M&V Protocol for Iron & Steel Sector

Perform-Achieve and Trade Scheme

An initiative supported by

SHAKTI SUSTAINABLE ENERGY FOUNDATION

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ABBREVIATIONS

BEE	*Bureau of Energy Efficiency*
BF	*Blast Furnace*
BOF	*Basic Oxygen Furnace*
CEA	*Central Electricity Authority*
CFBC	*Circulating Fluidized Bed Combustion*
CPP	*Captive power plant*
CU	*Capacity utilisation*
CUM	*Cubic meter*
DC	*Designated consumer*
DESL	*Dalkia Energy Services Ltd*
DRI	*Direct Reduction Iron*
EAF	*Electric Arc Furnace*
EC	*Energy conservation*
Escert	*Energy savings certificate*
FS	*Finished steel*
GCV	*Gross calorific value*
GtG	*Gate to gate*
kA	*Kilo amperes*
kAh	*Kilo ampere-hours*
KLPY	*Kilo liter per year*
LTPY	*Lakh tonnes per year*
MT	*Metric Ton*
M&V	*Measurement & Verification*
OHF	*Open Hearth Furnace*
PAT	*Perform achieve & trade*
PI	*Pig Iron*
SCUM	*Standard cubic meter*
SEC	*Specific energy consumption*
SMS	*Steel Melting Shops*
TOE	*Tonnes oil equivalent*
TPD	*Tonnes per day*
WHR	*Waste Heat Recovery*

EXECUTIVE SUMMARY

This protocol has been prepared to assist the stakeholders, particularly the Designated Consumers (DCs) in the Iron & Steel 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.

Iron and Steel sector is hugely diverse in terms of size, deployment of process technologies and range of products. A common protocol therefore, may not be able to address all the diversity issues. Every large integrated complex would have to have necessarily its own protocol. These units have well established energy management systems, which with minor modification can be used for PAT M&V. This protocol has been prepared mainly to address the medium sized units deploying direct reduction (DRI) and electrical arc (EAF) technologies for production of steel and ferro alloys.

Elaborate methodology has been prescribed in the PAT notification for conversion of various sub-products into a main product for determination of GtG SEC. It would be critically important to accurately monitor the electricity consumption in every sub-process as ratios of electrical SEC have been prescribed for conversion and determination of equivalent production in terms of the main product.

Coal is the main energy input both for thermal and electrical energy as most of these plants have coal based captive power plants for meeting the power need. It would be critically important to have a very robust system for measurement and monitoring of coal quantity and quality.

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. The baseline reports have provided data and information based on which CU GtG impact has been analysed. Clear corelationship between CU & GtG SEC could not be established. These reports have also included the list of identified projects. However, impact of such projects or other variables on GtG SEC has not been analysed. DESL has carried out summary analysis to assess the probability of the DC to achieve PAT target by implementing these projects. In one report, reference has been made about difficult in installation of WHR system due to problem associated with open charging, required due to poor quality of coal and manganese. This indicates that the GtG SEC would be impacted by raw material quality. Few more variables having impact on GtG SEC have been identified based on review of past DESL audit reports and literature survey.

Following key variables have been identified, which can impact the GtG SEC.

- Process technology
- Product mix
- Coal quality
- Other charge materials quality
- Plant capacity utilisation
- EE investment
- Source of power & heat & accounting system

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 for all variables, 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 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.

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 2014-15 in terms of energy saving and sustainability of the entire scheme. The PAT scheme has been designed to incentivize industry to 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 'Normalization' 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.

[1] PAT consultative document

2. IRON & STEEL-OVERVIEW

2.1 SECTORAL PERFORMANCE-A BRIEF OVERVIEW

The Indian steel industry is over 100 years old and was one of the 1st one to be freed of licensing regime post initiation of the liberalization process in 1991. Driven by the rising demand from the sectors like infrastructure, building and automobiles, the industry has found a prominent position in global steel map.

Text Box 1: Steel industry in India

India has emerged as the fourth largest steel producing nation in the world, as per the recent figures release by world steel association in April 2011. In 2010, India was the 5th largest producer, after China, Japan, USA and Russia had recorded a growth of 11.3% in steel production as compared to 2009. Overall domestic crude steel production grew at a compounded annual growth rate of 8.4% during 2005-06 to 2009-10. The Indian steel industry accounted for around 5% of the world's total production in 2010. Further, if the proposed expansion plans are implemented as per schedule, India may become the second largest crude steel producer in the world by 2015-16. (India Steel, 2013, Ministry of Steel)

From the figure below, it would be seen that production of sponge iron by DRI process has shown even more spectacular growth in the last five years (Till Dec, 2011 for 2011-12).

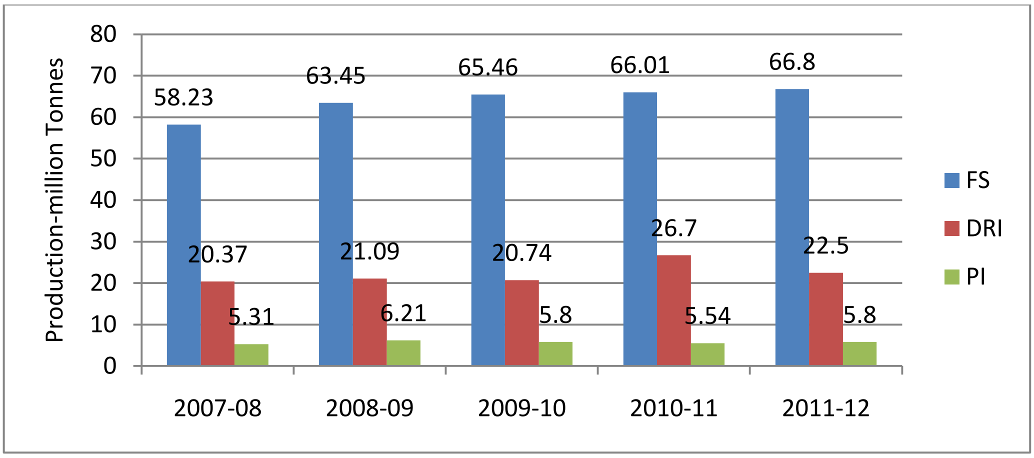


Figure 1: Production (Million Tonnes)[2]

(FS-Finished steel; DRI-Direct reduced iron; PI-Pig iron)

From the perspective of PAT, the industry can be divided into three sectors-very large integrated mills, other mills of different categories, who are also DCs and a very large number of smaller mills primary in the SME rerolling segments.

[2] Iron & Steel Industry in India, March, 2012

The larger industries have been successful in reducing their energy consumption sharply; many of such mills have achieved global benchmark. Similarly, mills in the DRI sector have also succeeded greatly in reducing their energy cost by adaptation of WHR based power generation technologies and advance technologies like WHR based charge pre-heating[3]. Many of the sponge iron units are currently exporting power to the grid.

2.2 OVERVIEW-MANUFACTURING PROCESS

The basic process of manufacture of iron and steel is carried out in two stages, sponge and pig iron through the reduction followed by production of crude steel. Secondary process involves production of merchant products from the crude steel.

