NORMALIZATION DOCUMENT AND MONITORING & VERIFICATION GUIDELINES

Aluminium Sector
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Aluminium Sector

MINISTRY OF POWER
GOVERNMENT OF INDIA
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Developed specifically for Designated Consumers notified under Perform Achieve and Trade (PAT) Program for National Mission for Energy Efficiency (NMEEE)

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Contents

1 Introduction .................................................................................................................................................. 1
  1.1 National Mission for Enhanced Energy Efficiency .................................................................. 1
  1.2 Perform, Achieve and Trade (PAT) Scheme ........................................................................ 2
2 Background .................................................................................................................................................. 2
3 Indian Aluminium Industry in context of PAT .................................................................................. 3
4 Methodology for Baseline and Energy Performance Index (EPI) .................................................. 4
  4.1 General Rules for Establishing Baseline Values ..................................................................... 4
    4.1.1 Definitions ......................................................................................................................... 4
    4.1.2 Data Consideration ........................................................................................................ 4
    4.1.3 Estimation of Gate-to-Gate Specific Energy Consumption (SEC)..................................... 5
5 Target Setting in Aluminium Plants .................................................................................................... 7
6 Normalization ............................................................................................................................................. 8
  6.1 Fuel Quality in CPP and Cogen ................................................................................................. 8
    6.1.1 Fuel Quality Normalization ............................................................................................. 9
    6.1.2 Pre-Requisite .................................................................................................................... 10
    6.1.3 Coal Quality Normalization Methodology ...................................................................... 10
    6.1.4 Normalization Calculation ............................................................................................. 10
    6.1.5 Documentation ............................................................................................................... 11
    6.1.6 Note on Proximate and Ultimate Analysis of Coal ....................................................... 12
  6.2 Low PLF Compensation in CPP ................................................................................................. 12
    6.2.1 Need for Normalization .................................................................................................... 12
    6.2.2 Normalization Methodology .......................................................................................... 12
    6.2.3 Normalization Calculation ............................................................................................ 14
  6.3 Smelter Capacity Utilization ......................................................................................................... 15
    6.3.1 Terms of Normalization calculation ............................................................................... 17
    6.3.2 Terms of Normalization .................................................................................................. 17
    6.3.3 Need for Normalization .................................................................................................. 18
Normalization Methodology for Aluminium Sector

6.3.4 Capacity Utilization Normalization ................................................................. 18
6.3.5 Normalization methodology on Capacity decrease due to external factor ... 18
6.3.6 Normalization Calculation on capacity decrease for Kiln Heat Rate .......... 19
6.3.7 Note on New Line /Production Unit installed after baseline year .......... 20
6.3.8 Documentation ........................................................................................................ 20

6.4 Bauxite Quality ........................................................................................................ 20
6.4.1 Need for Normalization ......................................................................................... 21
6.4.2 Normalization Calculation .................................................................................... 21
6.4.3 Documentation ........................................................................................................ 22

6.5 Carbon Anode Production ...................................................................................... 22
6.5.1 Methodology: ........................................................................................................ 22
6.5.2 Need for Normalization ......................................................................................... 23
6.5.3 Normalization Methodology ................................................................................. 23
6.5.4 Normalization Calculation: ................................................................................... 24
6.5.5 Documentation ........................................................................................................ 25

6.6 Power Mix .................................................................................................................. 25
6.6.1 Baseline Year Methodology: ................................................................................ 25
6.6.2 Need for Normalisation ......................................................................................... 25
6.6.3 Power Mix Normalisation methodology ............................................................. 25
6.6.4 Power Mix Normalisation Calculation ............................................................... 26
6.6.5 Normalization for Power Export .......................................................................... 26
6.6.6 Documentation ........................................................................................................ 27

6.7 Product Mix ................................................................................................................ 27
6.7.1 Common Methodology ......................................................................................... 28
6.7.2 Normalization Calculation .................................................................................... 28
6.7.3 Refinery Process .................................................................................................... 30
6.7.4 Smelter Process ..................................................................................................... 33

6.8 Import and Export of Intermediary Product (Applicable for Cold Sheet Process) ... 36
6.8.1 Baseline Year Methodology: ................................................................................ 37
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.8.2 Need for Normalisation</td>
<td>37</td>
</tr>
<tr>
<td>6.8.3 Normalization Methodology</td>
<td>37</td>
</tr>
<tr>
<td>6.8.4 Normalization calculation</td>
<td>38</td>
</tr>
<tr>
<td>6.8.5 Documents</td>
<td>42</td>
</tr>
<tr>
<td>6.9 Others</td>
<td>43</td>
</tr>
<tr>
<td>6.9.1 Environmental concern</td>
<td>43</td>
</tr>
<tr>
<td>6.9.2 Fuel replacements</td>
<td>44</td>
</tr>
<tr>
<td>6.9.3 Construction Phase or Project Activity Phase</td>
<td>44</td>
</tr>
<tr>
<td>6.9.4 Addition of New Line/Unit</td>
<td>45</td>
</tr>
<tr>
<td>6.9.5 Unforeseen Circumstances</td>
<td>47</td>
</tr>
<tr>
<td>6.9.6 Renewable Energy</td>
<td>47</td>
</tr>
<tr>
<td>7 Conclusion</td>
<td>48</td>
</tr>
<tr>
<td>8 Overriding Clause</td>
<td>49</td>
</tr>
<tr>
<td>9 Example-Normalization Factors</td>
<td>49</td>
</tr>
<tr>
<td>9.1 Normalization factor fuel quality in CPP</td>
<td>49</td>
</tr>
<tr>
<td>9.2 Normalization factor fuel quality in Cogen</td>
<td>50</td>
</tr>
<tr>
<td>9.3 Normalization factor for Low PLF Compensation in CPP</td>
<td>51</td>
</tr>
<tr>
<td>9.4 Normalization factor Smelter Capacity Utilization</td>
<td>56</td>
</tr>
<tr>
<td>9.5 Bauxite Quality</td>
<td>59</td>
</tr>
<tr>
<td>9.6 Normalization factor for Carbon Anode (Import &amp; Export)</td>
<td>60</td>
</tr>
<tr>
<td>9.6.1 Total Carbon anode Export</td>
<td>61</td>
</tr>
<tr>
<td>9.6.2 Total Carbon anode import</td>
<td>61</td>
</tr>
<tr>
<td>9.6.3 Notional energy for carbon anode exported</td>
<td>61</td>
</tr>
<tr>
<td>9.6.4 Notional energy for carbon anode imported</td>
<td>61</td>
</tr>
<tr>
<td>9.6.5 Net energy for carbon anode export and import</td>
<td>62</td>
</tr>
<tr>
<td>9.7 Normalization factor for Product Mix (Refinery)</td>
<td>62</td>
</tr>
<tr>
<td>9.7.1 Calculation of Equivalent product in Baseline year</td>
<td>62</td>
</tr>
<tr>
<td>9.7.2 Calculation of Equivalent product in Assessment year</td>
<td>65</td>
</tr>
<tr>
<td>9.8 Normalization factor for Product Mix (Smelter)</td>
<td>66</td>
</tr>
</tbody>
</table>
9.8.1 Calculation of Equivalent product in Baseline year................................. 66
9.8.2 Calculation of Equivalent product in Assessment year ......................... 67
9.9 Normalization factor for Cold Sheet Process............................................. 72
  9.9.1 Product mix Normalization................................................................. 72
  9.9.2 Input Normalization............................................................................. 82
9.10 Normalization factor for Power Mix....................................................... 83
9.11 Normalization Others.............................................................................. 89

