M&V Protocol for Chlor-Alkali Sector

Perform-Achieve and Trade Scheme

An initiative supported by

SHAKTI SUSTAINABLE ENERGY FOUNDATION

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ABBREVIATIONS

BEE	*Bureau of Energy Efficiency*
CD	*Current density*
CEA	*Central Electricity Authority*
CPP	*Captive power plant*
CU	*Capacity utilisation*
CUM	*Cubic meter*
DC	*Designated consumer*
DESL	*Dalkia Energy Services Ltd*
EC	*Energy conservation*
Escert	*Energy savings certificate*
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*
PAT	*Perform achieve & trade*
SCUM	*Standard cubic meter*
SEC	*Specific energy consumption*
TOE	*Tonnes oil equivalent*
TPD	*Tonnes per day*

EXECUTIVE SUMMARY

This protocol has been prepared to assist the stakeholders, particularly the Designated Consumers (DCs) in the chlor-alkali 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 normalized 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 utilization, product mix and fuel quality have been generally outlined in the BEE document. The baseline reports have identified more variables and outlined their impact. However, information and statistical analysis of variables and GtG SEC correlation have not been provided.

Some more 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 correlation 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 as has been highlighted in one of the baseline audit report for the sector. Normalisation process has been recommended to take care of such situation.

For the chlor-alkali sector, there may or may not be direct correlation between CU and GtG SEC due to influence of current density on the power consumption in the electrolytic cells. In fact GtG SEC is more likely to increase with increase in CU beyond certain optimum value due to increase in cell losses. Following variables have been identified having influence on the GtG SEC.

- Capacity utilization
- Plant loading & cell current density
- Membrane/Electrode life
- Change in captive and grid power mix

From the perspective of PAT, mathematical correlation of GtG SEC to identified variables is to be established and normalisation process carried out using the correlation factors so derived. For this, it would be necessary to have large number of data points for each of the variables for 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 reports 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 neutralized 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. CHLOR AKLALI INDUSTRY-OVERVIEW

2.1BRIEF OVERVIEW OF SECTOR PERFORMANCE

The chlor-alkali industry in India forms an important component of basic chemicals industry, comprising around 74% of the basic chemicals production in India. Caustic soda, soda ash, chlorine alongside hydrogen and hydrochloric acid comprise the chlor-alkali industry's product components. These chemicals find their applications in a number of industries such as textiles, chemicals, paper, PVC, water treatment, alumina, soaps & detergents, glass, chlorinated paraffin wax, among others. The demand for the two sub-segments – caustic soda & soda ash, has increased significantly registering a CAGR of 5.6% and 4.7% respectively, over the past five years[2].

Indian caustic soda capacity stood at 3.25 million metric tons per annum (MTPA), while domestic production was 2.46 million MTPA in FY11. According to Alkali Manufacturers' Association of India (AMAI), the Indian chlor-alkali market was estimated at around USD 1.9 billion in FY2010, vis-à-vis global market size of USD 48 billion[3].

2.2OVERVIEW-MANUFACTURING PROCESS

The Chlor-alkali process is so called due to simultaneous production of caustic soda and chlorine. The production process involves electrolysis of brine followed by other processes as shown in the following picture.

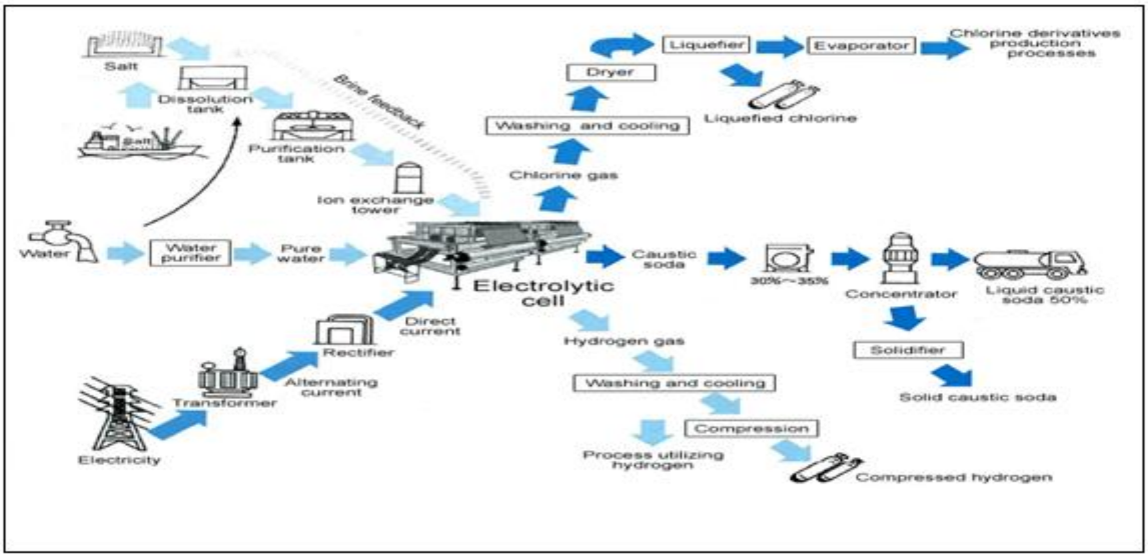

Figure 1: Chlor-alkali manufacturing process[4]

Electrolytic cell is the core of the process. Three cell technologies; Mercury, Diaphragm and Membrane are used for the electrolysis. Energy consumption is highest in the mercury cell process but it does not require steam for concentration of caustic soda. Membrane cell is most energy efficient but requires some steam for evaporation to concentrate the liquor of about 32-33% concentration to about 50%, the standard market product. Apart from higher level of energy

[2] www.researchmarkets.com
[3] www.bharatbook.com
[4] www.jsia.grp.jp

consumption, mercury cells are also polluting and as such have been almost totally phased out in India.

2.3 ENERGY USE IN THE CHLOR-ALKALI INDUSTRY

Electricity is the primary source of energy for the Chlor-alkali manufacturing process; though some small amount of thermal energy is needed for increasing the concentration of cell liquor produced in diaphragm and membrane cells. Typical use of energy in different processes is shown in the following table[5].

Table 1: Energy Need for Different Cell Technologies

Parameters	Units	Membrane	Diaphragm	Mercury
Decomposition Voltage - Theoretical	Volts	2.19	2.19	3.15
Current Density	kA/M^2	3-5	0.9-2.6	8-13
Caustic Strength	GPL	33	12	50
Electrolytic Energy	AC kWh/T Cl_2	2,650	2,720	3,360
Auxiliary Energy	AC kWh/T Cl_2	140	250	200
Total Electrical Energy	AC kWh/T Cl_2	2,790	2,970	3,560
Thermal Energy – Steam (Electrical Equivalent	AC kWh/T Cl_2	180	610	0
Total	AC kWh/T Cl_2	2,970	3,580	3,560
Electrolytic Energy Need	% of total	89	76	94

The electrolysis energy need in the membrane cell process is close to 90% of the total energy, balance 10% being almost equally shared by auxiliary and thermal energy consumption.

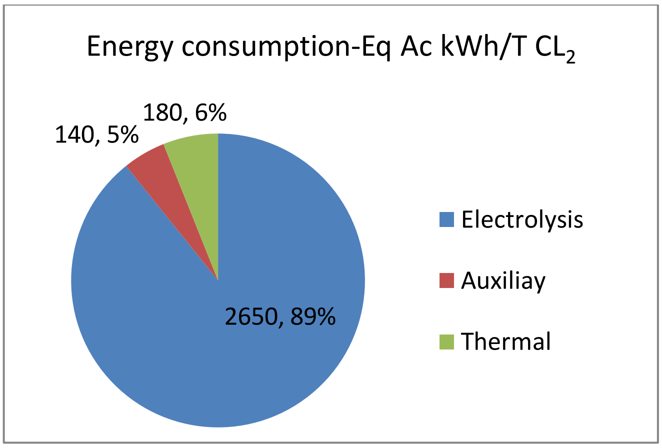

Figure 2: Energy consumption profile-membrane cell technology

It is therefore, obvious that for the Chlor-Alkali sector, the focus of energy conservation as well as M&V protocol has to be around the energy usage for electrolysis.

