M&V Protocol for Aluminium Sector
Perform-Achieve and Trade Scheme

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Prepared by :

DESL

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ABBREVIATIONS

BEE	*Bureau of Energy Efficiency*
CEA	*Central Electricity Authority*
CNG	*Compressed natural gas*
CPP	*Captive power plant*
CU	*Capacity utilisation*
CUM	*Cubic meter*
DC	*Designated consumer*
DESL	*Development Environergy (Formerly, Dalkia Energy) Services Ltd*
EC	*Energy conservation*
ECM	*Energy conservation measures*
EE	*Energy efficiency*
Escert	*Energy savings certificate*
GCV	*Gross calorific value*
GtG	*Gate to gate*
HFO	*Heavy fuel oil*
KA	*Kilo amperes*
Kcal	*Kilocalorie*
KLPY	*Kilo liter per year*
LDO	*Light diesel oil*
LNG	*Liquefied natural gas*
LTPY	*Lakh tonnes per year*
MKCal	*Million kilocalorie*
MT	*Metric Ton*
M&V	*Measurement & Verification*
PAT	*Perform achieve & trade*
LPG	*Liquefied petroleum gas*
SCUM	*Standard cubic meter*
SEC	*Specific energy consumption*
TOE/MTOE	*Tonnes oil equivalent*
TPD	*Tonnes per day*
TPY	*Tonnes per year*

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EXECUTIVE SUMMARY

This protocol has been prepared to assist the stakeholders, particularly the Designated Consumers (DCs) in the aluminium sector and the Accredited Energy Auditors to carry out the various tasks required for monitoring and verification of the achieved 'Gate to Gate specific energy consumption' against the target for the DC set as per the PAT notification by BEE and Ministry of Power. The recommended procedure has been outlined covering:

- Determination of the 'Gate to Gate Specific Energy Consumption' (GtG SEC) as per prescribed procedure
- Normalisation of the determined GtG SEC using the normalisation guideline recommended for each individual sector
- Data and information protocol for carrying out determination of GtG SEC exercise & normalisation
- Monitoring & verification (M&V) protocol for assessment of performance of ECM projects
- Validation process and reporting of normalised GtG SEC for the PAT cycle

The document has been prepared on the basis of review of BEE PAT consultation document, MOP/BEE notification booklet of July, 2012 , baseline audit reports (sample reports for the sector), & information from DESL energy audit report database & literature survey.

Treatment of variables such as capacity utilisation, product mix and fuel quality have been generally outlined in the BEE document. Some of the baseline reports have identified more variables and outlined their impact. In case of the two reports obtained for the aluminium sector, various production and energy consumption data and computed GtG SEC have been provided. Information and statistical analysis of variables and GtG SEC corelationship have not been provided.

Such variables have been identified based on DESL audit reports and literature survey and their impact studied. It has been observed that annual average value of production and energy usage as reported in the baseline reports may or may not truly reflect the corelatioship between CU & GtG SEC. More in depth analysis has been carried out for determination of relationship behaviors.

BEE has provided guideline on treatment for product mix and power source variables for computing GtG SEC and normalisation process. However, under certain conditions, errors can creep in due to change in the power mix and change of heat rates. Normalisation process has been recommended to take care of such situation.

This document pertains to smelting units only, for which copies of baseline reports could be obtained from BEE. Smelting units correspond to over 70% of the total sectoral consumption whereas refining sections account for about 12%.

For the smelting units, significant corelationship has been observed between capacity utilisation (CU) and GtG SEC. Following other key variables has been identified having influence on the GtG SEC.

- Process technology

- Plant capacity & capacity utilisation
- Anode sourcing
- Current density
- Coal quality & plant heat rate
- Change in captive and grid power mix
- EE investment

From the perspective of PAT, it would be necessary to establish mathematical corelationship of GtG SEC to identified variables and carry out normalisation process using the corelationship factors so derived. This has to be done specifically for every unit. For this, it would be necessary to have large number of data points, which can help in carrying out the statistical analysis and derive the desired level of accuracy. The data protocol has been proposed accordingly. It would also be desirable to develop sector specific statistical models at BEE end so that cost of carrying out the normalisation process itself does not become a barrier.

Even after such analysis, one may not be able to achieve the set objective of level of accuracy at 0.05%. It has therefore, been proposed to carry out a second check by reconciling with the verified savings achieved from implementation of energy conservation measures.

Summary process for carrying out normalisation and validation study has been developed and provided in this document. Similarly, data and information need have been assessed. The protocol for the same has also been provided in the document.

The normalisation process and M&V protocol have to be developed for every DC as the demanded accuracy can be obtained only with rigorous statistical analysis of unit specific performance data and parameters.

This document has been prepared for use only as a guiding document within the framework of principles and processes outlined by MOP/BEE.

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1. INTRODUCTION: PAT SCHEME & SIGNIFICANCE OF M&V PROTOCOL

The PAT framework has been developed considering the legal requirement under EC Act, 2001, situation analysis of designated consumers, national goal to be achieved by 2013-14 in terms of energy saving and sustainability of the entire scheme. The PAT scheme has been designed to incentivize industry for higher level of investment in energy efficiency projects. Numerous studies have indicated that investment in energy efficiency project offer attractive return due to reduced cost of energy. The PAT scheme would provide opportunity of additional revenue generation through trading of marketable instruments, which would be available as a result of achievement of higher level of savings. The additional certified energy savings can be traded with other designated consumers who could use these certificates to comply with their SEC reduction targets. The Energy Savings Certificates (ESCerts) will be traded on special trading platforms to be created in the two power exchanges (IEX and PXIL). The guiding principles for developing the PAT mechanism are Simplicity, Accountability, Transparency, Predictability, Consistency, and Adaptability. The PAT framework includes the following elements:

1. Methodology for setting specific energy consumption (SEC) for each DC in the baseline year
2. Methodology for setting the target to reduce the Specific Energy Consumption (SEC) by the target year from the baseline year.
3. The process to verify the SEC of each DC in the baseline year and in the target year by an accredited verification agency
4. The process to issue energy savings certificates (ESCerts) to those DCs who achieve SEC lower than the specified value
5. Trading of ESCerts

Specific energy consumptions (SEC) in any process would vary over time due to changes, which can be classified under controllable and uncontrollable variables. The controllable variables include those, which can be changed by internal intervention including through behavioral changes and investment in energy efficient technologies. The factors over which an individual DC does not have any control but that can impact the SEC are classified as uncontrollable. The design intent of the PAT process is to insulate the DC from variability due to changes in the uncontrollable factors. The baseline conditions are defined so that the impact of uncontrollable variables can be neutralised by application of suitable adjustment factors, which have been called 'Normalisation' factors in the BEE document[1]

The objectives of the M&V protocol are multi-fold including identification of controllable and uncontrollable variables, method of collection of data and information for the same and providing methodology to determine the normalization factors and finally development of the SEC figures in line with objectives set forth in the PAT process.

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[1] PAT consultative document

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2. ALUMINIUM SECTOR-OVERVIEW

2.1 SECTORAL PERFORMANCE-A BRIEF OVERVIEW

Fuelled by the boom in the construction, automobiles and consumer durable sectors, aluminium industry has been showing sustained growth rate at about 15% CAGR crossing the milestone of 2 MnT in 2011. It has been estimated that it may touch 5 MnT/year by 2015 and 10 MnT/year by 2020[2].
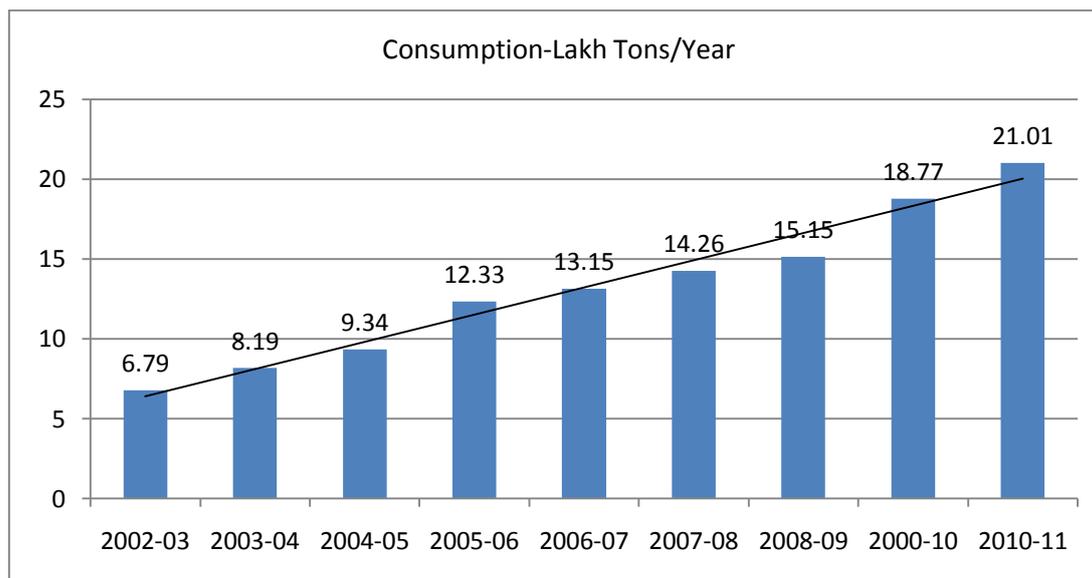
Figure 1: Consumption Growth of Aluminium in India

India is currently the 5th largest consumer of aluminium in the world. With about 7% of the global deposit of bauxite at about 2.3 BnT[3], it is expected that the sector would attract large investment in the next few plans.

2.2 ENERGY USE IN ALUMINIUM MANUFACTURE

The aluminium manufacturing process comprises of two primary sub-processes; bauxite refining for production of alumina and smelting for productions of aluminium metal and secondary process for conversion to merchant products.

Although considerable energy is also used in anode production, this is often accounted for under raw materials. In the overall context, typical distribution of energy usage in different sub-processes is as shown in the following figure.

