat Rate DHR (1,2…)=DHR1 x C1+DHR2 x C2+…./(C1+C2….).

113. Lump co-gen (extraction-cum-condensing): The total number of co-gen should be treated as lump power source and details are to be filled accordingly in the Pro-forma separately for extraction-cum-condensing turbine as per the example shown in Table No 14.

114. Lump co-gen (back pressure): The total number of co-gen should be treated as lump power source and accordingly details to be filled in the Pro-forma separately for back pressure turbine as per the example in Table No 14.

Table 14: Lump Co-Generation Treatment

Sr No	Description	Formulae	Unit	Remarks
(i)	Install Capacity (C1…..Cn)[11]	C1+C2+…Cn	MW	Sum of capacity
(ii)	Annual Gross Unit generation (AGG1…AGGn)	AGG1+AGG2+…AGGn	Lakh kWh	Sum of Generation
(iii)	Auxiliary Power Consumption (APC1…. APCn)	APC1 +APC2…APCn	Lakh kWh	Sum of APC
(iv)	Design Heat Rate	DHR (1,2…n)= DHR1 x C1+DHR2 x C2+…./(C1+C2….Cn)	kcal/ kWh	Weighted Average of Design Heat Rate w.r.t to Installed Capacity

[10] CPP: Steam Turbine Generator (STG)/ Gas Turbine (GT)/Gas Generator(GG)/Diesel Generator (DG)
[11] 1,2,3….n: No of Cogen Sources

Sr No	Description	Formulae	Unit	Remarks
(v)	Running Hours	(RH1xAGG1+RH2xAGG2+ ……… RHnx AGGn)/ (AGG1+AGG2+… AGGn)	Hrs	Weighted Average of Running Hours w.r.t to Annual Generation
(vi)	Auxiliary Power Consumption	(ii) x 100/(iii)	%	APC%
(vii)	Total Thermal energy used in Process	TEPr1+TEPr2+…TEPrn	Million kcal	Sum of Total Thermal Energy used in Process
(viii)	Total Thermal energy used in Power	TEPo1+TEPo2+…TEPon	Million kcal	Sum of Total Thermal Energy used in Power
(ix)	Heat Rate of Co-Gen	HR1xAGG1+…..+HRn x AGGn/ (AGG1+…+AGGn)	kcal/kwh	Weighted Average of Heat Rate

115. In case a DC commissions a new line/ production unit before or during the assessment/target year, the production and energy consumption of new unit will be considered in the total plant energy consumption and production volumes once the capacity utilisation of that line has touched/increased over 70%. However, the energy consumption and production volume will not be included till it attains 70% of capacity utilisation. Energy consumed and produced (if any) in the course of a project activity during the assessment year, need to be monitored exclusively and will be subtracted from the total energy and production in the assessment year. Similarly, the same methodology will be applied to a new unit installation for power generation (CPP) within the plant boundary.

The capacity utilisation will be evaluated based on the original equipment manufacturer (OEM) document on rated capacity or name plate rating on the capacity of new line/production unit and the production of that line/unit as per DPR/log sheet.

5.4. Normalisation General Issue

116. Normalisation Environmental Concern: Any additional equipment installed, to comply with environmental standards as applicable in the baseline, will not qualify for this normalisation i.e., if any plant has deviated from the environmental standards imposed in the baseline year and additional equipment installed later to comply with these standards, the plant will not be eligible for normalisation.

117. Unavailability of biomass/alternative fuel in assessment year as compared to the baseline year due to external factors. The normalisation for unavailability for biomass or alternative fuel takes place only if sufficient evidence in terms of authentic documents is produced. The plant is to furnish the data on replacement of biomass/alternative fuel (solid/ liquid) by fossil fuel in the assessment year with reference to baseline year. The energy consumption resulting from the use of fossil fuel will be deducted in the assessment year.

118. If a captive power or co-generation plant caters to two or more DCs for electricity and/or steam requirements, each DC shall consider that plant as existing within its boundary and the energy consumed by the plant shall be included in the total energy consumption. However, electricity in terms of calorific value (as per actual heat rate) and steam in terms of calorific

value (as per steam enthalpy) exported to other plants shall be subtracted from the total energy consumption.

119. **Normalisation for Start Stop:** The Designated Consumer has to furnish the Electrical and Thermal Energy Consumption by taking into account the saleable or intermediate production made during Hot-Cold Stop and Cold-Hot Start.

   a. **Hot to Cold Stop:** The Plant ceases to halt after abrupt tripping of main equipment due to external factor.

   b. **Cold to Hot Start:** The Plant is restarted after a brief halt/stoppages to reach the normal production

120. For the Start/Stop Normalization following factor may be considered:

   a. At the time of Hot to Cold stop, due to external factors, electric energy consumed in the major section/plant to maintain the essential plant loads of the plant shall be deducted from the total energy consumption.

   b. At the time of Cold to Hot start after Hot to Cold stop due to external factors, specific energy consumption of the major section/major equipment shall be multiplied with the actual production during this time and added to the total energy consumption.

   c. The actual equivalent production shall also be added to the total production. For the purpose of clarity, equivalent production means the amount of production of that major section/equipment converted into the major product output.

121. The designated consumer needs to produce authentic documents for normalisation factors, which became applicable due to external factors, for the baseline and assessment years. No normalisation factor will be applied or considered in the absence of these authentic documents. An undertaking from the Authorised Signatory is required on non-availability of document.

122. For investment for year 2010-11, 2012-13, 2013-14 and 2014-15 will be included in the assessment year of sector specific Pro-forma.

123. The empanelled accredited energy auditor will report separately any factor, which has not been considered in the document and Form 1, with possible solution for the same and annexed to Form B (Verification Form)

124. The sector specific Pro-forma, normalisation document and aforementioned guidelines are the major elements of the M&V process; additional sector specific M&V guidelines are provided in Annexures I-VIII.

125. Some of the information sought in these annexures could be considered as supporting information/documents, which may help the EmAEA in submitting Form B.

6. Abbreviations

NAPCC	National Action Plan for Climate Change
NMEEE	National Mission on Enhanced Energy Efficiency
PAT	Perform Achieve and Trade
M&V	Monitoring and Verification
MoP	Ministry of Power
BEE	Bureau of Energy Efficiency
SDA	State Designated Agency
EOC	End Of PAT Cycle
DCs	Designated Consumer
EmAEA	Empanelled Accredited Energy Auditor Firm
SEC	Specific Energy Consumption
Pro-forma	Sector Specific Pro-forma for Form 1
ECM	Energy Conservation Measures
GtG	Gate- to- Gate
PAD	Performance Assessment Document
ESCerts	Energy Saving Certificates
AEA	Accredited Energy Auditor
CPP	Captive Power Plant
AY	Assessment Year
BY	Baseline Year
DCS	Distributed Control System
CCR	Central Control Room
SCADA	Supervisory Control and Data Acquisition
SAP	System Application and Product Software
DPR	Daily Production Report
MPR	Monthly Production Report
DGR	Daily Generation Report
MGR	Monthly Generation Report
IEX	Indian Energy Exchange
PXIL	Power Exchange of India Limited
OEM	Original Equipment Manufacturer
GCV	Gross Calorific Value
NCV	Net Calorific Value
NABL	National Accreditation Board for Testing and Calibration Laboratories
TPP	Thermal Power Plant

7.   Annexure

(i)   Annexure I: Thermal Power Station

(ii)   Annexure II: Steel

(iii)   Annexure III: Cement

(iv)   Annexure IV: Fertilizer

(v)   Annexure V: Aluminium

(vi)   Annexure VI: Pulp & Paper

(vii)   Annexure VII: Textile

(viii) Annexure VIII: Chlor-Alkali

7.1. Annexure I: Thermal Power Plant

1. Auxiliary Power Consumption (APC)

EmAEA may verify the section/ equipment wise motor ratings. The sections/ equipment shall include

Table 15: Auxiliary Power Consumption Details (a,b,c)

a. Boiler and Auxiliaries

S. No.	Equipment	Power Rating (kW)	Current Rating (Amperes)
1.	Coal Grinding Mills		
2.	Coal Feeders		
3.	Boiler Re-Circulation Pump		
4.	Primary Air(PA) Fans		
5.	Secondary Air(SA) Fans		
6.	Induced Draught (ID) Fans		
7.	Seal Air fans		
8.	Scanner air fans		
9.	Air Pre-Heater (APH)		
10.	Miscellaneous/ Missed out equipment		

b. **Turbine and auxiliaries**

S.No.	Equipment	Power Rating (kW)	Current Rating (Amperes)
1.	Condensate Extraction Pump (CEP		
2.	Boiler Feed Pump (BFP)		
3.	Boiler Feed-booster Pump (BFBP)		
4.	Closed Circuit Cooling Water (CCCW) Pump/ De-Mineralised Cooling Water (DMCW) Pump		
5.	Auxiliary Cooling Water (ACW) Pumps		
6.	Condensate Polishing Unit (CPU)		
7.	Lube Oil Pumps		
8.	Seal Oil Pumps		
9.	Stator Water Cooling Pumps		
10.	Miscellaneous equipment		

c. Balance of Plant

S.No.	Equipment	Power Rating (kW)	Current Rating (Amperes)
1.	Compressed Air System		
a)	Instrument Air Compressor		
b)	Service Air Compressors		
2.	Cooling Water (CW) Pumps		
3.	Cooling Tower (CT) Fans		
4.	Water Treatment Plant (WTP)		
a)	Clarifiers		
b)	Filters		
c)	Pumps		
d)	Ion Exchangers		
e)	Miscellaneous/ Missed out equipment		
5.	Coal Handling Plant		
a)	Wagon Unloading System		
b)	Crushers		
c)	Belts Conveyors		
d)	Stacker Reclaimer		
e)	Miscellaneous/ Missed out equipment		
6.	Ash handling System		
a)	Pumps		
b)	Dry Ash Handling System		
c)	Wet Ash Handling System		
d)	Miscellaneous/ Missed out equipment		
7.	Fire Fighting System		
8.	Air Conditioning System		
9.	Lighting		
10.	Transmission System		
11.	Miscellaneousequipment		

This data shall be produced by the DCs for verification of section wise APC. If any item has been missed out in the table above, it shall be inserted by the DC.

The DC shall submit all design documents, manufacturers data sheet, etc. in support of the equipment ratings if required.

2. Coal Handling Plant

a. Coal Input

The DC shall submit a copy of Fuel Supply Agreement (FSA) in which the coal quality shall appear. Also, the DC shall submit the transportation agreement/ contract indicating the amount and quality of coal procured.

b. Scheme

A schematic representation of the coal handling plant shall be provided by the DC indicating the flow of coal from wagons to boilers. The description shall include hours of operation and number of equipment in running and standby condition.

c. Coal Quality

The ultimate and proximate analysis of coal shall be submitted by the DC. The coal sample shall be taken at coal unloading, stacking and bunker feeding. The lab report in this regard shall be accepted.

3. Heat Rate

The DC shall give the fully traceable calculation for turbine Heat Rate, Gross Heat Rate and Net Heat Rate. The values taken for heat rate calculation shall be backed by evidences, which can be screen shot of DCS for the particular parameter.

4. Parameter verification

The DCs shall make the log books and Daily Generation Report (DGR) available as and when needed.

5. Fuel Oil

The DCs shall submit the liquid oil supply contract mentioning the properties of oil. Also, the consumption shall be backed by calculation and pictures/ screen shot of level indicators/ flow counter, etc.

6. Balance diagrams

a. The DCs shall submit the Heat Mass Balance Diagrams showing the complete cycle.

b. Water Balance Diagram shall also be submitted.

7. Fuel Mix Normalisation in Gas based Thermal Power Plant

Due to change in fuel mix i.e., % of consumption of Gas and Oil/other fuel in the assessment year w.r.t. baseline year, the variation in Boiler efficiency is evident. The same needs to be normalized as per total generation from Gas and Oil/other fuel and design boiler efficiency at 100% for gas and Oil/other fuel.

8. General

a. The scheme/ layout diagram of all sub-systems, e.g., CHP, AHP, WTP, etc. shall be submitted by the DCs. This shall facilitate in identifying the boundary condition of systems/ plant.

b. The DCs shall submit the maintenance history of systems/ equipment.

9. Plant Boundary

a. The plant boundary shall consist of the BTG island, Water Treatment plant (WTP), Effluent Treatment Plant (ETP), Coal Handling Plant (CHP), Ash Handling Plant, CW System, Compressed Air System, Fire Fighting system, Transmission System, etc. A typical sample of Plant boundary condition is represented below

Figure 8: Ex-GtG Boundary for Thermal Power Plant
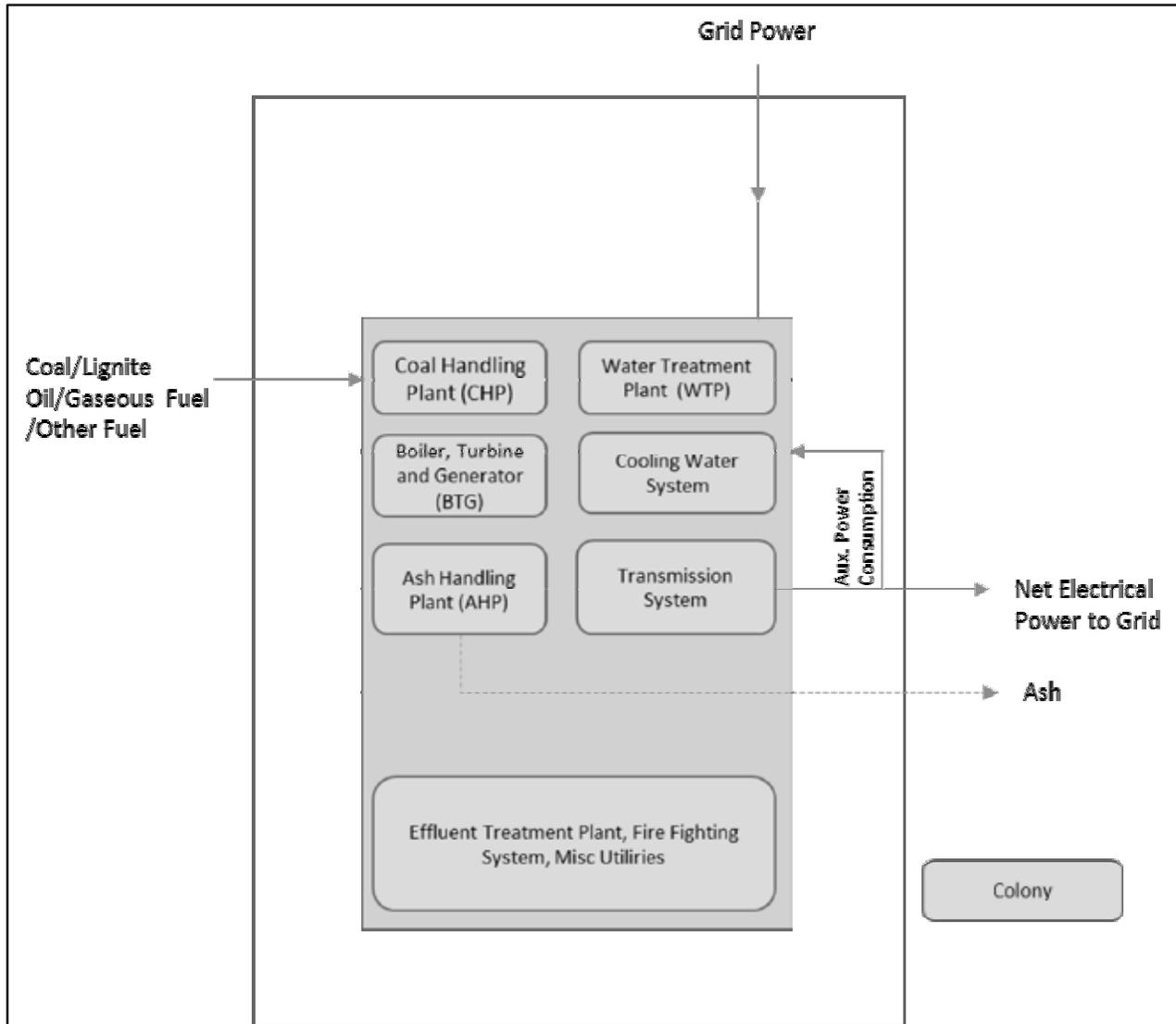
The residential colony does not form a part of the plant boundary and hence it is kept outside. In the figure above. The DC shall submit a latest Plot Plan of the station indicating all the systems/sub-systems.

b.   The station energy balance diagram to be included in the Verification report. A typical sample of the diagram is shown below for Coal/Lignite/Oil/Gas based Power Plant and Combined Cycle Gas Turbine

Figure 9: Ex-Coal/Lignite/Oil/Gas based Thermal Power Plant Energy balance diagram
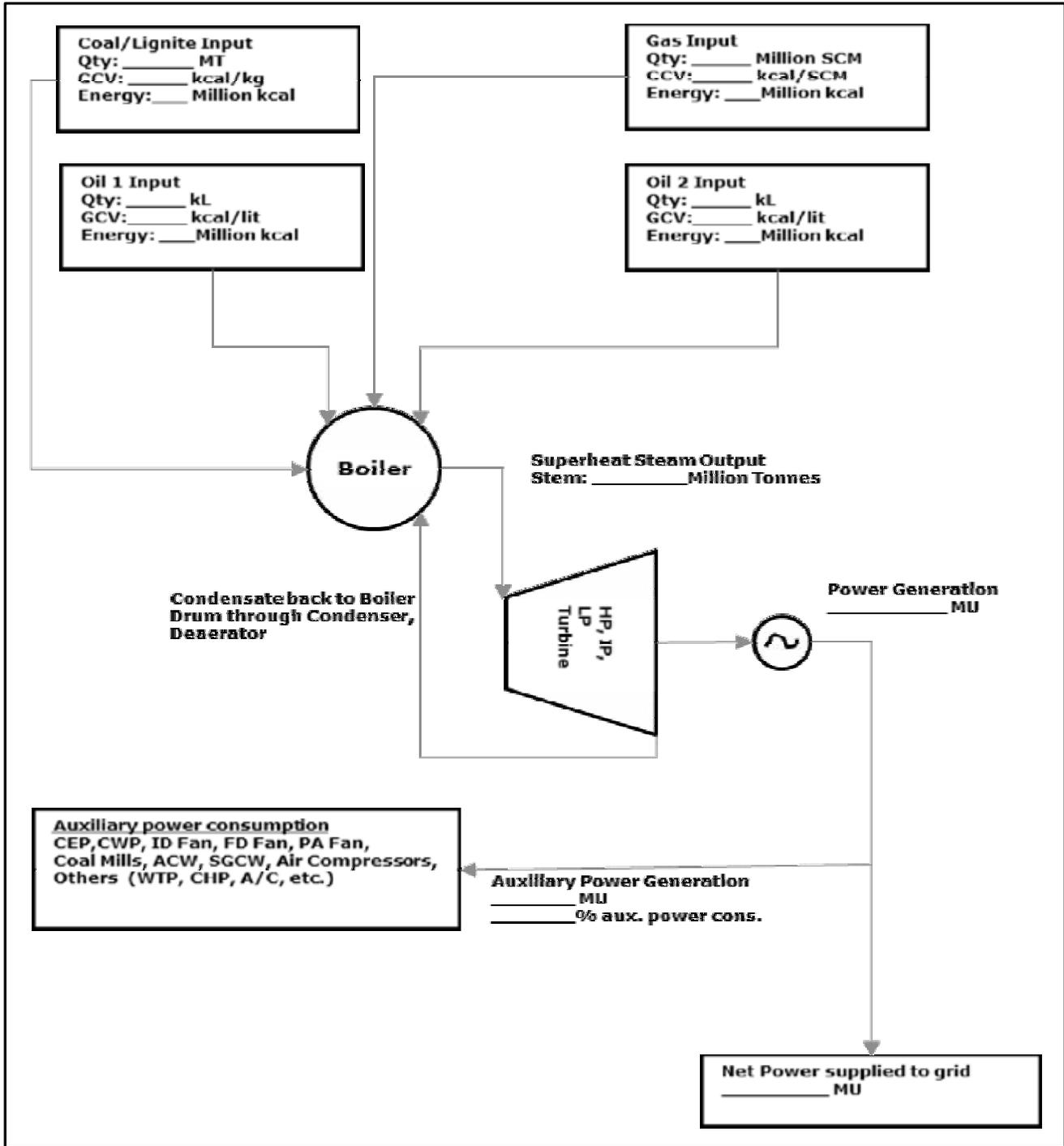
Figure 10: Ex-CCGT Energy balance diagram
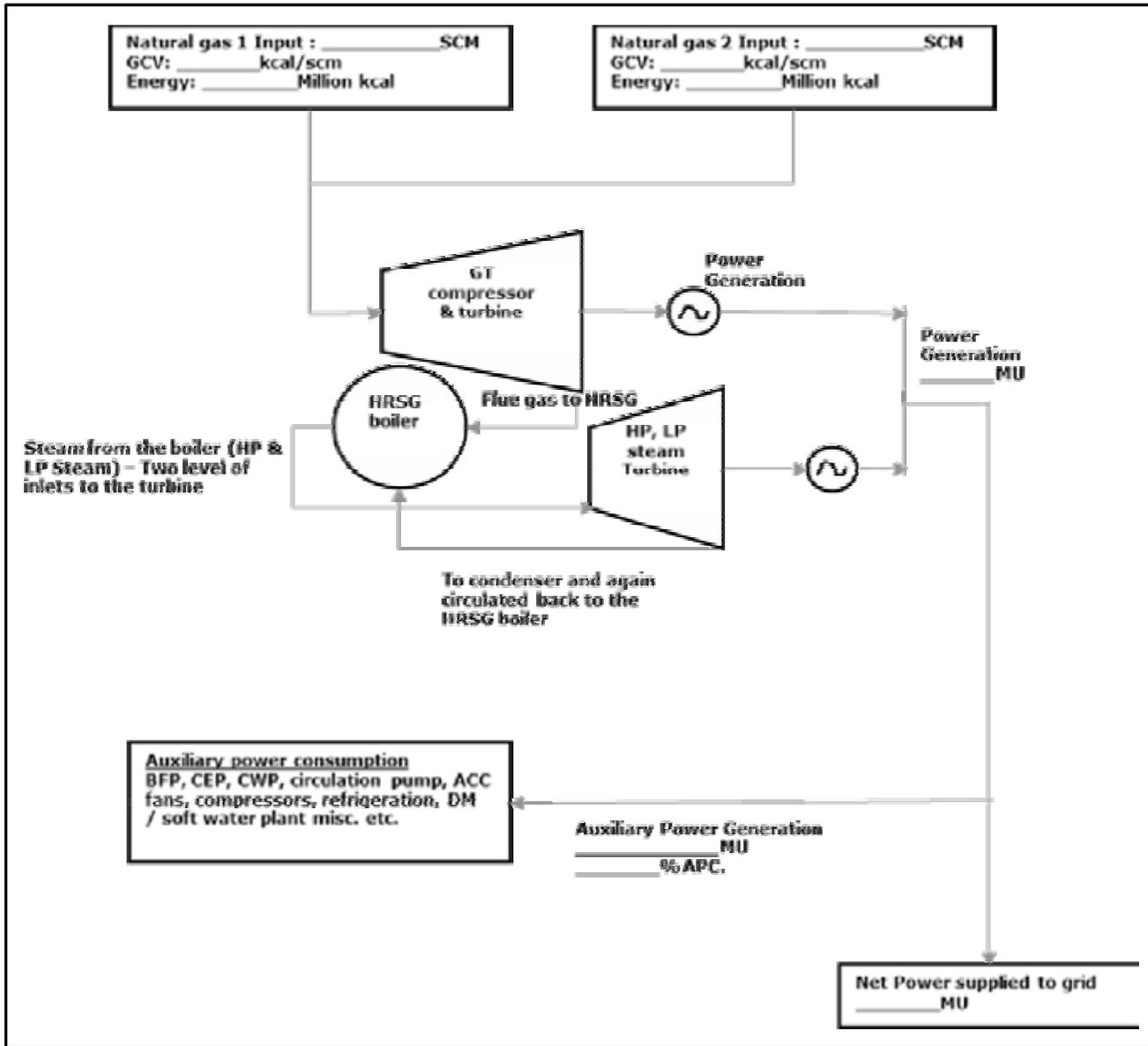
7.2. Annexure II: Steel