[5] Reference document for best available techniques in Chlor-alkali manufacturing process-EU commission, Oct 2000

3. DESIGNATED CONSUMERS-CHLOR-ALKALI

From the overall PAT perspective the Chlor-Alkali industry has a small role as the targeted share of savings from this sector is only 1% of the overall target, same as for the textile sector. Identified threshold limit for making a unit a DC is 12500 TOE. The sector has been categorized under two different segments based on the deployed process for electrolysis:

- Membrane
- Mercury

Out of over 30 manufacturing units[6], 22 units have been covered as DCs under the PAT scheme with overall targeted savings of little over 54000 TOE/year. The number of units and the range of savings target are fairly uniformly distributed as would be seen from the following figure.

Depending upon the source of energy use, DCs have been further categorized in two groups-those based on captive power and the 2nd category based on grid power.

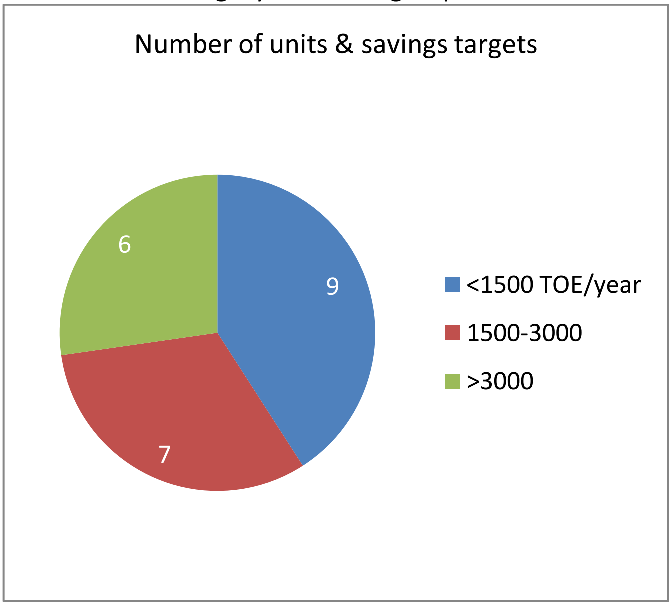

Figure 3: Units & savings targets

From the M&V perspective, the Chlor-alkali sector is relatively easy to manage:

- Smaller number of units with relatively low volume of savings target
- There is only one major operational aspect that needs to be monitored-electrolysis

[6] AMA website

4. BASELINE & NORMALIZATION-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).

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.

With a view to neutralize the impact of uncontrollable variables, the concept of baseline and normalisation has been introduced (Text box-2).

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 a 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.

The principles for the normalisation process have been outlined with capacity utilisation as the key variable. 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.

For the Chlor-Alkali sector, specific guidelines have been provided for products that need to be considered for determination of SEC (Table below).

Table 2: Normalization for Production Variables

Product	Unit	Factor for Conversion to Equivalent of Caustic Soda
Caustic Soda	T	1
Liquefied Chlorine	T	0.0615
Compressed Hydrogen	Lac NM^3	13.889
Solid Flakes	T	0.219

Adjustment factors have also been provided to take care of membrane/electrode life as follows:

1. 60 kWh/T per year is added into specific energy consumption in the baseline year for each plant. For example:
   - Addition of 60 kWh per year: 60 kWh × 860 kCal (In case of Non CPP plants) × 3 years/10000000 MTOE/T
   - Addition of 60 kWh per year: 60 kWh × 2717kCal (In case of CPP plants) × 3 years/10000000 MTOE/T
2. The permissible error shall be ±0.05% in terms of toe for the purpose of determining

4.2 PROPOSED METHODOLOGY

The proposed methodology has been developed considering the following:

- BEE/EESL guidelines
- Review of the baseline audit reports
- Review of case studies-DESL database & literature survey

Using BEE/EESL guideline

BEE document has provided clear guidelines on production and energy consumption variables for the chlor-alkali sector 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 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 utilization coefficient, the guideline has provided for consideration only if deviation is by 30% or more. For the chlor-alkali sector CU may not be considered as a significant variable for normalisation. The cell current density on the other hand has much larger impact on SEC and therefore, should be considered for normalisation.

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. Normalisation needs to be carried out on this account.

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 not carried out the statistical analysis to arrive at the CU GtG correlation. Information provided has been used to assess if such correlation could be established. However, following specific observations have been made on some of the factors impacting the SEC.

- Increase in SEC with increase of production
- Impact of change in power mix-this has been backed up with data and analysis
- Impact of cell life-however, specific data has not been provided
- Impact of grid power quality, not backed up with data

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 protocol, 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 Chlor-alkali sector, following important variables have been identified:

- Capacity utilization
- Plant loading & cell current density
- Membrane/Electrode life
- Change in captive and grid power mix

BEE guideline has provided methodology for normalisation on account of membrane life and conversion factors for normalisation of production and heat rate of power from different sources. A normalisation methodology has been recommended to take care of distortion, which may occur due to change in the ratio of power drawn from different sources.

The particulars of the two DCs are as shown in the following table.

Table 3: Particulars of the units

Parameter	Unit-1	Unit-2
Installed Capacity	56100 TPY Caustic lye	57750 TPY Caustic lye
Electricity Supply	Partly Captive Power Plant, Partly Grid power	100% grid dependent
Process Energy	42% FO, 58% Hydrogen	82% Furnace Oil(FO), 8% Hydrogen, 10% steam demand is imported
Technology	Mono Polar Membrane Cell	125 TPD Mono polar Membrane and 2x25 TPD Bipolar membrane
Products	Caustic Soda Lye & Flakes, Chlorine, Hydrogen, Hydro Chloric acid, Sodium Hypo Chlorite (NaOCl) , Ammonium Chloride	Caustic Soda Lye & Prills, Chlorine, Hydro Chloric acid, Sodium Hypo Chlorite (NaOCl)

5.1 UNIT-1

The energy auditors have reported the GtG SEC based on average of the three years as follows.

Table 4: Reported GtG SEC-MTOE/T

Basis	GtG SEC – MTOE/T Average of 3 years
Normalised Production	0.4354
Caustic Lye Production	0.462

They have further worked out the figures on three years arithmetic average. The usage of hydrogen as gas fuel has been clubbed in the audit report with LPG. The above SEC figures seem to have been worked out on the basis of total heat equivalent including the heat value of hydrogen, if the same has been used. Since hydrogen is generated internally in the process, the same needs to be excluded in computing GtG SEC figures. In DESL computation to follow, SEC has been computed both on total and net of gas fuel heat.

The relevant baseline data and computed total energy consumption data is as shown in the following table.