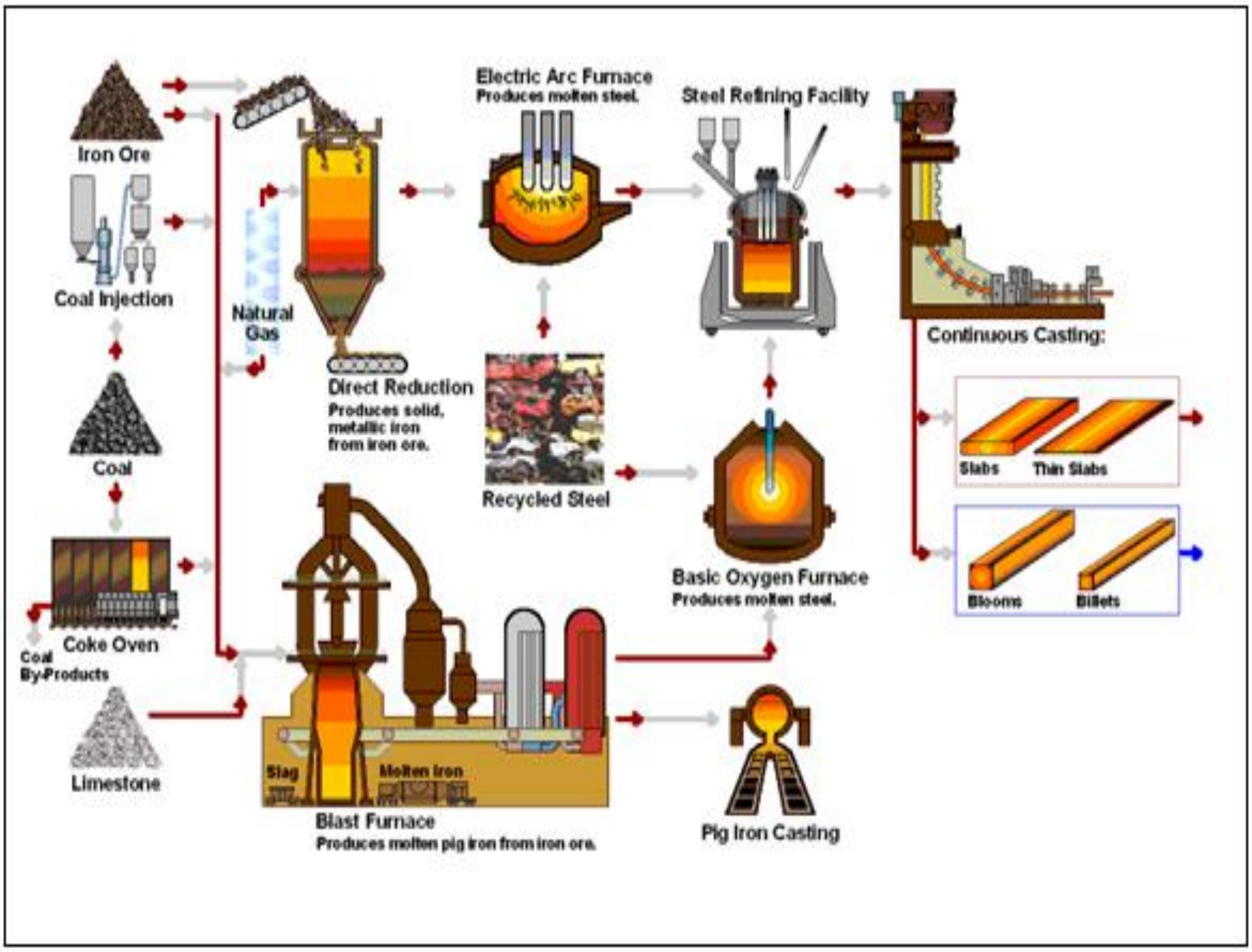


Figure 2: Manufacturing process[4]

The figure shows a process flow of the integrated manufacturing process for iron and steel using the blast furnace and basic oxygen furnace (denoted BF and BOF hereinafter, respectively), which is mostly used in the larger integrated mills and the DRI process for production of sponge iron. After the BF-BOF process, molten steel is controlled to a target composition and temperature and is then

[3] DRI Update-SIMA
[4] www.castechthailand.com

cast by continuous casting machine to produce slabs, blooms, and billets. These castings are rolled to the required dimensions by the rolling mill to produce steel products.

Sponge iron is produced by direct reduction process. Originally, natural gas based reformation technology used to be used in the DRI process. However, technology for using coal has since been developed and most of the Indian sponge iron units use coal both as fuel and reducing agent. Direct reduced iron along with steel scrap is then melted in an electric arc furnace (EAF) to produce molten steel and subsequent products.

2.3 ENERGY USE IN THE IRON & STEEL INDUSTRY

The energy used in steel making is classified under primary and secondary sources. Energy purchased from outside such as coal, coke, electricity, gas etc is classified as primary resource whereas recovered energy such as blast furnace and coke oven gas, waste heat from furnaces are classified as secondary resources. From the energy conservation perspective, major emphasis has always been increased use of secondary resources, such as recent spur in investment in WHR based power plants in large number of sponge iron making plants.

Iron making by far the most energy intensive process accounting for close to 60 to 70% of the total energy consumed (Table below).

Table 1: Energy use in different processes[5]

Process	BF-BOF		BF-OHF		DRI-EAF		Scrap-EAF	
Iron making	Gcal	%	Gcal	%	Gcal	%	Gcal	%
Sinter & pellet plant	0.7	11.6	0.7	10.3	0	0	0	0
Coke oven	0.4	6.6	0.4	5.9	0	0	0	0
Blast furnace/DRI	3.2	53.4	3	47	3.4	57.6	0	0
Sub-total	4.3	71.6	4.1	63.2	3.4	57.6	0	0
Steel making(BOF/OHF/DRI)	0.2	3.4	1.1	14.8	1.4	23.7	1.4	56
Rolling mills	1	16.6	1	14.7	1	16.9	1	40
Utilities	0.5	8.4	0.5	7.3	0.1	1.8	0.1	4

Thus, both from normalisation and M&V perspective, greater emphasis are to be laid on the iron making process.

[5] Energy efficiency in steel industry-Maurice Y Munier et el –World Bank technical paper-22

3. DESIGNATED CONSUMERS-IRON & STEEL

From the overall PAT perspective the Iron & Steel sector would play a major role next only to the thermal power plants. The target for the sector is close to 1.5 million ton oil equivalent (TOE), 22% of the overall target for all industries under the scheme. BEE has classified the DCs in the iron and steel sector into the following eight different categories[6]:

- Integrated steel plants
- Sponge iron
- Sponge iron with SMS & others
- Ferro alloys
- Ferro chromes
- Mini blast furnace
- Steel processing units

The sector is quite heterogonous with having quite a few numbers of units having individual savings target of less than 2000 TOE/T and a few very large ones having individual target of over 100000 TOE/T.

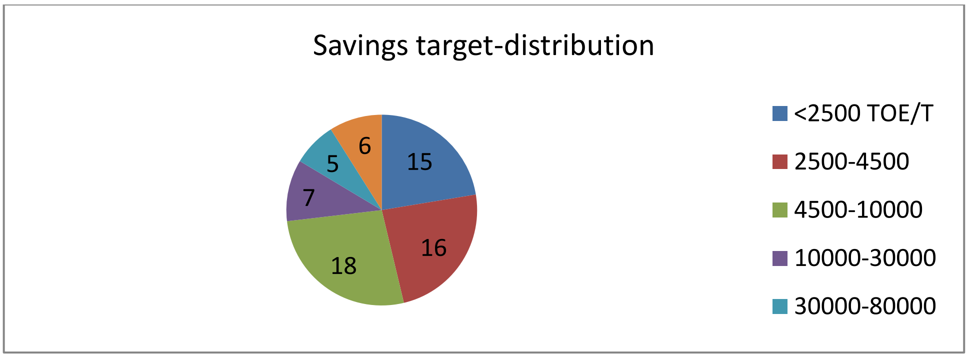


Figure 3: Units & savings targets

From the normalisation and M&V perspective, it would require major efforts addressing the complexities due to large diversities in processes and product mix and individual size of units.

[6] PAT booklet, July, 2012

4. BASELINE & NORMALISATION-OVERVIEW

4.1BEE 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 2: 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[7].

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.

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

Text Box 3: 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.

For the purpose of PAT, the Iron & Steel sector has been divided in eight segments listing the main and sub-products. The methodology for converting different sub-products in the individual segment to the main product for determination of GtG SEC has been detailed out in the PAT notification document of July, 2012 (Table-11 at annex-I)

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 as per BEE guideline.

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

The production for the target period can be determined using the BEE prescribed methodology. 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)
- CPP heat rate for crediting energy content of exported sub-products
- Credit for export of captive power at total export multiplied by grid national heat rate (2717 kCal/kWh)
- Heat rate of captive power plant (CPP) to be used while determining conversion factors for sub-products into main products

BEE guideline 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.

Using the baseline reports

Two baseline audit reports have been obtained with a view to analyze and assess the CU impact on 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 for Unit-1. For Unit-2, all relevant data for three years have not been provided. For this, GtG SEC has been analysed based on monthly data for the year 2009-10. Information on identified energy savings projects has also been provided. However their impact on reduction of GtG SEC has not been evaluated.

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 assessing 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. More number of data would be required to carry out the statistical analysis and deriving corelationship coefficient for normalisation. 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.

The reports have provided coal GCV and CPP heat rates. The relationships show divergent trends, the reason for which has not been analysed. In case of plant 2, it has been reported that due to inferior quality of charge material, WHR technology cannot be used.