10 Abbreviations............................................................................................... 101
Part-II

MONITORING & VERIFICATION GUIDELINES

1. Introduction
   1.1. Background
   1.2. Purpose
   1.3. Definition of M&V
   1.4. Empanelled Accredited Energy Auditor or Verifier
      1.4.1. Qualification of Empanelled Accredited Energy Auditor (EmAEA) for Verification and Check-Verification
      1.4.2. Obligation of Empanelled Accreditor Energy Auditor
   1.5. Important Documents required for M&V process
   1.6. Stakeholders

2. Broad Roles and Responsibilities
   2.1. General
   2.2. Designated Consumer
   2.3. Empanelled Accredited Energy Auditor (EmAEA)
   2.4. State Designated Agencies (SDA)
   2.5. Adjudicator
   2.6. Bureau of Energy Efficiency
   2.7. Ministry of Power
   2.8. Institutional Framework for PAT

3. Process & Timelines
   3.1. Activities and Responsibilities
   3.2. Process Interlinking
      3.2.1. Process of Issuance of Escerts
   3.3. Flow Chart showing verification process (Rules and Act required dates in bold Italics)

4. Verification requirement
   4.1. Guidelines for Selection Criteria of EmAEA by Designated Consumer
   4.2. Guidelines for Empanelled Accredited Energy Auditor
   4.3. Guidelines for Verification process
      4.3.1. Sector Specific Pro-forma
      4.3.2. Reporting in Sector Specific Pro-forma
4.3.3. Verification Process 124
4.3.4. Primary and Secondary source of Documentation 127

5. Understanding Conditions 151
5.1. Specific Issues 152
5.2. Fuel 153
5.3. Normalization Condition and calculation 154
5.4. Normalisation General Issue 156

6. Abbreviations 158

7. Annexure 159
7.1. Annexure I: Thermal Power Plant 160
7.2. Annexure II: Steel 165
7.3. Annexure III: Cement 170
7.4. Annexure IV: Fertilizer 174
7.5. Annexure V: Aluminium 191
7.6. Annexure VI: Pulp & Paper 194
7.7. Annexure VII: Textile 217
7.8. Annexure VIII: Chlor Alkali 223
Tables

Table 1: Activities and Responsibilities for PAT Cycle I
Table 2: Team Details (Minimum Team Composition)
Table 3: Production and Capacity Utilisation details
Table 4: Major Equipment capacity and Operating SEC
Table 5: Boiler Details (Process and Co-Generation)
Table 6: Electricity from Grid/Others, Renewable Purchase Obligation, Notified Figures
Table 7: Own generation through Captive Power Plants
Table 8: Solid Fuel Consumption
Table 9: Liquid Fuel Consumption
Table 10: Gaseous Fuel Consumption
Table 11: Documents for Quality Parameter
Table 12: Documents related to Environmental Concern, Biomass/Alternate Fuel availability, Project Activities, New Line commissioning, Unforeseen Circumstances
Table 13: Documents related to External Factor
Table 14: Lump Co-Generation treatment
Table 15: Auxiliary Power Consumption Details (a,b,c)
Table 16: Sponge Iron Subsector- Major Product details
Table 17: Section wise Specific Power Consumption Details
Table 18: Mass and Energy balance
Table 19: Clinker Factor calculation
Table 20: Material and Energy balance of Fertilizer sector
Table 21: Material balance of all inputs in Fertilizer sector
Table 22: Section wise Energy Consumption details
Table 23: Section wise Energy Consumption details
Table 24: Voltage Distribution
Table 25: General details required in wood based Pulp and Paper Mills
Table 26: Documents required wood based Pulp and Paper Mills
Table 27: General details required in Agro based Pulp and Paper Mills
Table 28: Document required for Agro based Pulp and Paper Mills
Table 29: General details required in RCF based Pulp and Paper Mills
Table 30: Documents required in RCF based Pulp and Paper
Table 31: Section wise Energy Consumption
Table 32: Section wise Energy Consumption
Table 33: Product Name in Fiber Sun-sector
Table 34: Section wise Energy Consumption
Table 35: Section wise Energy details
## Figures

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1</td>
<td>M&amp;V Documents</td>
<td>109</td>
</tr>
<tr>
<td>Figure 2</td>
<td>Stakeholders</td>
<td>110</td>
</tr>
<tr>
<td>Figure 3</td>
<td>Institutional Framework</td>
<td>116</td>
</tr>
<tr>
<td>Figure 4</td>
<td>Stakeholders Interlinking</td>
<td>118</td>
</tr>
<tr>
<td>Figure 5</td>
<td>Flow Chart of ESCerts issuance</td>
<td>119</td>
</tr>
<tr>
<td>Figure 6</td>
<td>Time Line Flow Chart</td>
<td>120</td>
</tr>
<tr>
<td>Figure 7</td>
<td>Stakeholders Output</td>
<td>125</td>
</tr>
<tr>
<td>Figure 8</td>
<td>Ex-GtG Boundary for Thermal Power Plant</td>
<td>163</td>
</tr>
<tr>
<td>Figure 9</td>
<td>Ex-Coal/Lignite/Oil/Gas based Thermal Power Plant Energy balance diagram</td>
<td>164</td>
</tr>
<tr>
<td>Figure 10</td>
<td>Ex-CCGT Energy balance diagram</td>
<td>165</td>
</tr>
<tr>
<td>Figure 11</td>
<td>Product Mix diagram</td>
<td>167</td>
</tr>
<tr>
<td>Figure 12</td>
<td>Ex-GtG Boundary boundary for Sponge Iron Sub-sector</td>
<td>168</td>
</tr>
<tr>
<td>Figure 13</td>
<td>Figure 14: Ex-GtG boundary for Cement Sector</td>
<td>172</td>
</tr>
<tr>
<td>Figure 15</td>
<td>Fertilizer plant Battery Limit block diagram</td>
<td>179</td>
</tr>
<tr>
<td>Figure 16</td>
<td>Overall Material and Energy balance</td>
<td>182</td>
</tr>
<tr>
<td>Figure 17</td>
<td>Ex- GtG boundary for Aluminium (Refinery sub sector)</td>
<td>192</td>
</tr>
<tr>
<td>Figure 18</td>
<td>Ex- GtG boundary for Aluminium (Smelter sub sector)</td>
<td>193</td>
</tr>
<tr>
<td>Figure 19</td>
<td>Ex- GtG boundary for Aluminium (Cold Sheet sub sector)</td>
<td>194</td>
</tr>
<tr>
<td>Figure 20</td>
<td>Ex- GtG boundary and metering details for Wood based Pulp and Paper Mill</td>
<td>198</td>
</tr>
<tr>
<td>Figure 21</td>
<td>Ex- GtG boundary and metering details for Agro based Pulp and Paper Mill</td>
<td>206</td>
</tr>
<tr>
<td>Figure 22</td>
<td>Ex- GtG boundary for Textile (Spinning sub sector)</td>
<td>219</td>
</tr>
<tr>
<td>Figure 23</td>
<td>Ex- GtG boundary for Textile (Composite/ Processing sub sector)</td>
<td>221</td>
</tr>
<tr>
<td>Figure 24</td>
<td>Ex- GtG boundary for Textile (Fiber) Sub- sector</td>
<td>223</td>
</tr>
<tr>
<td>Figure 25</td>
<td>Ex- GtG boundary for Chlor-Alkali sector</td>
<td>224</td>
</tr>
</tbody>
</table>
Foreword

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

Aluminium sector is one of the 8 notified energy intensive sectors under which a total of 10 plants are participating in this program. These plants have been mandated to reduce their Specific Energy Consumption (SEC) from baseline year of 2007-2010. It is expected that these plants may save 0.456 million tons of oil equivalent annually by the end of PAT cycle –I.