Table 5: Baseline data-Unit-1

Particulars	Unit	2007-08	2008-09	2009-10
Production Capacity	Tonne	56100	56100	56100
Actual Production	Tonne	55844	53040	51293
Capacity Utilization (%)	%	99.5	94.5	91.4
Purchased Electricity from Grid / Other	Million kWh	48.96	69.30	66.06
Purchased Electricity from Grid / Other	Million kCal	42109	59597	56812
Annual generation-DG on fuel oil (FO)	Million kWh	102.10	74.30	67
Gross calorific value of Fuel	kCal/ kg	10000	10000	10000
Annual fuel consumption	Tonne	21653	16549	14410
Total fuel energy consumption	MKCal	216528	165491	144100
Total Electricity Consumed	Million kCal	258637	225088	200913
Total FO for process	Tonne	1876.69	1764.5	1917.95
	Million kCal	18767	17645	19179
Liquefied Petroleum Gas / Hydrogen		Hydrogen	Hydrogen	Hydrogen
Gross calorific value	kCal/NCM	3050	3050	3050
Gas fuel-process	Million kCal	24583	26596	25238.75
Total energy-process	Million kCal	43349.89	44241.04	44418.29
Total energy use (elec & process heat)	TOE	30198.65	26932.89	24533.09
Total excluding hydrogen heat	TOE	27740.35	24273.29	22009.22

The normalised production figures have been worked out using the BEE guideline.

Table 6: Normalised production-Unit-1

Production	Unit	2007-08	2008-09	2009-10
Caustic Lye Produced	MT	55844	53040	51293
Flakes production as equivalent caustic lye (@ 0.219 T/T)	MT	5515.95	5833.72	5495
Liquid chlorine production as equivalent caustic lye (@ 0.0615 T/T)	MT	1584.85	1332.64	1301
Hydrogen production as equivalent caustic lye (@ 13.889 Lakh Nm^3/T)	MT	2190.52	2091.83	2012

Based on the production, normalised production and normalised energy data, GtG CU correlation figures have been determined and analyzed.

GtG SEC Correlation

The capacity and the capacity utilization and GtG SEC figures have been calculated using the BEE methodology as shown in the following tables. Since there has been come lack of clarity on use of gas fuel for process heating, the SEC figures have been computed on both basis.

Table 7: GtG SEC CU relationship

Particulars	Unit	2007-08	2008-09	2009-10
CU-Lye basis	%	99.5%	94.5%	91.4%
CU-Normalised	%	116%	111%	107%
SEC including hydrogen				
Lye basis	MTOE/T	0.5408	0.5078	0.4783
Normalised	MTOE/T	0.4636	0.4323	0.4020
GtG SEC excluding hydrogen				

Lye basis	MTOE/T	0.4967	0.4576	0.4291
Normalised	MTOE/T	0.4259	0.3896	0.3662

The pattern under both the conditions is showing similar inverse correlation i.e. SEC decreasing with decrease of CU. However, parallelism is more on normalised basis. This is further clarified with the illustrated figures below.

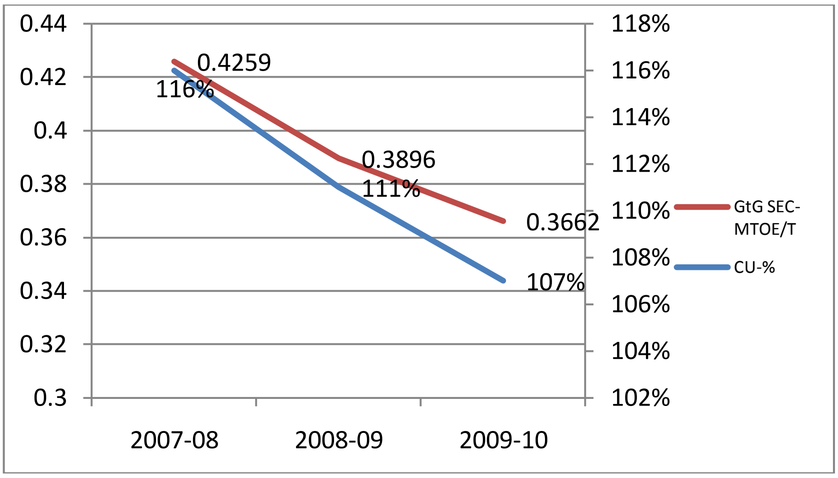

Figure 4: GtG SEC CU Correlation (Normalised)

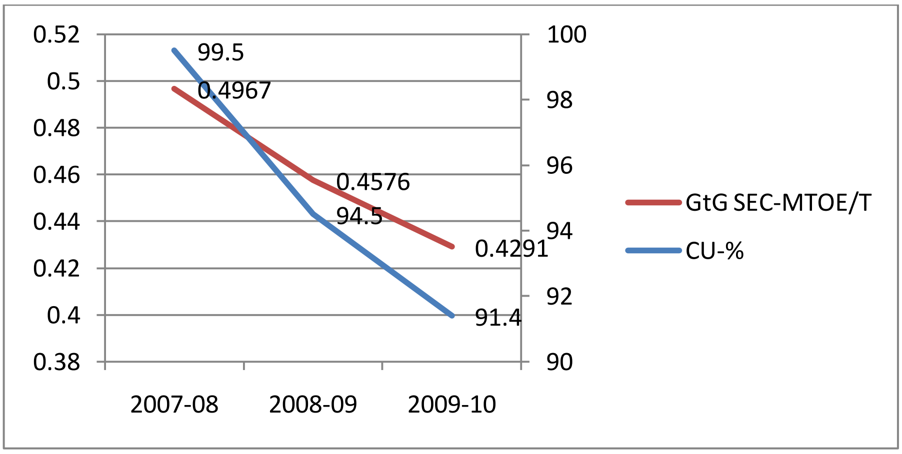

Figure 5: CU GtG SEC relationship-lye basis

Change in captive & grid power mix

The energy auditors have analyzed the impact of change in power usage from different source as shown in the table below.

Table 8: Impact of change in mix of Power

Grid Load	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
CPP Load	100%	90%	80%	70%	60%	50%	40%	30%	20%	10%	0%
SEC (MTOE)	0.706	0.658	0.61	0.562	0.513	0.465	0.417	0.368	0.32	0.272	0.224

The energy auditors have also made the following suggestions on modifications of the sector classification.

"It is seen from the above example that a plant operating with 100% CPP with SEC of 0.706 can reduce to 0.224 merely by switching over from CPP to grid and without undertaking any energy conservation activity. Hence, there is a need for rationalization of SEC based on mix of grid power to CPP power".

Impact of identified energy savings projects

List of identified energy saving projects (total of projects identified by the units and the auditors) is shown in the following table.

Table 9: Energy saving projects-Unit-1

Energy Saving Projects	Saving Potential Lakh kWh/year
Modifications in Liquid chlorine transfer line	0.7
Introduction of Surface condenser in fusion plant	9.7
Modifications in brine recovery system	
Bypass line in brine unit	3.9
Avoiding venting of air from air agitation blower	0.96
Recovering the waste heat from the fusion plant exhaust gas (utilizing in VAM instead of operating a refrigeration compressor)	6.57
Total	21.83

The identified saving opportunity represents about 1.5% of the overall consumption level of 133 MU for the baseline year 2009-10.

Conclusions:

- In the case of this plant, the GtG SEC is varying directly with CU that means higher the CU, higher is the GtG SEC
- Change in power mix has huge impact on reported GtG SEC due to different heat rate values for power from different sources
- The identified energy savings project has the potential impact of only about 1.5% on the overall energy consumption

5.2 Unit-2

The relevant baseline data for the unit is as in the following table.

Table 10: Baseline data-Unit-2

Particulars	Unit	2007-08	2008-09	2009-10
Production Capacity	Ton/yr	57750	57750	57750
Actual Production	Ton/yr	42298	47519	48922
Capacity Utilisation	%	73%	82%	85%
Electricity from Grid	Million kWh/yr	115.4	128.4	130.6
FO Consumption in process	Ton/yr	3100	3656	2935
FO Consumption in process	Million kCal/yr	31000	36560	29350
Gas consumption in process	Million kCal/yr	2544	2358	4477
Steam imported	Million kCal/yr	3750	3750	3750
Total consumption electrical & process heat	Million kCal/yr	133994	150734	145416

Specific Energy Consumption*	TOE/T	0.3168	0.3172	0.2972

*Excluding heat of gas assuming the same to be hydrogen

The auditors have reported the GtG SEC based on average of the three years as follows.