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[2] Scope & potential of Indian aluminium industry-European journal of business & management-Vol 3, No 4, 2012
[3] PAT Notification document-July, 2012
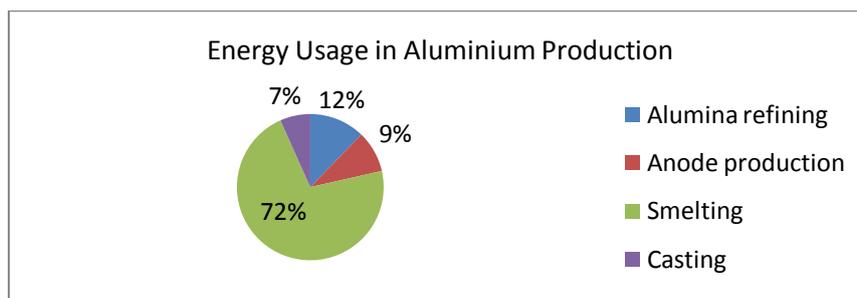
Figure 2: Energy Usage in Production of Aluminium[4]

In the refining and anode making process primarily thermal energy is used, for digestion and calcination for the former and baking for the later. However, if the energy content of the coke is also considered, it adds 30% more to the overall energy consumption. Electricity is used for the smelting process. For the secondary process, both thermal and electrical energy are used, thermal energy for die casting, pre-heating and stress relieving whereas electrical energy for rolling and extrusion.

Considering the huge requirement of electricity, the focus of the Indian manufacturers has always remained on:

- Continuous technology upgradation for reducing the energy consumption in the smelting process
- Supply side management through investment in high efficiency captive power plants.

Theoretical minimum energy need for the smelting process has been estimated using the thermodynamic analysis at about 9.03 kWh/Kg of aluminium metal[4]. Globally, actual benchmark achievement has been around 14kWh/Kg. In USA, the current average consumption is about 15 Kg/kWh, proposed to be reduced to 11kWh/Kg by 2020. Aluminum Industry in India has done well in continually improving the energy efficiency. Current benchmark consumption at about 14167 kWh/T[5] is very close to the global benchmark.

The electrical energy consumption is the product of the DC current and voltage across the cells known as the pots in the industry. The voltage drop across different sections of the cell (Figure 3), shows the typical voltage distribution and hence energy consumption in the different parts of the cell. Both scientific and engineering application research and development work are being carried out globally including in India for reducing the voltage drops in the non-productive parts.

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[4] US Energy requirement for aluminium production-prepared for DOE,BCS, Feb 2007

[5] TERI Energy Data Directory, 2010

	Volts	%
External	0.15	3.3
Anode	0.30	6.5
Polarization	0.60	13.0
Bath	1.75	38.0
Reaction	1.20	26.1
Cathode	0.45	9.8
Other	0.15	3.3
Total	4.60	100
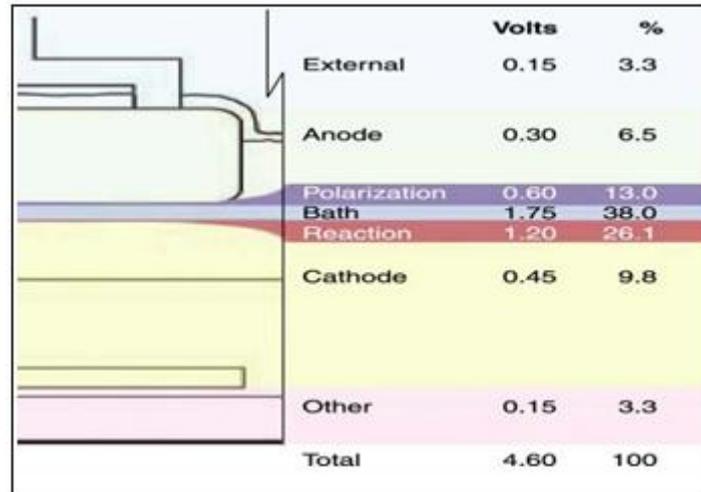
Figure 3: Energy Consumption in Smelting[4]

In addition to the basic technology, operation and maintenance also play very important role in maintaining the energy usage. Some of the critical areas of operational control include control of alumina feed rate, cell temperature, current densities, anode management, management of product extraction. Similarly, maintenance includes proper insulation levels and thermal balance, conductivity of various bus bar connections and joints etc.

The industry in India is fully aware of the global best practices and some of the units have already achieved benchmark specific energy consumption.

Further, all the plants in India have their coal based captive power plants meeting practically the entire power demand for the manufacturing process. In the context of GtG SEC, the heat rate of such power plants would also play a key role.

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3. DESIGNATED CONSUMERS-ALUMINIUM SECTOR

In the current PAT cycle, the Aluminium sector has been set a target for reducing the energy consumption by close to 0.5 MTOE representing little over 7% of the overall savings target.

Ten manufacturing units, notified as designated consumers have been classified under 4 sub-sectors:

- One integrated unit
- Four smelters
- Four Refineries
- One sheet mill

The four (integrated/smelter) units with combined target of about 0.38 MnTOE/year account for over 80% of the sectoral target.
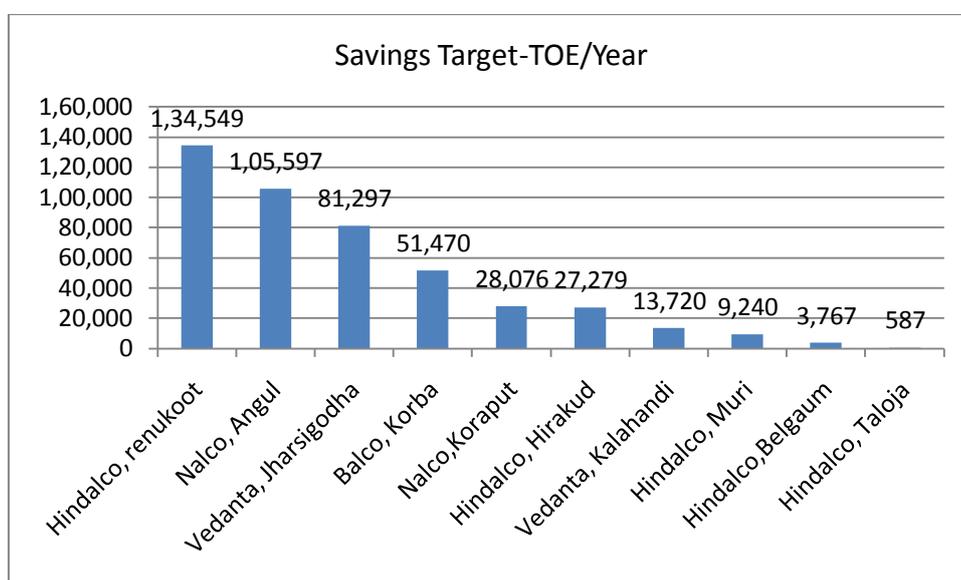
Figure 4: Units & Savings Targets

It is also interesting to note that there are only four business houses/groups (three in the private and one in the public sector), which are controlling the units. This should make it easy for achieving the PAT goal for the sector and implementation of the normalisation and M&V protocol.

4. BASELINE & NORMALISATION-OVERVIEW

4.1 BEE GUIDELINES

The PAT scheme is an operating unit-specific scheme, targeting reduction of energy intensity of the products being manufactured in the unit. The energy intensity has been defined as 'Gate to Gate' specific energy consumption (GtG SEC) determined by dividing the thermal equivalent of all energy inputs within the unit boundary by the product manufactured in the target period (Text box-1). With a view to neutralize the impact of uncontrollable variables, the concept of baseline and normalisation has been introduced (Text box-2).

Text Box 1: Gate to Gate SEC

The SEC of an industry would be calculated based on Gate-to-Gate concept with the following formula:
SEC = Total energy input to the plant boundary / Quantity of the Product

While calculating the total energy input to the plant, all energy sources would be converted to a single unit i.e. MTOE (metric ton of oil equivalent) using standard engineering conversion formula. In this calculation, the following would be considered:

a) All forms of energy (Electricity, Solid fuel, Liquid fuel, Gaseous fuel, by products used as fuel etc.) which are actually consumed for production of output, should be considered.
b) Energy consumed in colony and for outside transportation system should not be accounted.
c) Energy used through renewable energy sources should not be accounted.
d) The 'Product' is the key parameter. The definition of product for various sectors has been indicated for the purpose of calculating SEC. This has been arrived at considering the typical practice of defining SEC and consistency in product output.

The principles for the normalisation process have been outlined with capacity utilisation as the key variable. However, it has also been provided that such normalisation factor would be applied if the capacity utilisation has deviated by more than 30% due to uncontrollable factors described in rule 4[6].

The outlining objective is to insulate the DCs against uncontrollable variables (such as change in the market, non-availability of raw materials, force majeure causes), which can impact the SEC.

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[6] Section 1.4 © of Schedule (MOP/BEE)

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Text Box 2: Baseline & normalisation

The base line SEC would be calculated based on the following procedure:

a) All DCs would submit the details of production and annual energy consumption since 2005-6 to 2009-10 through a notified form which is mandatory as per EC Act, 2001. Few additional sector specific information like process technology, process flow, raw material, product mix etc. would also be collected.

b) The SEC calculated from step (a) would be the 'Reported SEC' by the DC. As there may be various variable factors which affect the energy consumption significantly, some 'Normalization Factors' would be considered. It is proposed to consider the 'capacity utilization' as one of the most important parameter to have a normalization factor. However, the rationale for developing the 'normalization factors' is underway by suitable agencies through a scientific manner.

c) Now the reported SEC will be normalized after incorporating the normalization factor.

d) Normalized SEC = f (Reported SEC, Normalization factors)

e) The base line SEC will be estimated by taking the average normalized SEC of last 3 years i.e. 2007-8, 2008-9, and 2009-10.

f) The base year may be defined as 2009-10.