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

I want to record my appreciation for members of the Sectoral Expert Committee on Aluminium Sector, chaired by Shri V. Balasubramanyakam, Director (Production), NALCO, Co-chairs of sub-Technical committee –Shri Abhijit Pati, Sesa Sterlite Limited, Jharsuguda and Shri S.M. Kulkarni Hindalco Corporate Office, Shri K.K.Chakarvarti, Energy Economist, BEE, Shri A.K. Asthana, Senior Technical Expert, GIZ, Shri Anupam Agnihotri, Director, JNARDDC, Shri K G Sudhan Ramkumar, Project Engineer, BEE. I especially want to record my appreciation for Shri S. Vikash Ranjan, Technical Expert, GIZ who has put together the data and methodology associated with normalization.

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

(Ajay Mathur)
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<table>
<thead>
<tr>
<th>S. No</th>
<th>Name of Member</th>
<th>Designation</th>
<th>Position</th>
</tr>
</thead>
<tbody>
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</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>S. No</th>
<th>Name of Member</th>
<th>Designation</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
</tbody>
</table>

### Special Thanks to Team NMEEE

<table>
<thead>
<tr>
<th>S. No</th>
<th>Name of Member</th>
<th>Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
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<tr>
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</tr>
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</tr>
</tbody>
</table>
1. Introduction

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

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

- National Solar Mission
- National Mission for Enhanced Energy Efficiency
- National Mission on Sustainable Habitat
- National Water Mission
- National Mission for Sustaining the Himalayan Ecosystem
- National Mission for a Green India
- National Mission for Sustainable Agriculture
- National Mission for Strategic Knowledge for Climate Change

1.1 National Mission for Enhanced Energy Efficiency

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

NMEE spelt out the following four new initiatives to enhance energy efficiency, in addition to the programmes on energy efficiency being pursued. These are:
Perform, Achieve and Trade (PAT), a market based mechanism to make improvements in energy efficiency in energy-intensive large industries and to make facilities more cost-effective by certification of energy saving that can be traded.

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

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

Framework for Energy Efficiency Economic Development (FEEED), for developing fiscal instruments to promote energy efficiency.

1.2 Perform, Achieve and Trade (PAT) Scheme

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

2. Background

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

3. Indian Aluminium Industry and PAT

The threshold limit of 7,000 tonnes of oil equivalent (toe) has been marked as the cut-off limit criterion for any unit in the aluminium sector to be identified as designated consumer under PAT. Ten designated consumers have been identified in India’s aluminium sector.

India has the fifth largest reserves of bauxite, the raw material used in production of aluminium, with deposits of about 2.3 billion tonnes (6.76% of the world deposits). The total aluminium production in India is about 3% of the global capacity. Primary aluminium production involves two major steps: one, refining of bauxite to alumina and two, smelting of alumina to aluminium. Smelting is an energy intensive process and consumes electrical energy, accounting for about 85%-90% of the electrical energy consumption.

In aluminium sector, to become a designated consumer the threshold limit is 7500 toe and in PAT cycle-I has identified the 10 designated consumers from Odisha, Karnataka, Jharkhand, Chhattisgarh, Maharashtra and Uttar Pradesh; their targets have already been notified. The aluminium sector has been categorised, on the basis of the processes involved, into four subsectors— Refinery, Smelter, Integrated and Cold sheet mill.

The total average reported energy consumption of these designated consumers is about 7.71 million tonnes of oil equivalent/year in the baseline period (2007-10). By the end of the first PAT cycle, the energy savings of 0.456 million tonnes of oil equivalent/year is expected to be achieved, which is around 7% of the total national energy saving targets assessed under PAT.

To achieve the targeted energy saving and to ensure unbiased implementation of the PAT scheme a technical sub-committee of industry representatives has been formed under the guidance of sector experts of Jawaharlal Nehru Aluminium Research Development and Design Centre (JNARDDC), Nagpur, to finalise normalization factors.

Aluminium sector has been categorized on the basis of their operation into four subsectors i.e. Refinery, Smelter, Integrated, and Cold Sheet Plants. The Total reported energy consumption of these designated consumers is about 7.71 million ton of oil equivalent (million toe). By the end of the first PAT cycle, the energy saving of 0.456 million ton of oil equivalent/year is expected to be achieved, which is around 7% of total national energy saving target assessed under PAT.
### Table 1: Sector-wise reduction target under PAT Cycle 1

<table>
<thead>
<tr>
<th>Sector</th>
<th>No. of Identified DCs</th>
<th>Annual Energy Consumption (Million toe)</th>
<th>Share Consumption (%)</th>
<th>Apportioned Energy Reduction For PAT Cycle-1 (Million toe)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power (Thermal)</td>
<td>144</td>
<td>104.56</td>
<td>63.38%</td>
<td>3.211</td>
</tr>
<tr>
<td>Iron &amp; Steel</td>
<td>67</td>
<td>25.32</td>
<td>15.35%</td>
<td>1.486</td>
</tr>
<tr>
<td>Cement</td>
<td>85</td>
<td>15.01</td>
<td>9.10%</td>
<td>0.815</td>
</tr>
<tr>
<td>Aluminium</td>
<td>10</td>
<td>7.71</td>
<td>4.67%</td>
<td>0.456</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>29</td>
<td>8.20</td>
<td>4.97%</td>
<td>0.478</td>
</tr>
<tr>
<td>Paper &amp; Pulp</td>
<td>31</td>
<td>2.09</td>
<td>1.27%</td>
<td>0.119</td>
</tr>
<tr>
<td>Textile</td>
<td>90</td>
<td>1.20</td>
<td>0.73%</td>
<td>0.066</td>
</tr>
<tr>
<td>Chlor- Alkali</td>
<td>22</td>
<td>0.88</td>
<td>0.53%</td>
<td>0.054</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>478</strong></td>
<td><strong>164.97</strong></td>
<td><strong>100.00%</strong></td>
<td><strong>6.686</strong></td>
</tr>
</tbody>
</table>

### 4. Methodology for Baseline and Energy Performance Index (EPI)

Because of the complexities, it becomes extremely difficult to come to a common model to arrive at standardized SEC per ton. Considering all these situations, the conversion factors and best possible combination and categorization have been worked out so that no Designated Consumer may have any grievance on the targets set out. While setting targets, units best in the group set as reference and then worked out targets for others.

Aspect while framing complete mechanism for PAT scheme:

- Methodology for establishing the baseline energy consumption
- Methodology for target setting for each sector
- The process of measurement and verification, in particular the verification agencies that need to be appointed by BEE for this purpose.
- The manner in which trading of the certificates can be encouraged, in particular instruments that could increase liquidity in the system.