Table 11: Reported GtG SEC-MTOE/T

Basis	GtG SEC – MTOE/T Average of 3 years
Normalised Production	0.293
Caustic Lye Production	0.317

Based on the production, normalised production and normalised energy data, GtG CU correlation figures have been determined and analyzed.

GtG SEC Correlation

The table provided in the audit report on normalised production could not be reconciled with the baseline data. The following table has been computed for normalised production on the basis of baseline data and BEE methodology.

Table 12: Normalised production-Unit-2

Calculating Equivalent Caustic Soda Production	Unit	2007-08	2008-09	2009-10
Caustic Lye Produced	MT/Yr	48922	47519.4	42298.2
Flakes production	MT/Yr	16421	14677	12985
Conversion factor (Flakes)	T/T	0.219	0.219	0.219
Liquid chlorine production	MT/Yr	12594	12782	12930
Conversion factor (Chlorine)	T/T	0.0615	0.0615	0.0615
Hydrogen production	$MnNM^3$	13.62	13.23	11.78
Conversion factor Hydrogen)	Lakh NM3/T	13.90	13.90	13.90
Total Equivalent Caustic Production for the year	MT/Yr	55186	53358	47574

The GtG SEC and CU relationships are shown in the following table.

Table 13: GtG SEC CU relationship-Unit-2

Particulars	Unit	2007-08	2008-09	2009-10
CU-Lye	%	73%	82%	85%
GtG SEC Lye	MTOE/T	0.3168	0.3172	0.2972
CU-normalised	%	82.4%	92.4%	95.6%
GTG SEC normalised	MTOE/T	0.2817	0.2825	0.2635

Under both lye and normalised production basis, similar trend is seen, marginal rise in GtG SEC with over 10% increase in CU in 2008-09 followed by significant drop in GtG SEC in 2009-10 despite increase in CU. This would be clearer from the following figure.

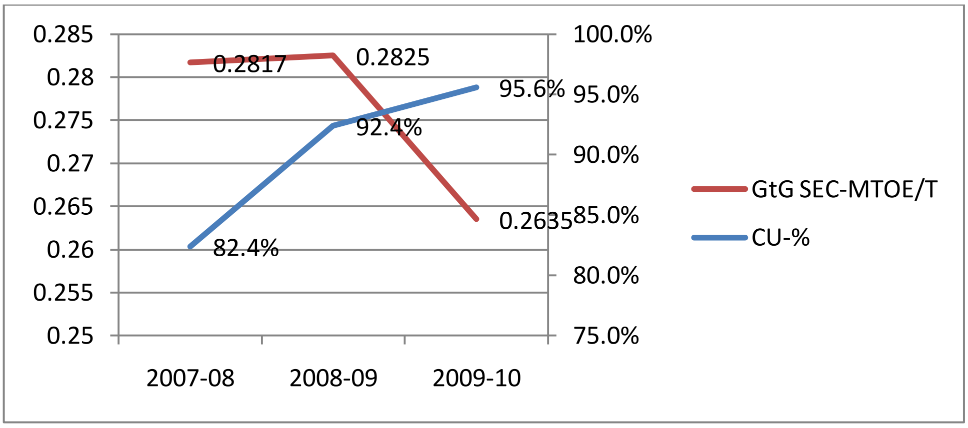

Figure 6: CU GtG SEC relationship (Normalised)-Unit-2

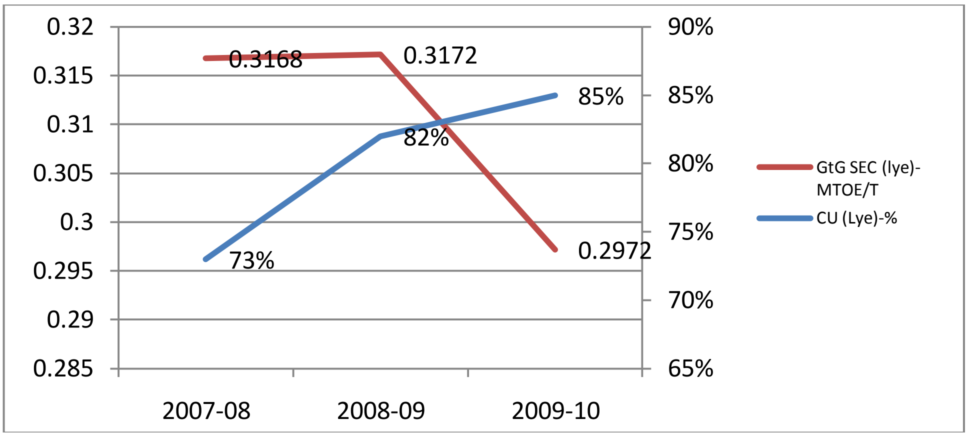

Figure 7: GtG SEC CU relationship (lye)-Unit-2

In case of unit-2 too no change in behaviors is observed by changing the production base from lye to equivalent main product.

Review of SEC by Auditors

The energy auditors have provided a summary review on the impact of variables in the SEC figures. The salient observations are:

- The plant has both mono and bipolar cells. The plant has not observed any reduction in SEC in bipolar cells. The plants attribute this to the relative capacity of the individual cells
- The plant is totally dependent upon grid power and any instability in the grid power (recently more such disturbances have been experienced) increases the cell power consumption
- Cell life has influence on power consumption
- There is increase in power consumption with increased capacity utilisation in case of chlor-alkali plant

- Considering the complexity of influencing factors, the auditors have recommended a benchmarking methodology based on specific DC power consumption for different types of cells

Impact of identified energy savings projects

The identified energy saving project and the overall potential is provided in the table below.

Table 14: Energy saving project-Unit-2

Energy Saving Projects	Annual Savings	
	Electricity GWh	Fuel kL
Installation of VFD for Raw Water Pump	0.82	-
Downsizing of process water pump	0.4752	-
Downsizing of Filtered brine pump	0.0433	-
Downsizing of Sulphuric Acid Circulation Pump	0.0174	-
Replacement of Motor with EE motor class	0.0065	-
Installation of VFD to Annolyte pumps	0.04	-
Using waste steam from FACT	-	384
The continuous caustic fusion plant cooling tower pump impeller size reduced	0.0108	-
Transformer load shifting	0.14	
Installation of VFD for Filtered Brine pump	0.084	-
Installation of VFD for Clarified Brine pump	0.0173	-
The continuous caustic fusion plant cooling tower pump impeller size reduced	0.0108	-
Transformer load shifting	0.14	-
Installation of VFD for Filtered Brine pump	0.084	-
Installation of VFD for Clarified Brine pump	0.0713	-
Installation of VFD for Dechlorinated Brine pump	0.075	-
Installation of 2 Nos Capacitor bank/Harmonic Filter	0.0634	-
Replacement of 40 nos 150 W HPSV Lamps with 70 W Metal Halide Lamps	0.0121	-
Replacement of old 750 kVA TR with a new one	0.0475	-
Total	2.1586	384
Total (Million Kcal)	5312.4	

The impact of the potential saving over the baseline consumption for the year 2009-10 is about 3.6%.