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
- Impact of implementation of identified energy saving projects
- 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 iron and steel sector, following important variables have been identified:

- Process technology
- Product mix
- Coal quality
- Other charge materials quality
- Plant capacity utilisation
- EE investment
- Source of power & heat & accounting system

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. Clear corelationship could not be established between CU and GtG SEC. Coal quality and power plant heat rates have significant impact on GtG SEC. Energy accounting methodology used seem to be also some effect in distorting the GtG SEC figures. Good quality data and information would be required on variability of GCV and plant heat rate for carrying out proper analysis.

5. REVIEW & ASSESSMENT-BASELINE AUDIT & DETERMINATION OF GtG SEC

The baseline reports for two representative units have been obtained and reviewed for development of the normalisation process and the M&V protocol for the same. The particulars of the two DCs are as shown in the following table.

Table 2: Particulars of the units

Parameter	Unit-1	Unit-2
Segment	Sponge iron & steel within gate and other products outside the gate	Ferro Alloy
Products & Installed Capacity	Sponge iron-495000 TPY Steel-400000 TPY	Silico Manganese-41000 TPY Ferro Manganese -46000 TPY Pig Iron-45000 TPY
Electricity supply	Coal & WHR based captive & grid	Partly Captive Power Plant, Partly Grid power
Process energy	Coal	Electricity
Technology	Direct reduction & SMS	EAF

The capacity and the capacity utilisation and GtG SEC figures calculated using the BEE methodology are as shown in the following tables & figures.

5.1 ANALYSIS-UNIT-1

The process and energy flow diagram for the unit-1 is as shown in the following figure.

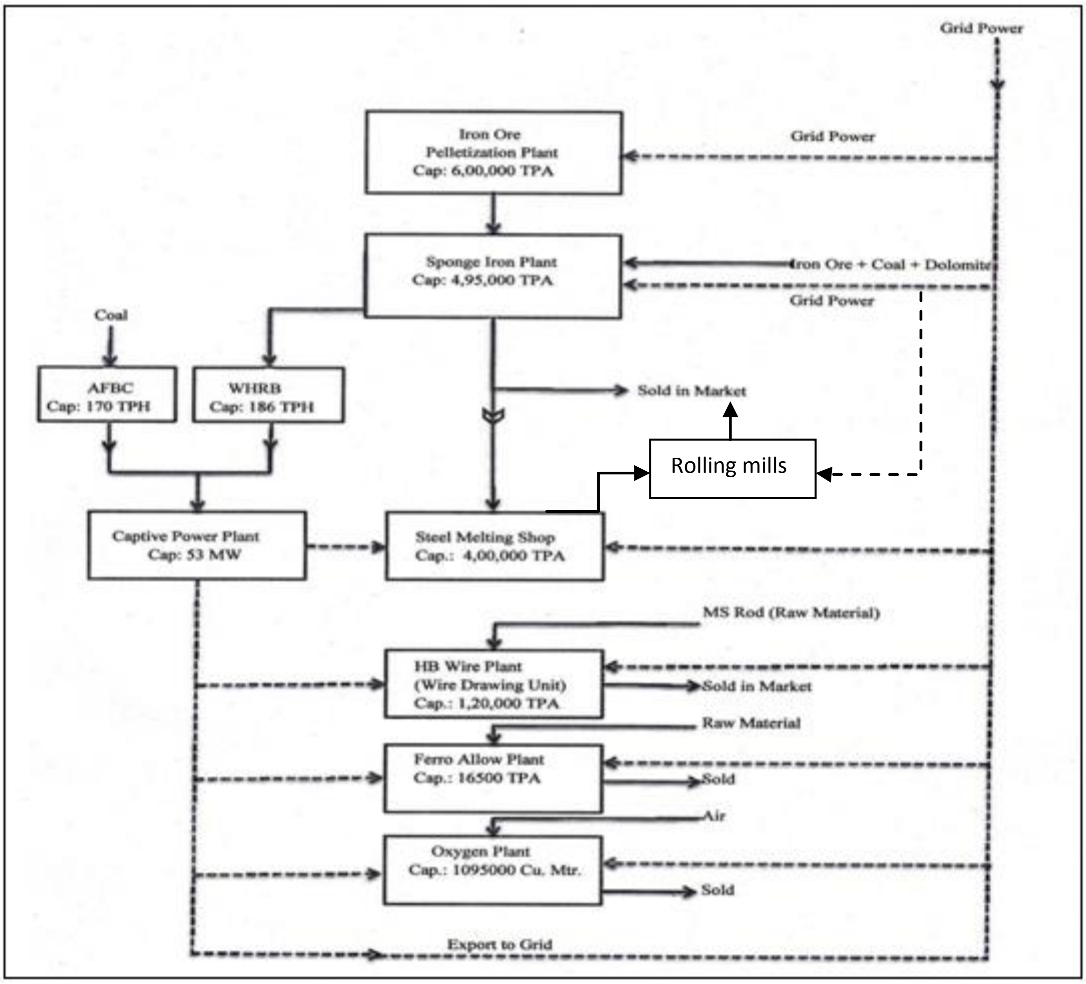


Figure 4: Typical process & energy flow diagram

Review of the baseline audit report indicates that sponge iron and steel billets have been considered as the GtG products whereas other products are considered outside the gate.

GtG SEC corelationship

Following summary table shows the various operating parameters and the calculated capacity utilisation and GtG SEC figures. The capacity utilisation has been computed based on the conversion factors for sub-products as per BEE guideline. For computation of thermal energy, net heat rate has been used. Power purchased from the grid has been accounted as energy export with export from captive units for the sister units. Credit on fuel account has been taken for the power export from the captive unit to the sister units.

Table 3: Baseline data-Unit-1

Particulars	Unit	2007-08	2008-09	2009-10
Production & CU				
Capacity-Sponge Iron	TPY	4,95,000	4,95,000	4,95,000
Capacity-crude steel	TPY	4,00,000	4,00,000	4,00,000
Production-SI	TPY	2,85,862	2,79,533	2,85,832

Particulars	Unit	2007-08	2008-09	2009-10
Production-CS	TPY	2,09,167	1,08,156	56,477
CU-SI	%	58%	56%	58%
CU-CS	%	52%	27%	14%
Power-Sourcing	Lakh kWh/year			
Purchase from grid	Lakh kWh/year	84.96	34.4	0.56
RE import	Lakh kWh/year	0	0	0
CPP generation	Lakh kWh/year	2,903	3,154	3,324
DG generation	Lakh kWh/year	0	0	0
Total captive	Lakh kWh/year	2,903	3,154	3,324
Total grid+captive	Lakh kWh/year	2,988	3,188	3,325
Power-Application	Lakh kWh/year			
Export to grid	Lakh kWh/year	0	0	0
Export to sister units	Lakh kWh/year	554	1,564	2,097
Total export	Lakh kWh/year	554	1,564	2,097
Self consumption	Lakh kWh/year	2434	1,624	1,228
Fuel-Purchased				
Indian coal-Qty	TPY	6,93,429	6,94,410	6,18,961
Indian coal-GCV	Kcal/Kg	3,346	3,969	3,854
Fuel-Application				
For sponge iron	TPY	5,91,206	6,10,663	5,70,844
For CPP	TPY	61,856	62,471	78,447
For sponge iron	Mn Kcal/year	19,78,175	24,23,721	22,00,033
For CPP	Mn Kcal/year	2,06,970	2,47,947	3,02,335
Total	Mn Kcal/year	21,85,145	26,71,669	25,02,368
Electrical to thermal				
Grid power heat rate	Kcal/kWh	2,717	2,717	2,717
CPP heat rate	Kcal/kWh	713	786	910
Electrical to equivalent thermal heat flow	Mn Kcal/year	1,73,530	1,27,700	1,11,653
Electrical energy-SI	Mn Kcal/year	15,570.8	20,634.6	26,335.8
Thermal energy-SI	Mn Kcal/year	19,78,175.3	24,23,721.4	22,00,032.8
Total energy-SI	Mn Kcal/year	19,93,746.1	24,44,356.1	22,26,368.6
SEC-SI	Kcal/T	69,74,505.4	87,44,427.6	77,89,081.1
SEC-SI	TOE/T	0.697451	0.8744428	0.7789081
SEC-Electrical-CS	kWh/T	911	940	955
Total equivalent SI	TPY*	3,05,340.7	2,88,672.97	2,92,130.19
Total thermal (Coal+elec)	Mn Kcal/year	21,51,705	25,51,421	23,11,686

Particulars	Unit	2007-08	2008-09	2009-10
GtG SEC	TOE/T	0.70	0.88	0.79
Capacity &CU				
Equiv CS to SI capacity	TPY	37,249.95	33,802.929	44,607.119
Annual equiv capacity	TPY	5,32,249.9	5,28,802.93	5,39,607.12
Equivalent CU	%	57	55	54

*Calculated as per BEE guidelines using specific electricty consumption indices for SI & CS. Data source for specific electricty consumptions not provided in the base line reports.