#### 4.1 General Rules for Establishing Baseline Values

**Baseline Year**
Baseline year is defined as 2009-10.

**Baseline Production ($P_{base}$)**
The arithmetic average of production figures of 2007-08, 2008-09 and 2009-10

**Baseline Specific Energy Consumption ($SEC_{base}$)**
The arithmetic average of SEC figures of 2007-08, 2008-09 and 2009-10

**Baseline Capacity Utilisation in % ($CU_{base}$)**
The arithmetic average of CU figures of 2007-08, 2008-09 and 2009-10

#### 4.1.2 Data Consideration

- In case of plants more than 5 years old, data
Normalization Methodology for Aluminium Sector

for the last 3 financial years will be considered, provided the CU is uniform. Normalization will be done in case of abnormality in CU in any of the three years.

- In case of plants more than 5 years old, but has data for less than 3 years, the same will be considered, provided the CU is uniform. If the CU is abnormally low in any of the years, the same will not be considered.

- In case of plants less than 5 years old and has data for less than 3 years, the available year’s (or years’) data will be considered, provided the CU is uniform. If the CU is abnormally low in any of the years, the same will not be considered.

- In case of new plants, the data would be considered for the years where the CU is greater than 70%. If data exists for only one year data, the same will be considered irrespective of the CU.

### 4.1.3 Estimation of Gate-to-Gate Specific Energy Consumption (SEC):

1. The baseline SEC is estimated on a GtG concept.

\[
GtG \text{ SEC} = \frac{\text{All forms of energy converted to tonnes of oil equivalent (toe)}}{\text{Product}}
\]

2. The following product definition is considered for the different sub-sectors

- Refinery : Calcined Alumina
- Smelter : Molten Aluminium
- Integrated : Molten Aluminium
- Sheet – Roll Mill : Cold Sheet

3. The following plant boundaries are considered in the different sub-sectors of this sector as per the data reported by DCs:

- Refinery : 

Smelter:

Integrated:

Sheet Roll Mill:
4. The following exclusions are considered:
   - Energy consumed in residential colonies
   - Energy consumed in internal transportation
   - Energy consumed in minor or major construction work

5. The equivalent thermal energy of the electricity supplied to the grid is DEDUCTED from the total energy input to the plant boundary. The following expression is used:

   \[ \text{Equiv. Thermal Energy (kCal)} = \text{Electricity supplied to Grid (kWh)} \times 2717 \text{ kCal/kWh} \]

6. Correction factors which may be developed for variability during the target period
   - Higher energy consumption due to environmental regulations
   - Energy consumption due to temporary construction works, capacity expansion, etc.

5. Target Setting in Aluminium Plants

1. Sectoral target for the aluminium sector is allocated on a pro-rata basis of total energy consumption among 7 sectors under the PAT scheme; the targets for the thermal power sector have been fixed separately.

2. Sub-sectoral target is allocated on a pro-rata basis of total energy consumption in the sub-sector.

3. The DC level target is allocated based on a statistical analysis derived from relative SEC. This approach will be applicable to all the DCs of only the sub-sector.

### Apportionment of Sub-Sector Target of Energy Saving in Aluminium Sector

<table>
<thead>
<tr>
<th>Sub-Sector</th>
<th>Avg. Energy Cons Million TOE</th>
<th>%</th>
<th>Target(Saving) TOE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refinery</td>
<td>0.917</td>
<td>11.89</td>
<td>0.054</td>
</tr>
<tr>
<td>Smelter</td>
<td>4.505</td>
<td>58.45</td>
<td>0.266</td>
</tr>
<tr>
<td>Integrated</td>
<td>2.277</td>
<td>29.54</td>
<td>0.134</td>
</tr>
<tr>
<td>Sheet-Roll Mill</td>
<td>0.010</td>
<td>0.13</td>
<td>0.001</td>
</tr>
<tr>
<td>TOTAL</td>
<td>7.71</td>
<td>100.00</td>
<td>0.455</td>
</tr>
</tbody>
</table>

4. Calculation of Energy Saving:

   \[ \text{Energy Saving} = P_{\text{base year}} \times (\frac{\text{SEC}_{\text{base year}} - \text{SEC}_{\text{target year}}}{\text{SEC}_{\text{base year}}}) \]

   Where:  
   - Energy Saving is in TOE
   - \( P_{\text{base year}} \) = Production in baseline year (Tonne)
   - \( \text{SEC} \) = Specific energy consumption in TOE/Tonne
6. Normalization

There are several factors that need to be taken into consideration in the assessment year such as change in the product mix, capacity utilisation, change in fuel quality, import/export of power, etc in calculating the specific energy consumption of the plant within the boundary, so that an undue advantage or disadvantage is not imposed on a DC while gauging the performance in the assessment year as compared to the baseline year.

The operating parameters in the assessment year have to be normalised with reference to the baseline year so as to avoid any favourable or adverse impact on the specific energy consumption of the plant. This will also assist on evaluating the correct impression of the energy efficiency projects implemented by the plant.

External Factors are:

- Market Demand
- Grid Failure/Breakdown (Grid not Sync with CPP)
- Raw Material Unavailability
- Natural Disaster (Flood, Earthquake, etc)
- Major change in Government policy (Hampering plant’s process system)
- Unforeseen Circumstances (Labour Strike / Lockouts / Social Unrest / Riots)

The energy performance of any aluminium smelter is affected by various factors (variables) like capacity utilisation, fuel quality, environmental concern, among others. Normalization of these variables is necessary to establish a proper baseline and target.

Normalization factors for the following areas have been developed in the aluminium sector, which will ultimately affect the gate-to-gate specific energy consumption in the assessment year. A broad categorisation of the factors are presented here.

- Fuel Quality in CPP and Co-Gen
- Low PLF in CPP
- Smelter Capacity Utilisation
- Bauxite Quality
- Carbon Anode (Import & Export)
- Product Mix (Equivalent product)
- Power Mix
- Environmental Concern (Additional Environmental Equipment requirement due to major change in government policy on Environment)
- Biomass/Alternate Fuel Unavailability
- Construction Phase or Project Activities
- Addition of New Line/Unit (In Process & Power Generation)
- Unforeseen Circumstances
- Renewable Energy

6.1 Fuel Quality in CPP and Cogen

Coal is extremely heterogeneous, varying widely in their content and properties from country to country, mine to mine and even from seam to seam. The principle impurities are ash-forming minerals and sulphur. Some are interspersed through the coal seam; some are introduced by the mining process, and some principally organic sulphur, nitrogen and some minerals salts.
These impurities affect the properties of the coal and the combustion process, therefore the plant’s boiler efficiency & Turbine Efficiency. The generating companies have no control over the quality of coal supplied. The raw coal mainly being supplied to the power stations could have variation in coal quality. Further, imported coal is also being used and blended with Indian coal by large number of stations, which could also lead to variations in coal quality.