Conclusions:

- In case of this unit, GtG SEC CU relationship has indicated trend in both directions i.e. GtG SEC increasing with increase of CU in 2008-09 but decreasing with increase in CU in 2009-10
- This could be linked to membrane life but no data on the same has been provided
- The plant is having both bi and mono polar cells and no difference has been observed in SEC
- The auditors have observed that disturbance in the grid power has impact on SEC but the observation is not backed by any data-in fact the SEC has reduced in 2009-10

- The auditors have also made observation that the life of cell has impact on SEC but again the same has not been backed by specific data
- Identified energy saving projects has the potential impact of reduction of SEC by 3.6%
- Since the relationship CU GtG SEC relationship behaviors remains the same on lye and equivalent production basis, the normalisation process can be simplified by just taking the lye production

5. VARIABILITY FACTORS AND NORMALIZATION-CHLOR-ALKALI

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 Chlor-alkali sector are:

- Production & capacity utilization
- Plant loading & cell current density
- Membrane/Electrode life
- Cell life
- Change in captive and grid power mix

6.1 PRODUCTION & CAPACITY UTILIZATION

BEE has provided guideline for determination of equivalent production using the conversion factors for the different sub-products. Trend in both direction have been observed in GtG SEC CU relationship. It has also been observed by the auditors that in chlor-alkali process, the SEC is likely to increase with capacity utilization. They have recommended use of benchmarking based on DC power consumption. Considering the influence of current density on SEC, it is recommended that CU may not be used for normalisation. Instead a factor can be developed based on plant loading and current density for individual DC as explained below.

6.2 PLANT LOADING & CURRENT DENSITY

Close to 90% of the entire energy consumption takes place in the electrolysis process. Thus, the focus of energy conservation has to be minimizing the process losses. The loss of electrical energy takes place due to:

- Loss in the conversion from AC to DC in the transformer and rectifier
- Resistive losses in the electrical system of the cell house

Impact of transformer-rectifier losses on SEC

Electrical systems are usually designed for highest efficiency at around 80 to 85% of the load unless otherwise specified by the purchaser[7]. This explains to some extent reason for adverse CU-SEC

[7] Best practice document-Transformers-Devki Energy for BEE/IREDA

correlation for the plants in the sector. It would be desirable to review the manufacturer's catalogue to establish the load-efficiency relationship and assess the impact on overall SEC at different operating points.

Impact of cell house losses

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. It rises with increase in concentration of electrolyte and decreases with increase in temperature. The decomposition voltage is about 2.19 Volts at 90 oC temperature. For increasing the rate of electrolysis and consequently production of cell liquor, current flow is increased. This results in increased voltage drops at various parts of the system and corresponding power loss. Typical voltage profile under good operating condition across the system for a membrane cell process operating at current density of about 3 kA/M^2 is as follows[8]:

- Theoretical minimum voltage-2.19
- Electrolytic resistive drop-0.45
- Membrane=0.38
- Cathode overvoltage-0.05
- Anode overvoltage-0.05
- Structural resistive drop-0.05
- Total-3.17 V

Therefore, about 1 V or 50% of the overall system voltage drop would be related to the current density. Thus, the GtG impact on higher current density can be recalculated based on an empirical equation factoring:

- Current densities at baseline & project cycle evaluation period
- Production at baseline & project cycle evaluation period (Since production is correlated to the current density)

The following picture shows the result of anodic voltage drop measurements for a typical plant8.

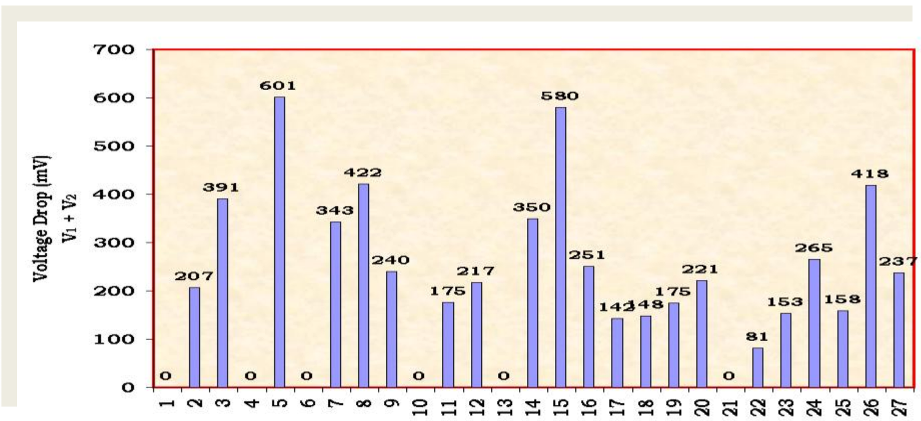

Figure 8: Illustrative example-loss reduction opportunity in cell house

[8] DESL database

Conclusions:

- SEC in Chlor-alkali plant would generally follow production when the CU is over 85%
- The energy performance of the plant can be evaluated based on deviation from the current-density, voltage drop, power consumption and cell liquor production
- At less than 85% load, the relationship has to be worked out based specifications and efficiency load relationship of the major equipments such as transformers and rectifiers
- For a particular technology and plant, the main controllable variable would be resistive losses, which can be monitored as energy performance as stated above

The typical relationship between current density and average cell voltage for a membrane cell facility is as shown in the following graph[9].

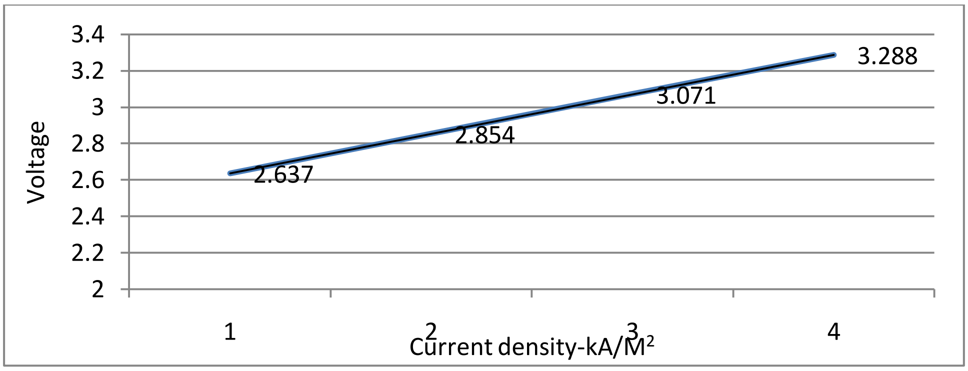

Figure 9: Voltage & current density relationship

With the help of this relationship and the baseline audit data for the unit-1, the GtG SEC has been reworked as shown in the following table.

Table 15: Normalisation principle based on Current density

Particulars	Unit	2007-08	2008-09	2009-10
Production Capacity	Ton/yr	56100	56100	56100
Actual Production	Ton/yr	55844	53040	51293
Electricity from Grid	Million kWh/yr	48.964	69.299	66.061
Electricity from Grid	MKCal/ year	42109	59597	56812
FO consumption of DG	Ton/yr	21653	16549	14410
FO consumption of DG	MKCal/ year	216530	165490	144100
Total energy consumption-electricity	MKCal/ year	258639.04	225087	200912
FO consumption in process	Ton/yr	1877	1765	1918
FO consumption in process	MKCal/ year	18770	17650	19180
Gas fuel for process	Million kCal/yr	24583	26596	25239
Total energy consumption*	Million kCal/yr	301992	269333	245331
	TOE	30199	26933	24533
Specific Energy Consumption	TOE/T	0.54	0.51	0.48
Capacity Utilisation	%	99%	95%	92%
Current density	kA/M^2	2.97	2.85	2.76

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Increase in current density	kA/M^2	0	-0.12	-0.21
Impact on losses	%	0	-0.3	-0.9
Adjusted SEC	TOE/T	0.54	0.538	0.535

*Including gas fuel for process heat

The impact of change in current density has been marginal. The factors for membrane/electrode life are likely to have more impact on GtG SEC. This example has been provided for illustration only. During the validation process, sufficient number of data needs to be collected to establish the clear relationship based on statistical analysis.