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For the purpose of PAT, the Aluminium sector has been divided into following four segments:

- Refinery
- Smelter
- Integrated
- Cold sheet mill

For the sector, BEE document has not provided any guideline on normalisation process except for the general guideline as summarised above. The document has however, listed the following important technological interventions for reducing the specific energy consumption:

- Replacement of primary smelter by point feeder prebaked system with inert/wetted cathode technology
- Changing of Soderberg process to the prebaked process
- Adoptation of tube digesters for bauxite dissolution and fluid bed calciners with pre-heaters of anhydrous alumina
- Improved electrolyte bath technology to minimize reoxidation of metal
- Higher amperage with point feeders and computerized control system
- Improved performance of carbon baking furnaces

4.2 PROPOSED METHODOLOGY

The proposed methodology has been developed considering the followings:

- BEE/EESL guidelines
- Review of the baseline audit reports
- Review of information available from DESL case studies and public domain

The production for the target period can be determined using the above methodologies. Similarly, energy consumption can be determined based on input electrical and fuel energy calculated from:

- Total fuel used multiplied by the GCV

- Grid electricity import multiplied by the heat rate (BEE guideline provides for taking this value at 860 Kcal/kWh)
- Credit for export of captive power at total export multiplied by grid national heat rate (2717 Kcal/kWh)
- Heat rate of captive power (CPP) to be used while determining conversion factors for sub-products into main products

Using BEE/EESL guideline

BEE document has provided clear guidelines on production and energy consumption variables as discussed at section 4.1 above.

Methodology for baseline energy audit adopted by auditing agencies as per EESL guidelines are as follows:

- Fixing up the plant boundary
- Analysis of production trends and capacity utilization
- Detailed process flow study
- Analysis of energy scenario
- Estimation of Specific Energy Consumption (SEC)
- Analysis of various factors affecting GtG SEC
- Listing of energy efficiency projects identified by the DC and assessment of impact

BEE guideline ((d) (ii) at text box-2) has rightly highlighted the need for statistical analysis for establishment of the relationship coefficient of identified variables for the purpose of normalisation. In respect of capacity utilisation coefficient, the guideline has provided for consideration only if deviation is by 30% or more. This issue would have to be reviewed for every DC after carrying out the statistical analysis.

BEE has provided guidelines on conversion of electrical energy to equivalent thermal energy for power drawn from different sources. In cases of significant switch from one source to another, this can impact the value of derived GtG SEC even if the net electrical energy use remains the same.

Using the baseline reports

Two baseline audit reports have been obtained with a view to analyze and assess the GtG SEC based on outlined principles and develop M&V protocol for the PAT cycle. The baseline audit reports have provided sufficient information for determination of GtG SEC and capacity utilisation on major products. Some Information on identified energy savings projects has also been provided. However, the impact of the same has not been quantified in energy terms nor their impact on reduction of GtG SEC evaluated. The graph has been provided for production and GtG SEC trends. Though this graph has included data for 2005-06 onward, the spread sheet has provided data for 2007-08 onward. DESL has therefore, used the information for three years from 2007-08 onward. The GtG

SEC relationship with CU has not been provided nor any comment made on the same. No other variables has been identified and analysed.

From the data and information provided, it appears that the performance of the captive power plant is playing more important role in influencing the GtG SEC.

Basic information available on the production and energy usage parameters has been used to study GtG SEC corelationship to CU. Available data and information has helped in establishing corelationship in broader term. From the perspective of PAT, it would be necessary to develop proper mathematical equations for determination of normalised values through statistical analysis. Number of data points available in the baseline report is limited-annual data for five years and monthly data for a year. More number of data would be necessary to carry out the statistical analysis and deriving desired level of accuracy. This can be done by using daily production and SEC data for the entire PAT cycle period of three years. With a view to avoid high cost of transactions for carrying out such at individual level, it would be good to develop sector specific statistical models.

Baseline reports have included adequate, though not comprehensive, information on data source and traceability. This information has been used for preparing more structured data and information format, which is recommended to be maintained by DCs and used during validation and verification processes. The frequency of data recording has been recommended keeping in mind the need for good quality statistical analysis required for establishing the desired level of accuracy.

DESL analysis & recommendations-other factors

With a view to assess the impact, DESL has carried out further analysis based on the available data and information in the baseline reports as well as further research based on DESL database and information available in the public domain. These include:

- Study of CU impact on SEC based on annual as well as monthly data for the latest year for which data is available
- Identification of other variables, data availability in respect of the same and their impact
- Impact of heat rate in case of change of power mix (Captive, grid, mix of both)

For the Aluminium sector, following important variables have been identified:

- Process technology
- Plant capacity & capacity utilisation
- Anode sourcing
- Current density
- Coal quality & plant heat rate
- Change in captive and grid power mix
- EE investment

The intent of the PAT scheme is to make investment in EE and process technology. As such, no normalisation needs to be carried out on these two accounts. In case of shift of sourcing for anodes,

normalisation would be required. Current density change can impact SEC both ways. Two different views could be taken-any change on this account is by design within the plant boundary and as such not to be considered for normalisation. On the other hand from the overall economical stand point, increased current density may have more beneficial impact. Normalisation for this factor has been proposed.

The GtG SEC is hugely impacted by performance of the captive power plant-so much so that PAT cycle result may not reflect changes in the EE scenario for the smelting plant at all. For future PAT cycle, it may be desirable to assign separate targets for the captive power plant and the smelting plant.

5. ILLUSTRATION-BASELINE AUDIT & DETERMINATION OF GtG SEC

Two reports obtained from BEE have been perused. The broad particulars of the units are as shown in the following table.

Table 1: Particulars of the Units

Parameter	Unit-1	Unit-2
Sub-sector	Smelter	Smelter
Capacity	4,66,900	1,55,000
Fuel-Primary -Process	Coal (Indian and imported) Fuel oil (LDO for emergency DG)	Coal (Indian) Fuel oil (LDO for emergency DG)
Electricity supply	Mainly captive power plant	Mainly captive power plant
Technology	Pre-baked, Hall-Haroult	Soderberg converted to pre-baked in 2008

The process technology is presently same in both the plants except that the 2nd plant uses imported anodes and only rodding operation carried out within gate boundary, whereas in unit no 1, anodes are manufactured in-house. The baseline audit has also been carried out by the same agency in both the units following the BEE guidelines. As such one of the units has been taken up for further analysis and development of the normalisation methodology and M&V protocol. The difference arising out of imported anodes and in-house manufactured anodes would be separately discussed in the section of this report on normalisation.

The process and energy flow diagram for the unit-1 is as shown in the following figure.
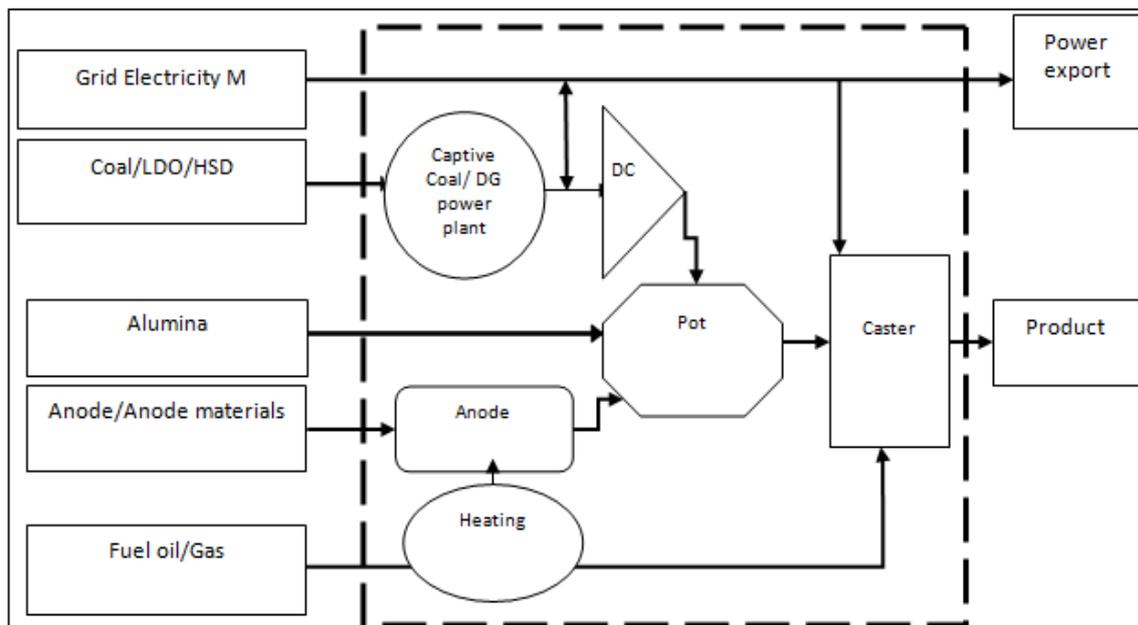
Figure 5: Process & Energy Flow Diagram

From the process and energy flow diagram, it can be seen that the process of determination of the GtG energy consumption is relatively easy for this sector. There is only one finished product. Also

practically the entire energy input is provided by coal barring a small quantity of fuel oil/gas, which is used for process heating.

GtG SEC corelationship

The detailed information on production, energy usage and GtG SEC as reported in the baseline report is shown in the following table.