<table>
<thead>
<tr>
<th>Sr No</th>
<th>Sub-Group</th>
<th>Elements</th>
<th>Reason/ Requirement</th>
<th>Impact</th>
<th>Documents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Coal</td>
<td>Use of coal with different calorific value in AY and BY</td>
<td>Coal quality is beyond the control of plant</td>
<td>Boiler Efficiency, Auxiliary Power Consumption</td>
<td>Fuel Quality and Quantity documentation, Energy consumption of mills in AY and BY</td>
</tr>
</tbody>
</table>

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

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

Where:

\[ A = \text{Ash percentage in coal} \]
\[ M = \text{Moisture percentage in coal} \]
\[ H = \text{Hydrogen percentage in coal} \]
\[ G.C.V = \text{Gross calorific value in kcal/kg} \]
\[ \text{Station heat rate (Kcal/kWh)} = \frac{\text{Turbine heat rate}}{\text{Boiler efficiency}} \]

### 6.1.1 Fuel Quality Normalization

- Change in coal GCV, moisture%, Ash% affect the properties of the coal and the combustion process, resulting in loss/gain in the plant’s boiler efficiency. To compensate for the change in efficiency of boiler with change in coal quality, the energy loss to be subtracted from the Total Energy consumption

- The plant/generating companies have no control over the quality of coal supplied, with Coal Linkage agreements.

- Further, variation in mix of imported coal with Indian coal could also lead to variations in coal quality. The normalization factor shall take care of the impact of variations in coal quality

- The Coal quality have impact on Boiler Efficiency of a captive Power Plant, with decrease in coal quality the efficiency of boiler will also decrease and hence the gross heat rate of CPP will also decrease as per above formulae.
6.1.2 Pre-Requisite

- The Proximate and Ultimate analysis of coal for baseline should be available to compare the same in assessment year.
- In case of unavailability of Ultimate analysis of coal in baseline year, the %H will be taken constant for baseline year as per assessment year data.

6.1.3 Coal Quality Normalization Methodology

- The Boiler Efficiency will be calculated for the baseline as well as assessment year with the help of Coal analysis constituents like GCV, %Ash, %Moisture, %H and Boiler Efficiency Equation provided to calculate the Boiler efficiency.
- Hence, by keeping the Turbine heat rate constant for both the years, the CPP heat rate will be calculated for the respective year.

6.1.4 Normalization Calculation

6.1.4.1 For CPP

Units Boiler efficiency in baseline year = \(92.5 - \frac{\{50 \times A + 630 \times (M+9H)\}}{GCV}\)

Units Boiler efficiency in assessment year = \(92.5 - \frac{\{50 \times A + 630 \times (M+9H)\}}{GCV}\)

Boiler efficiency for Station in BY = Unit \#n Capacity (MW) X Unit \#n Boiler efficiency (%) in BY / Unit \#n Capacity (MW)

Boiler efficiency for Station in AY = Unit \#n Capacity (MW) X Unit \#n Boiler efficiency (%) in BY / Unit \#n Capacity (MW)

The CPP heat rate in assessment year due to fuel quality = CPP heat rate in baseline year x (Boiler Efficiency in baseline year / Boiler Efficiency in assessment year)

Difference in the CPP heat rate of assessment year due to fuel quality = CPP Heat Rate due to Fuel Quality in AY (kcal/kWh)-Actual CPP Heat Rate of BY (kcal/kWh)

Energy to be subtracted w.r.t. fuel quality in CPP (Million kcal) = Difference in the CPP heat rate of AY due to fuel quality (kCal/kWh) X CPP Generation in AY Lakh kWh/10

6.1.4.2 For Co-Gen

Boiler efficiency in baseline year = \(92.5 - \frac{\{50 \times A + 630 \times (M+9H)\}}{GCV}\)

Boiler efficiency in assessment year = \(92.5 - \frac{\{50 \times A + 630 \times (M+9H)\}}{GCV}\)

Weighted Percentage of Coal Energy Used in steam Generation (Process Boiler) in BY = \(\frac{\sum_{n=1}^{5} (Operating \, Capacity \, of \, all \, Boilers \, used \, for \, Steam \, generation \, in \, TPH \times Percentage \, of \, Coal \, Energy \, Used \, in \, steam \, Generation \, in \, all \, the \, boilers \, for \, Steam \, generation \, in \, \%) \}}{\sum_{n=1}^{5} Operating \, Capacity \, of \, all \, Boilers \, used \, for \, Steam \, generation}\)

Weighted Percentage of Coal Energy Used in steam Generation (Process Boiler) in AY = \(\frac{\sum_{n=1}^{5} (Operating \, Capacity \, of \, all \, Boilers \, used \, for \, Steam \, generation \, in \, TPH \times Percentage \, of \, Coal \, Energy \, Used \, in \, steam \, Generation \, in \, all \, the \, boilers \, for \, Steam \, generation \, in \, \%) \}}{\sum_{n=1}^{5} Operating \, Capacity \, of \, all \, Boilers \, used \, for \, Steam \, generation}\)
Weighted Percentage of Coal Energy Used in steam Generation (Co-Gen Boiler) in BY = \( \frac{\sum_{n=6}^{10} (\text{Operating Capacity of all Boilers used for Steam generation in TPH} \times \text{Percentage of Coal Energy Used in steam Generation in all the boilers for Steam generation in %})}{\sum_{n=6}^{10} \text{Operating Capacity of all Boilers used for Steam generation}} \)

Weighted Percentage of Coal Energy Used in steam Generation (Co-Gen Boiler) in AY = \( \frac{\sum_{n=6}^{10} (\text{Operating Capacity of all Boilers used for Steam generation in TPH} \times \text{Percentage of Coal Energy Used in steam Generation in all the boilers for Steam generation in %})}{\sum_{n=6}^{10} \text{Operating Capacity of all Boilers used for Steam generation}} \)

Weighted Average Specific Steam Consumption in BY & AY (kcal/kg of Steam) = \( \frac{\sum_{n=1}^{5} (\text{Total Steam Generation at Process Boiler} \times \text{Specific Energy Consumption for Steam Generation in Process Boilers}) + \sum_{n=6}^{10} (\text{Total Steam Generation at Co-Gen Boiler} \times \text{Specific Energy Consumption for Steam Generation in Co-Gen Boiler})}{\sum_{n=1}^{10} \text{Total Steam generation at all the boilers}} \)

Normalized Specific Energy Consumption for Steam Generation (kcal/kg of Steam) = Weighted Average Specific Steam Consumption in BY x (Boiler efficiency at BY/Boiler Efficiency at AY)

Difference Specific Steam from BY to AY (kcal/kg of Steam) = Normalized Specific Energy Consumption for Steam Generation in AY - Weighted Average Specific Steam Consumption in BY

Energy to be subtracted w.r.t. Fuel Quality in Co-Gen (Million kcal) = Difference Specific Steam from BY to AY x \( \{(\text{Total Steam Generation at Process Boiler in AY} \times \text{Weighted Percentage of Coal Energy Used in steam Generation (Process Boiler) in AY}) + (\text{Total Steam Generation at Co-Gen Boiler in AY} \times \text{Weighted Percentage of Coal Energy Used in steam Generation (Co-Gen Boiler) in AY})\} / 1000 \)

Total Notional energy for Coal Quality deterioration to be subtracted w.r.t. fuel quality (Million kcal) = Energy to be subtracted w.r.t. Fuel Quality in CoGen (million kcal) + Energy to be subtracted w.r.t. Fuel Quality in CPP (Million kcal)

Notional Energy for fuel quality in CPP & Co-Gen (toe) = (Total Notional energy for Coal Quality deterioration to be subtracted w.r.t. fuel quality (Million kcal))/10