A: Integrated Steel Plant

1. The data submitted for verification and other figure for SEC calculation of any unit has to be in line with the units declared production and consumption figures as per the statutory financial audit and declaration in their annual report.

2. EmAEA, while verifying the SEC calculation should also cross verify the input figures based on the procurement plans and physical receipts.

3. The transit and handling losses have to be within the standard norms allowable under financial audit.

4. Crude steel is the product output of an Integrated Steel Plant (ISP). The term is internationally used to mean the 1st solid steel product upon solidification of liquid steel. In other words, it includes Ingots (in conventional mills) and Semis (in modern mills

with continuous casting facility). In PAT Scheme, for ISP, Crude steel is considered as the major product output.

5. The energy impact of any basic input such as Pellet, Sinter, DRI, Oxygen, Nitrogen, Argon, which has been either imported and/ or discontinued during assessment or baseline years, the upstream/notional energy impacts have to be apportioned in SEC as the case may be.

6. Import of any finished or semi-finished fuel input say coking coal vs coke,which has been either imported and/ or discontinued during assessment or baseline years, the upstream/notional energy impacts have to be apportioned in SEC as the case may be

7. For verification process, the DC shall provide all necessary information, supporting documents and access to the Plant site to EmAEA. It will be the responsibility of the EmAEA to maintain the confidentiality of the data collected and not to use for any other purpose except for the PAT scheme.

8. Quality of raw material for the purpose of normalisation needs to be maintained as per the frequency of monitoring of the particular raw material and has to be maintained and submit to EmAEA by the plant, duly signed by the authorized signatory of the Designated Consumer.

9. In case of normalisation benefit, unit has to provide metering and measurement of energy inputs for all the energy parameters, for which normalisation is claimed.

10. All the energy input calorific values for purchased energy and inputs that impact energy performance of unit shall be submitted based on suppliers documented analysis and contractually agreed and signed documents by competent authority. All these documents are mandatory to be counter signed by auditor. A third party determination of calorific Value of each fuel used in plant to be submitted for each quarter carried out by Government Accredited Laboratory (NABL) of each fuel used in the plant is to be submitted for each quarter.

11. Yield of Mills shall not be greater than 1. EmAEA needs to verify the yield for abnormal changes between baseline year and assessment year. The justification with calculation needs to be incorporated in the verification Report of EmAEA.

12. Coke Nut and Coke breeze is a part of BF grade Coke. EmAEA to take a note for the same in the verification Report of EmAEA.

13. Process route change Normalisation is applicable for change in major process due to external factor.

B:Sponge Iron Sub-Sector

14. The entire sub-sector is divided into 7 group on similarity of product

15. The major product in 7 group is as per table below

16. The Energy consumption of Pellet Plant shall not be included in the assessment year as well as in the baseline year. The calculation for the same is included in the summary sheet of Pro-forma.

17. For Inclusion of Pellet Plant in GtG Specific Energy Consumption, The DC needs to specify the same so that the Summary sheet needs to be modified.

18. The Electrical and Thermal energy of Pellet Plant should be verified through proper measurement and Energy meters

Table 16: Sponge Iron Subsector- Major Product details

Sr No	Sub-Sector Group	Major Product	Remarks
1	Sponge Iron	Sponge Iron	
2	Sponge Iron with Steel Melting Shop	Sponge Iron	
3	Sponge Iron with Steel Melting Shop and Others (Ferro Chrome, FeMn, SiMn, Pig Iron, Ferro Silicon, Rolling Mills etc)	Sponge Iron	
4	Ferro Alloy	SiMn	
5	Ferro Chrome	Ferro Chrome	
6	Mini Blast Furnace (MBF)	Pig Iron	
7	Steel Processing Unit (SPU)	Steel	

19. Calibration records of all weighing and measurement system with frequency of calibration to be included in the verification report

20. Section wise SCADA Screen shot if required to be included in the verification report by EmAEA

21. The Energy and Mass balance calculation is required to be included in the verification report.

22. Section wise energy consumption needs to be recorded and included in the verification report.

23. The equivalent product is calculated based on the Product Mix calculation in the proforma. A typical process flow along with the location of major product is shown in the diagram. The same shall be included in the verification report for different section of Sponge Iron sub-sector.

Figure 11: Product Mix diagram
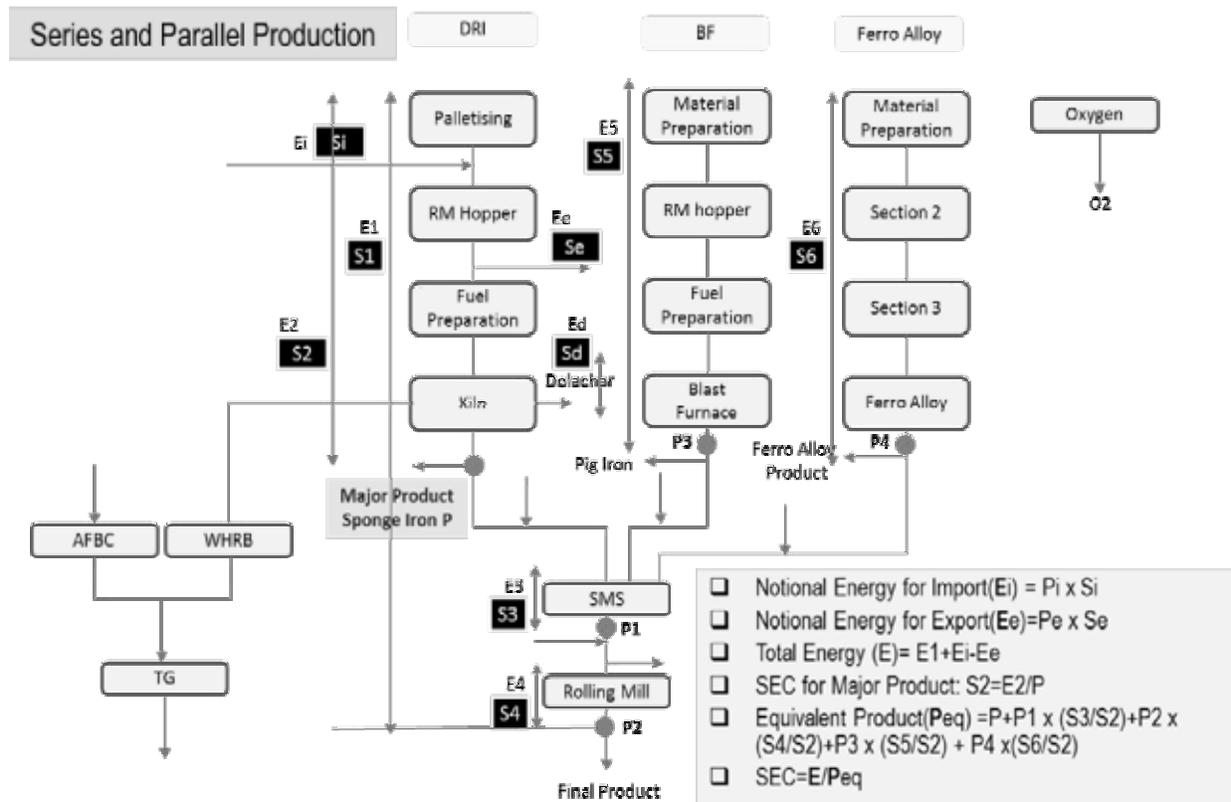
24. Demarcation of plant boundary is required with clear understanding of raw material input, Energy input, Power Import/Export, Intermediary product Import/Export, Colony Power, Construction/Others Power, Power supplied to other Ancillary unit outside the plant boundary. A typical sample of Plant boundary condition is represented below

Figure 12: Ex-GtG Boundary boundary for Sponge Iron Sub-sector
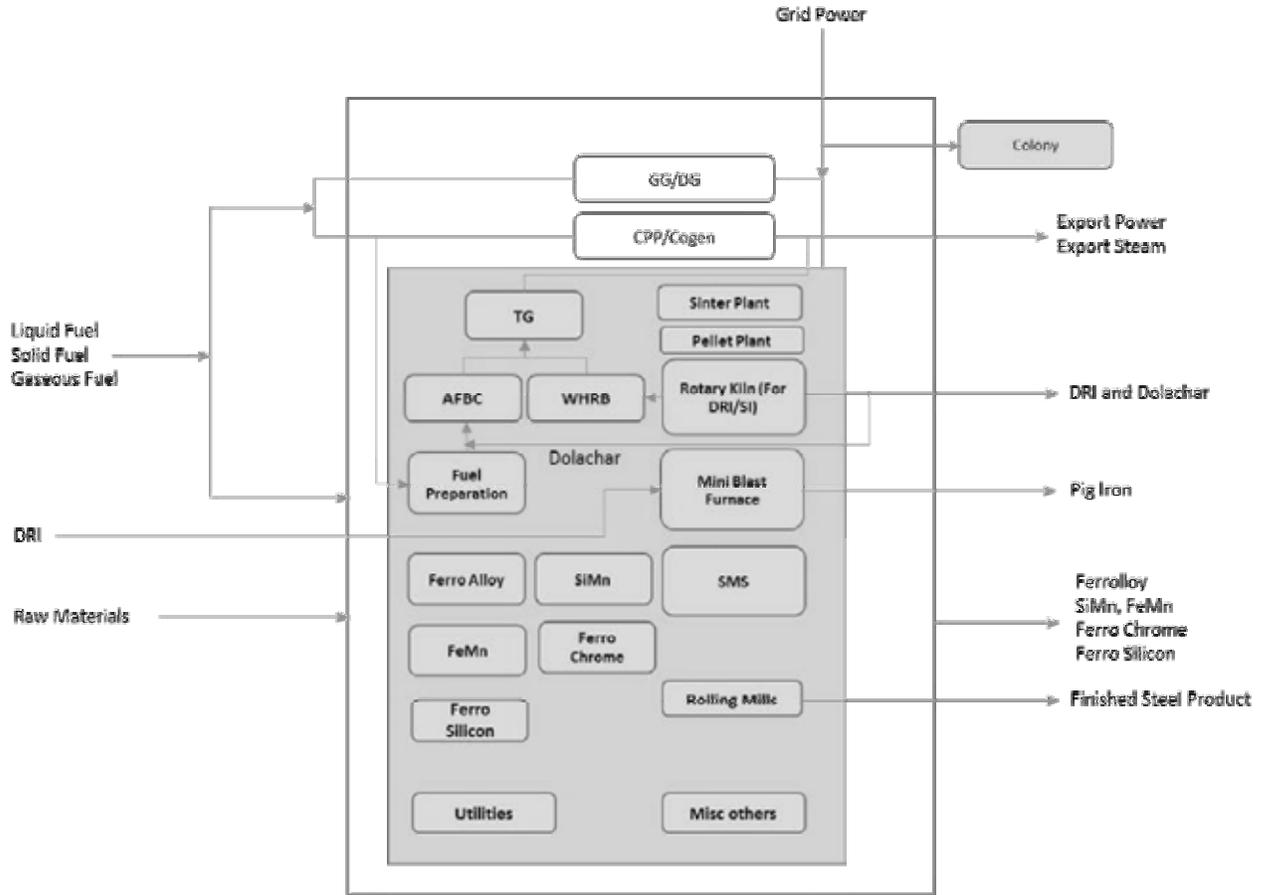
25. The energy and mass balance calculation is required to be included in the verification report

The ideal condition need to be assumed to find out the theoretical mass & heat balance of the kiln and its specific energy requirements. Once this is established, the actual mass & heat balance shall be worked out with SEC.

Comparison of actual SEC V/s. theoretical SEC shall give the kiln efficiency

a. Theoretical Heat Balance (Ideal Case)

To prepare the heat balance, "Hess's Law of constant Heat summation" is applied, which states "For a given chemical process the net heat charge will be same weather the process occurs in one or several stages.

Adding all reactions

$2Fe_2O_3 + 6C + 3O_2 = 4Fe + 6CO_2 + \Delta_{Hr}$ (Final reaction)
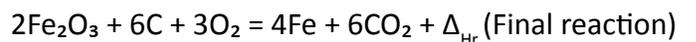
Standard heat of formation of Fe_2O_3

& CO_2 are -825.5 & -393.5 KJ/mole respectively. Heat of formation of element is taken zero.

The final reaction after applying thermodynamics principal.

$$\Delta_{Hr} = \Sigma \Delta_{H\,product} - \Sigma \Delta_{H\,reactants}$$

Negative sign indicates exothermic reaction or heat release and positive sign indicates requirement of heat

		Heat Supplied = 2058		
Iron ore	1.43 Kg		Sponge iron	1 Kg.
Coal	0.64 Kg.		Char	0.064 Kg.
Air	5.20 Kg.	-251 Kcal (Excess heat)	6.20 kg.	
Total Input	7.270 Kg		Total Output	

In Heat balance of ideal kiln (100% coal used as reducing agent and no coal is used as fuel)

S.No	Component	Heat Value (Kcal)
1	Sponge iron sensible heat, assuming Δ_t 1045° C	+124
2	Char sensible heat, assuming Δ_t 1045° C	+13
3	Flue gas sensible heat, assuming Δ_t 1045° C	+1555
4	Heat loss due to moisture present in the coal	+66
5	Heat Loss due to vapor formed from Hydrogen of fuel	+49
6	Heat of iron reduction reaction (exothermic)	-758
7	Heat gain from burning of VM of coal	-1300
8	Net heat surplus in overall	-251
9	Total Additional heat/coal requirement to produce 1 Kg Sponge Iron	Nil

b.   Sankey diagram of Kiln (Ideal condition)

EmAEA is required to include the heat balance report of Kiln as per actual condition of Plant operation
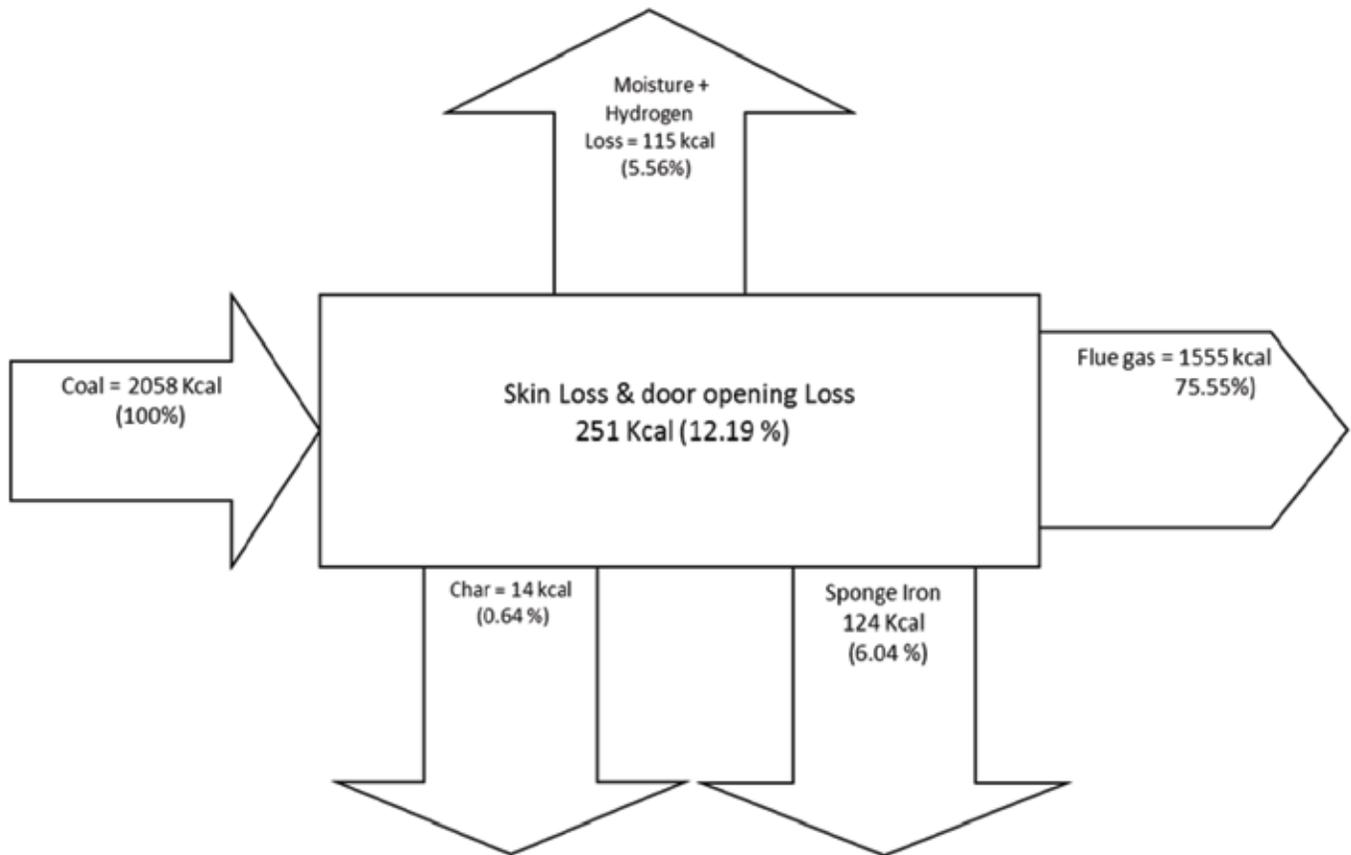
c. Ideal Mass balance condition

To produce 1 kg of Sponge Iron in ideal condition i.e. with no excess air (flue gas without O_2 & CO).

Input: 0.64 kg coal, 1.43 kg Iron Ore, 5.20 Kg of Air

Output: 6.206 Kg flue gas, 0.064 Kg (Ash of Coal), 1 kg sponge iron.