Table 2: Baseline data

Particulars	Unit	2007-08	2008-09	2009-10
Production				
Capacity-Molten aluminium	TPY	3,50,175	408537	4,66,900
Production-Molten aluminium	TPY	3,61,713	362098	4,34,528
CU	%	103%	89%	93%
Capacity-Cast aluminium	TPY	3,45,000	402500	4,60,000
Production-Cast aluminium	TPY	3,60,457	361262	4,31,488
CU	%	104%	90%	94%
Fuel				
Coal Indian-Quantity	MT	47,75,796	46,36,130	52,41,645
Coal Indian-GCV	Kcal/Kg	3,982	3,961	3,923
Coal Imported-Quantity	MT	1,40,749	2,21,381	4,65,407
Coal imported-GCV	Kcal/Kg	6,000	6,000	6,000
HFO-Quantity (Power)	MT	4,894	3,837	12,208
HFO-Quantity (Process)	MT	28,282	31,155	31,582
HFO-GCV	Kcal/Kg	10,000	10,000	10,000
LDO-Quantity (Power)	MT	1,785	1,463	4,320
LDO-Quantity (Process)	MT	85	106	97
LDO-GCV	Kcal/Kg	10,000	10,000	10,000
HSD-Quantity (Process)	MT	680	722	789
HSD-GCV	Kcal/Kg	11,840	11,840	11,840
LPG-Quantity (Process)	MT	16	19	18
LPG-GCV	Kcal/Kg	12,500	12,500	12,500
Total for power	MTOE	19,92,850.4	19,74,499.7	23,52,069.5
Total for process	MTOE	29,192.1	32,139.6	32,635.7
Grand total	MTOE	20,22,042.5	20,06,639.3	23,84,705.2
Power				
Generation	MU	6,267	6,199	6,849
Export	MU	308	215	72
Import	MU	49	72	184
Captive consumption	MU	6,008	6,056	6,961
Reported GtG SEC	**MTOE/T**	**5.293**	**5.335**	**5.419**

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The baseline report has included the graphical presentation of the production of molten metal and GtG SEC as illustrated below.
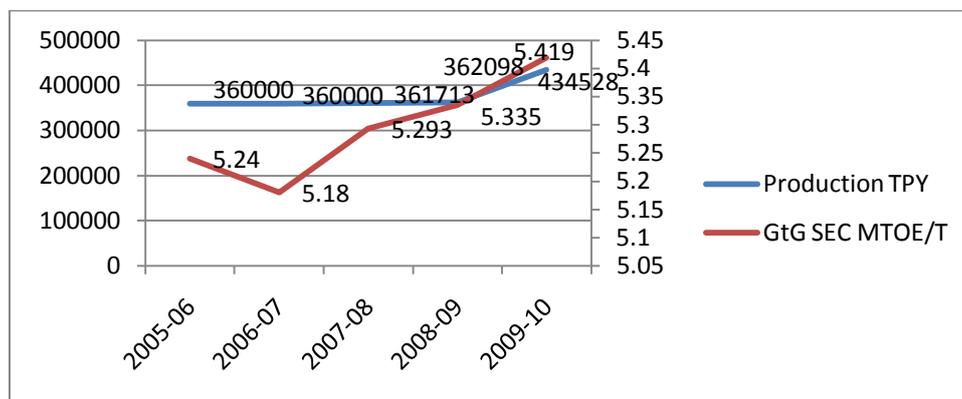
Figure 6 : Production & GtG SEC relationship-Unit-1

Based on the production and capacity data, CU and the GtG SEC relationship has been studied has shown in the following figures for both the units.
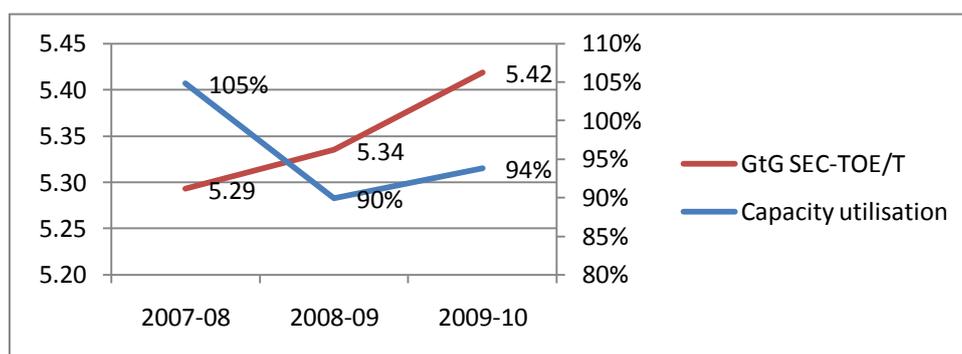
Figure 7: CU & GtG SEC Relationship-Unit-1

The baseline data and computed GtG SEC figures for the unit-2 is as shown in the following table.

Table 3: Baseline data & GtG SEC Unit-2

Particulars	Unit	2007-08	2008-09	2009-10
Production				
Capacity-Molten aluminium	TPY	1,20,000	1,43,000	1,55,000
Production-Molten aluminium	TPY	99,406	1,34,949	1,57,206
CU	%	83	94	101
Fuel				
Coal Indian-Quantity consumed	MT	15,20,965	20,66,370	24,72,258
Coal Indian-GCV	Kcal/Kg	3,222	3,218	3,082
HFO-Quantity (Process) consumed	MT	2,257	2,281	3,499
HFO-GCV	Kcal/Kg	10,000	10,000	10,000

LDO-Quantity (Power)consumed	MT	282	322	144
LDO-GCV	Kcal/Kg	10,000	10,000	10000
Total for power	MTOE	4,90,054.9	6,64,957.9	761949.9
Total for process	MTOE	2,539	2,603	3,643
Grand total	MTOE	4,92,593.9	6,67,560.9	7,65,592.9
Power				
Generation	MU	1,507	2,124	2,438
Export	MU	35	53	94
Import	MU	96	8	10
Captive consumption	MU	1,568	2,079	2,354
Power import/export adjustment	MTOE	1,369	13,887	24,990
Net GtG SEC	MTOE/T	4.94	4.84	4.71

The CU GtG SEC relationship (GtG SEC calculated by DESL is slightly deviating from the reported figures-for analysis reported figures have been used) is as shown in the following figure.
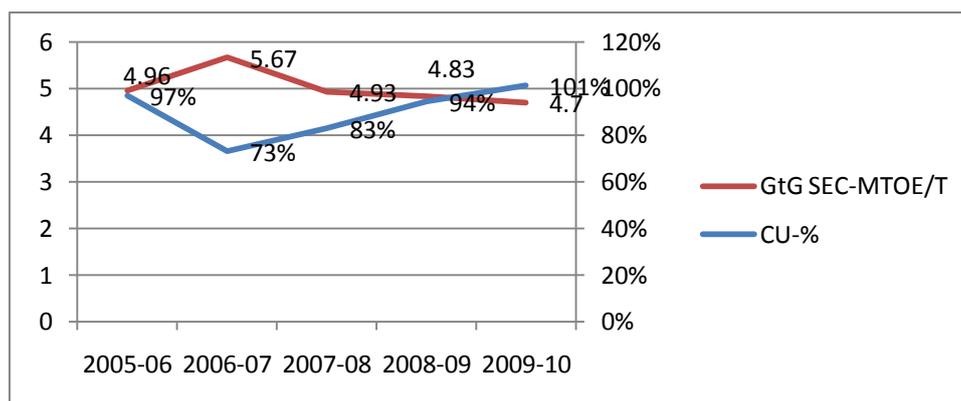
Figure 8: CU & GtG Relationship-Unit-2

It is seen that in case of unit-2, there is perfect correlation but same is not the case with unit-1. Further analysis has been made to assess the impact of variation in the heat rate of captive power generation from the thermal power plant. The heat rates for the three years have been:

Table 4: Heat Rate-CPP-Unit-1

Years	2007-08	2008-09	2009-10
Heat Rate (Kcal/kWh)	3,169	3,177	3,414

By simple normalisation of the GtG SEC by using the heat rate ratio between years 2008-09 and 2009-10, the relationship change is as shown in the figure below.
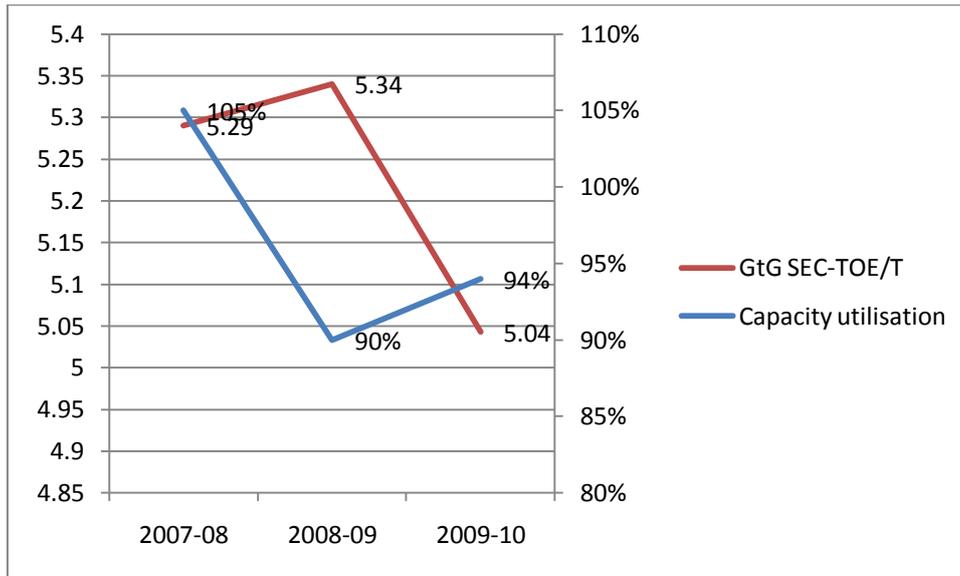
Figure 9: Normalized CU & GtG Relationship-Unit-1

It is seen that the relationship so derived conforms to the same pattern as in case of unit-2. Thus, for the aluminium sector the role of the captive power plant becomes very critical. Although the captive power plant is installed within the plant boundary, the normalisation methodology needs to address this issue separately. In case of adverse change due to design or coal factors, necessary adjustment should be made for normalisation (reference figures 10 & 11 at section 6.5).

In fact, it may be desirable to develop an integrated methodology combining what would be done for the thermal power plant and what is needed for the aluminium manufacturing process.

Impact of identified energy savings projects

A list of energy saving projects has been included with cost and financial data. Quantum of energy savings data has not been provided and as such it has not been possible to carry out impact assessment study. However, general methodology for carrying out such study has been provided and the same is recommended to be followed during the validation process.