6.1.5 Documentation

- Fuel Linkage Agreement
- Operating Coal Quality- Monthly average of the lots (As Fired Basis), Test Certificate for Coal Analysis including Proximate and Ultimate analysis (Sample Test from Government Lab for cross verification)
- Performance Guarantee Test (PG Test) or Report from Original Equipment Manufacturer (OEM) Design / PG test Boiler Efficiency documents
- Design/PG Test Turbine Heat Rate documents
6.1.6 Note on Proximate and Ultimate Analysis of Coal

If the ultimate analysis has not been carried out in the baseline year for getting %H result, following conversion formulae from Proximate to Ultimate analysis of coal could be used for getting elemental chemical constituents like %H

\[
\begin{align*}
%C &= 0.97C + 0.7(VM + 0.1A) - M(0.6 - 0.01M) \\
%H_2 &= 0.036C + 0.086(VM - 0.1xA) - 0.0035M^2 (1 - 0.02M) \\
%N_2 &= 2.10 - 0.020VM \\
\end{align*}
\]

Where
- \(C\) = % of fixed carbon
- \(A\) = % of ash
- \(VM\) = % of volatile matter
- \(M\) = % of moisture

6.2 Low PLF Compensation in CPP

6.2.1 Need for Normalization

Owing to fuel non-availability, Grid disturbance, Plant load unavailability due to external factors etc, plant forced to reduce the load on turbine leading to low efficiency of units and Station. Due to decreased loading, the Plant load Factor (PLF) will be worsened and affects the unit heat rate. The comparison between baseline year and assessment year will be carried out through characteristics curve of Load Vs Heat rate for correction factor.

Hence, Normalization is required to compensate for the change in heat rate of CPP due to variation in PLF from the baseline.

<table>
<thead>
<tr>
<th>Sr No</th>
<th>Sub-Group</th>
<th>Elements</th>
<th>Reason/ Requirement</th>
<th>Impact</th>
<th>Documents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Scheduling [External factor] or Backing down</td>
<td>PLF and Station heat rate</td>
<td>• Plant Load backing down due to lower power demand from the grid • Variations in demand from the estimated or forecasted values, which cannot be absorbed by the grid.</td>
<td>Plant Load Factor</td>
<td>i. Scheduling Documents ii. Reference documents are required for deterioration in Plant Load Factor iii. Characteristics curve [Load Vs Heat Rate]</td>
</tr>
<tr>
<td></td>
<td>Unscheduled Power and Outage [External Factor]</td>
<td>PLF and Station heat rate</td>
<td>Transmission outages resulting in reduced power availability.</td>
<td>Plant Load Factor</td>
<td>Characteristics curve-Heat Rate Vs Load</td>
</tr>
</tbody>
</table>

6.2.2 Normalization Methodology

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

To compensate for the change in heat rate of CPP due to variation in PLF from the baseline.

- The decrease in PLF due to external factor in Assessment year w.r.t. Baseline year may deteriorate the CPP heat rate, further increasing/decreasing the SEC
- The Normalization will take place with Plant’s respective Turbine Heat Rate Vs Loading curve with the help of Designed HMBD at different loading condition

---

**Weighted Average**

\[ y = 0.0016x^2 - 0.3815x + 21.959 \]

\[ R^2 = 1 \]

---

**Characteristics Curve**

*Load Vs Turbine Heat Rate*

Coal Based Thermal Power Plant Actual Curve

Excel topology of actual curve

Turbine Heat Rate 8HEL 500 MW

- The polynomial equation of the characteristics curve with accuracy R²=0.9991, will calculate the heat rate on any load
- The Plant has to submit the documents related to weighted PLF w.r.t. no of hrs (Running time in which the plant desires the Normalisation in loss of PLF influenced by external factor)
• If a plant shuts down due to external reasons, the difference energy consumed during shutdown/restart from Baseline to Assessment year will not be considered in the assessment year Energy Consumption [Proper documents to be provided]
• Curve should be plotted based on HMBD supplied by OEM
• In case of non-availability of HMBD or Curve, data from the similar Unit will be considered
• Curve will be plotted on Unit Basis

6.2.3 Normalization Calculation

Unit wise Plant Availability Factor in BY = (8760-(Forces Outage or Unavailability (hrs)-Planned Maintenance Outage or Planned Unavailability])/8760

Unit wise Plant Availability Factor in AY = (8760-(Forces Outage or Unavailability (hrs)-Planned Maintenance Outage or Planned Unavailability])/8760

Unit wise Total Operating hours in year as per Unit Availability factor = 8760 X Plant Availability Factor

Unit wise Operating hours at full load = Total Operating hours in year as per Unit Availability factor - Average Operating hours at Low ULF

Unit wise Percentage Difference between Design Turbine/Module Heat Rate and Design Curve or HBD Turbine/Module Heat Rate = (Design THR @ 100% Load (OEM) - Design THR @ 100% Load (Curve or HBD) X 100)/(Design THR @ 100% Load (OEM))

Where
THR = Turbine Heat Rate (kcal/kWh)
OEM = Original Equipment Manufacturer
HBD = Heat Balance Diagram

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

\[ y = ax^2 - bx + c \quad \text{(kcal/kWh)} \]

Where
\[ X = \text{Operating Load (MW)} \]
\[ A = \text{Equation Constant 1 } = 0.0171 \]
\[ b = \text{Equation Constant 2 } = 6.6159 \]
\[ c = \text{Equation Constant 3 } = 2684.8 \]

Turbine Heat Rate as per Load Vs Heat Rate Equation due to external factor (kcal/kWh) = Equation Constant 1*(Average Operating Load (MW) caused by low ULF,MLF due to external factor)^2 - Equation Constant 2* Average Operating Load (MW) caused by low ULF,MLF due to external factor + Equation Constant 3

Design Turbine Heat Rate after Curve correction and difference correction = THR as per Load Vs HR Equation due to external factor \[ X \left(1 + \left\{ \% \text{ Difference between Design Turbine or Module HR and Design Curve or HBD Turbine or Module HR/100} \right\} \right) \]

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

Normalised Design Turbine Heat rate due to external factor (kcal/kWh) = ((Design Turbine Heat Rate after Curve correction and difference correction (kcal/kwh) X Average Operating...
hours at Low ULF) + (Design Turbine Heat Rate @ 100% Load (OEM)(kcal/kwh) X Operating hours at full load))/ (Total Operating hours in year as per Unit Availability factor)

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

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

Where

THR = Turbine Heat Rate (kcal/kWh)
AY = Assessment Year
BY = Baseline Year

Energy to be subtracted per unit = (Difference of THR between AY and BY (kcal/kWh) X Gross Unit Generation (Lakh Unit))/10

**Total Notional Energy to be subtracted due to Low PLF (Million kcal)** = Energy to be subtracted in U#1 for AY (Million kcal) + Energy to be subtracted in U#2 for AY (Million kcal) + .

### 6.3 Smelter Capacity Utilization

Variation in plant Capacity utilization in assessment year may take place from baseline year. This will have impact on gate to gate specific energy consumption

With the decrease in capacity utilisation due to any external reason not controlled by plant such as Market demand, Grid Power holiday etc. in the assessment year, the heat rate and specific energy consumption will also get upset and deteriorates the performance of the plant. Thus, this effect will attract the Normalization in assessment year w.r.t. the baseline year.