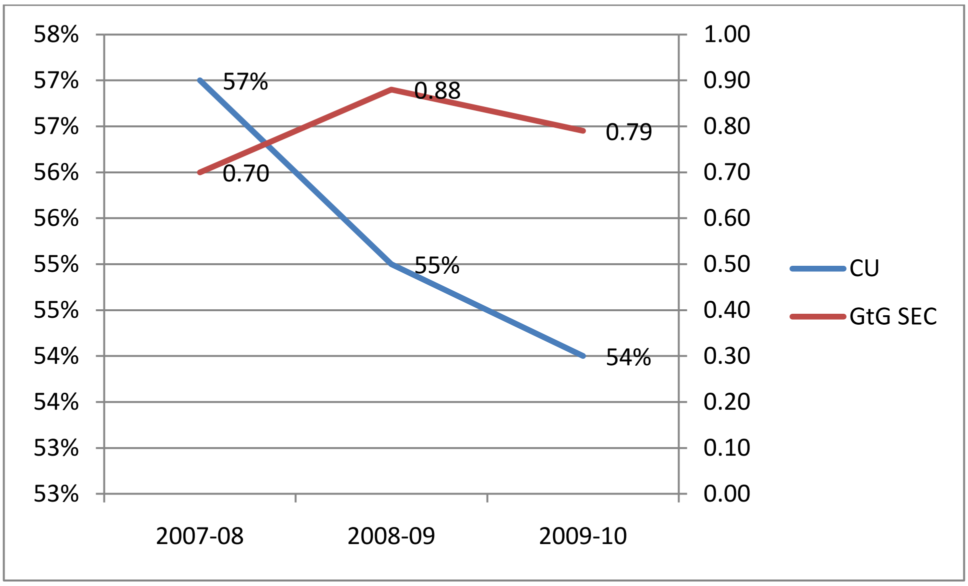


Figure 5: CU & GtG SEC relationship-Unit-1

Co-relationship between CU and GtG SEC could not be clearly established. In 2008-2009, CU was lower and the SEC had also increased. However, in 2009-10, the relationship reversed. With a view to assess the impact of assumptions on conversion factors for sub-products and electrical to thermal energy for power from different sources, calculation has been made using different methodologies as shown in the following two tables.

Table 4: GtG SEC calculation-Option II*

Particulars	Unit	2007-08	2008-09	2009-10
Net power export	Lakh kWh/yr	469.04	1,529.6	2,096.44
Export heat rate	Kcal/kWh	2,717	2,717	2,717
Heat eq.	MN Kcal/year	1,27,438.2	4,15,592.3	5,69,602.7
Fuel heat	MN Kcal/year	21,85,145	26,71,669	25,02,368
Net energy consumed	MN Kcal/year	20,57,707	22,56,077	19,32,765
SEC	TOE/T	0.674	0.782	0.662

*** Considering Only Fuel as Input Energy & Grid Power totally for other Industries**

Table 5: GtG SEC calculation-option III**

Particulars	Unit	2007-08	2008-09	2009-10
Power import	Lakh kWh/yr	84.96	34.4	0.56

Heat equivalent	MN Kcal/year	7,306.56	2,958.4	48.16
Fuel heat	MN Kcal/year	21,85,145	26,71,669	25,02,368
Power export	Lakh kWh/yr	554	1,564	2,097
Heat equivalent	MN Kcal/year	1,50,521.8	4,24,938.8	5,69,754.9
Net energy consumed	MN Kcal/year	20,41,930	22,49,689	19,32,661
GtG SEC	TOE/T	0.669	0.779	0.662

**** (Considering Import at 860 kCal/kWh)**

The relationship behaviour still remains the same as shown in table 4 & 5, though the GtG SEC values have changed.

Impact of coal quality variation

Total energy need of the plant is met from coal, 90% of which is used for heating and 10% for power generation. The plant has fairly large WHR based power plant and about 30 to 40% of the power is exported. The coal GCV and the heat rate reported are as shown in the following figure.

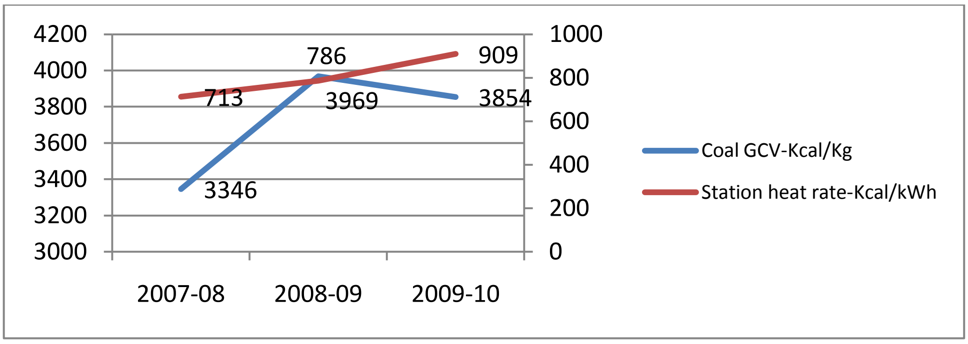


Figure 6: GCV & SHR relationship-Unit-1

The heat rate has increased with improved coal quality. Normally, it should have been the other way around. The auditors have not provided information on the methodology adopted for computation of heat rate. The methodology adopted for computation as illustrated below has become complex due to adaptation of multiple heat value for power depending upon the source and application.

- Credit for exported power is taken at 2717 Kcal/kWh. Export in 2009-10 at about 2097 Lakh kWh, which is almost 65% of the total generation against about 50% in the previous year. It appears that the overall heat rate has been computed adding the heat value of export.
- Credit for heat used for exported intermediate product is taken at the captive plant heat rate
- Heat rate for purchased power from the grid is taken at 860 Kcal/kWh but for computation of notional thermal energy, the value is taken at CPP heat rate (which has been again taken at a notional value of 3208 KCal/kWh) minus 860

Normally, it would not have mattered from the PAT perspective, as GtG energy is not impacted by internal accounting system. But, in case of coal based plant such as is the case, it would be very important to establish energy balance (thermal as well as kWh).

Impact of identified energy saving projects

The list of identified projects and their financials have been reported in the baseline report as shown in the following table.

Table 6: Energy saving projects-Unit-1

Sl. No.	EC Projects	Annual saving potential (kWh/year)
1	***Installation of VFD's***	
	Roof Blower for fuel injection in Pelletisation & Sponge Iron Kiln's.	205920
	Cooling fans for kiln structure	99790
	Flush water pump in GCR pump house	35640
	Dedusting fan-Sponge Iron Kiln No. 1.	79200
2	***Replacement of old GRP fan blade with energy efficient FRP blade***	
	Cooling Tower-1 fan	15840
	Cooling Tower-2 fan	15840
3	***Replacement of old solid FRP fan into energy efficient FRP fans***	
	Cooling Tower 9 & 10 fans.	4750
	Cooling Tower 11 & 12 fans.	4750
4	Reduction of heat time in furnaces by mix change	866250
5	Modification in WHRB-3 &4 ash handling system	142560
	Total	**1470540**

The identified savings represent about 1.2% of the baseline year's (2009-10) consumption of about 1226 Lac kWh.

5.2 ANALYSIS-UNIT-2

GtG SEC corelationship

Almost similar behaviour is observed even for unit-2 as would be seen from the following table and figure. This is only a steel making units and as such all the products have been clubbed together for determination of the overall production and capacity utilisation figures.