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6. VARIABILITY FACTORS AND NORMALIZATION-ALUMINIUM

In addition to the review of the baseline reports and own database, DESL has carried out survey of literature available in the public domain and interaction with sectoral experts to establish the variables, which can impact the energy consumption and therefore, need to be factored for the process of normalisation. The key variable impacting the SEC for the aluminium sector are:

- Process technology
- Plant capacity & capacity utilisation
- Anode sourcing
- Current density
- Coal quality & plant heat rate
- Change in captive and grid power mix
- EE investment

6.1 PROCESS TECHNOLOGY

By and large all the smelters in India have changed over to baked anode technology. Next versions of technologies under development such as 'wetted cathode' and 'inert anode' are unlikely to be commercially deployed during the current PAT cycle. As such, this factor need not be considered for normalisation. In any case, the purpose of the Pat scheme is to attract investment in technology and as such this factor would not qualify for normalisation.

6.2 PLANT CAPACITY & CAPACITY UTILISATION

As already illustrated above, there is close corelationship between CU & GtG SEC. However, available data points are not adequate to establish statistical corelationship to the desired level of accuracy. It would be necessary to develop such model based on extended data points during the validation process.

6.3 ANODE SOURCING

It has been seen at figure-2 that anode manufacturing process consumes about 9% of the total energy consumption. Unit no-1 is manufacturing green anode within the gate whereas unit-2 is importing the same. It is possible for a unit to shift from self manufacture to import and vice-versa. Necessary provision has to be therefore, kept to carry out normalisation on this account.

6.4 CURRENT DENSITY

Thermodynamically, certain minimum voltage required to start the electrolysis at zero load current. This is called the cell decomposition voltage. The cell decomposition voltage is the function of electrolyte temperature and concentration. As shown in figure-3, at 960 $^{\circ}$C temperatures, this

decomposition voltage is about 1.2 V representing about 26% of the total voltage drop across the cell. For increasing the rate of electrolysis and consequently production of metal, current flow is increased. This results in increased voltage drops at various parts of the system and corresponding power loss. It is usually a tradeoff between increased production and increased cell losses.

It is therefore, recommended that the baseline SEC is related to the baseline current density and provision kept for normalisation due to change in the current density.

6.5 COAL QUALITY & PLANT HEAT RATE

The quality of coal received by the two plants has shown marginal decline as would be seen from the following table.

Table 5: GCV of Coal

Units	Quality (GCV kCal/kg)		
	2007-08	2008-09	2009-10
Unit-1-Indian	3,982	3,961	3,923
-Imported	6,000	6,000	6,000
Unit-2-Indian	3,222	3,218	3,082

It would be seen that there has been progressive deterioration in the GCV value of Indian coal. In case of unit-2, degradation in the year 2009-10 has been over 6%. In case of unit-1, share of imported coal has been progressively increasing and the weighted average GCV value of the coal is as shown in the following table.

Table 6: Weighted Average GCV of Coal-Unit-1

Parameters	2007-08	2008-09	2009-10
Indian coal-TPY	47,75,796	46,36,130	52,41,645
-GCV (Kcal/Kg)	3,982	3,961	3,923
Imported coal-TPY	1,40,749	2,30,716	5,25,892
-GCV (Kcal/Kg)	6,000	6,000	6,000
Weighted average			
-GCV (Kcal/Kg)	3,943	4,058	4,112

These changes seem to have impacted differently for the two units as would be seen from the following figures.
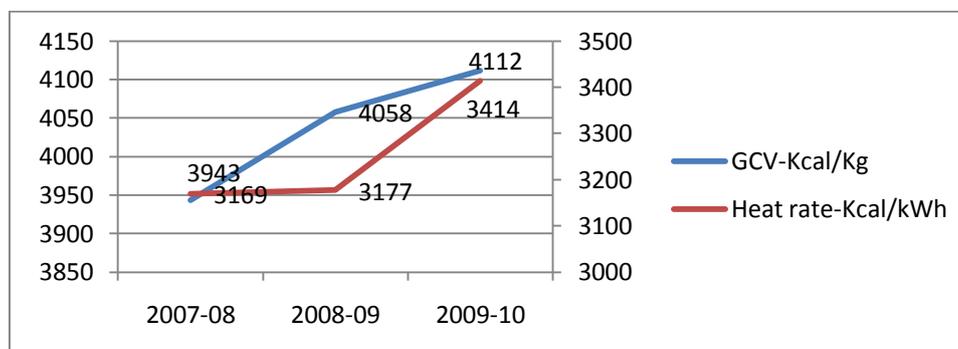
Figure 10: GCV Heat Rate Relationship- Unit 1

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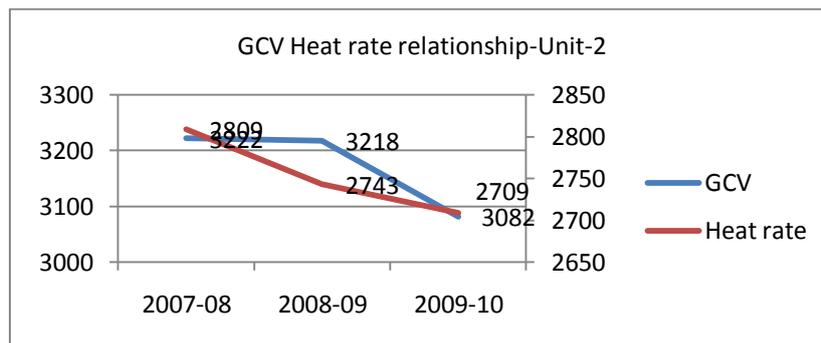
Figure 11: GCV Heat Rate Relationship-Unit 2

In case of unit-1, the heat rate has worsened with increased GCV of coal. On the other hand, in case of unit-2, despite reduction of GCV, the heat rate has improved. Normally with improved coal quality (higher level of GCV), heat rate tends to improve due to improved efficiency of the boilers. In both these cases, different behaviors are exhibited. Reasons for the same could be several including:

- Physical & Chemical composition of the coal (carbon-volatile ratios being the primary one), which can impact combustion efficiency
- Design parameters of boilers-sometime higher quality coal with low ash content can cause higher loss as unburnt carbon
- Operating & maintenance conditions
- Investment in EE equipments & systems

It is recommended that in each case, the reasons are clearly established by carrying out a detailed assessment for the baseline as well as PAT project cycle years. In case the adverse behavior is due to fuel characteristics or boiler limitation, the same should be factored for normalisation. However, in case any negative behavior is due to poorer operating and maintenance conditions, no such adjustment need be made for normalisation.

6.6 CHANGE IN CAPTIVE & GRID POWER MIX

BEE guideline provides for taking the following factors for determination of equivalent MTOE for electricity usage from different sources:

- Grid import @ 860 Kcal/kWh
- Export credit at overall national heat rate for the grid connected thermal power plants (2717 Kcal/kWh)

Only the fuel heat value is factored for determination of GtG SEC for the operating captive power plant. Such heat rate has been assessed at different values ranging around 3000 Kcal/kWh. Thus, any change in the power mix can significantly alter the GtG SEC without in anyway reflecting reduction or increase in energy consumption. A methodology has therefore been proposed for normalisation on this account.

6.7 EE INVESTMENT

PAT scheme has been designed to make EE investment more attractive. This is not a factor to be considered for normalisation. However, it would be desirable for validators to include an investment analysis report to enable BEE to improve the design of the program for the next PAT cycle.

Conclusions:

Due to various complexities involved in establishing all the variabilities and their normalisation, the validation process would require reconciliation exercise based on assessment of impact of EE projects implemented during the PAT project cycle.

The recommended normalisation process is summarized in the following table.

Table 7: Normalisation Process

Parameters	Baseline report	Recommendation	Remarks
Process technology	Not considered	Not required	
Plant capacity & CU	Graph provided for production & GtG SEC	Important normalisation factor	30% limit provided in the BEE document needs to be reviewed
Anode sourcing	Information provided	Needs consideration	
Current density	Not considered	May be considered	Actual relationship needs to be established considering higher production and higher losses at increased current density
Coal quality & plant heat rate	Not considered	Needs critical considerations	Boiler design considerations to be factored
Change in captive and grid power mix	Not considered	Needs consideration	Methodology for normalisation of any change in power and steam mix developed and recommendation provided at annexure.
EE investment	List provided but information on energy savings estimate not provided	Methodology for M&V & reconciliation recommended	It would be desirable for BEE to develop a standard M&V methodology for performance and impact assessment for ECM project

6.8 ILLUSTRATIVE EXAMPLE - RECONCILIATION

It should be necessary to adopt a muli step approach for carrying out the normalisation process during the validation stage. Suggested steps are:

- Review of larger number of representative baseline audit reports to assess the CU GtG SEC relationship, which can stand to statistical scrutiny

- The reasons for deviations particularly for units showing distinctly contra behavior need to be further analysed based on collection of larger number of data for hourly, daily, monthly and annual basis and impacts of other variables established.
- Even after exhaustive statistical analysis, it may become difficult to achieve the targeted accuracy level of 0.05% as provided in the PAT document of July, 2012. It has therefore, been recommended to carry out a project based assessment and reconcile the same with derived and normalised GtG SEC
- The following process is recommended for carrying out the reconciliation process.
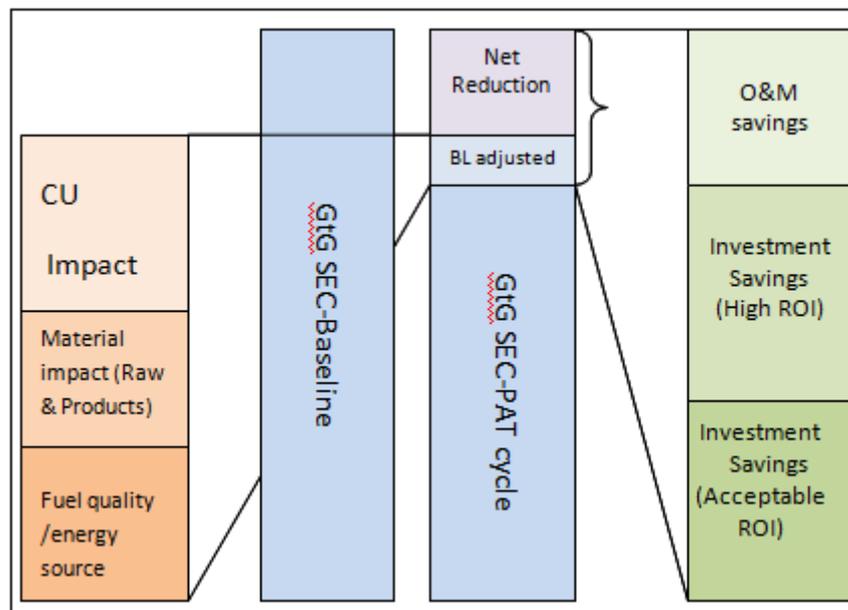
Figure 12: Normalisation & Baseline Adjustment

As illustrated, the unit has achieved the GtG SEC target, though the reported reduction figure may be lower (presented as net reduction in the figure). The gap is on account of change in baseline. The component of the baseline adjustment value has to be apportioned under each head based on proper analysis of data as explained above.