7.3. Annexure III: Cement

1. Preservation Power for Stopped Kiln: For kiln which goes under stoppages due to external factors, a certain quantity of power is required for safety and certain operations which needs to be maintained. The normalization for this power will be considered provided the DC has the baseline and assessment year data. Thisdifference of preservation power in the baseline as well as the assessment year shall be subtracted from the total energy consumed.

2. Frequency of Lab Analysis from NABL accredited Laboratories for providing normalization for Raw material Quality in the subsequent cycles:

   2.1. Burnability analysis for raw mix – Once in each quarter

   2.2. Limestone Bond index – Once in a year

3. Normalisation due to Non availability of fly ash due to external factor: DC to submitin support of claim on unavailability of fly ash during Assessment year to the EmAEA with sufficient data and documentation.

EmAEA to establish the facts whether in the vicinity of the particular DC, other Plants/DCs are getting Fly ash or not.

4. The status quo to be maintained in the assessment year for the basis of measuring GCV of Fuel (For Ex. As Received Basis, As Fired Basis, As Dried Basis etc.) as followed in the baseline year i.e., if DC has submitted GCV value on "as received basis", the basis will be same in the assessment year as well. The DC has to write in the remarks/source of data field on basis of GCV taken in the assessment year. However, The EmAEA is requested to report the Fuel GCV "As fired basis" in the verification report, which may become baseline for subsequent PAT cycles.

5. Plant Stoppages and Start due to high Clinker stock or Silo Full to be considered as external factor: Necessary

documentation to be provided by DC as per the instructionsgiven in Cement sector Pro-forma.

6. Normalisation on Use of Wet Fly Ash due to non-availability of dry Fly Ash: DC has to submit proper authentic documents to establish the increase in energy during AY due to usage of wet fly ash due to external reason. EmAEA to establish the facts whether in the vicinity of the particular DC, other Plants/DCs are getting dry Fly ash or not

7. Some of the information sought under this annexure could be considered as supporting information/documents, which may help EmAEA in submitting the Form B.

8. Review of Section wise specific power consumption (Line wise)

Table 17: Section wise Specific Power Consumption Details

Sr No	Section	kWh/tonne of Material	Conversion Factor to Clinker	kWh/tonne of Clinker	kWh/tonne of Cement	Remarks
1	Crusher					
2	Raw Mill					
3	Kiln					
4	Coal/Petcoke Mill					
5	Cement Mill					
6	Packing					
7	Utilities					
8	Misc					
	Sum					

9. Demarcation of plant boundary is required with clear understanding of raw material input, Energy input, Power Import/Export, Intermediary product Import/Export, Colony Power, Construction/

Others Power, Power supplied to other Ancillary unit outside the plant boundary. A typical sample of Plant boundary condition is represented below

Power Generation	Qty	Energy Million kcal
Coal (Indian) (MT)	0.000	0.000
Coal (Imported) (MT)	0.000	0.000
Coal (Imported 2)- SA	0.000	0.000
Coal (Imported 3)	0.000	0.000
Coal (Lignite) (MT)	0.000	0.000
Coal Fine	0.000	0.000
Coal Dollar	0.000	0.000
Coal Dust	0.000	0.000
Pet Coke (MT)	0.000	0.000
Bio Mass (MT)	0.000	0.000
Pet Coke rejects	0.000	0.000
Others	0.000	0.000

CPP
Lakh kwh 0.000
CPP
Heat rate 0

Grid Export 0.000 Lakh kWh

FO (Tonne)	0.000	0.000
HSD (KL)	0.000	0.000
LSHS	0.000	0.000
LDO	0.000	0.000
Colony (lakh kwh)	0.000	0
Grid Electricity (Lakh kwh)	0.000	

DG
Heat Rate 0
Lakh kwh 0.000
DG

Process		
Coal (Indian) (MT)	0.000	0.000
Coal (Imported) (MT)	0.000	0.000
Coal (Imported 2)- SA	0.000	0.000
Coal (Imported 3)	0.000	0.000
Coal (Lignite)(MT)	0.000	0.000
Coal Fine	0.000	0.000
Coal Dollar	0.000	0.000
Coal Dust	0.000	0.000
Pet Coke (MT)	0.000	0.000
Bio Mass	0.000	0.000
petcoke rejects	0.000	0.000
Others	0.000	0.000

Clinkerisation-
Crushing/Raw Mill/Pyro

Grinding

Clinker Export 0.000 MT

OPC 0.000 MT

PPC 0.000 MT

Others 0.000 MT

FO (Tonne)	0.000	0.000
HSD (Tonne)	0.000	0.000
LSHS	0.000	0.000
LDO	0.000	0.000

limestone
Iron ore
Bauxite
Clay

Clinker Imp 0.000 MT
Gypsum 0.000 MT
Fly Ash 0.000 MT
Slag 0.000 MT
Others 0.000 MT

Thermal Energy	=	0.000 Million kCal
Total Equivalent major product of Cement	=	0.000 Lakh Tonne
Total Energy consumed (Thermal+Electrical)	=	0.000 Million kCal
Notional Energy Required for grinding of exported clinker	=	0.000 Million kCal
Notional Energy Required for clinkerization of imported clinker	=	0.000 Million kCal
Notional Energy for Power Purchased	=	0.000 Million kCal
Gate to Gate Energy Consumption	=	0.000 Million kCal
Gate to Gate SEC	=	0.000 kCal/kg

10. Mass and Energy balance verification

The clinker balance verification is required from Cement produced and Clinker factor with actual clinker produced by taking into account the Clinker stock difference and Clinker Import export. Similarly Energy balance up to clinkerisation could be verified as per the tabulated formulae

Table 18: Mass and Energy balance

Mass Balance Verification (A=B) Clinker Balance							
Sr No	Description	Unit	Year 1, 2007-08	Year 2, 2008-09	Year 3, 2009-10	Year 4, 2014-15	Remarks
A	Equivalent Clinker from total cement produced: [OPC x CFOPC]+[PPC x CFPPC)]+[PSC x CFPSC)]	Lakh tonnes					
B	Clinker Produced: Total Clinker Produced + (Clinker Imported- Clinker Exported)+(Opening Clinker Stock-Closing Clinker Stock)	Lakh tonnes					

Sr No	Description	Unit	Year 1, 2007-08	Year 2, 2008-09	Year 3, 2009-10	Year 4, 2014-15	Remarks
	% Variation	(A-B) x 100/A					
	Energy Balance Verification(C=D)						
C	FinalSEC (Before Normalisation)	kcal/kg equivalent cement					
D	(Thermal SEC for Clinkerization * PPC Clinker Factor) + (Electrical SEC for Clinkerization in thermal equivalent * PPC Clinker Factor) + (Electrical SEC for Cement grinding in thermal equivalent)	kcal/kg equivalent cement					
	% Variation	(C-D) x 100/C					

11. Section wise Screen shot of SCADA from CCR/DCS is to be included in the verification report

12. Raw material input in the Plant boundary to be recorded for inclusion in the verification report

13. Heat balance of Kilns (Kiln wise)for the assessment year is required to be included in the verification report with boundary and understanding on CV basis i.e., NCV or GCV of fuel

14. Calibration records of all weighing and measurement system with frequency of calibration to be included in the verification report

15. Clinker Factor Verification

The Clinker factor calculation is to be documented and produced in the verification report, the verification could be done by taking following factor into account from the pro-forma A1-A20

Table 19: Clinker Factor calculation

Item	Unit	Year1	Year2	Year3	Year 4	Remarks
Gypsum % in Cement	%					
Clinker used for PPC	tonne					
Clinker used for OPC	tonne					
Clinker used for PSC	tonne					
Clinker Used for Cement	tonne					
Gypsum used in OPC	tonne					
Gypsum used in PPC	tonne					
Gypsum used in PSC	tonne					
Clinker factor for PPC	factor					
Clinker Factor for OPC	factor					
Clinker Factor for PSC	factor					

16. Establishment of clear inclusion and exclusion from the plant boundary is maintained as in the baseline year.

17. Some of the factors, which are not covered in the cement sector pro-forma, the EmAEA is required to report it separately

7.4.   Annexure IV: Fertilizer

Fertilizer industry is maintaining an elaborate system of measurement and reporting of production and energy data in the form of "Technical Operating Data (TOP)", as per the guidelines of Fertilizer Industry Coordination Committee (FICC), Department of Fertilizers. The TOP data is also audited by cost accountant. TOP data can be accepted as such. In case of multi-product plants, distribution of raw materials, power, steam and other utilities to be segregated and quantities allocated for urea production are to be brought out distinctly.

1.0   Measurement & recording

In the following table, items have been identified, which are required for calculating material & energy balance at battery limit of the complex. Against each item, following information is to be furnished :-

a)   Measuring device: Name, tag number, model, location

b)   Accuracy level of measurement or date of last calibration. Correction factors (if any)

c)   Type of record: Data logger/ digital recorder, charts, direct reading/log book/ log sheet etc.

d)   Frequency of reading: Hourly, shift wise, daily, periodically

e)   Whether the quantities are ascertained by material balance?

f)   Stock verification

Table 20: Material and Energy balance of Fertilizer sector

Sr. No.	Item	Unit	Measuring device Name/ tag no/model/ location	Accuracy level / correction factors (if any)	Records Type/ Location	Frequency of reading	Remarks
1.0	**Final/ intermediate products**						
1.1	**Urea production**	MT					
1.2	**Ammonia**						
1.2.1	Production	MT					
1.2.2	Consumption for urea	MT					
1.2.3	Consumption for other products	MT					
1.2.4	Sent to storage	MT					
1.2.5	Received from storage	MT					
1.2.6	Export	MT					
2.0	**Input raw materials**						
2.1	Natural gas						
2.1.1	Properties						
a	GCV	Kcal/ SCM					
b	NCV	Kcal/ SCM					
2.1.2	Total receipt						
a	Main receiving station	MMSCMD					

Sr. No.	Item		Unit	Measuring device Name/ tag no/model/ location	Accuracy level / correction factors (if any)	Records Type/ Location	Frequency of reading	Remarks
2.1.3	Distribution							
	a	Reformer feed	MMSCMD					
	b	Reformer fuel	MMSCMD					
	c	Gas turbine	MMSCMD					
	d	HRU	MMSCMD					
	e	Boilers	MMSCMD					
	f	Others	MMSCMD					
2.2	**Naphtha**							
2.2.1	**Properties**							
	a	Sp. Gravity	gm/cc					
	b	GCV	Kcal/kg					
	c	NCV	Kcal/kg					
2.2.2	**Total receipt**							
	a	Volume	kl					
	b	Weight	MT					
2.2.3	**Distribution**							
	a	Reformer feed	MT					
	b	Reformer fuel	MT					
	c	Others	MT					
2.3	**Diesel**							
2.3.1	**Properties**							
	a	Sp. Gravity	gm/cc					
	b	GCV	Kcal/kg					
	c	NCV	Kcal/kg					
2.3.2	**Total receipt**							
	a	Volume	kl					
	b	Weight	MT					
3.3	**Distribution**							
	a	DG Sets	kl					
	b	Others						
2.4	**Furnace oil /LSHS etc.**							
2.4.1	**Properties**							
	a	Sp. Gravity	gm/cc					
	b	GCV	Kcal/kg					

Sr. No.	Item	Unit	Measuring device Name/ tag no/model/ location	Accuracy level / correction factors (if any)	Records Type/ Location	Frequency of reading	Remarks
c	NCV	Kcal/kg					
2.4.2	**Total receipt**						
	Volume	kl					
	Weight	MT					
2.4.3	**Distribution**						
a	Boiler	MT					
b	Other furnaces (specify)	MT					
c	Misc (if any)						
2.5	**Coal**						
2.5.1	**Properties**						
a	GCV	Kcal/kg					
b	NCV	Kcal/kg					
2.5.2	**Total receipt**						
a	Weight	MT					
2.5.3	**Distribution**						
a	Boilers(1+2+3)	MT					
b	Others (specify)	MT					
c	Stock variation						
2.6	**Any other fuel**						
3.0	**Steam**						
3.1	**Production**						
3.1.1	Boiler (Individual)						
3.1.2	GTG/HRU						
3.1.3	Service/auxiliary boiler						
3.1.4	Others						
3.2	**Consumption**						
3.2.1	Steam turbo generator						
3.2.2	Ammonia plant						
3.3.3	Urea plant						
3.3.4	Others						

2. Material balance of all inputs at battery limit of entire complex

Following information is to be filled-in as follows:-

(i) One month having best operation as per TOP.

(ii) For financial year, as per TOP.

Table 21: Material balance of all inputs in Fertilzer sector

Sr. No.		Item	Unit	Received at plant battery limit	Allocated for urea production	Allocated for other products	Difference if any	Remarks
1.0		**Purchased items**						
1.1		Purchased power	MWh					
1.2		Natural gas	MMSCMD					
1.3		Naphtha						
	a	Volume	Kl					
	b	Weight	MT					
1.4		Diesel	Kl					
1.5		Furnace oil /LSHS etc.						
	a	Volume	Kl					
	b	Weight	MT					
1.6		Coal	MT					
1.7		Any other fuel						
2.0		Steam						
2.1		Production						
2.1.1		Boiler (Individual)	MT					
2.1.2		GTG/HRU	MT					
2.1.3		Service/auxiliary boiler	MT					
2.1.4		Others	MT					
2.2		Consumption	MT					
2.2.1		Steam turbo generator	MT					
2.2.2		Ammonia plant	MT					
2.2.3		Urea plant	MT					
2.2.4		Others	MT					
3.0		**Power**						
3.1		**Generation**	MWh					
3.1.1		GTG	MWh					
3.1.2		Others	MWh					
3.2		**Consumption**						
3.2.1		Ammonia plant	MWh					
3.2.2		Urea plant	MWh					
3.2.3		Others	MWh					

3. Pro-forma

a. Pro-forma

Under the PAT scheme, all DCs are required to fill-in and submit to BEE, Pro-forma, which is mandatory, with following salient features:

i. Plant capacity, production & capacity utilization

- Installed capacity
- Production
- Capacity utilization

ii. Purchased electricity – Purchased quantity, cost, consumption

iii. Generated electricity through DG/ turbo gen/gas turbine/co-generation

iv. Fuels – Gaseous (NG, LNG), Liquid (Naphtha, fuel oil, diesel) solid (coal, coke) – Purchased quantity, calorific value (GCV).

v. Consumption of energy input for

- Power generation
- Process raw material
- Process heating

vi. Using waste as fuel

vii. Use of non-conventional energy (Solar, wind, etc)

ix. Total energy input at BL

b. **Sector Specific Pro-forma**

Keeping in view the special requirements in fertilizer sector, the Pro-forma has been modified with following changes:-

i. Plant capacity is reported in following formats:-

1. **Name plate capacity:** The original name plate capacity at the time of installation of plant.

2. **Re-assessed capacity:** As revised by "Fertilizer Industry Coordination Committee (FICC) " in the year 2002.

3. **Baseline production:** As worked out (for urea product only) under PAT scheme. It is an average of production for three baseline years viz 2007-08, 08-09, 09-10.

4. **Re-vamp capacity:** Subsequent to baseline period i.e. 2007-10, some plants carried out major revamp to enhance capacity further. The capacity is as reported by DCs to Department of Fertilizers.

ii. **Calorific value of fuel**

In fertilizer sector, all the energy calculations are based on net calorific value (NCV) of fuel. NCV will also be furnished along with GCV.

iii. **Total inputs at plant battery limit**

In the existing Pro-forma, only the inputs, which are allocated for urea production, are furnished. Modified Pro-forma, provides for furnishing total inputs at plant battery limit in addition to the inputs allocated for urea product.

iv. **Quantity of natural gas**

Presently, natural gas is being received from a number of sources. Instead of giving quantity of natural gas received from different sources separately, total quantity shall be furnished at one place only. However break up of this quantity may be furnished for Feed and fuel along with respective NCV. Other fuels which are not in use in fertilizer sector have been removed.

4. **Annexure to Pro-forma**

The Pro-forma being of generic nature does not contain information specific to fertilizer sector. Therefore, additional technical information is furnished through "Annexure to Pro-forma. Information furnished in Annexure to Pro-forma is as following:

A. Installed capacity, production, CU, on-steam days for ammonia / urea for base 5 years.

B. Installed capacity has been substituted with re-assessed capacity.

C. Inputs to Ammonia Plant

- NG/RLNG/LNG/PMT (Feed, fuel) – Quantity, NCV
- Naphtha (Feed, fuel) – Quantity, NCV

- Steam / power – Quantity, conversion factor

- Credits / debits – DM Water heating, LP steam export etc.

- Ammonia production

D. **Inputs to Urea Plant**

- Ammonia consumption for urea

- Power/steam

- Credits/debits– DM Water heating, LP steam export etc.

E. Conversion factor for power generated.

F. Heat value of steam generated.

G. Information available in log sheets, log books, data logger print outs and other plant documents need to be verified with appropriate references.

5. **Plant battery limit block diagram**

Block diagram showing total energy input at Plant BL as well as credit / debit of energy at intermediate stages for establishment of " Base Line SEC"
To be filled-in by Designated Consumers (DC's)
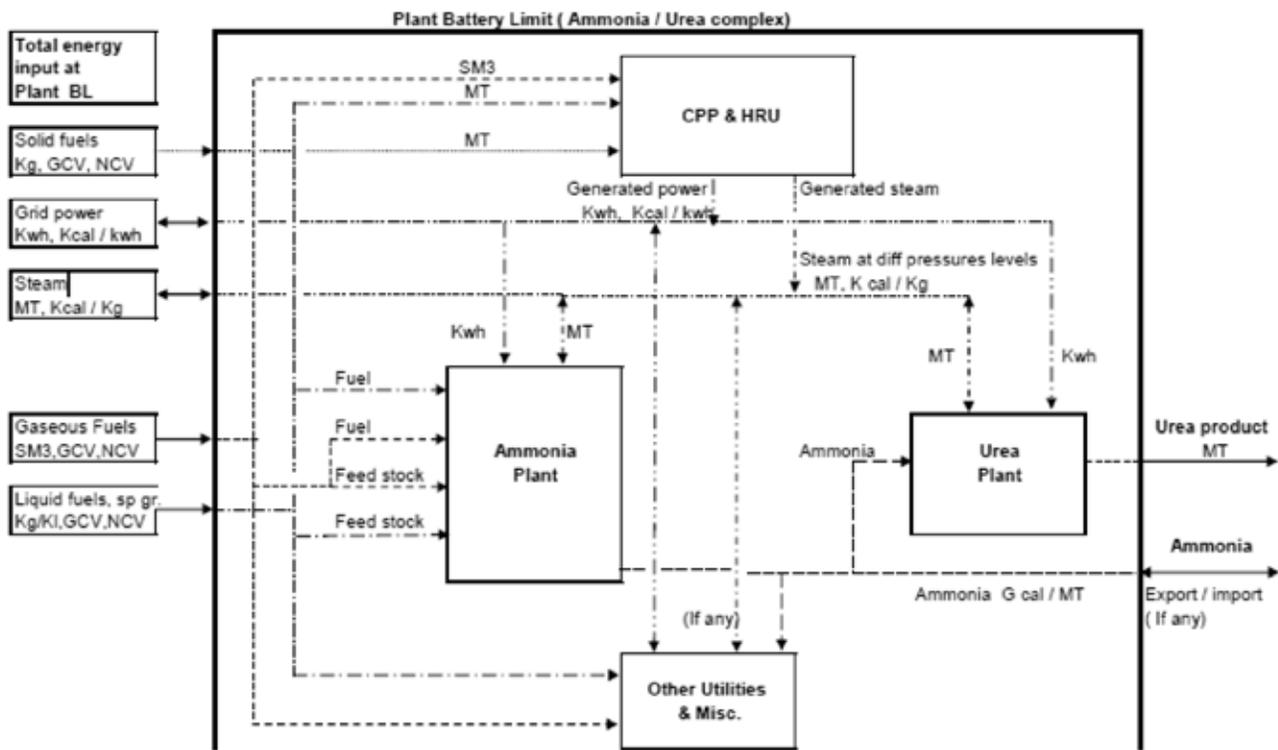
6. **Data not available in Pro-forma and Annexure – 1**

- Fuel input to boilers

- Waste gases available from ammonia/ urea plants and fed to boilers.

- Quantity of steam produced.

- Other energy inputs like pre-heated DM water

- Calculations for conversion factors of steam/power.

a. Additional information in Block diagram

The illustrative block diagram in sections - 5 above, when, filled adequately, incorporates missing information.

i. It depicts all inputs at plant battery limit, which may be

consumed for production of urea as well as other products.

ii. It also depicts all inputs allocated for urea production.

iii. Gives details on various imports/exports, debit/credit etc.

iv. One set of sample calculations of gate-to-gate energy balance to be furnished by DC.

v.   Basis of calculations, conversion factors, assumptions, import/export, credit/debit etc; to be mentioned specifically.