Table 7: Capacity, CU & GtG SEC-Unit-2

Particulars	Unit	2007-08	2008-09	2009-10	Average
Production & CU					
Capacity-Silico manganese	TPY	35,000	35,000	41,000	37,000
Capacity-ferro manganese	TPY	40,000	40,000	46,000	42,000
Capacity-pig iron	TPY	30,000	45,000	45,000	40,000
Production-SM	TPY	19,638	18,429	15,298	17,788
Production-FM	TPY	6,950	1,014	4,185	4,050
Production-PI	TPY	0	1,056	0	352
CU-SM	%	56	53	37	
CU-FM	%	17	3	9	
CU-PI	%	0	2	0	
Power-Sourcing					
Purchase from grid	Lakh kWh/year	0	0	108	36
RE import	Lakh kWh/year	0	0	0	0
CPP generation	Lakh kWh/year	1,350	1,180	1,402	1,311
DG generation	Lakh kWh/year	0	0	0	0
Total captive	Lakh kWh/year	1,350	1,180	1,402	1,311
Total grid+captive	Lakh kWh/year	1,350	1180	1,510	1,347
Power-Application	Lakh kWh/year				
Export to grid	Lakh kWh/year	0	0	501	167
Export to sister units	Lakh kWh/year	0	0	0	0
Total export	Lakh kWh/year	0	0	501	167
Self consumption	Lakh kWh/year	1,350	1,180	1,009	1,180
Fuel-Source					
Imported coal-Qty	TPY	0	0	0	0
Imported coal-GCV	Kcal/Kg	0	0	0	0
Indian coal-Qty	TPY	2,20,328	2,04,918	2,08,609	2,11,285
Indian coal-GCV	Kcal/Kg	2,381	2,425	2,613	2,473
Fuel-Application					
For process	TPY	0	0	0	0
For CPP	TPY	2,20,328	2,04,918	2,08,609	2,11,285
For SM	Mn Kcal/year	0	0	0	0
For CPP	Mn Kcal/year	5,24,601	4,96,926	5,45,095	5,22,207
Total	Mn Kcal/year	5,24,601	4,96,926	5,45,095	5,22,207
Calculation-GtG SEC					
Electrical to thermal					
Grid power to thermal	Kcal/kWh	2,717	2,717	2,717	2,717
CPP heat rate	Kcal/kWh	3,886	4,211	3,888	
Thermal eq.(electrical) energy	Mn Kcal/year	5,24,601	4,96,926	3,92,298	
Total production- equivalent SM	TPY	26,588	20,499	19,483	22,190

Particulars	Unit	2007-08	2008-09	2009-10	Average
Total thermal energy (coal&elec)	Mn Kcal/year	5,24,601	4,96,926	3,92,298	
GtG SEC	TOE/T	1.97	2.42	2.01	2.124

Since SEC (electrical) figures are not available for sub-products and contribution of the sub-products to the overall production is not significant, all the sub-products have been clubbed together for determination of the overall annual production.

The export of power is more than the import. Hence, it has been assumed that the entire process electrical energy demand has been met from the captive power and the thermal energy equivalent has been computed based on CPP heat rate.

The following figure shows the GtG SEC to CU relationship.

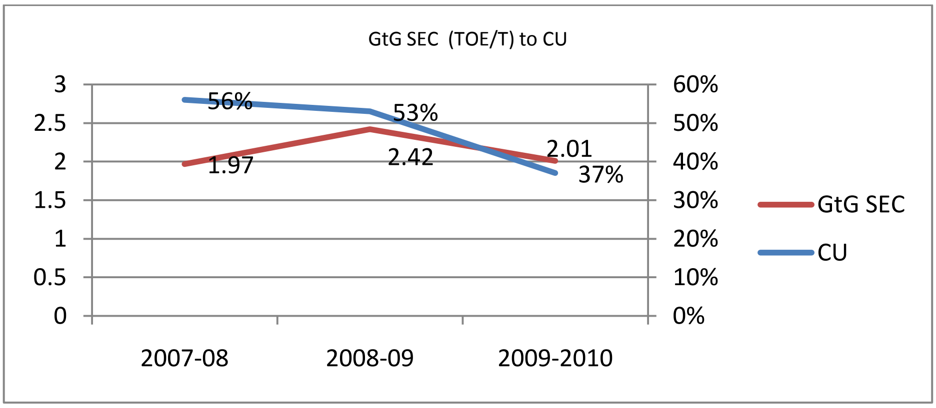


Figure 7: CU & GtG SEC relationship-Unit-2

It is seen that the trend of SEC from 2008 to 2009 conformed to the general phenomenon of higher SEC at lower CU but in 2009, it was reversed. In case of unit-2, there was significant improvement in the fuel quality in 2009-2010. Since the entire fuel is getting consumed for power generation, it can be argued that GtG SEC has been significantly and positively impacted by improvement in the fuel quality.

Impact of coal quality variation

The plant is practically 100% dependent for its energy need on the coal based captive power plant. Reported GCV and heat rate for the three years is as shown in the following figure.

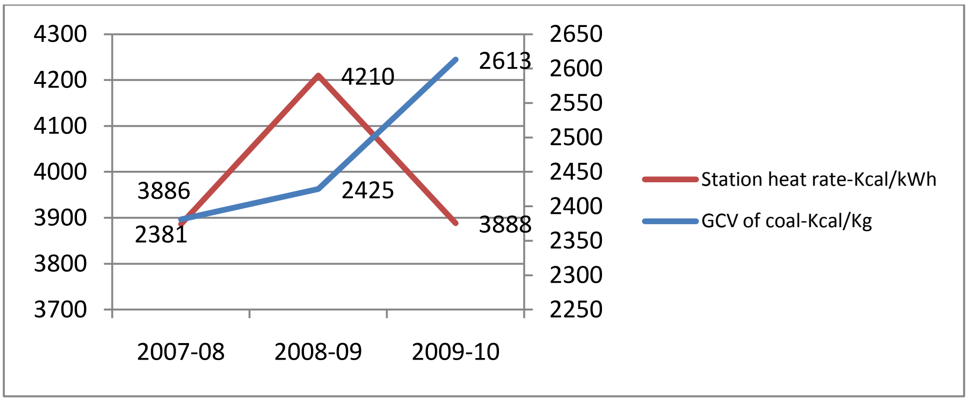


Figure 8: GCV & SHR relationship-Unit-2

Following observations would be made:

- With about 1.8% improvement in the GCV value in 2008-09 over previous year, the SHR increased by 7.8%, the improvement seems to be disproportionately high
- On the other hand, despite improvement in the coal quality by 7.8% in 2009-10, the SHR decreased by 7.6%
- Both the situations look improbable unless there have been some other accentuating situations, which impacted the operation of the thermal power plant

The audit report has not provided any information on factors, which could have caused these abnormalities. It has also been reported that this plant depends upon market coal for meeting its requirement. For such plants, it would be essential to have a robust monitoring methodology for quality and quantity of coal purchased. Otherwise, the determined GtG SEC figures can get distorted.

Impact of identified energy saving projects

The list of identified projects and their financials have been reported in the baseline report as shown in the following table.

Table 8: Energy saving projects-Unit-2

SI. NO.	Recommendation	Potential Saving (kWh/year)
1	Optimization of Boiler feed pump rpm to control the Boiler feed water flow through DC drive panel.	350400
2	Installation of VFD in condensate Extraction Pump for speed control of CEP pump to optimize the condensate flow from CST to de-aerator	87600

3	Automation in switching on & off in lighting circuit.	1764
4	Replacement of conventional luminaries with energy efficient luminaries.	10368
5	Installation of VFD in service compressor No.2	191000
6	Installation of VFD in Auxiliary Cooling Water Pump	43800
	TOTAL	**684932**

Identified saving at 684932 kWh/year represents only about 0.6% of the base year's (2009-10) consumption of over 100 MU.

Conclusions:

- Clear corelationship could not be established between CU & GtG SEC
- Heat rate of captive power plants seems to be not relatable to coal quality. It would be critically important to measure and monitor coal quality as in these plants, GtG SEC would be hugely impacted on this account
- It would better to use actual heat rate for all SEC calculations, particularly since electrical SEC ratios are being used as conversion factors for calculation of equivalent main product.

6. VARIABILITY FACTORS AND NORMALIZATION-IRON & STEEL

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, factored for the process of normalisation. The key variable impacting the SEC for Iron and Steel sector are[8]:

- Process technology
- Product mix
- Coal quality
- Other charge materials quality
- Plant capacity utilisation
- EE investment
- Source of power & heat & accounting system

In addition, the sources of power and methodology for energy accounting process would also have some impact on the calculated SEC.