The gross reduction has to be reconciled by assessing the impact of energy savings projects under different heads as shown in the figure.

The entire protocol and the M&V process is therefore, proposed to be carried out in two parts:

- Gross assessment based on input-output measurement & accounting
- Project performance evaluation and impact assessment

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7. M&V PROCESS AND PROTOCOL

7.1 INPUT OUTPUT M&V

The metering & measurement systems for both the plants, as detailed out in the baseline report are adequate for determination of GtG SEC and most of the parameters for the normalisation. Some additional provisions are required (may be already existing in the plants but not reported in the baseline document). The suggested overall metering and measurement plans are presented in the following flow sheet.
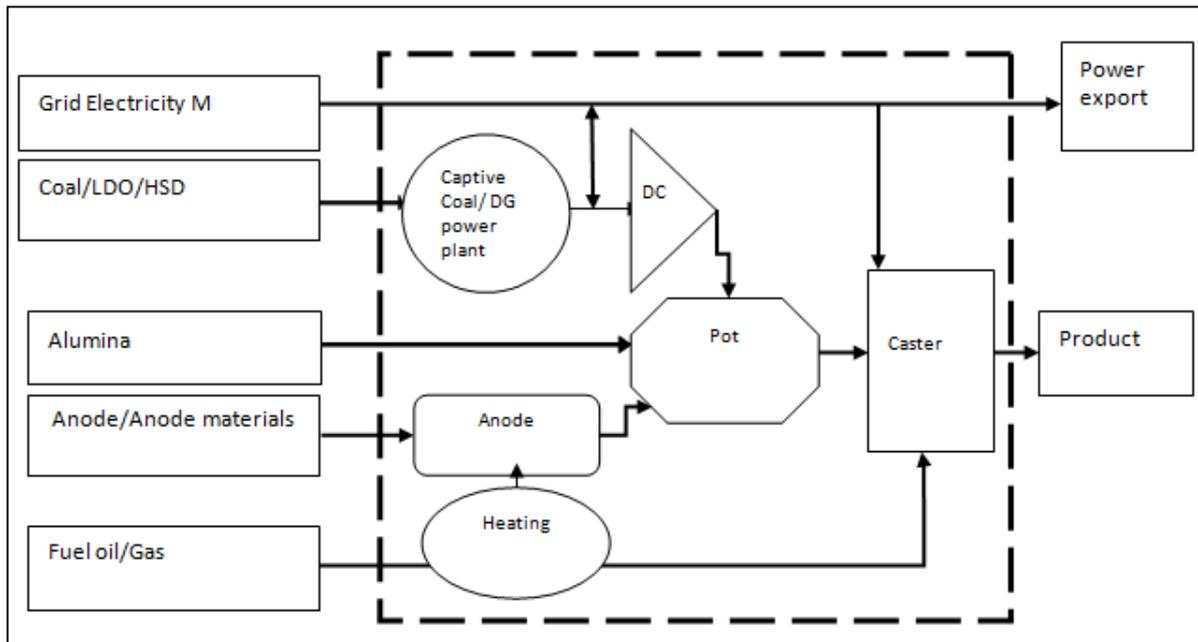
Figure 13: Metering & Measurement

The metering & measurement plant would consist of primary and secondary systems:

- Primary system
    - Grid power import
    - Export of power
    - Primary & secondary fuel for power
    - Fuel for process heating
    - Finished product
- Secondary system
    - Power generation
    - Power from grid for process
    - AC Power at the rectifier transformer input
    - DC Current & power at the outlet of rectifier
    - Power for auxiliaries including caster
    - Process heat to anode plant
    - Process heat to caster

The primary system would be used for determination of GtG SEC whereas the secondary system would be used only for reconciliation.

The data and information management system has been accordingly proposed as shown at the section 7.2 below.

7.2 DATA PROTOCOL

Table 8: Data & information protocol

ID	Data Variable	Source of Data	Data Unit	Measured (M), calculated (C) or estimated (E)	Recording Frequency	How will the data be archived? (electronic, E/ paper, P)	Comment
A	*Production*						
A1	Production Capacity	Balance sheet	TPY	E	Annual	P	
A2	Production	Daily production report	MT	M/C	Daily	E/P	
A3	Opening stock	Cost Audit Report	MT	M/C	Annual	E/P	
A4	Closing stock	Cost Audit Report	MT	M/C	Annual	E/P	
B	*Power*						
B1	Power import	Utility bill	Million kWh (MU)	M/C	Monthly	P	
B2	Power export	Utility billing	Million kWh (MU)	M/C	Monthly	P	
B3	Import of power from renewable	Utility billing	Million kWh (MU)	M/C	Monthly	P	
B4	Gross generation-Unit-1	DCS/Monthly report	Million kWh (MU)	M/C	Monthly	P/E	
B5	Gross generation-Unit-2	DCS/Monthly report	Million kWh (MU)	M/C	Monthly	P/E	
B6	DG Generation	DCS/Monthly report	Million kWh (MU)	M/C	Monthly	P/E	
B7	Auxiliary power consumption	Monthly report	Million kWh (MU)	M/C	Monthly	P/E	
B8	AC Power to rectifiers	DCS/Daily report	Million kWh (MU)	M/C	Daily	P/E	
B9	DC current to pot line	DCS	KA	M	Continuous	E	
C	*Fuel purchased*						
C1	Imported coal quantity	Monthly cost audit reports	LTPY	M/C	Monthly	P/E	

C2	Imported coal GCV	Lab analysis report	Kcal/Kg	M/C/E	Per Consignment	P/E
C3	Domestic coal quantity	Monthly cost audit reports	LTPY	M/C	Monthly	P/E
C4	Domestic coal GCV	Lab analysis report	Kcal/Kg	M/C/E	Per Consignment	P/E
C5	Lignite/petcoke quantity	Monthly cost audit reports	LTPY	M/C	Monthly	P/E
C6	Lignite/petcoke quality	Lab analysis report	Kcal/Kg	M/C/E	Per Consignment	P/E
C7	Biomass quantity	Monthly cost audit report	LTPY	M/C	Monthly	P/E
C8	Biomass quality	Lab analysis report	Kcal/Kg	M/C/E	Per Consignment	P/E
C9	HSD quantity	Monthly cost audit report	Kilo Liter/year	M/C	Monthly	P/E
C10	HSD quality-density	Lab analysis report	Kg/Liter	M/C	Per Consignment	P/E
C11	HSD quality-GCV	Lab analysis report	Kcal/Kg	M/C	Per Consignment	P/E
C12	Furnace oil (FO) quantity	Monthly cost audit report	Kilo Liter/Year	M/C	Monthly	P/E
C13	FO quality-density	Lab analysis report	Kg/Liter	M/C	Per Consignment	P/E
C14	FO quality-GCV	Lab analysis report	Kcal/Kg	M/C	Per Consignment	P/E
C15	PNG/LNG-Quantity	Utility bill	Million SCUM/year	M	Monthly	P/E
C16	PNG/CNG-Quality	Lab analysis report	Kcal/CUM	M/C	Daily	P/E
D	***Fuel Usage for Power Generation***					
D1	Imported coal	Monthly cost audit report	LTPY	M/C/E	Monthly	P/E
D2	Indian coal	Monthly cost audit report	LTPY	M/C/E	Monthly	P/E
D3	Lignite	Monthly cost audit report	LTPY	M/C/E	Monthly	P/E
D4	Biomass	Monthly cost audit report	LTPY	M/C/E	Monthly	P/E
D5	HSD/FO	Monthly cost audit report	KLPY	M/C/E	Monthly	P/E
D6	PNG/LNG	Monthly cost audit report	Mn SCUM Y	M/C/E	Monthly	P/E
D7	Fuel for process heating	Monthly cost audit report	KLPY	M/C/E	Monthly	P/E
E	***Anode***					
E1	Opening stock	Cost Audit	MT	M/C	Annual	E/P

		Report				
E2	Purchase	Cost Audit Report	MT	M/C	Annual	E/P
E3	Manufacture	Cost Audit Report	MT	M/C	Annual	E/P
E4	Consumption	Cost Audit Report	MT	M/C	Annual	E/P
E5	Closing stock	Cost Audit Report	MT	M/C	Annual	E/P

7.3 M&V PROTOCOL-EE PROJECT

It is proposed to use the international performance measurement & verification protocol (IPMVP) for assessment of impact of EE projects. The IPMVP is being administered by USA based organisation EVO. For assessment of performance of EE projects, one or more of the four following methodologies can be used.