As the specific energy consumption (SEC) is calculated on a Gate-to-Gate (GTG) concept, the plant boundary shall be selected in such a manner that the total energy input and the output product be fully captured and the entire designated consumer’s plant.

Aluminium smelter’s boundary consists of two areas namely Captive Power Plant (CPP) and Smelter plant. The colony, residential complex and transportation system, mining operations of Aluminum sector are not a part of designated consumers’ boundary.

The same boundary shall be considered for entire cycle, and any change in the said boundary such as capacity expansion, merger of two plants, division of operation etc. shall be duly intimated to the Bureau of Energy Efficiency.
Smelter and captive power plant of aluminum sector is highly energy intensive. The production of aluminium consists of three steps: bauxite mining, alumina production and electrolysis. Bauxite - a rock composed of hydrated aluminium oxides - is the main ore of aluminium oxide (Al2O3), commonly known as ‘alumina’, which is used to make aluminium (Al). Mined bauxite is refined into alumina, which is then converted into metallic aluminium via an electrolytic process when high amperage DC current is passed through from anode to cathode in a pot cell. Aluminium thus dissociated from alumina gets collected at cathode.

Once aluminium is formed, the hot, molten metal is alloyed with other metals to make a range of primary aluminium products with different properties and suitable for processing in various ways to make end-user products.

A typical aluminum smelter consumes 95% of total energy in Electrolysis process (i.e. DC Electrical energy) and remaining energy is consumed in auxiliary loads of smelter and CPP.

Most of the smelter plants in India operate with coal fired captive power plants and the power plants performance depends on plant load factors and coal quality also.

Hence for normalization of “GTG SEC” in aluminium sectors two major energy performance indicators.
6.3.1 Terms of Normalization calculation

- Variation in plant Capacity utilization in assessment year may take place from baseline year.
- The variation in capacity utilisation in the assessment year w.r.t. baseline year will be normalised.
- Aluminium Smelter’s electrolysis process is highly power sensitive and power intensive hence normalization procedure is proposed to be applied due to external factors including power failure factor.
- Normalization has been done performing statistical analysis of the specific energy consumption and production data for the industry.
- For smelter plant specific DC energy consumption versus % capacity utilization (for hot metal production) data shall be plotted after collecting design data from all DCs.

- Specific DC energy consumption shall be considered for normalization as it is 95% of total energy consumption in a smelter.

6.3.2 Terms of Normalization

- Aluminium smelter pot line which is commissioning and starting production will not be considered in PAT cycle if capacity utilization is below 50%, as below 50% capacity utilization smelter is in start-up phase and the fixed energy losses are very high and specific DC energy consumption is skewed. Above 50% capacity utilization the smelter energy is mostly variable and fixed energy loss component is marginal.
- Normalization shall not be applicable if there is an enhancement of capacity utilization between baseline period and assessment year and benefit of SEC reduction if any on account of production increase should be given to the DC for achieving higher capacity utilization.
In case a DC commissions a new line/production unit before or during the assessment/target year, the production and energy consumption of new unit will be considered in the total plant energy consumption and production volumes provided the CU of that Unit/line ≥70%. However, the energy consumption and production volume will not be included till it attains 70% CU for calculating SEC in assessment year considering it as project phase. For Pot Line, three months stabilization period may be granted after achievement of 70% CU condition.

Power failure on account of Grid collapse or due to any other external reason as a factor for SEC normalization if this has caused capacity reduction or plant disturbance for e.g. pot shut down to be applied for the period the plant normal operation is restored. Normalization as per Sr No ii/iii to be considered for smelter and Refinery plant i.e., the energy and production to be deducted from the total energy consumption in the assessment year during stabilization back to equivalent SEC based on normalized curve (CU Vs SEC). Proper documentation is required for Energy and Production data during this period.

6.3.3 Need for Normalization

The normalization on capacity utilisation factor will be influenced by following external condition

- Market Demand
- Raw Material availability
- Grid Power holiday
- Natural Disaster
- Rioting/Social Unrest/Labour Problem
- Unforeseen Circumstances

The deterioration of Capacity Utilization due to Internal Factor of plant such as Breakdown of Machine, Power breakdown, Poor maintenance practices, Plants management policy etc. will not be considered.

6.3.4 Capacity Utilization Normalization

The capacity utilization normalization of the plant would be calculated for two different situations

1. Number of Operating pots(NOP) decrease due to external factor i.e., plant has to run at lower capacity as compared to the baseline operating capacity due to alumina non availability
2. Potline capacity (NOP/NOPP) loss due to market demands/power cuts/power holiday’s etc leading to Shutdown of pots due to outages not controlled by plant.

6.3.5 Normalization methodology on Capacity decrease due to external factor

1. Design parameters are considered for plotting normalization curve for smelter capacity utilization.
2. The normalization curve of best fit, may be plant specific based on design data as different plants have different constants (K1 and K2, which are based on No of operating Pots and Nos of Pots/Potline).
3. Normalization in case of capacity utilization may be applicable if there is a decrease in capacity w.r.t baseline period due to external factors as per PAT guideline.
4. The Potline wise plant capacity in the assessment year will be compared from the baseline year in terms of kWh/Tonne design.
JNARDDC study indicates that smelter capacity utilization CU Vs SEC curve of best fit may be derived for each smelter between 50% to 100% capacity utilization as below 50% Capacity Utilisation the fixed energy consumption is high.

6.3.6 Normalization Calculation on capacity decrease for Kiln Heat Rate

- Unit wise K1 – constant 1 in BY & AY= 
  
  \( \frac{(\text{Design Bus Bar Voltage Drop} + \text{No of Pots}/\text{Potline} \times \text{Dead pot voltage}) \times 298000}{(\text{No of Pots}/\text{Potline} \times \text{Current Efficiency of Pots})} \)

- Unit wise K2 – constant 1 in BY& AY= 
  
  \( \frac{(\text{Design Pot voltage} - \text{Dead pot voltage}) \times 2980}{(\text{Current Efficiency of Pots})} \)

- Unit wise Capacity Utilisation in BY& AY= 
  
  \( \frac{(\text{No of operating pots}/\text{No of pots}/\text{potline}) \times 100)}{100} \)

- Unit wise SEC Design at CU% (kWh/tonne) in BY& AY = 
  
  \( \frac{(\text{K1}/\text{Capacity utilisation}) + \text{K2}}{100} \)

- Unit wise Notional Specific Energy Consumption = Unit wise SEC Design at CU % in AY - Unit wise SEC Design at CU % in BY

- Unit wise Electrical Energy to be deducted due to lower capacity utilisation (Million kWh)
  
  If capacity utilization % in AY < capacity utilization % in BY, Electrical energy to be deducted = Notional Specific Energy Consumption forPotline 1 x Production /10^6
If capacity utilization % in AY > capacity utilization % in BY, Electrical energy to be deducted = 0

- **Total Electrical Energy to be deducted due to lower capacity utilisation** = Electrical Energy to be deducted due to lower capacity utilisation for AY of Line 1 + Electrical Energy to be deducted due to lower capacity utilisation for AY of Line 2 + ……………….Line 10

- **Electrical Energy to be deducted due to lower capacity utilisation** = Total Electrical Energy to be deducted due to lower capacity utilisation (Million kWh) X Weighted Heat Rate ( kcal/kWh)

- **Notional Energy for Smelter capacity utilization (toe)** = (Electrical Energy to be deducted due to lower capacity utilisation (Million kcal))/10

### 6.3.8 Documentation

- A. Documentary proof for unavailability of Raw Material, Alumina and Fuel
- B. Power Cut/ Power Holiday documents from respective Boards
- C. Force Major condition documents: Flood, Earthquake, Labor Strike, Rioting or Social unrest, Change in Government policy
- D. Production documents for Molten Aluminium [MPR/CCR Trend/Lab Report or Register or other supporting documents]
- E. Casting Product (Import and Export) (Excise documents/Internal transfer details)
- F. The individual potline wise production, Current efficiency and run hours data required for the baseline years with supporting documents

### 6.3.7 Note on New Line /Production Unit installed after baseline year

In case a DC adds capacity within the boundary by commissioning a new Potline after baseline year, the production and energy consumption of new Potline will be considered in the total plant’s production volume and energy consumption while calculating SEC provided CU of new pot line is more than 70% and the Pot line has completed at least 90 days of normalization period after commissioning of 70% of pots. If the above condition is not satisfied then the energy consumption & production of the pot line may be excluded for calculating plant’s SEC.