The review and recommendations are as follows.

6.1 PROCESS TECHNOLOGY

The Iron & Steel sector has already been classified into eight sub-sectors based on the process technology used for different products. Even within the same sub-sector, it may become necessary to make changes, which can be major (such as change from gas based to coal based system for DRI sponge iron), heavy investment oriented driven by consideration other than energy efficiency but may have consequential impact on energy efficiency (such as CFBC boiler for use of char) or purely energy efficiency projects such as (charge pre-heating based on waste heat). Two views could be taken on how the impact of such changes to be considered for baseline normalisation. So long there is net positive impact on energy efficiency due to such change; there would not be any issue. However, should there be negative impact, particularly at low load (as happens sometime for high efficient technologies), it would be necessary to review and adjust the baseline, if the same can be justified.

6.2 PRODUCT MIX

BEE has provided scientific guideline for normalisation factors for conversion of sub-products into main products. This has been designed mainly based on key ratio of specific electrical energy consumption for sub-products to the overall specific thermal energy consumption for the main product. BEE guideline has also provided for targeted accuracy level of 0.05% for the assessed energy savings and issue savings certificates.

[8] Energy efficiency in steel industry-K K Singhal, SAIL, International convention on clean, green & sustainable technologies in iron & steel making-Bhubaneswar

Primarily electrical SEC has been chosen for conversion of sub-products into main products for determination of total production value. Treatment of thermal value for the electrical energy taken differently for different purposes can make impact particularly if there are changes in the mix (such as higher draw from grid and accounting at lower value of 860 kCal/kWh against higher CPP heat rate) or changes in the allocation-more fuel can be allocated for the thermal plant (not taking the actual CPP heat rate but the normative value) under both baseline and PAT. The impact of such a change needs to be thoroughly checked based on statistical analysis for achieving the desired confidence level on the reported SEC.

6.3 COAL QUALITY

Coal is the major energy input and variation in the quality would have impact on both thermal and electrical energy conversion processes and consequently GtG SEC.

6.4 OTHER CHARGE MATERIALS

The impurities in the iron ore have significant impact on energy consumption in the furnace. Thermal energy is needed for:

- Ore melting & reduction
- Heating and melting of the gangue
- Heating and melting of the lime that is added for removal of phosphate impurities
- Heating and melting of the ferrous oxide present in the slag phase in steel making

Indian iron ore contains higher level of alumina and also higher alumina-silica ratio often with higher level of phosphorous. The first problem relates to the fact that alumina requires very high temperatures in order for it to be removed thus wasting energy in the steel production process. These contaminants produce thick scaling in the DRI kilns and impede the heat transfer process and have to be removed periodically, requiring plant shut down.[9]

In the blast furnace too, productivity is significantly affected due to the presence of alumina in the feed. High alumina slag which is highly viscous and requires larger quantity of flux (10% MgO) and relatively larger slag volumes resulting in an increase in coke consumption and a decrease in blast furnace productivity. According to one estimate, a decrease in alumina content in the sinter from 3.1 to 2.5% will improve the degradation reduction index (RDI) by at least six points, lower blast furnace coke rate by 14 kg per tonne of hot metal and increase its productivity by about 30% under Indian operating conditions[10].

The combined impact of impurities (gangue & phosphorous) have very high impact on energy consumption for melting. Under certain condition, additional heat required for complete removal of

[9] www.cdeglobal.com
[10] Processing of alumina rich iron ore slimes-Pradip, Tata research development and design centre, Pune

phosphorous at gangue content of 11% is almost heat that is required for melting of 1 ton of pure metal. At 20% gangue content, this amount exceeds twice as much[11].

The baseline reports do not have data and information on usage and quality of raw materials. As such it is difficult to assess if there have been any changes in quality and if, so what have been their impact.

At the validation stage this aspect would also need a close look.

6.5 PLANT CAPACITY UTILISATION

This issue has been adequately covered in the BEE guideline document. However, in cases where clear relationship cannot be established, the impacts of other factors have to be assessed and CU factor modified.

6.6 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.

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.

6.7 SOURCE OF POWER AND HEAT & ACCOUNTING SYSTEM

At section 6.2 of this report, the effect of heat rate considerations for power from different sources has been discussed. Most of the baseline reports have followed the following guidelines for calculation of overall energy consumption:

- Grid power import at 860 kCal/kWh
- CPP heat rate for determination of actual thermal energy content for the consumption of electricity from captive power plant
- National thermal power heat rate (2717 kCal/kWh) for providing credit for power export
- Notional heat rate of (3208-860) kCal/kWh for conversion of electrical energy to thermal energy for calculation of GtG energy impact for purchased energy

This methodology can distort the overall picture particularly, if there is any change in the energy mix of the power source. The CPP heat rate is required to be established for product normalisation in any case. It would therefore, be best to take the CPP heat rate for all calculation.

[11] Effect of impurities on energy requirements in electrical steel making-K Sardnezhaad, Scientia Iranica, Vol-3; 1.2.3

Necessary protocol can be developed (Illustrative example provided) to maintain the existing and targeted GtG to SEC values with some changes in the various equations.

Table 9: Normalisation process

Parameters	Baseline report	Recommendation	Remarks
Process technology	Not considered	Not considered	Provision to be made in the baseline & M&V protocol on treatment to be made in case of major change in the process
Product mix	For integrated plant, conversion factors used for converting sub-products into equivalent main products For Steel making plant, all products clubbed together	Same as in baseline report	In case contribution from sub-products is less than 10%same may be ignored to make the computation process simpler
Coal quality	Data on GCV and SHR provided		
Raw materials	None	Impact of alumina & phosphorous in the iron ore should be factored Quality of other charge materials and their impact should be studied	No normalisation recommended in the current cycle but a framework needs to e put in place for future reference
Capacity utilisation	CU figures worked out based on computed production figures	The capacity figure is also normalised using the same methodology	from sub-products is less than 10%same may be ignored to make the computation process simpler
EE investment	List provided but their impact on SEC is negligible	Methodology for reconciliation developed	
Power & steam	860 Kcal/kWh for grid power, 2717 Kcal/kWh for captive power and fuel for steam	As per actual heat rate based on HMBD methodology	

6.8ILLUSTRATIVE EXAMPLE – RECONCILIATION & NORMALIZATION

It would be desirable 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
- Impact of other variable factors such as the ones listed above need to be assessed
- Methodology for baseline adjustment and reconciliation is to be developed for each unit as illustrated below.

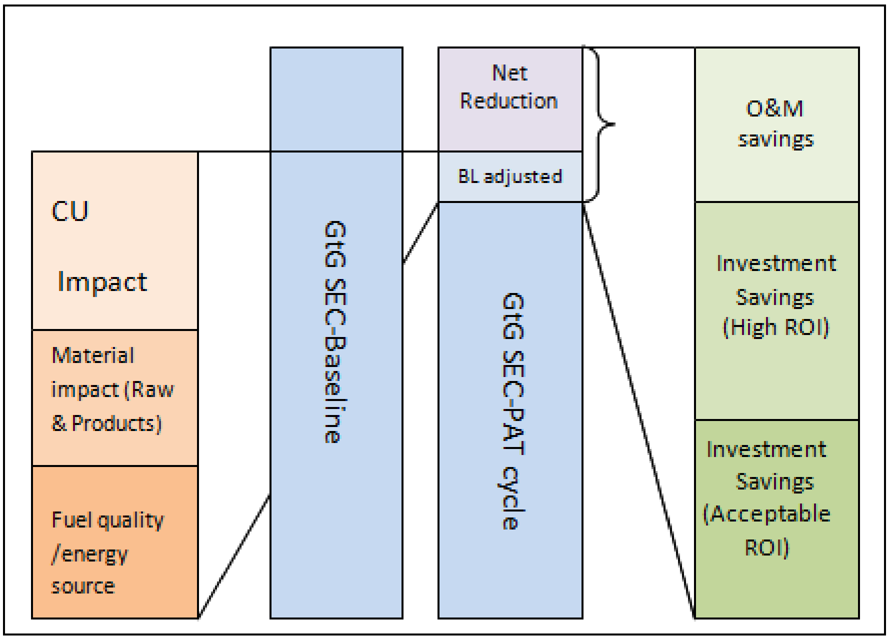


Figure 9: Normalisation & baseline adjustment

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

7. M&V PROCESS AND PROTOCOL

7.1 INPUT OUTPUT M&V

The suggested metering and measurement plans presented in the following flow sheet.