7. Procedure for calculation of specific energy consumption (SEC)

In general specific energy consumption (SEC) is calculated by dividing total energy input at battery limit by final product. However, in case of ammonia / urea complex, part of the input energy is utilized for manufacturing ammonia wherein Carbon-di-oxide (CO_2) is also produced as by-product. Ammonia and CO_2 are then reacted to produce urea. Part of the steam/power energy is consumed in urea plant. Further, full quantity of ammonia produced is not necessarily consumed for urea manufacture. Part of ammonia may go to storage or export. Similarly, part of steam / power may be either exported or imported. Therefore, in fertilizer sector, SEC of urea cannot be calculated directly by dividing total energy input by urea product. Following procedure is to be adopted for calculating SEC:-

a. Allocation of fuel for production of ammonia, power/steam and other products/facilities (wherever applicable).

b. Calculation of conversion factor for power generated (Kcal/Kwh) and its distribution.

c. Conversion factor for purchased power (taken as 2860 Kcal/Kwh).

d. Calculation of heat value of steam produced (Kcal/Kg) and its distribution.

e. Calculation of SEC for ammonia by considering the following:-

   i.   Feed & fuel energy input to ammonia plant directly

   ii. Allocation of steam/power to ammonia plant along with conversion factors.

   iii. Credit/debit of energy at ammonia plant battery limit like pre-heating of DM water, burning 'Off gases" in boiler furnace etc.

f. Calculation of SEC for urea by considering the following:-

   i.   Allocation of ammonia, separately as manufactured or purchased, for urea production.

   ii. Allocation of steam/power to ammonia plant along with conversion factors.

   iii. Credit/debit of energy by way of export of steam, burning vent gases etc.

Sr. No.	Description	Unit	Illustrative figures	Actual for 2014-15	Remarks
1.0	**Overall plant battery limit**				
1.1	**Inputs**				
1.1.1	Natural gas (NG)				
a	Quantity	MMSCM			
b	NCV of NG	Kcal/SCM			
1.1.2	Naphtha				
a	Quantity	kl			

Sr. No.	Description	Unit	Illustrative figures	Actual for 2014-15	Remarks
b	NCV of naphtha	Kcal/lit Kcal/kg			
c	Density of naphtha	gm/cc			
1.1.3	Grid power	MWh			
1.1.4	Steam	MT			
1.1.5	Ammonia	MT			
1.2	Output				
	Urea	MT			
	Power export	kWh			
2.0	**CPP/HRU**				
2.1	**Input**				
2.1.1	Natural gas	MMSCM			
2.2	Output				
2.2.1	Power	MkWh			
	Heat rate	Kcal/kWh			
2.2.2	Steam	MT			
	Heat content	Kcal/kg			
3.0	**Ammonia Plant**				
3.1	**Input**				
3.1.1	NG feed	MMSCM			
3.1.2	NG fuel	MMSCM			
3.1.3	Naphtha feed	kl			
3.1.4	Naphtha fuel	kl			
3.1.5	Steam	MT			
3.1.6	Power	MkWh			
3.2	**Output**				
3.2.1	Ammonia product	MT			
4.0	**Urea Plant**				
4.1	**Input**				
4.1.1	Ammonia	MT			
4.1.2	Steam	MT			
4.1.3	Power	MkWh			
4.2	**Output**				
4.2.1	Urea product	MT			
5.0	**Service boiler / Utilities**				
5.1	**Input**				
5.1.1	NG Fuel	MMSCM			
5.1.2	Naphtha fuel	kl			

8. Gate to Gate specific energy consumption (SEC)

i. Overall material & energy balance

An illustrative material & energy flow diagram of an ammonia/urea fertilizer complex is given below
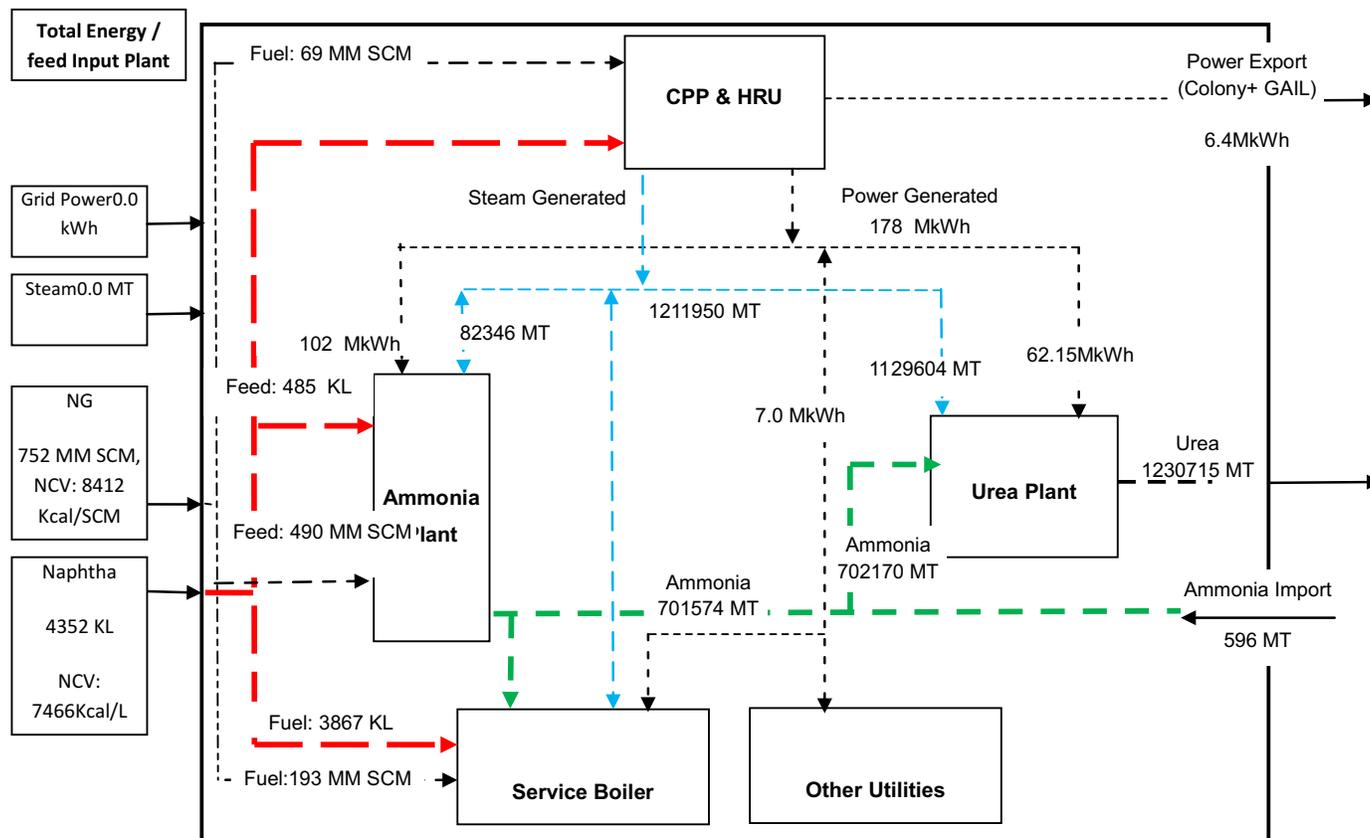
Figure 16: Overall Material and Energy balance. Figures mentioned above are indicative and used for representational purpose only . The actual data will vary from unit to unit .

II. CALCULATION OF SPECIFIC ENERGY CONSUMPTION (SEC) OF AMMONIA

(a)   Material balance of Natural Gas

Description	Quantity (MM SCM)	NCV (Kcal/SCM)	Heat content (Gcal) 2 x 3	Remarks
1	2	3	4	
Total input				
	752	8412	6325824	
Distribution				
CPP/HRU	69	8412	580428	
Reformer feed	490	8412	4121880	
Reformer fuel	193	8412	1623516	

(b)   Material balance of Naphtha

Description	Quantity (KL)	NCV (Kcal/ L)	Heat content (Gcal) 2 x 3	Remarks
1	3	2	4	5
Total input				
	4352	7466	32492	
Distribution				
Reformer feed	485	7466	3621	
Service boiler	3867	7466	28871	

c)   Energy balance in Ammonia Plant

Item	Unit	Quantity	NCV/ Heat value	Heat content Gcal	Specific energy consumption
Ammonia production	MT				
NG feed	MM SCM				
NG fuel	MM SCM				
Naphtha feed	MT				
Naphtha fuel	MT				
Steam	MT				
Power	MkWh				
Total feed energy	Gcal				
Total fuel energy	Gcal				
Power + steam	Gcal				
Total SEC	Gcal/MT				
Non plant energy	Gcal/MT				
SEC including non-plant energy	Gcal/MT				

(d)   Energy balance in Urea Plant

Item	Unit	Quantity	NCV/ Heat value	Heat content Gcal	Specific energy consumption
Urea production	MT	1230715			
Ammonia feed	MT	701574	7.691	5395806	4.384
Steam	MT	1129604	743	839295	0.682
Power	MkWh	62150	511	31759	0.026
Total energy	Gcal			6266860	
Total SEC	Gcal/MT				5.092
Non plant energy	Gcal/MT				0.079
SEC including non plant energy	Gcal/MT				5.171

9. Computing Baseline data

Under first cycle of PAT scheme, the baseline period constitutes the years 2007-08, 08-09 and 2009-10. Urea product has been taken as basis for calculating Specific energy consumption "SEC".

a. Production

Baseline production of urea is obtained by averaging urea production for three baseline years i.e. 2007-08, 08-09, 09-10. Production during target year (2014-15) is reported in the following table.

Sr. No.	Description	Unit	Baseline data				Assessment year
			2007-08	2008-09	2009-10	Average	2014-15
1.0	Urea product						
1.1	Installed capacity	MT				n.a.	
1.2	Actual production	MT					
1.3	Capacity Utilization	%				n.a.	

b. Specific energy consumption (SEC)

Baseline specific energy consumption (SEC) of urea is obtained by weighted average for three baseline years i.e. 2007-08, 08-09, 09-10. Specific energy consumption (SEC) during target year (2014-15) is reported in the following table.

Sr. No.	Description	Unit	Baseline data				Assessment year
			2007-08	2008-09	2009-10	Total	2014-15
1.0	Urea production	Tonnes				n.a.	
1.1	SEC	Gcal/ MT				n.a.	
1.2	Total energy	Gcal					
1.3	Weighted average	Gcal/MT	n.a	n.a	n.a		

10. Normalization factors

PAT procedure provides for "Normalization" of reported data based on capacity utilization factor, when plant load factor (PLF) has a deviation of more than 30%. The PAT procedure also provides for normalization by statistical analysis methods. In fertilizer sector, apart from capacity utilization, there are some other important factors viz. number of forced shut down of the plant, use of naphtha due to unavailability of natural gas, quality of coal and commissioning period after major revamp of the plant, which also affect specific energy consumption of product. Identified causes of un-productive energy consumption on account of factors, which are beyond the control of the plant are as follows:

(i) Forced shut down of the plant and subsequent Cold start up

(ii) List of critical equipment, which on failure, cause forced shut down.

(iii) Plant operation at low load

(iv) Reduction of ammonia synthesis and CO shift catalyst

(vi) Use of naphtha due to non-availability of gas

(vi) Deterioration in quality of coal

For calculating the unproductive energy consumption against individual factor, formats were developed showing illustrative calculations.

a. Low capacity utilization

In addition to the reasons for lower capacity as given in PAT document, lower capacity utilization due to following reasons has also been considered for normalization(i) shortage of raw material including feed, fuel, water, electricity etc. (ii) high cost of inputs leading to unviable urea production beyond certain capacity (iii) major equipment failure (iv) force majeure.

Factors like shortage of raw materials (mainly the gas), decline in market demand, change in Govt. policy etc. are beyond the control of DCs. These factors may force the plant to be operated at lower capacity, thus causing adverse effect on energy consumption. In such cases, normalization shall be allowed as follows.

i. Pre-requisites for Normalization

1. A DC shall furnish detailed and convincing reasons with supporting documents for reduction in capacity utilization, due to factors, beyond their control.

2. Following criteria shall be adopted:-

   a) No compensation shall be allowed if the capacity utilization of urea plant on annual basis is 95% or above.

   b) Compensation shall be allowed for capacity utilization between 70-95%.

   c) Below 70%, the data shall be discarded.

3. The claim will be based on Technical operating data (TOP), which is being reported to Fertilizer Industry Coordination Committee (FICC) of Department of Fertilizers, Govt. of India.

4. Normalization due to low capacity utilization will be considered only in one of the plants i.e. either ammonia or urea.

5. Subsequent to the baseline year i.e.2007-10, some DCs have carried out major revamp of their plant for capacity enhancement in line with New Investment Policy for urea notified by the Govt. in 2008. Govt. recognized enhanced capacity, while reimbursing cost of production under the pricing policy. The enhanced capacity shall be considered, while calculating capacity utilization for normalization, subject to confirmation from DoF, Government of India and also verification certificate issued by an Accredited Energy Auditor to DC which seek to declare their enhanced installed capacities, production and energy use. Cost of this audit will be borne by the DC. Check tests of such verification could be carried out by BEE, if needed.

6. Some plants are having ammonia plant capacity higher than the quantity of ammonia required for urea production and thus, diverting surplus ammonia for production of other products or direct sales. In such cases, due to Govt. policy and/or market conditions, consumption of surplus ammonia for production of other products becomes unviable and under these circumstances, ammonia plant is operated at lower capacity, thus resulting in higher energy consumption per MT of ammonia, which also get transferred to urea, even if the urea plant is operated at full load; Normalization shall be allowed.

7. In case of ammonia / urea complex having ammonia capacity matching with urea production, capacity utilization of urea plant shall be considered.

ii. Calculation of normalization factor

1. Based on the operating data collected from plants at 100%, 85% and 70% plant load, average normalization

---

factor works out to be 0.02 Gcal per MT of urea per percentage reduction in plant load below 95% up to 70%.

2. Impact of Lower Capacity utilization shall be worked out as follows:-

   a. Maximum permissible value (Gcal/ MT urea) = (95 - % Capacity utilization) * 0.02.

   b. Actual unproductive energy (Gcal/ MT urea) = Annual Energy, Gcal/MT of Urea - Weighted Average of Monthly Energy Consumptions for the months with Capacity Utilization of 100% or more

   c. Lowest of the either (a) or (c) shall be considered for allowing the impact of lower capacity utilization.

3. Impact of Lower Capacity utilization of plants where ammonia is surplus than required for urea production, shall be worked out as follows:

   a. Maximum permissible value (Gcal/ MT ammonia) = (95 - % Capacity utilization of ammonia plant) * 0.02 Gcal.

   b. Actual unproductive energy (Gcal/ MT urea) = Annual Energy, Gcal/ MT of ammonia - Weighted Average of Monthly Energy Consumptions for the months with ammonia plant Capacity Utilization of 100% or more

   c. Lowest of the above two shall be considered for allowing the impact of lower capacity utilization. In such cases, normalization due to low capacity utilization (i.e. <95%) will be allowed only in one of the plants i.e. either ammonia or urea.

4. Capacity utilization for urea plant will be calculated based on "Baseline urea Production".

   iii. Supporting data / documentation Data shall be maintained in the following formats:-

A.   Month-wise production & energy consumption during the year

Sr. No.	Month	Ammonia				Urea			
		On stream	production	CU	SEC	On stream	production	CU	SEC
		days	MT	%	Gcal/MT	days	MT	%	Gcal/MT
1	April								
2	May								
3	June								
4	July								
5	August								
6	September								
7	October								
8	November								
9	December								
10	January								
11	February								
12	March								

B.   Data for best operating months

Sr. No.	Best operating month	Ammonia production	CU	Urea production	CU	SEC Ammonia	SEC Urea	Reference
		MT	%	MT	%	Gcal/ MT	Gcal/ MT	

(i)   Take the month in which , plants have run for all the calendar days.

(ii)   Capacity utilization during the month should be equal to or above 100%.

b.   Cold startup of the plant after forced shut down

In case of sudden failure of a critical equipment as per the list below, or external factors (as notified), ammonia plant undergoes a forced shut down. Restarting the plant from cold conditions (Cold start up) , consumes unproductive energy and shall be normalized.

i.   Pre-requisites for Normalization

A.   The list of critical equipment failure of which leads to complete shutdown of plant and consequent cold start up, allowed under this normalization factor is   given below :-

1.   Primary Reformer

2.   Secondary Reformer

3.   Heat Exchange Reformer

4.   Reformed Gas Boiler

5.   Carbon dioxide absorber and stripper

6.   Air, Refrigeration and synthesis compressors

7.   Synthesis converters

8.   Synthesis Gas Waste Heat Boilers

9.   High pressure urea reactor, stripper and carbamate condenser

10.   Carbon dioxide compressor

11.   Utility boiler furnace

12.   Gas turbine/HRSG

13.   Cooling Tower

14.   Major Fire leading to complete shutdown of plant and cold startup

15.   Turbo generator along with GTG

16.   Purifier

17.   CO Shift Converter

B.   The Designated Consumer (DC) shall furnished a detailed report on failure of such equipment and its impact on energy consumption.

C.   The Designated Consumer shall declare with back up documentation, what portion of such unproductive consumption during the month is due to cold shutdown and startup activity.

D.   This actual energy loss due to shut down and cold startup in Gcal/MT of Urea shall be compensated, subject to maximum of 0.03 Gcal/MT of Urea.

ii. Calculation of normalization factor

A.   Energy loss during the month(s) for which additional cold startup is being claimed shall be calculated as follows:-

(i)   (Monthly Energy per MT of Ammonia during the month– Weighted Average Monthly Energy Consumption for the months with 100% on-stream days) X Monthly Ammonia production for the month of Startup.

(ii) This Energy Loss shall be divided by Annual Urea Production to identify total unproductive loss in a month.

(iii) The Designated Consumer shall declare what portion of such unproductive consumption during the month is due to cold shutdown and startup activity.

(iv) This actual energy loss due to shut down and cold startup in Gcal/ MT of Urea shall be compensated, subject to maximum of 0.03 Gcal/ MT of Urea.

(v) The failure of critical equipment leading to complete shutdown of plant and consequent cold start up, allowed under this normalization factor is given at Annexure -

iii. Documentation

Sr. No.	Description	Unit	2007-08	2008-09	2009-10	2014-15
1	Ammonia production	MT				
2	Urea production	MT				
3	Total no of cold start up	Nos				
4	Cold start up due to failure of major equipment	Nos				
5	For each start up					
a	Duration	hours				
b	Energy consumed	Gcal				

Note: For each shut down / cold start up, information to be filled-in separately.

c. Use of naphtha

A. Using part naphtha involves additional energy consumption as follows:-

    a) For each startup of facilities to use naphtha as feed including pre-reformer

    b) For the period of use of naphtha as feed

    c) For the period of use of naphtha as fuel

B. DCs shall furnish detailed and convincing reasons with supporting documents for use of naphtha due to non-availability of gas on account of factors, beyond their control.

i. Pre-requisites for Normalization

A. As per directives from Department of Fertilizers, Govt. of India, use of naphtha is to be discontinued in phased manner. As such, use of naphtha is not foreseen. However, provision is being made, in case naphtha has to be used due to shortage of natural gas in future, with permission from DoF.

B. In case of use of naphtha, DC will furnish details regarding non-availability of gas, leading to use of naphtha.

ii. Calculation of normalization factor

A. Following formula shall be used

Energy loss (Gcal/MT Urea) = (185*S + 0.625 * Nfeed + 0.443 * Nfuel) / urea production in MT

S=   1   if naphtha is used as feed in startup

S=   0   if naphta is not used as feed in startup

N_{Feedc}=   quantity of naphtha used as feed in MT.

N_{Fuelc}=   quanity of naphtha/LSHS/FO used as fuel in MT.

iii.   Documentation

Sr. No.	Description	Unit	2007-08	2008-09	2009-10	2014-15
1	Ammonia production	MT				
2	Urea production	MT				
3	NG consumption	MMSCMD				
4	Shortfall in NG	MMSCMD				
5	Equivalent naphtha	kl				
6	Actual naphtha used	kl				

d.   Catalyst reduction

Fresh catalyst is in oxidized form and needs to be reduced with synthesis gas, wherein hydrogen reacts with oxygen and gets converted into water. Whole plant is operated at 60-80% load for around 48 to 120 hours, depending upon type and quantity of catalyst. Thus, replacement / reduction of **ammonia synthesis and CO shift catalysts** consumes large amount of unproductive energy. Therefore, normalization due to replacement / reduction of these catalysts will be allowed.

i.   Pre-requisites for Normalization

A. In case of ammonia synthesis catalyst, in the older plants, oxidized form of the catalyst is used which takes around 4-5 days for reduction, causing corresponding un-productive energy consumption. Presently, " Pre-reduced catalyst" is also available, which is expansive but takes around 48 hours for reduction, thus consuming lesser un-productive energy. This aspect will be taken care , while calculating normalization factor.

B. This will be considered subject to certification by DCs and furnishing to BEE information as follows:

(i) Year in which the catalyst were last changed along with copies of purchase order, last placed with the vendor , time taken in commissioning of catalyst , facts and figures clearly indicating and quantifying rise in the energy consumption of plant due to the replacement of this catalyst.