Table 9: M&V Protocol-EE Projects

Option	Description	Pros	Cons	Recommendation
C-whole facility	Energy savings can be directly determined by actual measurements of inputs and outputs	Most accurate Results & impact can be transparently established Easy to vary out baseline adjustment	Difficult to implement in retrofit applications particularly where inputs and outputs cannot be specifically linked to the EE projects	Can be implemented for utility systems like pumps, compressors, lighting etc.
D-Calibrated simulation	The energy savings are determined based on pilot study and applying simulation methodology for application to the whole facility or sub-facility	Reasonably accurate system can be developed for determination of energy savings by periodic test & performance analysis	Requires higher skill for carrying out simulation. Information asymmetry can create problem of acceptability	Best suited for systems like furnace, boilers etc
A-Partial retrofit isolation	Savings are estimated based on partial measurements and assumptions for certain parameters	Very easy and low cost of M&V	Lower level of acceptability particularly when responsibility for operation control is not clear-for example streetlight system	Would be the practical system for most of the retrofit projects
B-Retrofit isolation	Same as above except full systems are to be measured & monitored	Robust and accurate	Very high cost of metering & monitoring	Only for high investment projects, where high cost of metering would be justified

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8. NORMALISATION PROCESS

The normalisation process is proposed to be carried out in three stages:
Sep-1-Determination of GtG SEC as has been done in the baseline audit report
Step-2-Determination of the overall normalisation factors
Step-3-Verification & validation based on evaluation of implemented EE projects
The process and illustrative examples are as follows:

Step-1-Determination of GtG SEC

Identify & list all input & export energy streams Review energy flow diagram

Developed process & energy flow diagram

Identify all the major product streams Review process flow diagram

Identify & list all energy metering & measurement devices- codify, if already not

Check calibration status of field & laboratory instruments

Study & document energy accounting methods & information system
- Real time & batch
- Periodicity & methods for reading, sampling & testing
- Method of record keeping
- Statistical validation average heat value for solid fuels

Validation of production reports based on review of auditors report & assessment of measurement system for relevant sub-processes & intermediate products
- Product classification
- Assessment of meters & measurement systems for relevant sub-products & processes

Report on calibration of metering & overall measurement & accounting system

Apply conversion factors and determine the production for determination of GtG SEC
- BEE prescribed e.g. steel, cement
- Industry standard e.g. paper, textile

Assess & validate the total heat value of energy received & used

Assess heat value of energy used net of export

- Determine GtG SEC
- Assess against target
- Identify gaps, if any
- Obtain DC report on gap analysis

Step-2: Normalisation

Capacity utilisation impact-Statistical analysis
- Widen production & energy consumption database (From annual to more frequent-daily preferred)
- Carry out statistical analysis based on the daily record
- Eliminate exceptional highs & lows
- Establish CU impact
- Determine normalisation factor (N1)

↓

Fuel impact analysis (Fuel switch/solid fuel usage)
- Review fuel receipt & analysis reports
- Establish adequacy of data for statistical corelatioship
- Carry out statistical analysis (Quantitative reconciliation, heat value, ash & moisture content)
- Determine normalisation factor (N2)

↓

Power source change impact-Heat rate analysis
- Review & revalidate the process energy flow with specific reference to change in power usage mix (grid & captive)
- Review & assess the heat rate of captive power (baseline & PAT cycle) using HMBD
- Develop fuel adjustment formula taking standard heat rate for grid power & actual heat rate for captive power
- Determine normalisation factor (N3)

↓

Impact of other variables
- List key variables (recommendation for individual sector provided in this report)
- Carry out pareto analysis on sampling basis and select variables for moralization for the DC
- Review metering, measurement, recording & accounting systems for the variables & their relevant attributes
- Carry out statistical analysis on the basis of daily reports
- Establish corelatioship between the attributes & SEC
- Determine normalisation factor (N4)

↓

Normalised GtG SEC & Gap analysis
- Determine the overall normalisation factor (N=N1*N2*N3*N4)
- Determine normalised GtG SEC
- Review normalised GtG SEC against gap analysis report from DC
- Identify steps for reconciliation based on reports on implemented energy efficiency projects reported by DC along with M&V reports on the same
- Spot M&V & revalidation

Step-3: Verification & validation

Review of audit report
- Review of report of identified energy efficiency projects-form II & form III (Ref Form B under rule 5 & Form C under rule 7 of BEE notification)
- Establish linkage of expected results of projects on reduction of GtG SEC
- Review of M&V protocol as provided in the audit report

Assessment of implementation status
- Review of investment approval and project implementation organisation & systems
- Physical verification of implemented projects
- Physical assessment of implementation of project M&V protocol
- Carry out spot check by performing M&V for few major impact making projects
- Review of the report on project performance from the project M&V reports of DC & spot M&V verification reports

Validation
- Review of the project M&V protocol against GtG SEC normalisation M&V protocol
- Assessment of effective reduction of SEC from the implemented projects on GtG SEC
- Determination of the revalidated GtG SEC
- Preparation of revalidation & verification report

9. ANNEX-I-ILLUSTRATIVE METHODOLOGY FOR POWER ACCOUNTING

The GtG energy consumption is to be determined by converting all forms of energy into equivalent heat expressed in TOE. It is therefore, important that the process of conversion and normalisation for power and heat used is clearly established from both technical and accounting perspectives. This impact of Heat rate difference is illustrated with the following narratives for a hypothetical case wherein power and steam for processes are drawn from different types of systems.
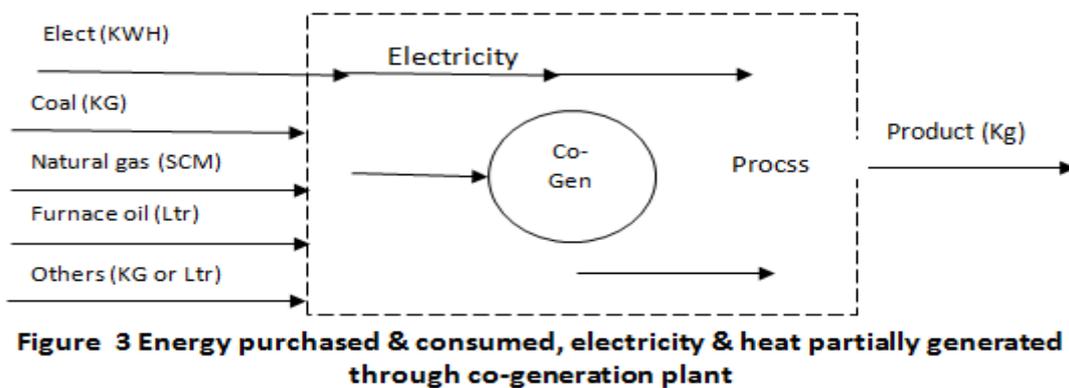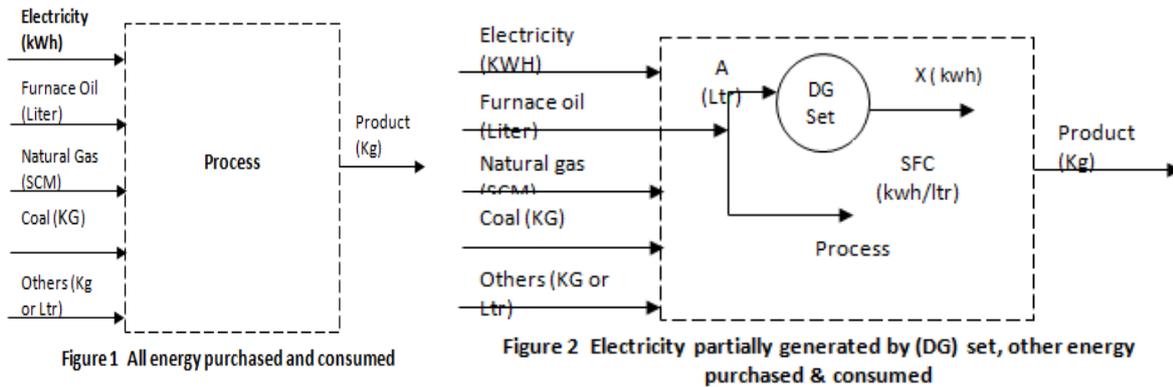

Figure 1 All energy purchased and consumed

Figure 2 Electricity partially generated by (DG) set, other energy purchased & consumed

Figure 3 Energy purchased & consumed, electricity & heat partially generated through co-generation plant

Figure 14: Gate to Gate energy consumption

Briefly the scenario cases are:

1. Entire electricity is purchased from outside and fuel is used in boilers for steam generation and supply to the process
2. Part of the electricity is purchased from outside and balance generated using DG set. Steam is used by burning fuel in the boilers
3. Bulk of the electricity and process steam is supplied from captive cogeneration project; balance need for electricity is purchased from grid.

For the purpose of this document, we are considering fuel to include biomass also. Biomass is renewable fuel and as such can be considered for exclusion under clause 'C' of the GTG definition, if one goes by literal meaning-but we believe that renewable energy in the context means on-site generation using wind or solar technologies, which may in some cases make some marginal contribution.

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More importantly, the calculation methodology for determination of overall SEC (in MJ/T or MTOE/T) needs to be assessed from energy efficiency and M&V perspective. The SEC can be calculated based on both direct and indirect method. The guideline document relies on direct method. In this method, overall energy consumption is determined by adding total fuel heat value and heat value of electricity computed by taking the heat content at 860 kCal/kWh.

Indirect method on the other hand would be a bottom up approach. Steam consumption in different processes would be aggregated on the basis of enthalpy values and overall heat value computed adjusting for losses in the boilers. Direct methodology would continue to be used for computation of electricity consumption in this case too.