Conclusions:

It is therefore, proposed that the following methodology is adopted for assessment of GtG SEC performance of individual plants.

- Current level of GtG SEC is correlated to the operating current density and cell voltages (Practically all the plants are having DCS system from which data and information on cell voltage would be available)
- Effect of annual deterioration of membrane/electrode is taken into account as per BEE guideline
- Validation is carried out factoring the cell liquor production, current densities, voltages and impact of membrane/electrode life

6.3 MEMBRANE/ELECTRODE LIFE

BEE has provided guideline for adjustment on this account as follows:

- 60 kWh/T per year is added into specific energy consumption in the baseline year for each plant. For example:
  - Addition of 60 kWh per year: 60 kWh × 860 kCal (In case of Non CPP plants) × 3 years/10000000 MTOE/T
  - Addition of 60 kWh per year: 60 kWh × 2717kCal (In case of CPP plants) × 3 years/10000000 MTOE/T

6.4 CELL LIFE

The auditors have made observation about impact of cell life though no back up data has been provided. Apart from the membrane, the anode coating can also deteriorate (except for permanent metal anode cells), which would have impact on cell efficiency and hence the SEC. However, there could be counter argument about coating being an essential maintenance factor and as such plants are expected to maintain the cells for achieving optimum efficiency. In any case, BEE has already provided for adjustment due to aging of vital components (membrane and electrode).

For the next PAT cycle, this factor is therefore, not to be considered.

6.5 CHANGE IN CAPTIVE & GRID POWER MIX

The auditors have highlighted how the SEC figure can get distorted due to change in the captive and grid power mix. This is due to use of different normative conversion factors for determination of equivalent thermal energy for electricity drawn from different sources. DESL has made detailed study on this issue covering both electrical and thermal energy. The detailed analysis, findings and solution options have been provided at annex-I of this document. Summary recommendations are as follows:

Various scenarios for change in power mix could be projected as:

- Grid to DG or vice versa
- Grid to captive or vice versa
- Grid to Cogen/CHP of vice versa

It would be desirable to harmonize the system with a view to achieve the following desirable objectives:

- Determination of true GtG SEC
- Encouraging industry to adopt cogeneration/CHP systems

The BEE protocol requires that the heat value of grid power be taken at 860 Kcal/kWh for import and 2717 Kcal/kWh (national average of all thermal power stations) for export. A system can be developed for accounting methodology, which would be able to achieve the harmonization objectives as stated above and at the same time maintaining the BEE guidelines.

This can be done by giving fuel credit for the difference between the heat rates as illustrated below.

Table 16: Illustrative case-heat rate accounting

Baseline Case	Project Case
Power-3000 KW, totally drawn from grid Steam-10 TPH @ 700 Kcal/Kg enthalpy generated from a boiler	Power-2000 KW generated from Cogen plant @ heat rate of 1300 Kcal/kWh -1000 KW purchased from grid Steam supplied from extraction system

Cogen installation has increased the heat rate for 2000 KW power from 860 Kcal/kWh to 1300 Kcal/kWh. Thus, by usual accounting methodology plant would have adverse impact on computed GtG SEC. This can be overcome by giving fuel credit as per the following formula:

Cogen power generation-2000 KW (a)
Cogen PLF-0.8 (b)
Plant heat rate-1300 kCal/kWh (c)
National heat rate of power-2717 kCal/kWh (d)
Credit to plant-1417 kCal/kWh (e=d-c)
Annual fuel savings-(e*a/b)/ (10000*10^3) TOE (assuming GCV of oil at 10000 Kcal/kg) (f)
Annual fuel purchase as per M&V protocol-g
Fuel for computation of GtG SEC=g-f

This would ensure that due credit has been given for adaptation of cogeneration. In fact higher the cogeneration efficiency, more benefit would be derived in line with global objective of the PAT scheme. Same logic can be applied for non-cogeneration/captive plant too except in case of adaptation of higher heat rate power from captive plant due to non-availability of grid power. In such events, power from captive plant should be treated as grid power and credit provided in fuel account for the difference.

Detailed computation using a developed heat and mass balance diagram on the hypothetic case has been provided at Annex-I (Section 8 of this report).

6.6SUMMARY RECOMMENDATIONS – VARIABLES AND NORMALIZATION

Table 17: Normalisation process

Parameters	Baseline Report	Recommendations	Remarks
Production	As per defined normaisation factors for chlorine, hydrogen, flakes	Only cell liquor production can also be taken as similar GtG SEC CU relationship has been observed	This would simplify the validation process and establish better energy performance correlation with production
Capacity utilization/Current density	Commented about non-applicability of CU guideline as in Chlor-alkali process SEC increases with CU	Current density factor to be taken instead of capacity utilization and establish energy performance with current density based on technology suppliers data & historical performance	GtG SEC under both baseline and PAT cycle period can be easily correlated to current density and voltage performance based on historical data from the DCS records However, it is also possible to eliminate this factor and carry out normalisation only on current density factor
Membrane/Electrode life	Membrane/Electrode impact not assessed	As per BEE guideline	
Cell life	As above	Not to be factored	
Change in captive & grid power mix	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	Can be fitted into the BEE regulation guideline.

6. M&V PROCESS AND PROTOCOL

7.1METERING & MEASUREMENT

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

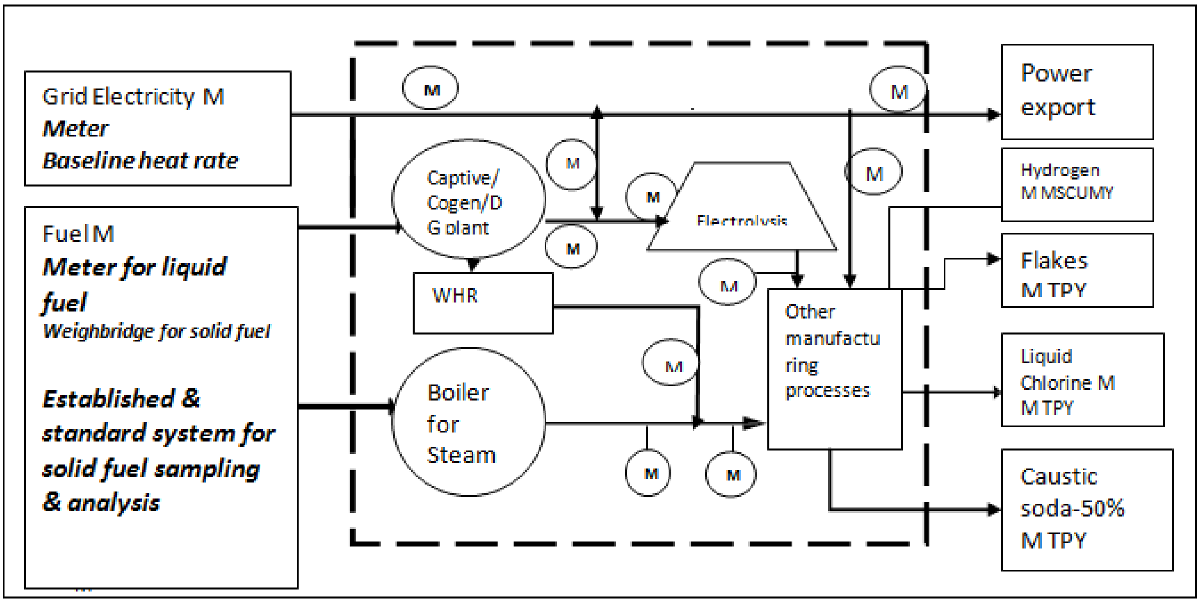


Figure 10: Metering & measurement

The metering & measurement plant to clearly determine:

- Production of different intermediate & finished products-Cell liquor, liquid caustic, flakes, liquid chlorine
- Fuel quantity & quality
  - Power generation
  - Steam/heat production
- Imported & exported power
- Power from wind and solar systems
- Power generation in CPP
- DC current
- Power for electrolysis

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 utilization. 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 made 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 correlation 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 18: Data protocol

ID	Data Variable	Source of Data	Data Unit	Measured (M) Calculated (C) Estimated (E)	Recording Frequency	Archival Method	Remarks
A	Production						
A1	Production Capacity (Caustic soda)	Balance sheet	TPY	E	Annual	Electronic – E Paper-P	
A2	Production Capacity(Flakes)	Balance sheet	TPY	E	Annual	E/P	
A3	Production Capacity(Liquid Chlorine)	Balance sheet	TPY	M/C	Annual	E/P	
A4	Production (Caustic soda)	Daily production report	MT	M/C	Daily	E/P	
A5	Production (Flakes)	Daily production report	MT	M/C	Daily	E/P	
A6	Production (Liquid chlorine)	Daily production report	MT	M/C	Daily	E/P	
A7	Production (Hydrogen)	Daily production report	Lakh CUM	M/C	Daily	E/P	
A8	Production (Cell liquor)	Daily production report	MT	C	Daily	E/P	
A9	Opening stock (Caustic soda)	Cost Audit Report	MT	M/C	Annual	E/P	
A10	Closing stock (Caustic soda)	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	M/C	Monthly	P	

ID	Data Variable	Source of Data	Data Unit	Measured (M) Calculated (C) Estimated (E)	Recording Frequency	Archival Method	Remarks
			kWh (MU)				
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-Unit-3	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	DC Current flow	DCS	kAh	M	Daily	P/E	
B9	Power for electrolysis	Monthly report	Million kWh (MU)	M/C	Daily	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 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-	Lab analysis	Kcal/CUM	M/C	Daily	P/E	

ID	Data Variable	Source of Data	Data Unit	Measured (M) Calculated (C) Estimated (E)	Recording Frequency	Archival Method	Remarks
	Quality	report					
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	Cell management						
E1	Cell loading- Current density	Daily report	kA/m^2	M/C	Daily	E	
E2	Membrane replachlor-alkali	Annual cost audit report	Numbers	C/E	Annual	P/E	
E3	Anode coating	Monthly report	Numbers	C	Monthly	P/E	

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 organization EVO. For assessment of performance of EE projects, one or more of the four following methodologies can be used.

Table 19: M&V Protocol-EE Projects

Options	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	Reasonably accurate system can be developed	Requires higher skill for carrying out simulation.	Best suited for systems like furnace, boilers, cells,

Options	Description	Pros	Cons	Recommendation
	study and applying simulation methodology for application to the whole facility or sub-facility	for determination of energy savings by periodic test & performance analysis	Information asymmetry can create problem of acceptability	transformers/rectifiers loading efficiency 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

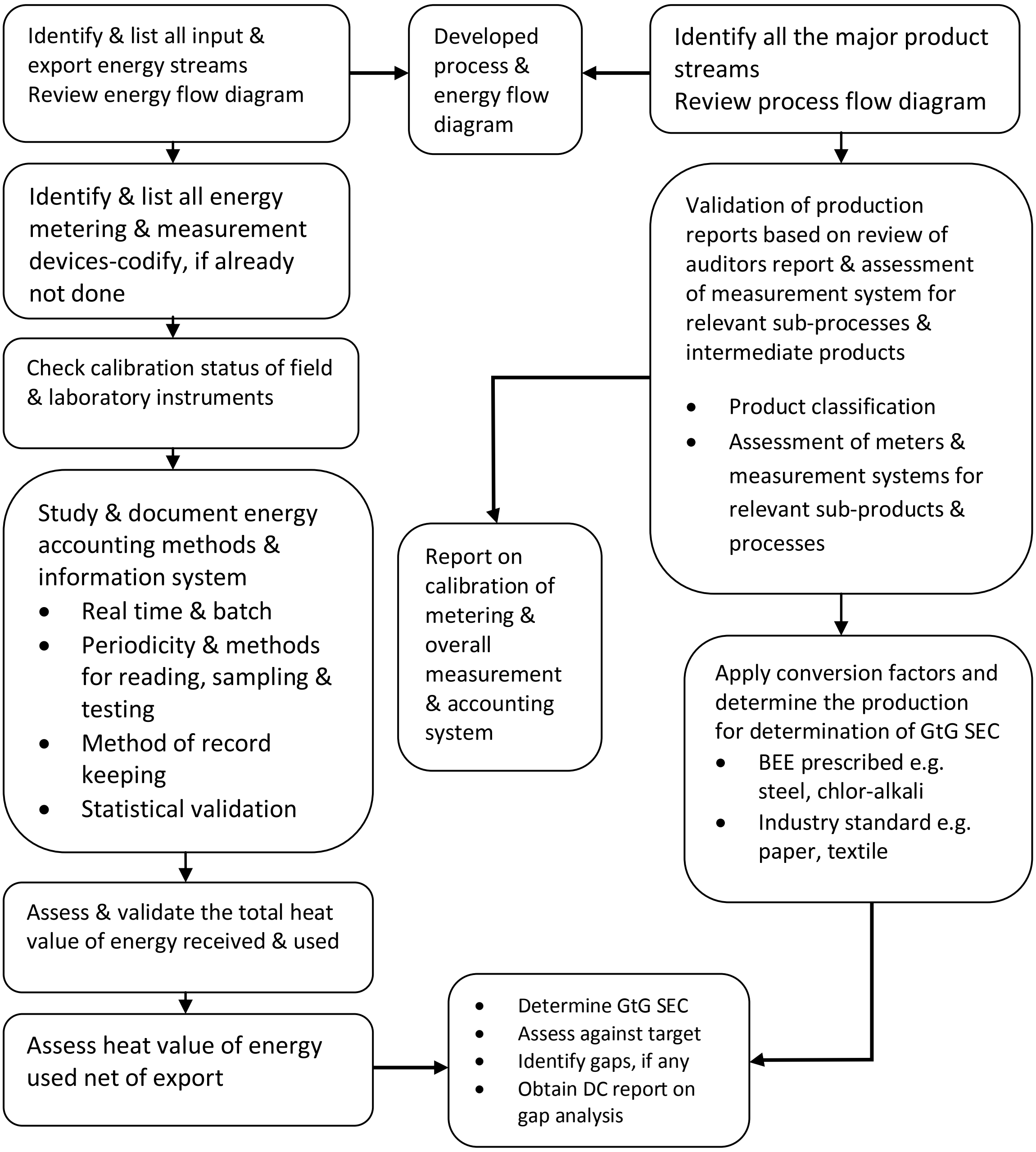
7. NORMALISATION PROCESS

The normalisation process is proposed to be carried out in three stages:

- Step-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)

↓

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

8. ANNEX-I- CHANGE IN CAPTIVE & GRID POWER MIX

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.