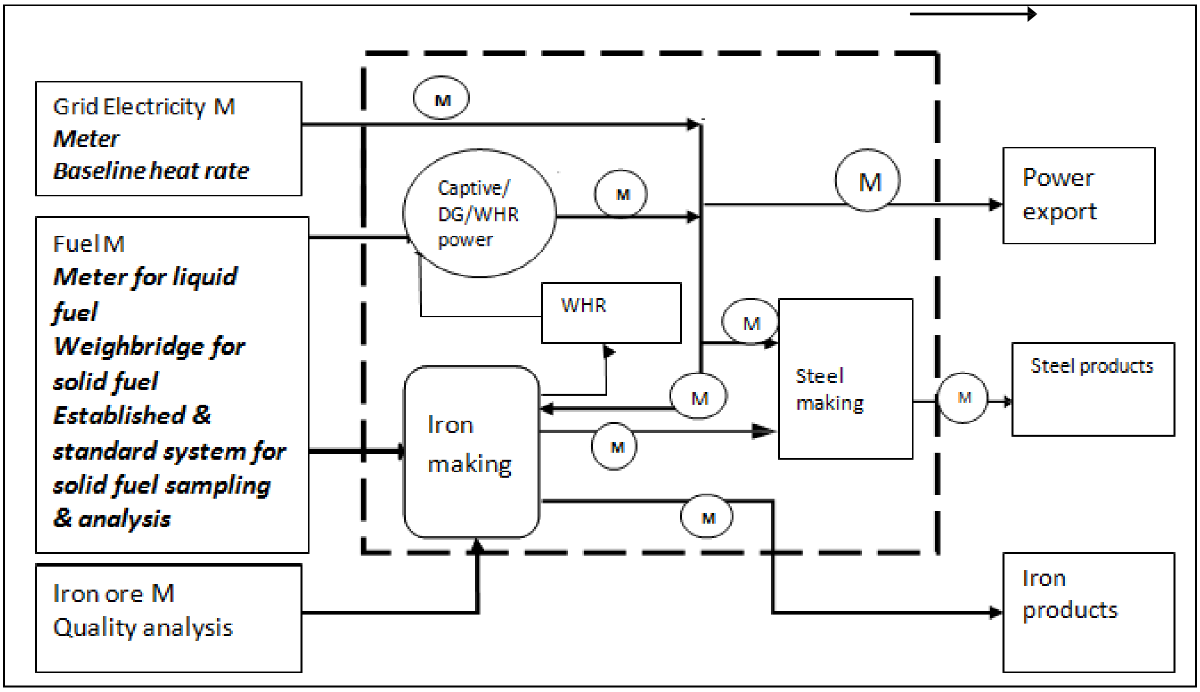


Figure 10: Metering & measurement

The metering & measurement plant to clearly determine:

- Production of different products-steel & iron
- Import of iron ore
- Import of product intermediate
- Fuel quantity & quality
  - Power generation
  - Steam/heat production
- Imported & exported power
- Power from wind and solar systems
- Power generation in CPP

The data and information management system has BEE accordingly proposed as shown at the section 7.2 below. The 'Schedule' annexed with the PAT document of July 2012 has provided guideline for carrying out the normalisation process in respect of capacity utilisation. The proposed M& V protocol for validation has been designed to address to the following specific provisions:

- The normalisation process for CU to be applied only if there is deviation of more than 30% due to uncontrollable factors

- In case of multiple products, major product can be considered for GtG SEC and normalised production value of the major product taken for both baseline & PAT cycle
- The normalisation process shall be done by performing a statistical analysis

It is but natural that for other identified variables too, similar methodology has to be adopted.

Statistical analysis would require lot more data than what could be accessed during baseline audit. The recording frequency of data has been proposed accordingly. The validators would be expected to carry out statistical analysis based on such data and determine the annual factor.

The review of the baseline audit data has indicated that in many cases, clear corelatioship between CU & GtG could not be established. With availability of data on other identified variables, it would be possible for validators to carry out the statistical analysis required for validating the normalised GtG SEC data for issuance of certificates.

7.2 DATA PROTOCOL

Table 10 : Data 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 -Iron	Balance sheet	TPY	E	Annual	E/P	
A2	Production Capacity-Steel	Balance sheet	TPY	E	Annual	E/P	
A3	Production Capacity-Alloys	Balance sheet	TPY	M/C	Annual	E/P	
A4	Production- Iron	Daily production report	MT	M/C	Daily	E/P	
A5	Production-Steel	Daily production report	MT	M/C	Daily	E/P	
A6	Production-Alloys	Daily production report	MT	M/C	Daily	E/P	
A7	Opening stock- Iron	Cost Audit Report	MT	M/C	Annual	E/P	
A8	Closing stock - Iron	Cost Audit Report	MT	M/C	Annual	E/P	
A9	Opening stock- Steel	Cost Audit Report	MT	M/C	Annual	E/P	

A10	Closing stock - Steel	Cost Audit Report	MT	M/C	Annual	E/P
A11	Opening stock-Alloy	Cost Audit Report	MT	M/C	Annual	E/P
A12	Closing stock - Alloy	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	Gross generation-WHR unit	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
C	***Fuel***					
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	Kg/Liter	M/C	Per	P/E

		report			Consignment	
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
E	***Iron ore***					
E1	Opening stock	Cost Audit Report	MT	M/C	Annual	E/P
E2	Purchase	Cost Audit Report	MT	M/C	Annual	E/P
E3	Consumption	Cost Audit Report	MT	M/C	Annual	E/P
E4	Closing stock - Iron	Cost Audit Report	MT	M/C	Annual	E/P
E5	Analysis report	Lab report		C/E	Batch-wise	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 10: M&V Protocol-EE Projects

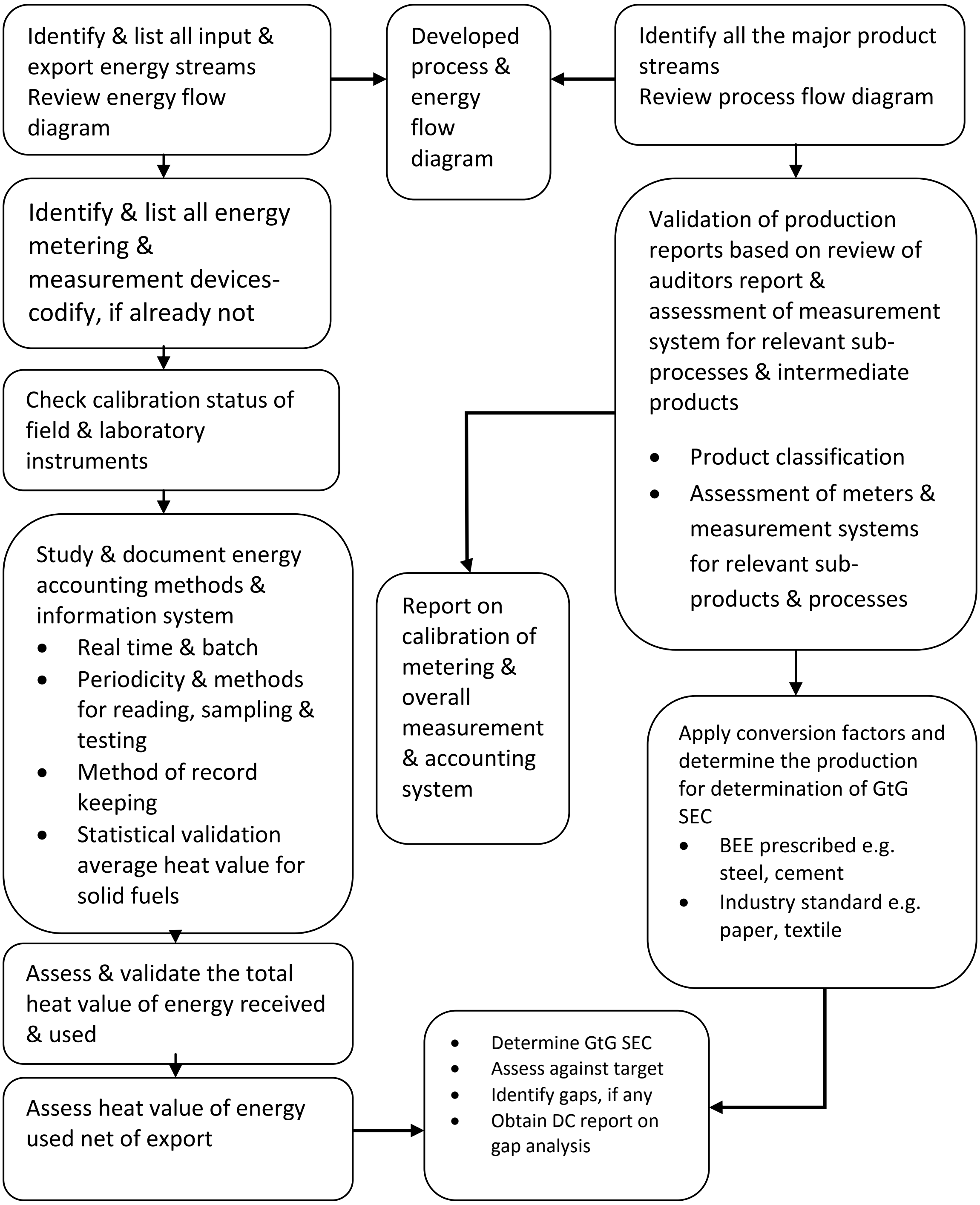
Option	Description	Pros	Cons	Recommendation
C-whole facility	Energy savings can be directly determined by actual measurements of inputs and	Most accurate Results & impact can be transparently established Easy to vary out	Difficult to implement in retrofit applications particularly where inputs and	Can be implemented for utility systems like pumps, compressors, lighting etc.