(ii) Copies of purchase orders placed by units with the vendors for supply of fresh catalysts.

ii.   Calculation of normalization factor

Adjustment shall be allowed on the basis of actual plant data, subject to a maximum of 0.04 Gcal/MT of Urea.

e.   Deterioration in quality of coal

The quality of indigenous coal has been deteriorating gradually, thus affecting boiler efficiency adversely. The reduction in boiler efficiency due to poor quality of coal shall be compensated.

i.   Pre-Requisites for Normalization

Weighted average of three years data shall be worked out. In case there is significant variation, then normalization factor shall be applied based on the actual impact due to the variation.

ii. Calculation of normalization factor

A. Quality of coal affects boiler efficiency, which shall be calculated by following empirical formula:-

Boiler Efficiency = 92.5 – ((50*A+630 (M+9H)) / GCV.

Where

A = Ash content of coal (%)

M = Moisture (%)

H = Hydrogen (%)

GCV = Kcal/Kg

B. Boiler efficiency shall be converted into specific energy consumption, as follows:

Additional Energy Consumption, Gcal/ MT of Urea = Energy of Coal per MT of Urea in Target Year, Gcal/MT of Urea * (Boiler Efficiency in Base Year – Boiler Efficiency in Target Year)/Boiler Efficiency in Target Year.

iii. Documentation

A.   Coal consumption and analysis

Sr. No.	Parameters	Unit	2007-08	2008-09	2009-10	2014-15
1	Quantity of coal used	MT				
2	GCV (Weighted average)	Kcal/kg				
3	NCV (Weighted average)	Kcal/kg				
4	**Proximate analysis**					
A	Fixed carbon	%				
B	Volatile matter	%				
C	Moisture	%				
D	Ash	%				
5	**Ultimate analysis**					
A	Carbon	%				
B	Hydrogen	%				
C	Sulphur	%				
D	Nitrogen	%				
E	Oxygen	%				

f.   Additional provisions

i. Normalization factors to be applied during assessment year, shall also be applied on baseline data for 2007-10.

B. Provision of normalization factors is intended solely to save plants from penalties for non-achieving the saving targets, for reasons which are beyond the control of DCs. However, availing of any of the normalization factors shall render the DC ineligible for issuance of E-certificates under PAT scheme. Therefore DC should seek normalization only when specified energy saving target is not met due to reasons beyond control of DCs.

C. DC's claim will be examined based on Technical operating data (TOP), which is being reported to Fertilizer Industry Coordination Committee (FICC)   of Department of Fertilizers, Govt. of India as well as by auditors designated by Bureau of Energy Efficiency (BEE).

7.5. Annexure V: Aluminium

1. The energy required to transport mined bauxite to refining operations with inthe plant boundary, alumina to smelting operations, ingots to metal processors, and scrap from collection to melting is accounted as inside transportation and consider as energy used in plant.

2. Plant stoppages and start due to external factor: Necessary documents has to be provided by DC

3. Proper documents on Bauxite Quality for the purpose of normalization have to be maintained and submitted to EmAEA.

4. Refinery Mass Balance (Bauxite to alumina ratio): The DC has to provide necessary calculation document to EmAEA during M&V for verification of alumina product ratio.

5. Smelter Mass Balance (Alumina to Molten Aluminium ratio): The DC has to provide necessary calculation document to EmAEA during M & V for verification of Molten Aluminium product ratio

6. In Smelter Plant EmAEA has to verify BusBar Voltage drop and Anode-Cathode Distance in reduction cell.

7. DC needs to submit HMBD of Turbine system or characteristics curve between Load and Turbine Heat Rate PLF normalization. Equivalent capacity HMBD or characteristics curve shall be used, if OEM data is not available with the DC

8. In case of addition of new Potline, a DC shall submit all relevant design data of new Pot line to EmAEA for inclusion in the verification report

9. The baseline SEC factor used for product equivalent will be used for assessment year product equivalent. The major product of the baseline period will be considered in the assessment year. In case if any new product is introduced in the assessment year the SEC factor of assessment year will be used for converting to equivalent major product for the assessment period.

10. For Import or Export of Carbon Anode, DC shall be required to fill the Pro-forma the type of anode (i.e., Green Anode, Baked Anode or Rodded Anode) exported or imported in the Remarks Column. The SEC shall be for the type of Carbone Anode i.e., SEC up to the type of Carbon Anode produced. Generally for importing or exporting anodes, the energy shall be booked till the energy of baked anodes

1. Refinery

11. Review of Section wise Specific Energy Consumption

Table 22: Section wise Energy Consumption details

S. No	Section	Thermal energy Consumption	Electrical Energy Consumption	kWh/tone of Alumina	kWh/tone of Aluminium	Remarks
1	Grinding					
2	Digestion					
3	Clarification					
4	Precipitation					
5	Calcination					

12. Plant Boundary

Demarcation of plant boundary is required with clear understanding of raw material input, energy input, power import/ export, Intermediary product import/ export, Colony power, Construction power, power supplied to other ancillary unit outside of the plant boundary. Typical plant boundary conditions are produced below.
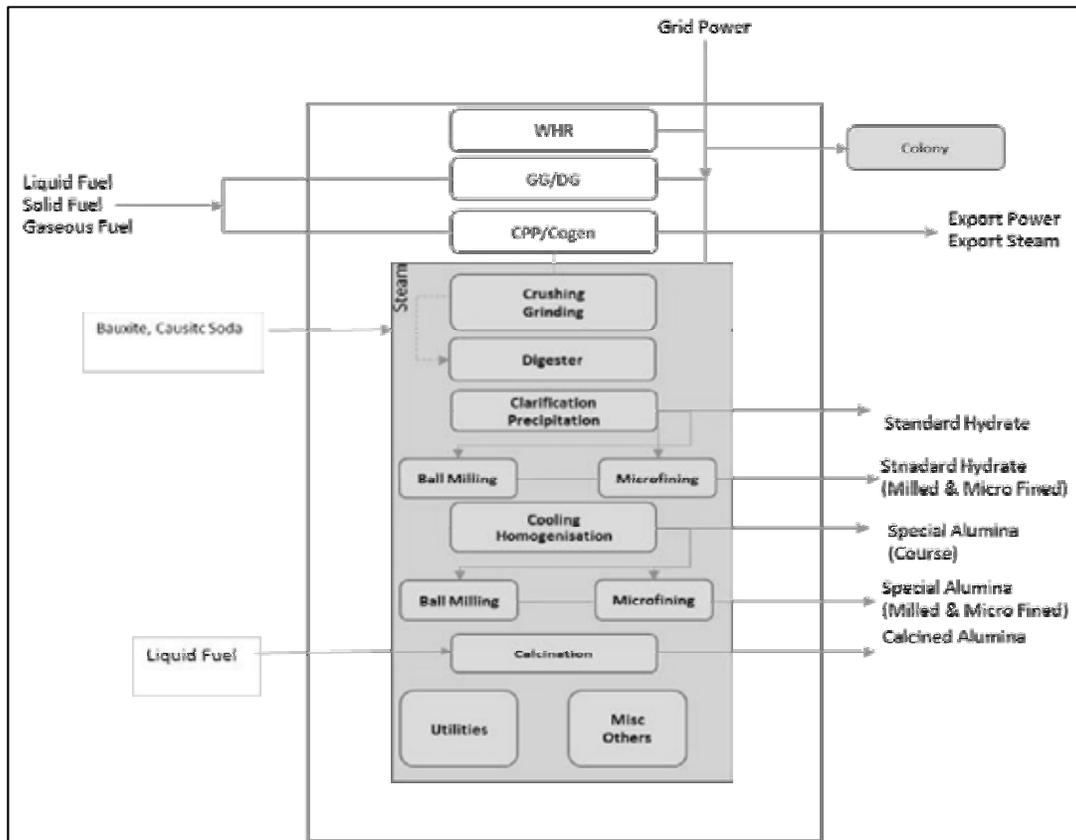
Figure 17: Ex- GtG boundary for Aluminium (Refinery sub sector)

B. Smelter

13. Carbon Anode to Molten Aluminium ratio: The DC has to provide necessary document to EmAEA during M & V. Approximately 0.45 kilograms of carbon anode were needed to produce one kilogram of aluminum

14. The smelter Energy consumption shall be taken up to Molten Alumina in the pro-forma

15. The additional cast house product shall be converted into one product and inserted in the Product "other" details in pro-forma

16. The energy used in smelter for imported scrap/ cold metal for production of finished products shall be considered for product equivalent hot metal SEC calculation

Table 23: Section wise Energy Consumption details

S.No	Section	Thermal Energy Consumption	Electrical Energy Consumption	kWh/tone of Anode	kWh/tone of Aluminium	Remarks
1	Pitch					
2	Coke					
3	Baking					

17. Electrolytic reduction energy consumption:

Table 24: Voltage Distribution

S.No	Reduction Cell (Section wise)	Voltage Distribution
1	External	
2	Anode	
3	Polarization	
4	Bath	
5	Reaction	
6	Cathode	
7	Other	

18. Plant Boundary

Demarcation of plant boundary is required with clear understanding of raw material input, energy input, power import/export, Intermediary product import/export, Colony power, Construction power, power supplied to other ancillary unit outside of the plant boundary. Typical plant boundary conditions are produced below
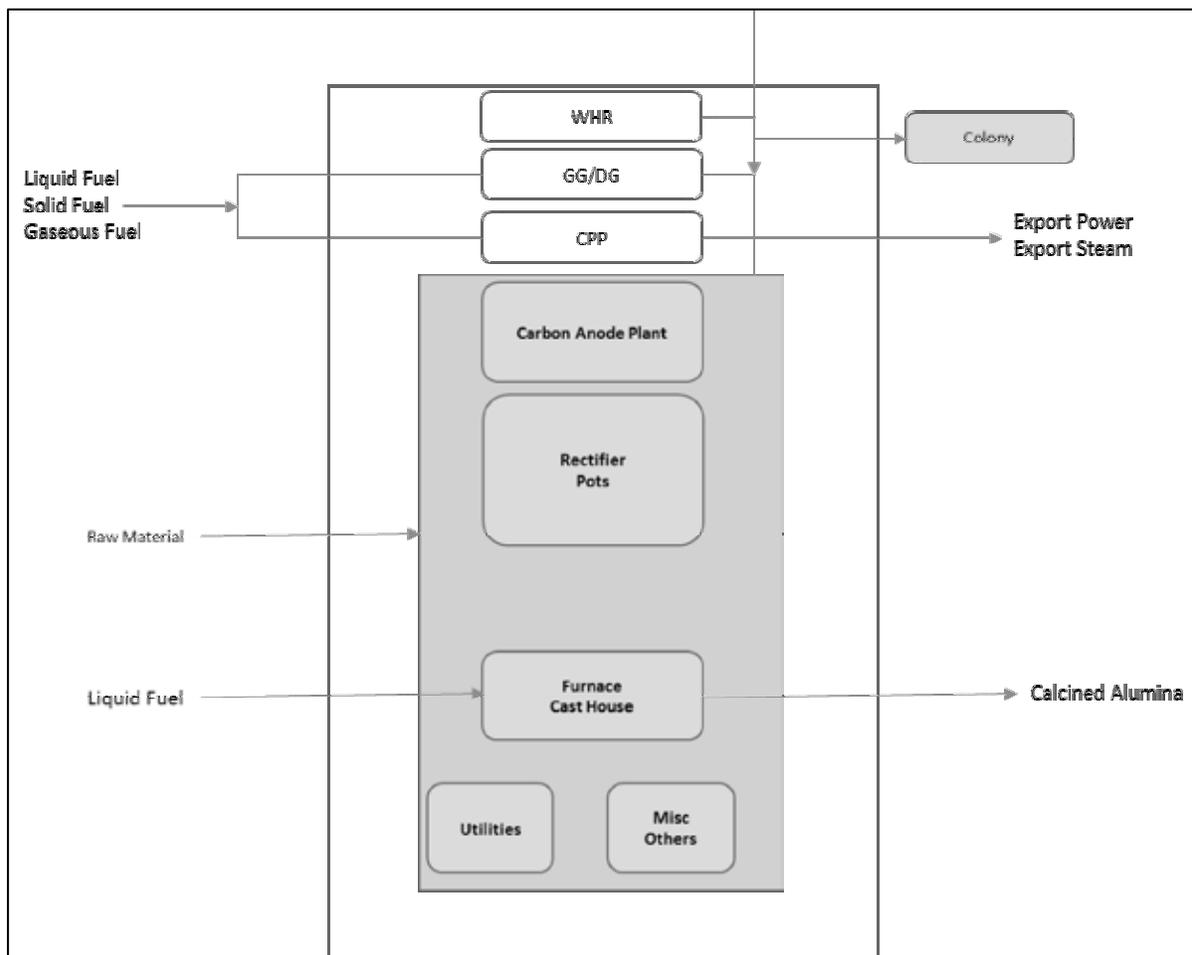
Figure 18: Ex- GtG boundary for Aluminium (Smelter sub sector)

C. Cold Sheet

19. Necessary documents as per the instruction in Form 1 need to be provided by DC to EmAEA for verification of section wise energy consumption and Specific Energy Consumption.

20. Product equivalent of other cold rolled products shall be calculated offline to to single cold rolled product through conversion from SEC of different cold rolled product.

21. Plant Boundary

Demarcation of plant boundary is required with clear understanding of raw material input, energy input, power import/export, Intermediary product import/export, Colony power, Construction power, power supplied to other ancillary unit outside of the plant boundary. Typical plant boundary conditions are produced below
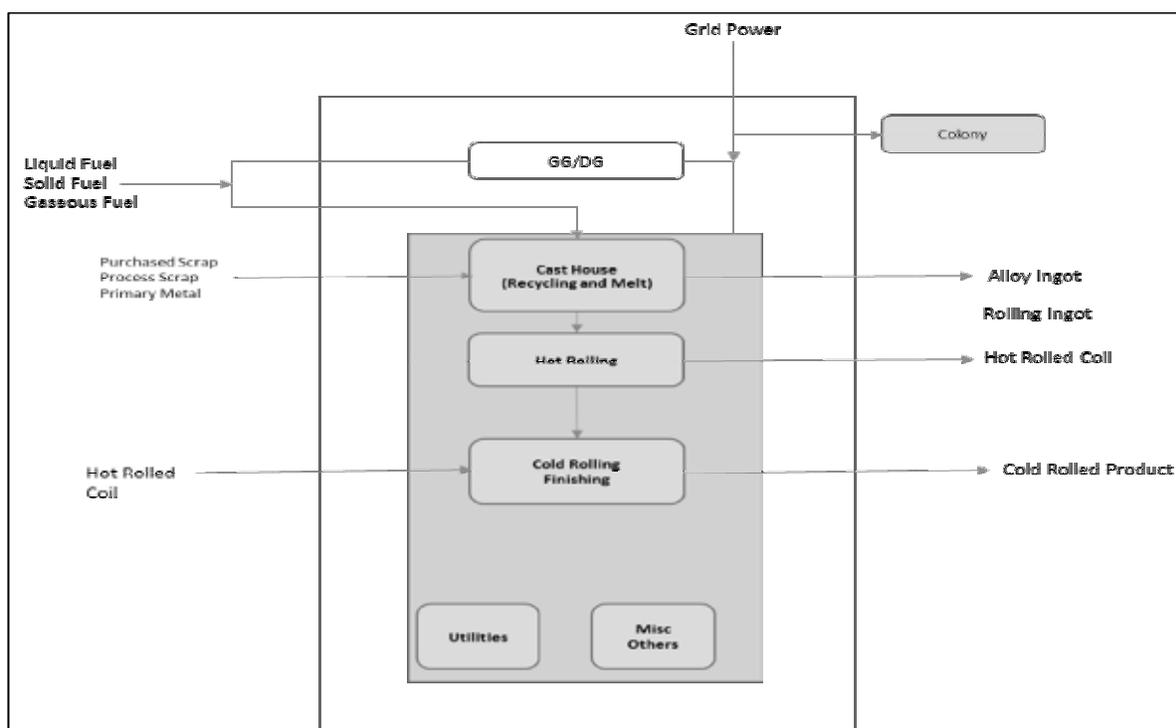
Figure 19: Ex- GtG boundary for Aluminium (Cold Sheet sub sector)

7.6. Annexure VI: Pulp & Paper

1. The boundary can be drawn virtually by including CPP or Cogen in the boundary limit of DCs, if nos DCs exist in a same boundary limit.

2. The captive power plant (CPP) or cogen will be taken into the virtual boundary of each DCs and accordingly import and export of power and steam will be treated as per Pro-forma data entry system.

3. If a captive power plant or cogeneration plant caters to two or more DCs for the electricity and/or steam requirements. In such scenario, each DC shall consider such captive power plant or cogeneration plant in its boundary and energy consumed by such captive power plant or cogeneration plant shall be included in the total energy consumption. However, electricity in terms of calorific value (as per actual heat rate) and steam in terms of calorific value (as per steam enthalpy) exported to other plants shall be subtracted from the total energy consumption.

4. It is to be noted that the same fuel input needs to be considered in case CPP is being taken into the boundary limit. By import and export of energy, the energy consumption from the CPP is automatically left out for the particular DC for SEC calculation.

5. Mill wise verification data are required to be included in the verification report

A. Wood Based Mills:-

a. The auditors may collect details required in M&V format by mentioning the source and document from where data is collected. Subsequently the data may be verified from the, data provided by the DC in sector specific Pro-forma for normalization.

b. The information required is shown in the flow chart for wood based pulp and paper mill

c. List of documents required for monitoring and verification

Table 25: General details required in wood based Pulp and Paper Mills

A.1 Raw Material Details

Type of Wood:-

Sr No	Name of the raw material	Moisture, %	Quantity, tonne/annum	Source/ document
1				
2				
3				
4				
5				

A.2 Wood Pulp Mill (Including Raw material, Chipper , Digester , WSC, ODL , Bleach Plant, Recovery , WTP, and ETP)

i) Pulping Processes Used

Sr No	Type of pulping	Capacity tonne/annum	Production tonne/annum	Total Yield (Including screening losses)	Source / Document
1	Chemical				
2	Semi Chemical				
3	Chemi Thermo Mechanical				
4	Other				

ii) Extended Delignification (ODL)

Sr No	Item	Unit	Value	Source / Document
1	Capacity	tonne/ annum		
2	Date of Installation of ODL Plant	Date		

---

iii)   Bleaching

Sr No	Item	Chemical Pulp	Semi Chemical	Chemical Thermo Mechanical Pulp
1	Type of Bleaching	ECF/conv.	ECF/conv.	ECF/conv.
2	Sequence Used			
3	Bleaching Losses %			
4	Bleached Pulp Yield %			
5	Brightness of pulp, %			

Sr No	Item	Unit	Value	Source / Document
1	Capacity	Tonne/ annum		
2	Date of Installation of ECL Plant	Date		

iv)   Energy Consumption in Pulp Mill

Sr No	Item	Qty	Source/ Document
1	Steam Consumption, LP/a		
2	Steam Consumption, MP/a		
3	Power Consumption, kWh/a		

v)   Pulp Dryer

Sr No	Item	Unit	Qty	Source / Document
1	Capacity	Tonne/annum		
2	Production of salable pulp, t/a	Tonne/annum		
3	Energy Consumption in pulp dryer	kcal		
4	LP Steam Consumption	Tonne/annum		
5	MP Steam Consumption	Tonne/annum		
6	Power Consumption	kWh/annum		

vi)   Chemical Recovery

Sr No	Item	Unit	Data	Source / Document
1	Type of chemical recovery	Conventional/Non-Conventional		
2	Total Black liquor Solids generated	Tonnes		
3	In Lime Kiln Installed	Yes/No		
4	Date of Installation of Lime Kiln I	Date		
5	Date of Installation of Lime Kiln II	Date		
6	Date of Installation of Lime Kiln III	Date		

vii)   Over-all Energy consumption in pulp mill

Sr No	Item	Qty	Source / Document
1	LP Steam consumption, t/a		
2	MP Steam consumption, t/a		
3	Power consumption, kWh/a		

A.3 Paper Machine (including stock preparation, chemical preparation / addition plant, finishing house)

(i)   Paper Machine Details

Number of Paper Machines

Item	PM-1	PM-2	PM-3	PM-4	PM-5	Source/ document
Type of paper machine						
Capacity,t/a						
Type of paper produced						
Production, t/a						
Annual weight average GSM						
Energy Consumption in paper machine (including Stock Preparation, chemical addition and finishing house)						
LP Steam consumption t/a						
MP Steam consumption, t/a						
Power consumption, kWh/a						

(ii)   Coating / Value addition

Coating If any   Yes /No

Type of coating   online / offline

Item	Qty	Source/ document
Capacity of offline coating plant, t/a		
Production of coated paper/board, t/a		
LP Steam consumption,t/a		
MP Steam consumption, t/a		
Power consumption, kWh/a		

(iii) Over-all Energy consumption in paper machine,stock preparation, chemical preparation and addition plant , finishing house and offline coating plant add (i+ii)

	Qty	Source/ document
LP Steam consumption,t/a		
MP Steam consumption, t/a		
Power consumption, kWh/a		