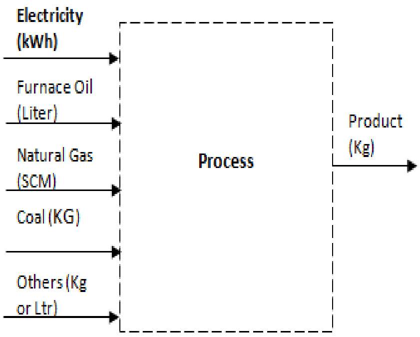


Figure 1 All energy purchased and consumed

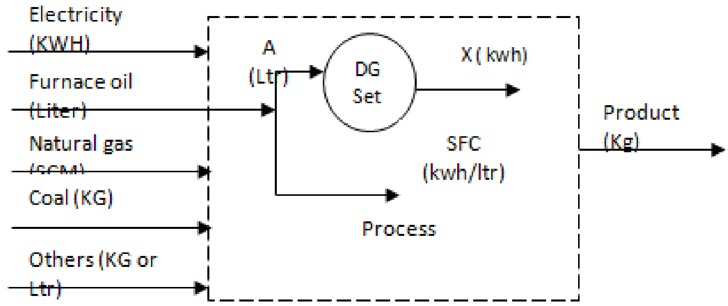


Figure 2 Electricity partially generated by (DG) set, other energy purchased & consumed

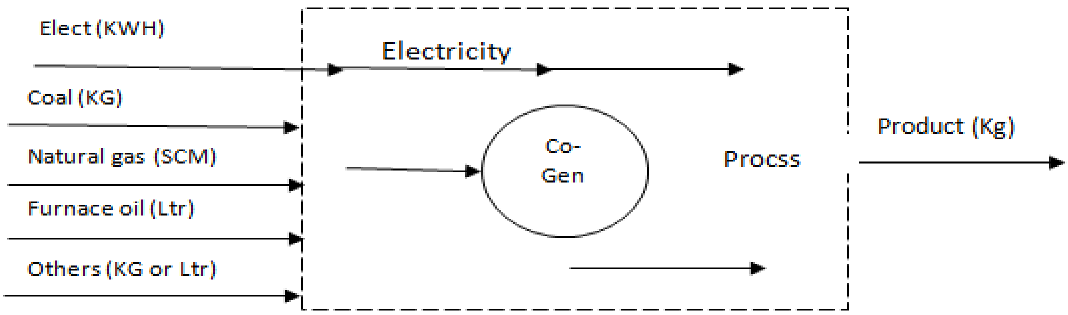


Figure 3 Energy purchased & consumed, electricity & heat partially generated through co-generation plant

Figure 11: Gate to Gate energy consumption

Briefly the scenario cases are:

- Entire electricity is purchased from outside and fuel is used in boilers for steam generation and supply to the process
- Part of the electricity is purchased from outside and balance generated using DG set. Steam is used by burning fuel in the boilers
- 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.

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).

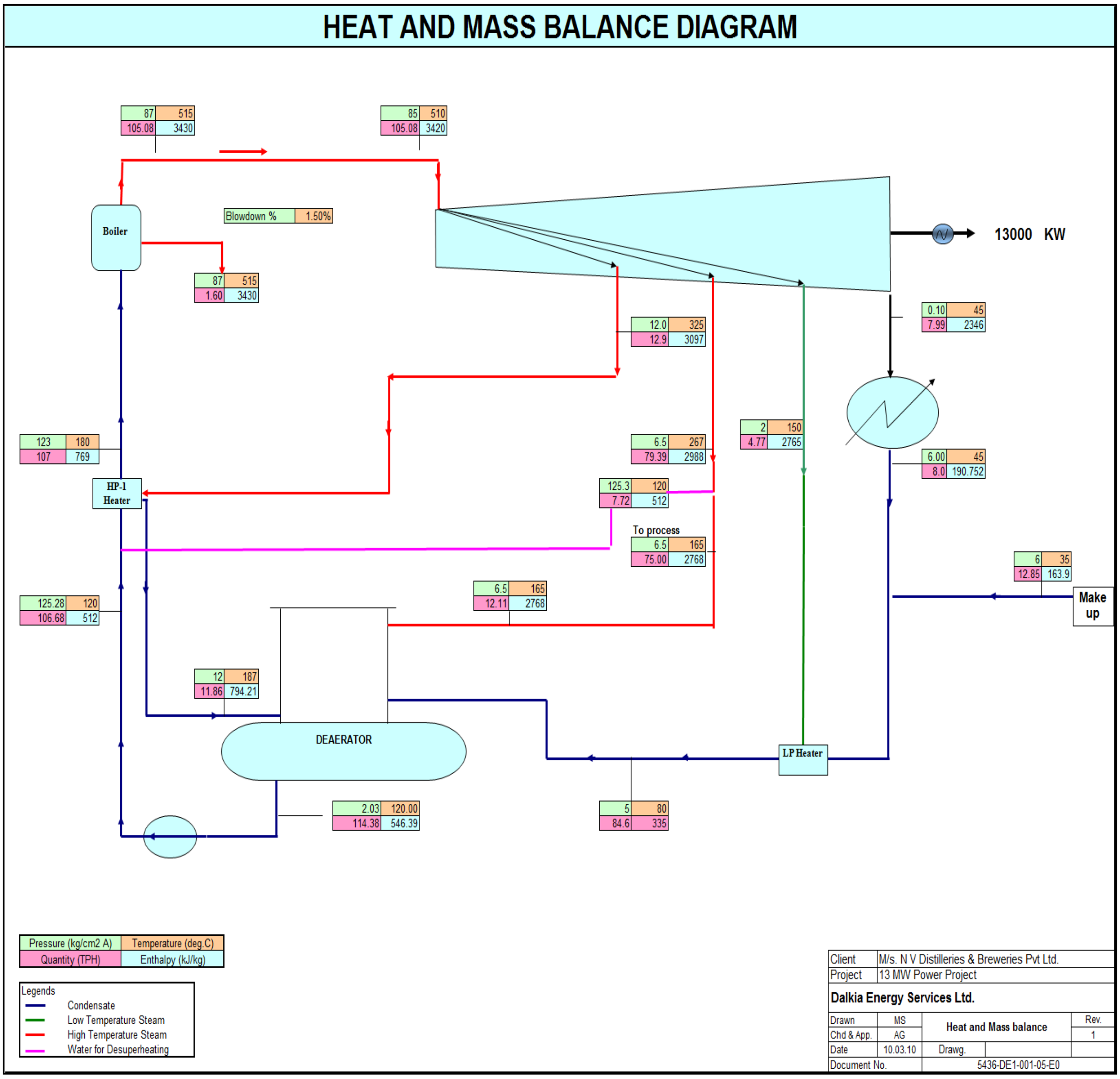


Figure 12 : Heat and Mass Balance Diagram

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

Table 20: Overall energy consumption

Particulars	Units	Amount	Specific Heat kCal	Equivalent Heat Value kCal
Scenario-1				
Fuel	Kg	3000	3000	9000000
Power generated	kWh	0	0	0
Power Purchased	kWh	3000	860	2580000
Baseline Energy				11580000
Steam for Process	kg	10000	700	70000000
Scenario-2				
Fuel	Kg	4000	3000	12000000
Power generated	kWh	2000	0	0
Power Purchased	kWh	1000	860	860000
PAT Energy				12860000
Steam for Process	kg	10000	700	70000000

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 Cogeneration 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 21: Heat value at real heat rate

Particulars	Units	Amount	Specific Heat kCal	Equivalent Heat Value kCal
Scenario-3				
Fuel	Kg	3000	3000	9000000
Power generated	kWh	0	0	0
Power Purchased	kWh	3000	2717	8151000
Baseline Energy				17151000
Steam for Process	kg	10000	700	70000000
Scenario-4				
Fuel	Kg	4000	3000	12000000
Power generated	kWh	2000	0	0
Power Purchased	kWh	1000	2717	2717000
PAT Energy				14717000
Steam for Process	kg	10000	700	70000000

* 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 disadvantage:

- 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).

- Disincentive for investment in Cogeneration from PAT perspective.

Similarly, if a plant has to use emergency power using DG set, 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 22: 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:

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.