The implications of using the two methodologies are explained in more detail with the help of the following Heat & Mass Balance Diagram (HMBD)
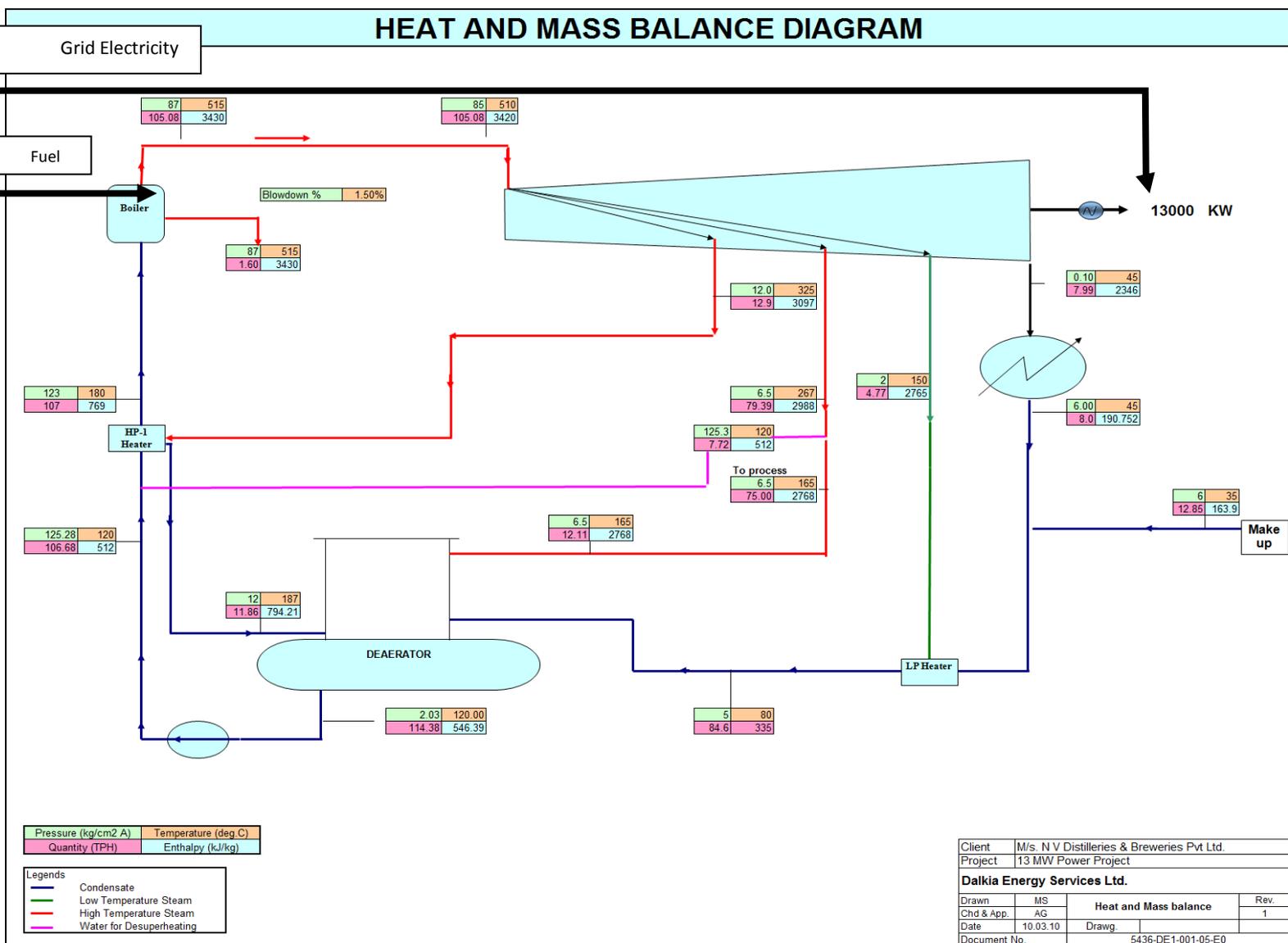

Figure 15: Heat & mass balance diagram

Let us take the following assumptions for development of case scenario:

Table 10: Overall energy consumption

Particulars	Units	Amount	Specific Heat kCal	Eq. Heat Value kCal
Scenario-1				
Fuel	Kg	3,000	3000	90,00,000
Power generated	kWh	0	0	0
Power Purchased	kWh	3,000	860	25,80,000
Baseline Energy				1,15,80,000
Steam for Process	kg	10,000	700	7,00,00,000
Scenario-2				
Fuel	Kg	4,000	3,000	1,20,00,000
Power generated	kWh	2,000	0	0
Power Purchased	kWh	1,000	860	8,60,000
PAT Energy				1,28,60,000
Steam for Process	kg	10,000	700	7,00,00,000

The figures under scenario-2 have been derived from the HMBD for a hypothetical plant. In this case, the incremental fuel consumption for power generation is only 0.5 Kg/kWh. Even then by adopting cogeneration, apparent gross energy consumption for same amount of end use energy has increased. This has happened as in the 2nd scenario (HMBD scenario); the fuel value captures the loss in the Rankine cycle since the Cogen plant is within the gate. In the Scenario-1, this loss happens outside the Gate, thus providing an artificial benefit to the plant. But, by taking the real heat value of grid power, the scenario changes (Table below).

Table 11: Heat value at real heat rate

Particulars	Units	Amount	Specific Hear kCal/Unit	Heat Value kCal
Scenario-3				
Fuel	Kg	3,000	3,000	90,00,000
Power generated	kWh	0	0	0
Power Purchased	kWh	3,000	2,717	81,51,000
Baseline Energy				1,71,51,000
Steam for Process	kg	10,000	700	7,00,00,000

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Scenario-4				
Fuel	Kg	4,000	3,000	1,20,00,000
Power generated	kWh	2000	0	0
Power Purchased	kWh	1,000	2,717	27,17,000
PAT Energy				1,47,17,000
Steam for Process	kg	10,000	700	7,00,00,000

* Boiler Efficiency considered at 80 % for all cases

Now, this table shows the real situation of how cogeneration plant has helped in reducing the overall heat content of the total energy system of the plant. This also shows how the unit would benefit under PAT scheme because of investment in Cogeneration.

Thus, using the methodology discussed at scenario-1 would have the following implications:

- The incentive for reducing power consumption would be low particularly for the plants buying power from the grid since the plant would get credit only for 860 kCal/kWh though nationally we would be saving at least at 2717 kCal/kWh (Current grid heat rate).
- There would be disincentive for investment in cogeneration projects
- Similarly, if a plant has to use emergency power using DG set due to non-availability of grid power, the gross heat value would be much higher compared to grid power though end use efficiency might not change.

From the perspectives of scientific rationale, energy efficiency and robustness of the verification system, it would be more appropriate to adopt the following methodology for determination of gross energy consumption for power usage.

- Plant heat rate determined from the development of heat and mass balance diagram (HMBD) from individual plant (For the cases analysed by DESL, this value was varying from 1800 to 2600 kCal/kWh)
- 2717 kCal/kWh for grid electricity (Based on current value to be kept as the baseline value for the entire duration of the PAT cycle)
- 2300 kCal/kWh for DG electricity

However, there would be certain complexity in adopting this methodology for the present PAT cycle due to the following reasons.

- The entire baseline energy consumption and macro target has been worked out using 860 kCal/kWh for all the sectors
- It would be necessary to carry out the baseline audit once again to determine the HMBD heat rate of individual DC, which is impractical considering the status of implementation
- Using HMBD heat rate would significantly increase the baseline energy consumption value, which would not be desirable from overall perspective at this stage of the project
- Targets for individual DCs have already been set -it would be very difficult to reopen the same considering time required for consultation with stakeholders

- High level of skill and competency is required for development of HMBD for which training and capacity building exercise have to be carried out

These issues have been discussed in great detail in a meeting held with BEE experts on 20th March, 2012 while making presentation on the draft M&V protocol for the paper & pulp segments. DESL was advised to develop a methodology which can harmonise 'Gate to Gate' energy accounting system as per the PAT guideline document with the system proposed by DESL. The basic framework of the hybrid system was outlined as follows.

- Target setting exercise would be completed using the methodology as per PAT guideline document
- During the verification stage gross energy value would be computed using both the methodologies
- In case of deviation by more than 10%, further detailed audit would be carried out to reconcile the two values
- Computation methodology would also be developed to give due credit for cogeneration/power savings

Accordingly, DESL has developed the computation methodology to harmonise both the systems. This methodology has been developed on the basis of providing additional credit for power saving/cogeneration by netting the gross kCal saving from the fuel consumption considering the different heat rates as per DESL proposal. This is illustrated using the same hypothetical case.

Table 12: Harmonization of Heat rate Impact

Particulars	Units	Amount	Specific heat	Heat value	Particulars	Units	Amount	Specific heat	Heat value
			kCal/unit	kCal				kCal/unit	kCal
Fuel	Kg	3000	3000	9000000	Fuel	Kg	4000	3000	12000000
Power generated	kWh	0	0	0	Power generated	kWh	2000	0	0
Power purchased	kWh	3000	860	2580000	Power purchased	kWh	1000	860	860000
Baseline Energy				**11580000**	**PAT Energy**				**12860000**
Steam for process	Kg	10000	700	7000000	Steam for process	Kg	10000	700	7000000
					HMBD heat rate	kCal/kWh	1300		
					Savings	kCal/kWh	1417	Assuming national rate at 2717	
					Fuel savings	kCal			2834000
					Revised PAT energy				10026000
					Additional power savings	kWh	500		1358500
					Equivalent fuel saving		All power savings should be considered as deemed export		
					PAT savings for Escert				**8667500**
					%age saved				25%

As would be seen from the table, computation method has been developed to harmonise the methodology in the guideline document with the HMBD methodology suggested by DESL. This has been done by taking the following steps:

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1. Both baseline and target SEC would be determined using the methodology as per guideline document
2. During the validation process, following methodology would be adopted:
    a. Determine the gross energy level using the same concept
    b. Determine the HMBD heat rate using a simplified concept
        i. Carry out efficiency test of boiler
        ii. Determine the gross heat of steam (Fuel GCV*Efficiency)
        iii. Determine the gross heat of steam to process
        iv. Determine the heat used for power generation
        v. Determine the HMBD heat rate
    c. Assess the overall heat content of power based on HMBD heat rate
    d. Assess the gain due to cogeneration using the baseline heat rate of grid power
    e. Credit the savings so determined for calculation of savings under the PAT scheme
    f. For any additional power savings achieved through implementation of energy saving measures , it should be considered as deemed export for which guideline already provides grid heat rate for computation of energy value
    g. PAT energy would be computed after giving credit for both Cogen and power savings as has been illustrated in the table above.