A.3   The Information required is shown in the Flow Chart for Wood Based Pulp and Paper Mill
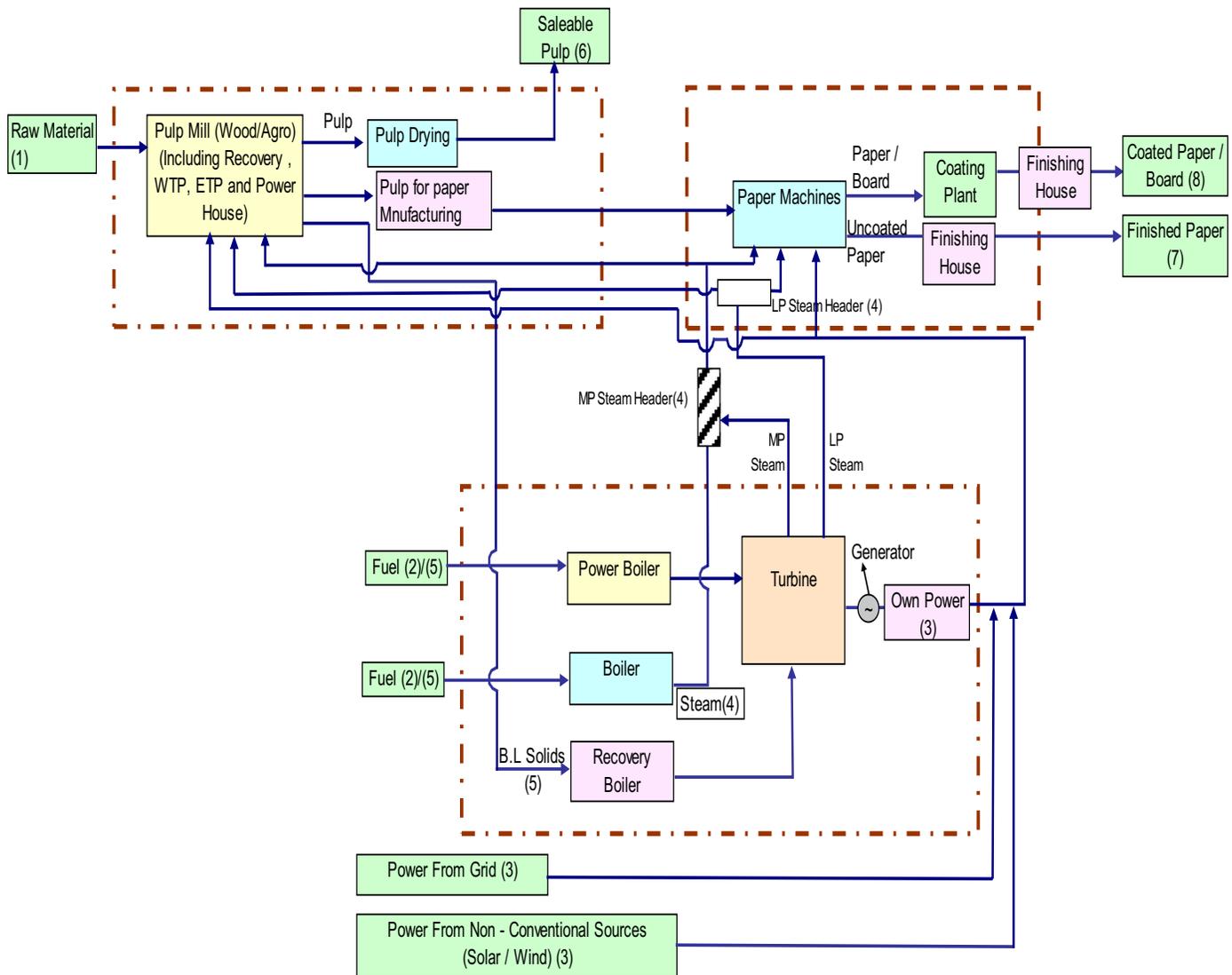
Figure 20: Ex- GtG boundary and metering details for Wood based Pulp and Paper Mill

Monitoring & Verification Guidelines

Table 26: Documents required wood based Pulp and Paper Mills

S.No.	Details of input and output	Source / Type of document required	Details of the Source / document and frequency
1	Raw Materials	Lab Report	Report on moisture(%), Ash (%) and other analysis of the raw materials used by the mill
			Frequency: Daily/ weekly/ monthly/ annual lab reports may be produced for different types of raw materials used by the mills.
		Purchase Document From Purchase Department	Purchase documents providing details of raw material purchased by the mill
			Frequency: Daily/ weekly/ monthly/ annual purchase documents may be produced for purchase of different types of raw materials used by the mills
		Raw Material Consumption Reports	Consumption reports giving details of raw material consumed by the mill. The report may be for raw material chip production, digester loading etc. from the concerned department.
			Frequency: Daily/ weekly/ monthly/ annual consumption documents may be produced for different types of raw materials used by the mill in chipper / digesters house..
		Annual Report	Annual report showing details of raw materials consumed on annual basis by the mill.
			Frequency: Annual consumption of raw materials by the mill.
2	Purchased Fuels	Fuel Purchase report/ documents	Purchase documents providing details of fuel purchased by the mill.
			Frequency: Daily/ weekly/ monthly/ annual purchase documents may be produced for purchase of different types of fuels used by the mills.
		Lab report for GCV moisture and Ash	Lab report on GCV, moisture(%), Ash (%) and other analysis (proximate and ultimate) density etc, of the fuel used by mill.
			Frequency: Daily/ weekly/ monthly/ annual lab reports may be produced for different types of fuels used by the mills.
		Fuel Consumption Report	Consumption reports giving details of fuel consumed by the mill in boilers, DG sets etc. The consumption report may be from the concerned department showing details of fuel consumption.
			Frequency: Daily/ weekly/ monthly/ annual fuel consumption documents may be produced for different types of fuels used by the mill in boiler/DG sets etc.
		Annual Report	Annual report showing details of fuels consumed on annual basis by the mill.
			Frequency: Annual consumption of fuels by the mill.

S.No.	Details of input and output	Source / Type of document required	Details of the Source / document and frequency
3	Power	Electricity Purchased from Grid	Purchased electricity bill from state electricity board providing details of the electricity purchased by the mill.
			Frequency: monthly/ annual purchased electricity bills may be produced by the mills.
		Own power generation	Details of own power generation from different sources such as turbines(gas, steam etc), DG sets.
			Frequency: Daily/ weekly/ monthly/ annual own generation reports may be produced by the mills. These reports may be the log sheets/ production reports from power house.
		Production of power from Non Conventional sources, e.g. Solar / wind power	Details of power generation from different Non-conventional sources such as Solar / wind turbines, bio gas etc.
			Frequency: Daily/ weekly/ monthly/ annual Power generation reports may be produced by the mills. These reports may be the log sheets/ production reports from concerned power houses / departments
		Annual Report	Annual report showing details of Power purchased from grid, own power generation, power from non-conventional sources etc.
			Frequency: Annual report of power purchased , own generation, generation from non- conventional sources etc.by the mill.
4	Steam	Steam generation by the mill	Details of Steam generation from different boilers, extraction of steam from turbines, steam generation from waste heat recovery and non-conventional sources(Solar steam generators)
			Frequency: Daily/ weekly/ monthly/ annual steam generation reports may be produced by the mills. These reports may be the log sheets/ production reports for steam generation from boiler house etc.
		Steam consumption by the mill	Details of Steam consumption in different sections of the mill such as pulp mill, chemical recovery, paper machine, power house and other plants of the mill.
			Frequency: Daily/ weekly/ monthly/ annual steam consumption reports may be produced by the mills. These reports may be the log sheets/ consumption reports for steam consumption by individual section of the mill or power boiler house.
		Annual Reports	Annual report showing details of Steam Generation and consumption from various sources. The generation and consumption of steam may be in individual departments as well as for the whole mill, boilers, extraction steam, steam from non-conventional sources etc.
			Frequency: Annual report of steam generation and consumption by the mill.

S.No.	Details of input and output	Source / Type of document required	Details of the Source / document and frequency
5	Internally Generated Fuels (Black liquor solids, pith, chipper dust)	Generation report of Black liquor, pith, chipper dust, etc	Details of generation of black liquor, pith, chipper dust or any other combustible waste by the mill from different sections such as chipper house, pulp mill, other plants.
			Frequency: Daily/ weekly/ monthly/ annual Black liquor, dust etc generation reports may be produced by the mills. These reports may be the log sheets/ production reports for Black liquor and pith generation from boiler house etc.
		Lab reports for GCV, solids, moisture, ash etc.	Lab report on GCV, solids (%) moisture(%), Ash (%) and other analysis (proximate) of the Black liquor, pith, dust etc. used by the mill.
			Frequency: Daily/ weekly/ monthly/ annual lab reports may be produced for different types of Black liquor, pith, dust etc. used by the mill.
		Annual Report	Annual report showing details of Black liquor generation, dust and pith generation, from various sources such as pulp mill, chippers, etc.
			Frequency: Annual report of Black liquor, pith and dust generation by the mill.
6	Saleable Pulp	Opening and closing stock of saleable pulp	Documents providing details of opening and closing of saleable pulp records by the mill.
			Frequency: Daily/ weekly/ monthly/ annual opening and closing records of the saleable pulp stock may be produced for different types of pulps produced by the mill.
		Saleable pulp production	Documents providing details of production of saleable pulp from different raw materials by the mill.
			Frequency: Daily/ weekly/ monthly/ annual production records/ documents providing details of saleable pulp from different types of raw materials produced by the mill.
		Annual Report	Annual report showing details of saleable pulp production from different raw materials and its consumption etc. Also the annual stock closing and opening of the saleable pulp from annual report may be produced
			Frequency: Annual report of saleable pulp production, consumption and stock (opening/ closing) by the mill.
7	Uncoated paper/ board, Newsprint, Specialty grade	Opening and closing stock reports	Documents/ records providing details of opening and closing of Uncoated paper / board, Newsprint, Specialty grade paper products by the mill.
			Frequency: Daily/ weekly/ monthly/ annual opening and closing records of Uncoated paper / board, Newsprint, Specialty grade paper products, produced by the mill.

S.No.	Details of input and output	Source / Type of document required	Details of the Source / document and frequency
		Paper production report / documents	Documents providing details of production of Uncoated paper/board, Newsprint, Specialty grade paper products, produced by the mill
			Frequency: Daily/weekly/ monthly/ annual production records/documents providing details of Uncoated paper/board, Newsprint, Specialty grade paper products, produced by the mill.
		Annual Report	Annual report showing details of Uncoated paper / board, Newsprint, Specialty grade paper products, produced by the mill.
			Also the annual stock closing and opening of the Uncoated paper / board, Newsprint, Specialty grade paper products, produced by the mill
			from annual report may be produced
			Frequency: Annual report of Uncoated paper / board, Newsprint , Specialty grade paper products, produced and stock (opening/ closing) by the mill.
8	Coated Paper / board	Opening and closing stock reports	Documents/ records providing details of opening and closing of Coated Paper / board by the mill.
			Frequency: Daily/ weekly/ monthly/ annual opening and closing records of Coated Paper / board, produced by the mill.
		Paper production report / documents	Documents providing details of production of Coated Paper / board produced by the mill
			Frequency: Daily/ weekly/ monthly/ annual production records/ documents providing details of Coated Paper / board produced by the mill.
		Annual Report	Annual report showing details of Coated Paper / board, produced by the mill.
			Also the annual stock closing and opening of the Coated Paper / board, produced by the mill
			from annual report may be produced
			Frequency: Annual report of Coated Paper / board, produced and stock (opening/ closing) by the mill.

B.   Agro Based Mills:-

a.   The auditor may collect details required in M&V by mentioning the source and document from where data is collected. Subsequently the data may be verified from the data provided by the DC in pro-forma for normalization.

b.   The information required is shown in the flow chart for Agro based pulp and paper mill.

c.   List of documents required for various monitoring and verification

Table 27: General details required in Agro based Pulp and Paper Mills

B.1 Raw Material Details

Type of Agro Paper

Name of the raw material	Moisture, %	Quantity, t/a	Source/ document

Whether Depithing at Mill Site   Yes / No

B.2 Depither Details

Item	Unit	Qty	Source/ document
No. of Depithers	Nos		
Capacity	Tonne/annum		
Type of depithing,	Wet/dry		
Moisture	%		
Pith removal	%		

B.3   AgroPulp Mill (Including Raw material, Pulper, Digester , WSC, ODL , Recovery, Bleach Plant, WTP, and ETP)

i)   Pulping Process Used

Type of pulping	Capacity t/a	Production t/a	Total Yield (Including screening losses)	Source / Document
Chemical				
Semi Chemical				
Chemi Thermo Mechanical				
Other				

ii)   Refining Details

Items	Unit	Qty	Source / Document
Type of refiners			
Capacity of Refiner, t/a	Tonne/annum		
Pulp Yield, %	%		

---

iii)   Extended Delignification (ODL)

Item	Unit	Qty.	Source / Document
Extended Delignification (ODL)	Yes/No		
Capacity	Tonne/annum		
Date of Installation of ODL Plant	Date		

v)   Bleaching

Item	Chemical Pulp	Semi Chemical	Chemical Thermo Mechanical Pulp
Type of Bleaching	ECF/conv.	ECF/conv.	ECF/conv.
Sequence Used			
Bleaching Losses %			
Bleached Pulp Yield %			
Brightness of pulp, %			

Item	Date	Source / Document
Date of Installation of ECF Bleach Plant		

vi)   Energy Consumption in Pulp Mill

Item	Qty	Source/ Document
LP Steam Consumption, t/a		
MP Steam Consumption, t/a		
Power Consumption, kWh/a		

v)   Pulp Dryer

Sr No	Item	Unit	Qty	Source / Document
1	Capacity	Tonne/annum		
2	Production of salable pulp	Tonne/annum		
3	Energy Consumption in pulp dryer	kcal		
4	LP Steam Consumption	Tonne/annum		
5	MP Steam Consumption	Tonne/annum		
6	Power Consumption	kWh/annum		

vi)   Chemical Recovery

Sr No	Item	Unit	Data	Source / Document
1	Type of chemical recovery	Conventional/ Non-Conventional		
2	Total Black liquor Solids generated	Tonnes		
3	In Lime Kiln Installed	Yes/No		
4	Date of Installation of Lime Kiln I	Date		
5	Date of Installation of Lime Kiln II	Date		
6	Date of Installation of Lime Kiln III	Date		

vii)   Over-all Energy consumption in pulp mill

Item	Qty	Source / Document
LP Steam consumption, t/a		
MP Steam consumption, t/a		
Power consumption, kWh/a		

B.4   Paper Machine (including stock preparation, chemical preparation/addition plant, finishing house)

(i)   Paper Machine Details

Number of Paper Machines

Item	PM-1	PM-2	PM-3	PM-4	PM-5	Source/ document
Type of paper machine						
Capacity, t/a						
Type of paper produced						
Production, t/a						
Annual weight average GSM						
Energy Consumption in paper machine (including Stock Preparation , chemical addition and finishing house)						
LP Steam consumption t/a						
MP Steam consumption, t/a						
Power consumption, kWh/a						

(ii)   Coating / Value addition

Coating If any   Yes /No
Type of coating   online / offline

Item	Qty	Source/ document
Capacity of offline coating plant, t/a		
Production of coated paper/board, t/a		
LP Steam consumption, t/a		
MP Steam consumption, t/a		
Power consumption, kWh/a		

(iii)   Over-all Energy consumption in paper machine,stock preparation, chemical preparation and addition plant , finishing house and offline coating plant add (i+ii)

	Qty	Source/ document
LP Steam consumption, t/a		
MP Steam consumption, t/a		
Power consumption, kWh/a		

B.5 The Information required is shown in the Flow Chart for Agro Based Pulp and Paper Mill

Figure 21: Ex- GtG boundary and metering details for Agro based Pulp and Paper Mill
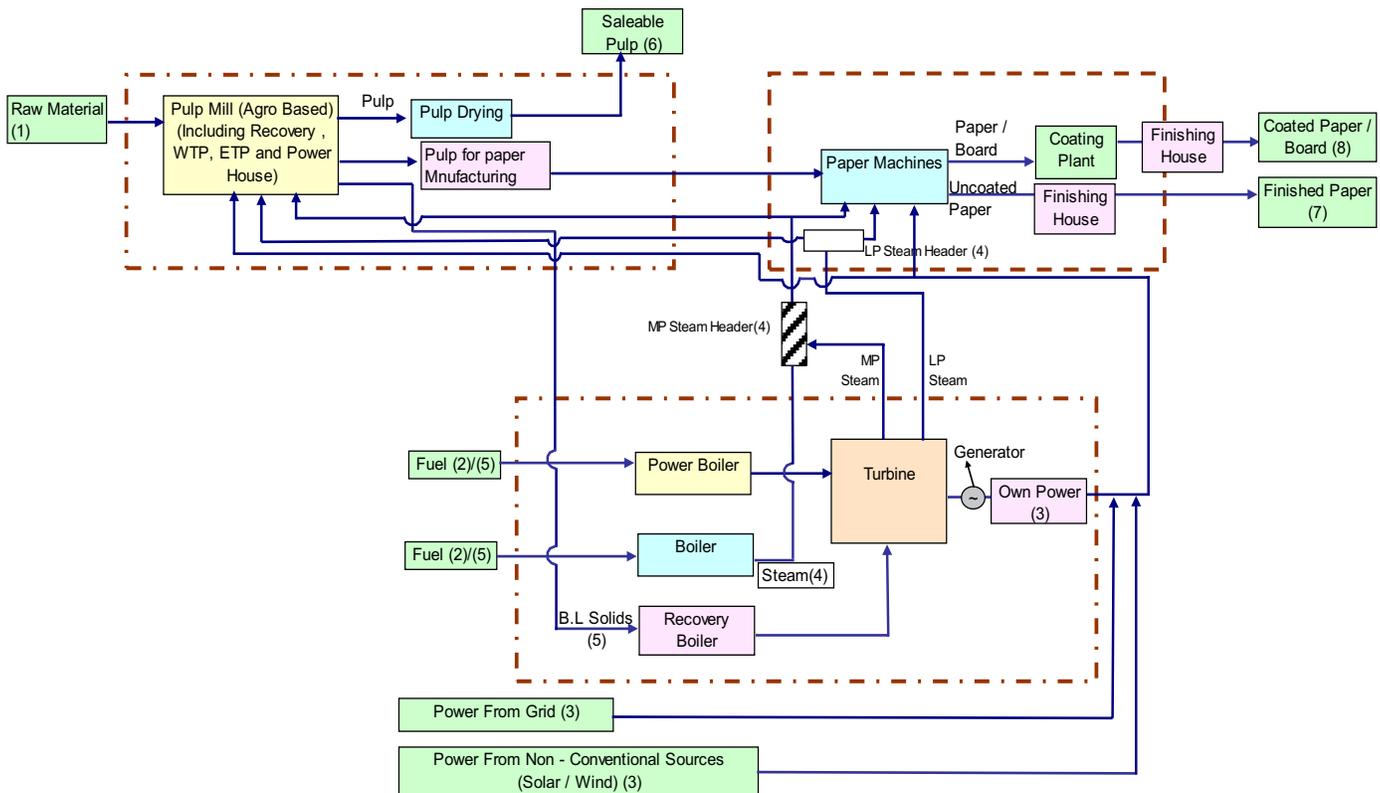
Table 28: Document required for Agro based Pulp and Paper Mills

S.No.	Details of input and output	Source / Type of document required	Details of the Source / document and frequency
1	Raw Materials	Lab Report	Report on moisture(%), Ash (%) and other analysis of the raw materials used by the mill Frequency: Daily/ weekly/ monthly/ annual lab reports may be produced for different types of raw materials used by the mills.
		Purchase Document From Purchase Department	Purchase documents providing details of raw material purchased by the mill Frequency: Daily/ weekly/ monthly/ annual purchase documents may be produced for purchase of different types of raw materials used by the mills
		Raw Material Consumption Reports	Consumption reports giving details of raw material consumed by the mill. The report may be for raw material chip production, digester loading etc. from the concerned department. Frequency: Daily/ weekly/ monthly/ annual consumption documents may be produced for different types of raw materials used by the mill in chipper / digesters house..
		Annual Report	Annual report showing details of raw materials consumed on annual basis by the mill. Frequency: Annual consumption of raw materials by the mill.
2	Purchased Fuels	Fuel Purchase report / documents	Purchase documents providing details of fuel purchased by the mill. Frequency: Daily/ weekly/ monthly/ annual purchase documents may be produced for purchase of different types of fuels used by the mills.
		Lab report for GCV moisture and Ash	Lab report on GCV, moisture(%), Ash (%) and other analysis (proximate and ultimate) density etc, of the fuel used by mill. Frequency: Daily/ weekly/ monthly/ annual lab reports may be produced for different types of fuels used by the mills.
		Fuel Consumption Report	Consumption reports giving details of fuel consumed by the mill in boilers, DG sets etc. The consumption report may be from the concerned department showing details of fuel consumption. Frequency: Daily/ weekly/ monthly/ annual fuel consumption documents may be produced for different types of fuels used by the mill in boiler/DG sets etc.
		Annual Report	Annual report showing details of fuels consumed on annual basis by the mill. Frequency: Annual consumption of fuels by the mill.