	outputs	baseline adjustment	outputs cannot be specifically linked to the EE projects	
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

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



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)

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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)

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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)

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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

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

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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

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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-BEE Guidelines-Production normalisation

For the iron & steel sector detailed guidelines have been provided for conversion of co-products into equivalent main products for computation of GtG SEC as reprinted in the following table.

Table 11: Equivalent production conversion process

Sl No	Plant/Products	Normalisation process
A	Integrated steel plant	The energy indices of the major integrated steel plants captured from the annual reports and reported during the baseline audits have been taken for the below calculations. The Gate to Gate Specific Energy Consumption may be calculated as follows- Gate to Gate Specific Energy Consumption (SEC) =Energy index of the plant Submitted to Ministry of Steel (kcal/tone of crude steel). As regards the total energy consumed in plant for these major integrated steel plants, the following formula can be given- Total Energy Consumed in Plant Total Energy Consumption (MKCal) = [Total Thermal Energy (MKCal) + {Purchased Electricity from Grid (MkWh) *860 kcal/kWh} – {Exported Electricity to grid (MkWh) * Captive Power Plant Heat Rate kcal/kWh}]. Where, Total Thermal Energy (MKCal) = [Fuel Quantity used (tonne) *Gross Calorific Value of Fuel (kcal/kg)]/1000
B	Sponge iron	Sponge Iron: - Only standalone plants are considered, having no downstream products. The gate to gate SEC may be given as follows: Gate to Gate Specific (MKCal/ tonne) = Total Energy Consumption Iron (tonne)/Production of Sponge (tonne)
C	Sponge iron with steel melting shop	In this Group sponge iron is first converted to Steel melting shop and again equivalent Steel Melting Shop to sponge iron as follows- Specific Energy Consumption of Coal for sponge Iron = Tonne of Coal Consumption/Tonne of sponge iron Electrical Specific Energy Consumption for sponge Iron = kWh/Tonne of Sponge Iron. Thermal Specific Energy Consumption for Sponge Iron = {(Tonne/Tonne* Gross Calorific Value of Coal) + (kWh/Tonne)*

		CPP Heat Rate kcal/kWh)} Electrical Specific Energy Consumption for Steel Melting Shop = kWh/Tonne of Steel Melting Shop. Steel Melting Shop Equivalent to Sponge Iron Production = [{(kWh/Tonne)*CPP Heat Rate}*production of Steel melting shop] / (Total Specific Energy Consumption of Sponge Iron) Total Equivalent Sponge Iron Production (Tonne) = Production of Sponge Iron (Tonne) + Steel Melting Shop production equivalent to sponge iron (Tonne) (Gate to Gate SEC) Gate to Gate Specific Energy Consumption (MKCal/Tonne) = Total Energy consumed (MKCal)/Total Equivalent Sponge Iron Production (Tonne)
D	Sponge iron with steel melting shop and others	For this sub sector, plants considered are sponge Iron plants with SMS (Steel Melting Shop) and other products like Ferro Manganese, Silicon Manganese, and Pig Iron etc. The gate to gate SEC can be calculated as follows: In this subsector, equivalent Steel melting shop is first converted to Sponge Iron and thereafter equivalent Ferro Alloy is converted to sponge Iron by using the given formulae. Equivalent Ferro Alloy Manganese to Sponge Iron = [{Electrical SEC of Ferro Manganese (kWh/Tonne)*Heat Rate}*Production of Ferro Alloy Ferro Manganese}/(Total Specific Energy Consumption of Sponge Iron) Equivalent Ferro Alloy Iron Manganese to Sponge Iron = [{Electrical SEC of Sponge iron Manganese (kWh/Tonne)*Heat Rate}*production of Ferro Alloy Sponge iron Manganese}/ (Total Specific Energy Consumption of Sponge Iron) Equivalent Pig Iron to Sponge Iron = [{Electrical SEC of Pig Iron (kWh/Tonne)* CPP Heat Rate}* production of Ferro Alloy Pig Iron}/(Total Specific Energy Consumption of Sponge Iron) Total Equivalent Sponge Iron Production = Total Sponge Iron +Ferro Manganese to Sponge Iron + Sponge Iron Manganese to Sponge Iron + Pig Iron to Sponge Iron

		Gate to Gate Specific Energy Consumption = Total Energy consumed/Total Equivalent Sponge Iron Production
E	Ferro Alloy	In this Group, all products are converted to equivalent Ferro alloy (Sponge iron Manganese) using given formula Equivalent Ferro Alloy Manganese to Ferro Alloy Sponge iron Manganese = (Electrical SEC of Ferro Manganese * Production of Ferro Manganese)/ Electrical SEC of Sponge iron Manganese) Equivalent Ferro alloy Sponge iron Manganese to Sponge iron Manganese = (Electrical SEC of Sponge iron Manganese * Production of Sponge iron Manganese)/ Electrical SEC of FA Sponge iron Manganese) Equivalent Ferro Chrome to Ferro Alloy Sponge iron Manganese = (Electrical SEC of Ferro Chrome * Production of Ferro Chrome)/Electrical SEC of Sponge iron Manganese) Equivalent Pig Iron to Ferro Alloy Sponge iron Manganese = (Electrical SEC of Pig Iron * Production of Pig Iron)/ Electrical SEC of Sponge iron Manganese) Total Equivalent Ferro Alloy Sponge iron Manganese Production = (Ferro Manganese to Ferro sponge iron Manganese) + (Fe Sponge iron Manganese equivalent to Ferro Sponge iron Manganese) + (Ferro Chrome equivalent to Ferro Sponge iron Manganese) + (Pig Iron to Ferro Sponge iron Manganese) Gate to Gate Specific Energy Consumption = Total Energy consumption (MKCal))/Total Equivalent Ferro Alloy Sponge iron Manganese Production
F	Ferro Chrome	Ferro Chrome: - The Gate to Gate SEC for this subsector is given as follows Gate to Gate Specific Energy Consumption of Ferro Chrome = Total Energy Consumption (MKCal)/Total Ferro Chrome Production (Tonne).
G	Mini Blast furnace	Mini Blast Furnace:- The G to G SEC for this subsector is given as follows Gate to Gate Specific Energy Consumption of Mini Blast Furnace = Total Energy Consumption (MKCal)/Total Production (Tonne)
H	Steel	Steel Processing Units: - This subsector contributes towards

processing unit	plants like rerolling, wiredrawing, cold rolling, hot rolling etc. The Gate to Gate SEC for this subsector is given as follows Gate to Gate Specific Energy Consumption of Steel Processing Unit = Total Energy Consumption (MKCal)/Total Production of Steel Processing Unit (Tonne)