S.No.	Details of input and output	Source / Type of document required	Details of the Source / document and frequency
3	Power	Electricity Purchased from Grid	Purchased electricity bill from state electricity board providing details of the electricity purchased by the mill. Frequency: monthly/ annual purchased electricity bills may be produced by the mills.
		Own power generation	Details of own power generation from different sources such as turbines(gas, steam etc), DG sets. Frequency: Daily/ weekly/ monthly/ annual own generation reports may be produced by the mills. These reports may be the log sheets/ production reports from power house.
		Production of power from Non Conventional sources, e.g. Solar / wind power	Details of power generation from different Non-conventional sources such as Solar / wind turbines, bio gas etc. Frequency: Daily/ weekly/ monthly/ annual Power generation reports may be produced by the mills. These reports may be the log sheets/ production reports from concerned power houses / departments
		Annual Report	Annual report showing details of Power purchased from grid, own power generation, power from non-conventional sources etc. Frequency: Annual report of power purchased , own generation, generation from non- conventional sources etc.by the mill.
4	Steam	Steam generation by the mill	Details of Steam generation from different boilers, extraction of steam from turbines, steam generation from waste heat recovery and non-conventional sources(Solar steam generators) Frequency: Daily/ weekly/ monthly/ annual steam generation reports may be produced by the mills. These reports may be the log sheets/ production reports for steam generation from boiler house etc.
		Steam consumption by the mill	Details of Steam consumption in different sections of the mill such as pulp mill, chemical recovery, paper machine, power house and other plants of the mill. Frequency: Daily/ weekly/ monthly/ annual steam consumption reports may be produced by the mills. These reports may be the log sheets/consumption reports for steam consumption by individual section of the mill or power boiler house.
		Annual Reports	Annual report showing details of Steam Generation and consumption from various sources. The generation and consumption of steam may be in individual departments as well as for the whole mill, boilers, extraction steam, steam from non-conventional sources etc. Frequency: Annual report of steam generation and consumption by the mill

S.No.	Details of input and output	Source / Type of document required	Details of the Source / document and frequency
5	Internally Generated Fuels (Black liquor solids, pith , chipper dust)	Generation report of Black liquor, pith, chipper dust, etc	Details of generation of black liquor , pith , chipper dust or any other combustible waste by the mill from different sections such as chipper house, pulp mill, other plants. Frequency: Daily/ weekly/ monthly/ annual Black liquor, dust etc generation reports may be produced by the mills. These reports may be the log sheets/ production reports for Black liquor and pith generation from boiler house etc.
		Lab reports for GCV, solids, moisture, ash etc.	Lab report on GCV, solids (%) moisture(%), Ash (%) and other analysis (proximate) of the Black liquor, pith, dust etc. used by the mill. Frequency: Daily/ weekly/ monthly/ annual lab reports may be produced for different types of Black liquor, pith, dust etc. used by the mill.
		Annual Report	Annual report showing details of Black liquor generation, dust and pith generation, from various sources such as pulp mill, chippers, etc. Frequency: Annual report of Black liquor, pith and dust generation by the mill.
6	Saleable Pulp	Opening and closing stock of saleable pulp	Documents providing details of opening and closing of saleable pulp records by the mill. Frequency: Daily/ weekly/ monthly/ annual opening and closing records of the saleable pulp stock may be produced for different types of pulps produced by the mill.
		Saleable pulp production	Documents providing details of production of saleable pulp from different raw materials by the mill. Frequency: Daily/ weekly/ monthly/ annual production records/ documents providing details of saleable pulp from different types of raw materials produced by the mill.
		Annual Report	Annual report showing details of saleable pulp production from different raw materials and its consumption etc. Also the annual stock closing and opening of the saleable pulp from annual report may be produced Frequency: Annual report of saleable pulp production, consumption and stock (opening/ closing) by the mill.
7	Uncoated paper / board, Newsprint , Specialty grade	Opening and closing stock reports	Documents/ records providing details of opening and closing of Uncoated paper / board, Newsprint , Specialty grade paper products by the mill. Frequency: Daily/ weekly/ monthly/ annual opening and closing records of Uncoated paper / board, Newsprint , Specialty grade paper products, produced by the mill.

S.No.	Details of input and output	Source / Type of document required	Details of the Source / document and frequency
		Paper production report / documents	Documents providing details of production of Uncoated paper/board, Newsprint, Specialty grade paper products, produced by the mill Frequency: Daily/ weekly/ monthly/ annual production records/ documents providing details of Uncoated paper / board, Newsprint , Specialty grade paper products, produced by the mill.
		Annual Report	Annual report showing details of Uncoated paper / board, Newsprint, Specialty grade paper products, produced by the mill. Also the annual stock closing and opening of the Uncoated paper/board, Newsprint, Specialty grade paper products, produced by the mill from annual report may be produced Frequency: Annual report of Uncoated paper / board, Newsprint , Specialty grade paper products, produced and stock (opening/ closing) by the mill.
8	Coated Paper / board	Opening and closing stock reports	Documents/ records providing details of opening and closing of Coated Paper / board by the mill. Frequency: Daily/ weekly/ monthly/ annual opening and closing records of Coated Paper / board, produced by the mill.
		Paper production report / documents	Documents providing details of production of Coated Paper / board produced by the mill Frequency: Daily/ weekly/ monthly/ annual production records/ documents providing details of Coated Paper / board produced by the mill.
		Annual Report	Annual report showing details of Coated Paper / board, produced by the mill. Also the annual stock closing and opening of the Coated Paper / board, produced by the mill from annual report may be produced Frequency: Annual report of Coated Paper / board, produced and stock (opening/ closing) by the mill.

C.   RCF Based Mills:-

a.   The auditor may collect details required in M&V format) by mentioning the source and document from where data is collected. Subsequently the data may be verified from the, data provided by the DC in pro-froma for normalization.

b.   The information required is shown in the flow chart for RCF based pulp and paper mill.

c.   List of documents required for various monitoring and verification

Table 29: General details required in RCF based Pulp and Paper Mills

A.1 Material Details

Type of Waste Paper

Name of the raw material	Moisture, %	Quantity, t/a	Source/ document

A.2 RCF Pulp Mill (Including Pulper, Pulp Cleaning and Screening, Deinking, Bleaching, WTP, and ETP)

i) Pulper / Pulp Cleaning and Screening Process Used

No. of Unit	Capacity t/a	Production t/a	Source / Document
Pulper			
HD Cleaner			
Screening			
Cleaning and screening rejects, t/a			
No. of Deinking loops			

ii) Deinking / Bleach Process

Item	Qty.	Source / Document
Capacity, t/a		
Pulp yield, %		
Fibre Loss, %		
Ink removal Efficiency, %		
Bleaching Stages Yes/No		
Bleaching losses, t/a		

iii) Refining

Item	1	2	3	Source / Document
Type of Refiners				
No. of Refiners				
Initial Pulp Freeness oSR /CSF				
Final Freeness oSR /CSF				

iv) Energy Consumption in Pulp Mill

Item	Qty	Source / Document
LP Steam consumption, t/a		
MP Steam consumption, t/a		
Power consumption, kWh/a		

v) Pulp Dryer

Sr No	Item	Unit	Qty	Source / Document
1	Capacity	Tonne/annum		
2	Production of salable pulp, t/a	Tonne/annum		
3	Energy Consumption in pulp dryer	kcal		
4	LP Steam Consumption	Tonne/annum		
5	MP Steam Consumption	Tonne/annum		
6	Power Consumption	kWh/annum		

vi) Over-all Energy consumption in pulp mill

Item	Qty	Source / Document
LP Steam consumption, t/a		
MP Steam consumption, t/a		
Power consumption, kWh/a		

A.3 Paper Machine (including stock preparation, chemical preparation/addition plant, finishing house)

(i) Paper Machine Details

Number of Paper Machines

Item	PM-1	PM-2	PM-3	PM-4	PM-5	Source/ document
Type of paper machine						
Capacity, t/a						
Type of paper produced						
Production, t/a						
Annual weight average GSM						
Energy Consumption in paper machine (including Stock Preparation , chemical addition and finishing house)						
LP Steam consumption t/a						
MP Steam consumption, t/a						
Power consumption, kWh/a						

(ii)   Coating / Value addition

Coating If any   Yes / No
Type of coating   online / offline

Item	Qty	Source/ document
Capacity of offline coating plant, t/a		
Production of coated paper/board, t/a		
LP Steam consumption, t/a		
MP Steam consumption, t/a		
Power consumption, kWh/a		

(iii)   Over-all Energy consumption in paper machine,stock preparation, chemical preparation and addition plant, finishing house and offline coating plant add (i+ii)

	Qty	Source/ document
LP Steam consumption, t/a		
MP Steam consumption, t/a		
Power consumption, kWh/a		

A.4 The Information required is shown in the Flow Chart for RCF Based Pulp and Paper Mill
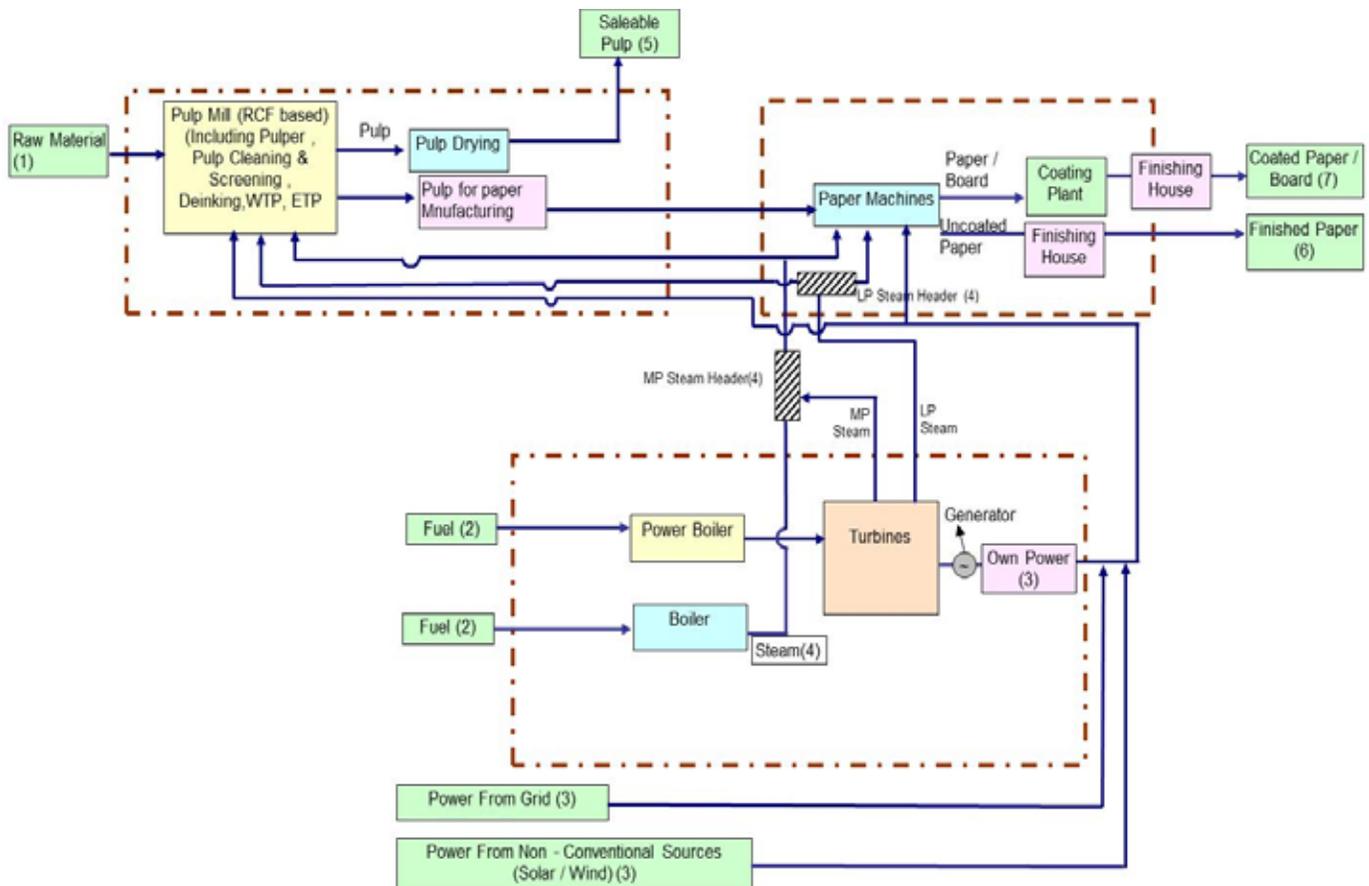
Table 30: Documents required in RCF based Pulp and Paper

S.No.	Details of input and output	Source / Type of document required	Details of the Source / document and frequency
1	Raw Materials	Lab Report	Report on moisture(%), Ash (%) and other analysis of the raw materials used by the mill
			Frequency: Daily/ weekly/ monthly/ annual lab reports may be produced for different types of raw materials used by the mills.
		Purchase Document From Purchase Department	Purchase documents providing details of raw material purchased by the mill
			Frequency: Daily/ weekly/ monthly/ annual purchase documents may be produced for purchase of different types of raw materials used by the mills
		Raw Material Consumption Reports	Consumption reports giving details of raw material consumed by the mill. The report may be for raw material chip production, digester loading etc. from the concerned department.
			Frequency: Daily/ weekly/ monthly/ annual consumption documents may be produced for different types of raw materials used by the mill in chipper / digesters house..
		Annual Report	Annual report showing details of raw materials consumed on annual basis by the mill.
			Frequency: Annual consumption of raw materials by the mill.
2	Purchased Fuels	Fuel Purchase report / documents	Purchase documents providing details of fuel purchased by the mill.
			Frequency: Daily/ weekly/ monthly/ annual purchase documents may be produced for purchase of different types of fuels used by the mills.
		Lab report for GCV moisture and Ash	Lab report on GCV, moisture(%), Ash (%) and other analysis (proximate and ultimate) density etc, of the fuel used by mill.
			Frequency: Daily/ weekly/ monthly/ annual lab reports may be produced for different types of fuels used by the mills.
		Fuel Consumption Report	Consumption reports giving details of fuel consumed by the mill in boilers, DG sets etc. The consumption report may be from the concerned department showing details of fuel consumption.
			Frequency: Daily/ weekly/ monthly/ annual fuel consumption documents may be produced for different types of fuels used by the mill in boiler/DG sets etc.
		Annual Report	Annual report showing details of fuels consumed on annual basis by the mill.
			Frequency: Annual consumption of fuels by the mill.

S.No.	Details of input and output	Source / Type of document required	Details of the Source / document and frequency
3	Power	Electricity Purchased from Grid	Purchased electricity bill from state electricity board providing details of the electricity purchased by the mill. Frequency: monthly/ annual purchased electricity bills may be produced by the mills.
		Own power generation	Details of own power generation from different sources such as turbines(gas, steam etc), DG sets. Frequency: Daily/ weekly/ monthly/ annual own generation reports may be produced by the mills. These reports may be the log sheets/ production reports from power house.
		Production of power from Non Conventional sources, e.g. Solar / wind power	Details of power generation from different Non-conventional sources such as Solar / wind turbines, bio gas etc. Frequency: Daily/ weekly/ monthly/ annual Power generation reports may be produced by the mills. These reports may be the log sheets/ production reports from concerned power houses / departments
		Annual Report	Annual report showing details of Power purchased from grid, own power generation, power from non-conventional sources etc. Frequency: Annual report of power purchased , own generation, generation from non- conventional sources etc.by the mill.
4	Steam	Steam generation by the mill	Details of Steam generation from different boilers, extraction of steam from turbines, steam generation from waste heat recovery and non-conventional sources(Solar steam generators) Frequency: Daily/ weekly/ monthly/ annual steam generation reports may be produced by the mills. These reports may be the log sheets/ production reports for steam generation from boiler house etc.
		Steam consumption by the mill	Details of Steam consumption in different sections of the mill such as pulp mill, chemical recovery , paper machine, power house and other plants of the mill. Frequency: Daily/ weekly/ monthly/ annual steam consumption reports may be produced by the mills. These reports may be the log sheets/ consumption reports for steam consumption by individual section of the mill or power boiler house.
		Annual Reports	Annual report showing details of Steam Generation and consumption from various sources. The generation and consumption of steam may be in individual departments as well as for the whole mill, boilers, extraction steam, steam from non-conventional sources etc. Frequency: Annual report of steam generation and consumption by the mill

S.No.	Details of input and output	Source / Type of document required	Details of the Source / document and frequency
5	Saleable Pulp	Opening and closing stock of saleable pulp	Documents providing details of opening and closing of saleable pulp records by the mill. Frequency: Daily/ weekly/ monthly/ annual opening and closing records of the saleable pulp stock may be produced for different types of pulps produced by the mill.
		Saleable pulp production	Documents providing details of production of saleable pulp from different raw materials by the mill. Frequency: Daily/ weekly/ monthly/ annual production records/ documents providing details of saleable pulp from different types of raw materials produced by the mill.
		Annual Report	Annual report showing details of saleable pulp production from different raw materials and its consumption etc. Also the annual stock closing and opening of the saleable pulp from annual report may be produced Frequency: Annual report of saleable pulp production, consumption and stock (opening/ closing) by the mill.
6	Uncoated paper / board, Newsprint, Specialty grade	Opening and closing stock reports	Documents/ records providing details of opening and closing of Uncoated paper / board, Newsprint , Specialty grade paper products by the mill. Frequency: Daily/ weekly/ monthly/ annual opening and closing records of Uncoated paper / board, Newsprint, Specialty grade paper products, produced by the mill.
		Paper production report / documents	Documents providing details of production of Uncoated paper/board, Newsprint, Specialty grade paper products, produced by the mill Frequency: Daily/ weekly/ monthly/ annual production records/ documents providing details of Uncoated paper / board, Newsprint , Specialty grade paper products, produced by the mill.
		Annual Report	Annual report showing details of Uncoated paper / board, Newsprint, Specialty grade paper products, produced by the mill. Also the annual stock closing and opening of the Uncoated paper / board, Newsprint , Specialty grade paper products, produced by the mill from annual report may be produced Frequency: Annual report of Uncoated paper / board, Newsprint , Specialty grade paper products, produced and stock (opening/ closing) by the mill.

S.No.	Details of input and output	Source / Type of document required	Details of the Source / document and frequency
7	Coated Paper / board	Opening and closing stock reports	Documents/ records providing details of opening and closing of Coated Paper / board by the mill.
			Frequency: Daily/ weekly/ monthly/ annual opening and closing records of Coated Paper / board, produced by the mill.
		Paper production report / documents	Documents providing details of production of Coated Paper / board produced by the mill
			Frequency: Daily/ weekly/ monthly/ annual production records/ documents providing details of Coated Paper / board produced by the mill.
		Annual Report	Annual report showing details of Coated Paper / board, produced by the mill.
			Also the annual stock closing and opening of the Coated Paper / board, produced by the mill
			from annual report may be produced
			Frequency: Annual report of Coated Paper / board, produced and stock (opening/ closing) by the mill.

7.7. Annexure VII: Textile

1. Section wise Energy metering (Electrical and Thermal) is required for making Equivalent Product in Textile sub-sectors. Proper calculation document should be maintained, if energy figures are arrived by calculation method.

2. SCADA Screen shot is required for Major and Auxilliary systems.

3. Inclusions and Exclusion should be clearly marked in the Gate to Gate Boundary Diagram.

4. It is essential to express quantities of different product types in a single unit for calculation of specific energy consumption from Gram per Linear Meter (GLM) or Gram per Square Meter (GSM). DC to furnish back up calculation of conversion to EmAEA.

5. Mass balance is required to be furnished in the verification report.

6. EmAEA is advised to convert other special product or value added product in to the major equivalent product through Energy Consumption and the calculation is to be included in the verification report

7. Spinning Sub-Sector

    a. Count of Yarn is one of the important parameter. Change in the count of the yarn may result in the change in the UKG of the plant. So normalization for count of yarn is important. Hence, all the product needs to be converted to 40s count s per SITRA guidelines for UKG calculation at TFO - AutoConer output. The calculation for conversion shall be an integral part of the verification report.

    b. The open end yarn to be converted to 10s count for UKG calculation.

    c. Section wise energy consumption to be provided for backup calculation as per sample table. EmAEA is required to insert or delete the section as per the requirement

Table 31: Section wise Energy Consumption

Sr No	Item	Electrical SEC (kwh/kg)	Thermal SEC (kcal/kg)	Remarks
1	Blow Room			
2	Carding			
3	Combing			
4	Draw Frame			
5	Speed Frame			
6	Ring Frame			
7	Winding			
8	TFO			
9	AutoConer			
10	Doubling			
11	Singing and Sizing			
12	Humidification			
13	Lighting			
14	Utilities			
15	Misc Others			

d. The calculation used to convert other type of yarn (Like PV, Worsted etc) into the singular yarn in the baseline year will remain same in the assessment year. EmAEA is advised to use the same formulae as per Baseline Year Report.

e. All special product yarn (Melange/ Fibre dyed Yarns, High value blended yarns mixed with Wool, Silk, Modal, Nylon, etc, Slub Yarns, Compact yarns, TFO doubled yarns, Jaspe yarns, Jaspe slub yarns, Nep effect yarns) needs to be converted in to single major product. The conversion formulae for baseline and assessment year will be same.

f. Production and capacity to be equated w.r.t. the Nos, speed, weight and running hours of Ring Frame and Autoconer.

g. Mention clear bifurcation of energy in Major Product (GtG boundary as per PAT) and other products as per Boundary Limit Example.
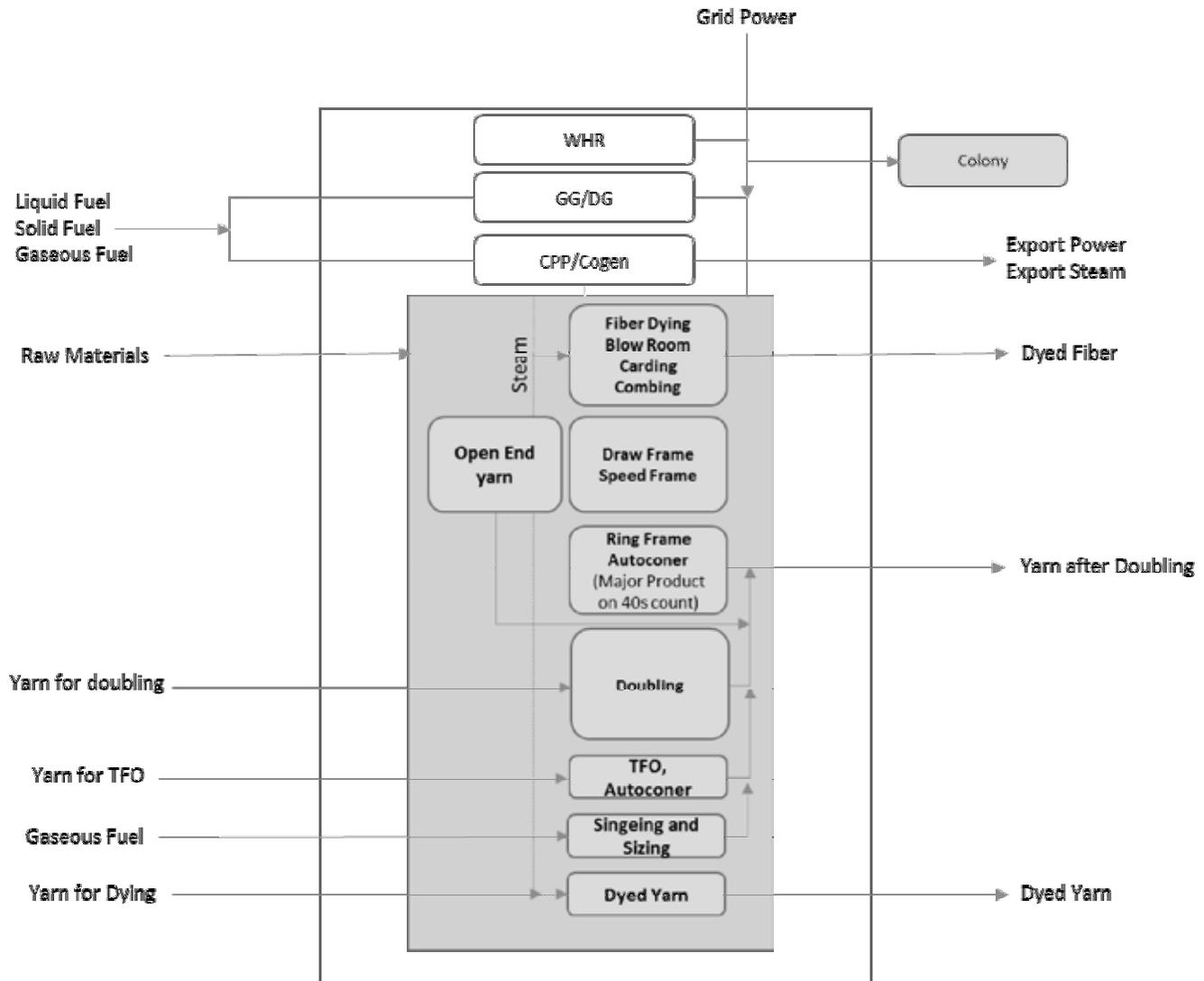
Figure 22: Ex- GtG boundary for Textile (Spinning sub sector)

8. Composite and Processing Sub sector

    a. There are five finished product defined in the Composite sub-group, all other special or value added product shall be converted into either of these five major products through energy consumption of making those special or value added product. The calculation of conversion is to be included in the verification report of EmAEA.

    The final five finished products in the Composite sub group are:

    i. Cotton

    ii. Polyster Cotton

    iii. Lycra

    iv. Non Cellulosic Product (100% Synthetic)

    v. Wool based product

    b. Picks as standard for taking production in case of Weaving. In case of weaving, in order to streamline products of all the DCs 60 PPI (Picks per Inch) as standard value and DCs should

convert their weaving production at different picks to production at 60 PPI. EmAEA to include the conversion calculation in the verification report.

c. Similarly for Knitting, conversion factors shall be in terms of Wales on weight basis.

d. Mass and Energy balance calculation is required to be included in the verification report by EmAEA

e. Steam balance diagram is required to be included in the verification report by EmAEA

f. Section wise Specific Energy Consumption is required to be specified as per table below

Table 32: Section wise Energy Consumption

Sr No	Item	Electrical SEC (kwh/kg)	Thermal SEC (kcal/kg)	Remarks
Spinning				
1	Blow Room			
2	Carding			
3	Combing			
4	Draw Frame			
5	Speed Frame			
6	Ring Frame			
7	Winding			
8	TFO			
9	AutoConer			
10	Doubling			
11	Singing and Sizing			
Knitting/Weaving				
1	Wraping			
2	Sizing			
3	Knotting			
4	Weaving			
Processing				
1	Singeing			
2	Desizing			
3	Mercerizing			
4	Bleaching			
5	Sueding			
6	Dying			
7	Printing			
Misc and Others				
1	Humidification			
2	Lighting			
3	Utilities			
4	Others			

EmAEA is required to add the section as per the requirement and need

g. Demarcation of plant boundary is required with clear understanding of raw material input, Energy input, Power Import/Export, Intermediary product Import/Export, Colony Power, Construction/Others Power, Power supplied to other Ancillary unit outside the plant boundary. A typical sample of Plant boundary condition is represented below
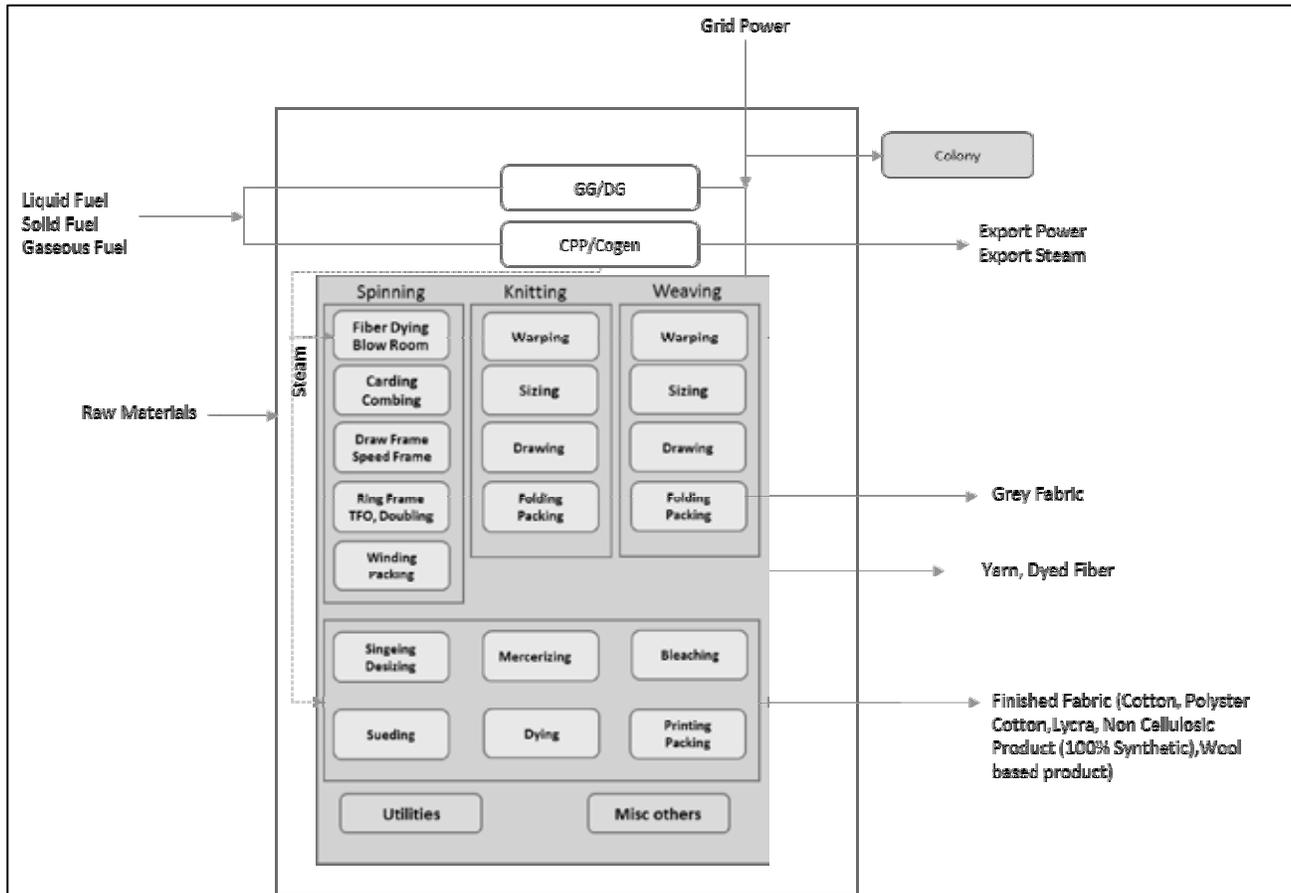

Figure 23: Ex- GtG boundary for Textile (Composite/ Processing sub sector)

9. Fiber Sub-Sector

a. Section wise production and Energy performance is required for each Fiber Product

b. The Products and sections are different in Fiber sub-sector, hence the Pro-forma of the subsector specify the major product and other Products from 1-5.

c. EmAEA to specify the product details with sectional Process Flow Diagram in the verification report.

d. Mass balance calculation w.r.t. input raw material and output product with conversion factor is required to be produced

e. Fuel used as raw material should not be considered from the input energy and reported in the verification report by EmAEA

f. DC has to submit weighted average denier value for their products. Plant has to submit production value in single denier by converting all the denier value

g. DCs have to convert all of their products in single major product equivalent by taking ratio of the SEC of the other products to the main product

h. EmAEA to include the details of major products and other products as mentioned in Pro-forma as per following table

Table 33: Product Name in Fiber Sun-sector

Sr No	Item	Name	Unit	Remarks
1	Raw Material			
2	Major Product			
3	Product 1			
4	Product 2			
5	Product 3			
6	Product 4			
7	Product 5			
8	Denier			

i. Steam Balance Diagram of the Plant from Steam generation to Steam consumption is required to be included in the verification report

j. Product wise, sectional (Sub Process) yearlyThermal and Electrical Energy details is required as per following sample table for Product 1

Table 34: Section wise Energy Consumption

Sr No	Item	Electrical SEC (kwh/kg)	Thermal SEC (kcal/kg)	Remarks
1	Polymerisation Process			
2	Spinning Process			
3	Draw line Process			
4	Utilities			
5	Misc Others			

k. Boundary Condition

Mention clear bifurcation of energy in

Major Product (GtG boundary as per PAT) and other products as per Boundary Limit Example
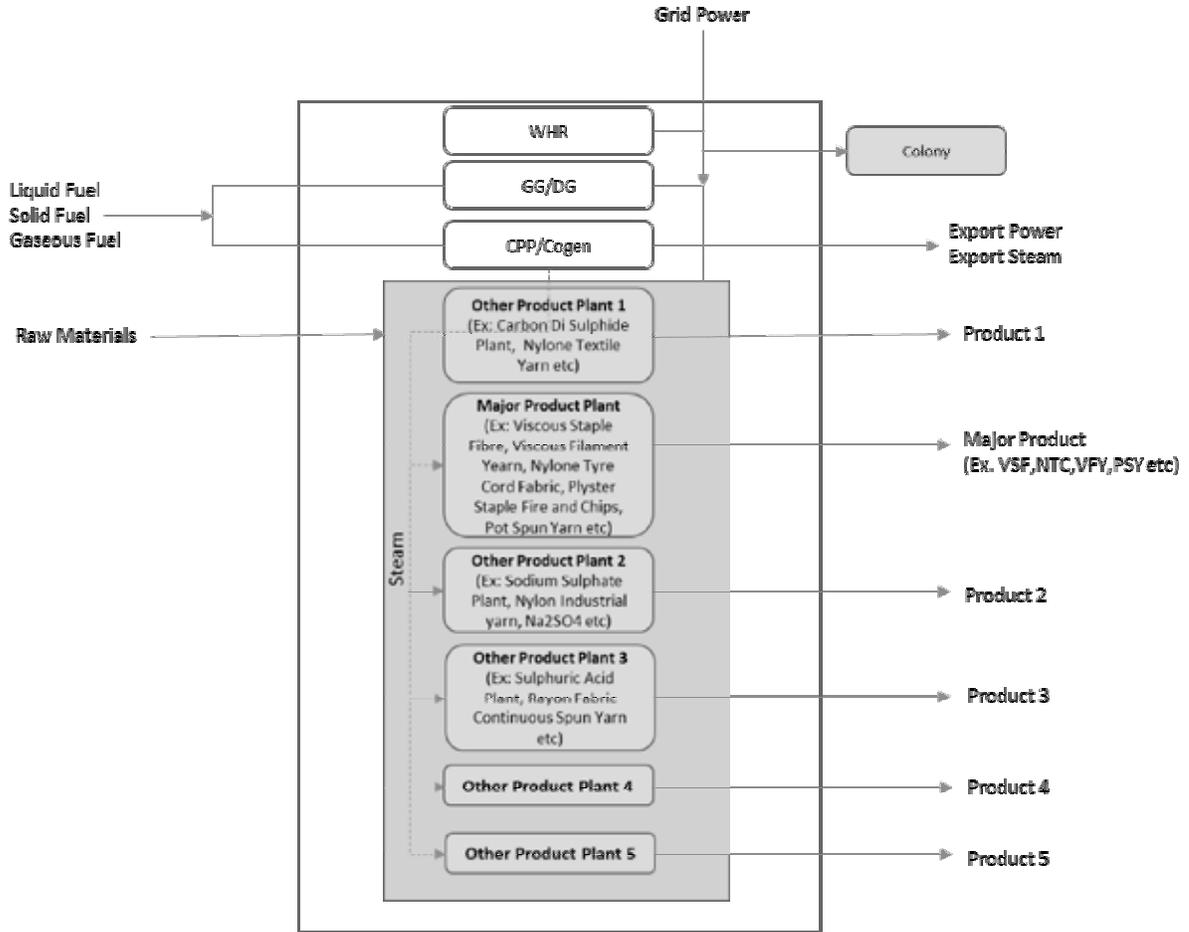
Figure 24: Ex- GtG boundary for Textile (Fiber) Sub- sector

7.8. Annexure VIII: Chlor Alkali

1. Section wise Details

Section wise Specific Power consumption and Specific Thermal consumption shall be specified and provided to EmAEA as per following format. EmAEA can add section if required

Table 35: Section wise Energy details

Sr No	Section	SPC kwh/tonne	SEC kcal/kg	Remarks
1	Primary Brine Plant.			
2	Secondary Brine Plant.			
3	Membrane Cell Plant.			
4	Chlorine / Hydrogen Treatment Plant			
5	HCl / Sodium Hypo Plants.			
6	Caustic Concentration and evaporation units.			
7	Utilities Plant.			
8	Waste Water Treatment Plant.			

2. Membrane Change verification: Details regarding membrane change for each cell shall be provided along with the membrane configuration

3. Maximum allowable capacity of chlorine storage in the DC shall be specified and provided to the EmAEA

4. Cathode- Anode coating verification: Details regarding Cathode- Anode coating shall be provided along with the membrane configuration

5. EmAEA shall ensure and verify production of Caustic Soda lye (49% concentration) and Hydrogen as per quantity of Chlorine produced during the electrolysis process. EmAEA shall also ensure that these productions should not exceed the stoichiometric limit

6. If a captive power plant or cogeneration plant caters to two or more DCs for the electricity and/or steam requirements. In such scenario, each DC shall consider such captive power plant or cogeneration plant in its boundary and energy consumed by such captive power plant or cogeneration plant shall be included in the total energy consumption. However, electricity in terms of calorific value (as per actual heat rate) and steam in terms of calorific value (as per steam enthalpy) exported to other plants shall be subtracted from the total energy consumption.

7. Boundary Condition

Mention clear bifurcation of energy in Caustic Soda plant (GtG boundary as per PAT) and other products as per Boundary Limit Example

Figure 25: Ex- GtG boundary for Chlor-Alkali sector
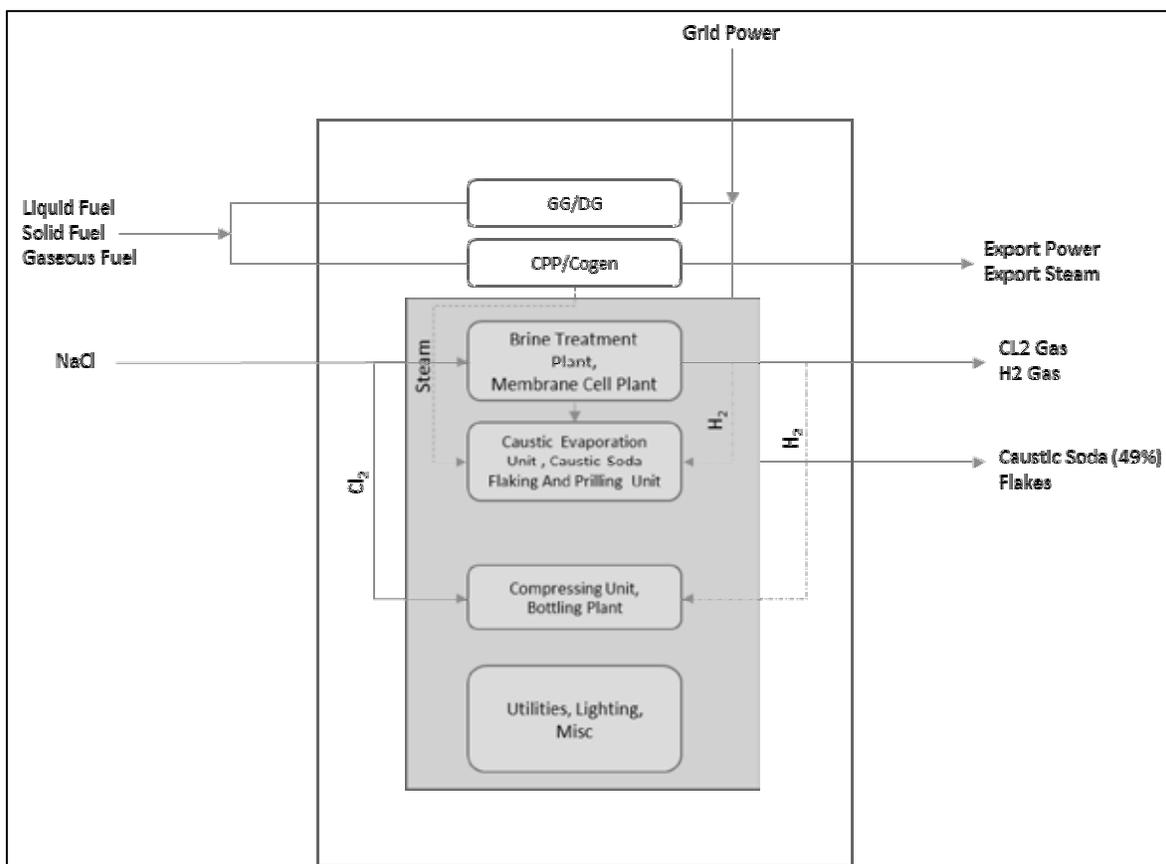
For all practical and legal purposes in connection with M&V guidelines, the English version of the notified PAT rules 2012 and EC Act 2001 will be considered as final.

ENERGY IS LIFE

BEE

CONSERVE IT

Bureau of Energy Efficiency

4th Floor, Sewa Bhawan

R.K.Puram, New Delhi - 110 066 (India)

Telephone: +91 11 26179699

Fax: +91 11 26178352

www:beeindia.in