In case of addition of new Potline, a DC may submit all relevant design data of new Pot line to JNARDDC and BEE for calculating normalization curve for the newly commissioned Potline.

### 6.4 Bauxite Quality

Bauxite, the most important ore of aluminium, contains only 30–54% aluminium oxide, (alumina), Al₂O₃, the rest being a mixture of silica, various iron oxides, and titanium dioxide. The Bayer process is the industrial route to produce alumina, Four Tonne of bauxite required to produce one tonne of alumina.

- Roughly 5,900 kg of earth are mined to produce 5,100 kg of bauxite, which is refined into 1,930 kg of alumina (2.65 t of bxt/t of Alumina).
- The 1,930 kg of alumina are electrolytically processed with 446 kg of carbon to produce one metric ton (1,000 kg) of aluminium (5.1 t of bxt/t of Aluminium)
Bauxite residue (red mud) is a by product of the Bayer process and contains the insoluble impurities of bauxite.

The amount of residue generated per kilogram of alumina produced varies greatly depending on the type of bauxite used and impurities present in bauxite, from 0.3 kilograms for high-grade bauxite to 2.5 kilograms for low-grade bauxite.

Its chemical and physical properties depend primarily on the bauxite used and, to a lesser extent, the manner in which it is processed.

### 6.4.1 Need for Normalization

- The quality of the bauxite available for manufacturing alumina hydrate is deteriorating over a period of time. This has significant effect on the overall energy consumption of the plant.
- Energy consumption will increase with the decrease in TAA% in Bauxite in Evaporation.
- The evaporation section helps in Bayer circuit by removing plant dilution caused by wash water and Bauxite Moisture.
- The evaporation of excess moisture w.r.t Baseline year increases Steam consumption so as the energy consumption in the assessment year.
- Normalization with respect to bauxite quality (ATH/THA/TAA) and its impact on excess energy requirement in evaporating accompanying bauxite moisture and excess water for red mud washing has been developed.
- Change in ATH, THA, TAA affect the quality of the bauxite and the Bayer process, resulting in loss/gain in the plant’s energy consumption. To compensate for the change in efficiency of Plant with change in bauxite quality, the energy loss to be subtracted from the Total Energy consumption.
- The plant have no control over the quality of bauxite supplied.
- The excess electrical energy consumed because of deviation in bauxite quality is not considered as it is negligible as compared to the thermal energy.

### 6.4.2 Normalization Calculation

#### Specific Bauxite Factor (SBC): \(1/(\text{TAA}\% \times (100-\text{Moisture})\% \times \text{Ov’ll Recovery}\%\))

#### Wash Water required in Tonnes (WW) : \(\text{SBC} \times (100-\text{Moisture})\% \times \text{Mud Factor} \times \text{Wash Water per ton Mud}\)

#### Excess Steam Consumption (ESCAY) = \(((\text{SBCAY}\times\text{SBCBY}) \times M_{AY} + (\text{WWAY} - \text{WWBY})))/(\text{ESEAY})\)

#### Notional Energy for Moisture Evaporation = \(\text{ESCAY} \times \text{SEAY} / (\eta_{AY}\times10^3)\)

Where

- \(M_{AY}\) = Moisture in Bauxite in Assessment year
- \(\text{SBC}_{AY}\) = Specific bauxite factor in Assessment year
- \(\text{WW}_{AY}\) = Wash Water requirement in Assessment year
- \(\text{SBC}_{BY}\) = Specific bauxite factor in Baseline year
- \(\text{WW}_{BY}\) = Wash Water requirement in Baseline year
- \(\text{ESE}_{AY}\) = Evaporation Steam Economy in Assessment year
- \(\text{ESCAY}\) = Excess Steam Consumption in Assessment year
- \(\text{SE}_{AY}\) = Steam Economy in Assessment year
- \(\eta_{AY}\) = Boiler Efficiency in Assessment year
Detailed Calculation of Normalization

- **Specific bauxite Factor in BY & AY (tonne of Bauxite/Tonne of Alumina)**
  \[
  \frac{1}{(TAA \text{ in Bauxite for BY} \times (100 - \text{Moisture content in Bauxite for BY}) \times \text{Overall recovery from Bauxite for BY})}
  \]

- **Mud Factor in BY & AY (tonne of mud/Tonne of Bauxite)**
  \[
  \frac{\text{Fe in Bauxite for BY}}{\text{Fe in Mud for BY}}
  \]

- **Wash Water in BY & AY (Tonns)**
  \[
  \text{Specific bauxite factor in BY} \times (100-\text{Moisture content in Bauxite for BY})\% \times \text{Mud Factor} \times \text{wash water required for cleaning one Tonne of mud}
  \]

- **Excess wash water (Tonne)**
  \[
  \text{Wash water for AY (Tonne)} - \text{wash water for BY (Tonne)}
  \]

- **Excess Moisture (Tonne)**
  \[
  (\text{Specific bauxite factor in AY} - \text{Specific bauxite factor in BY}) \times \text{Moisture content in AY}
  \]

- **Excess Steam (tonne)**
  \[
  \text{Excess Moisture (Tonne)} + \text{Excess wash water (Tonne)} / \text{Steam economy (tonne/tonne) in AY}
  \]

- **Notional energy for moisture (kCal/Tonne)**
  \[
  \text{Excess steam (Tonne) in AY} \times \text{Actual steam Enthalpy (kCal/kg)} \times 1000 / \text{Boiler efficiency (}) \%
  \text{in AY}
  \]

- **Notional energy to be subtracted (Million Kcal in AY)**
  \[
  \text{Notional energy for moisture (kCal/Tonne)} \times \text{Total Hydrate alumina production (Tonne)} / 10^6
  \]

6.4.3 Documentation

- Fuel Linkage Agreement
- Operating Bauxite Quality-Monthly average of the lots, Test Certificate for Bauxite Analysis

6.5 Carbon Anode Production

- Carbon anodes are a major requirement for the Hall-Heroult process.
- About 0.5 tons of carbon is used to produce every ton of aluminum.
- There are two main types of carbon anode used
  - Prebaked: Prebaked anodes consist of solid carbon blocks with an electrically conductive rod (e.g., copper) inserted and bonded in position usually with molten iron.
  - Soderberg: A mixture of petroleum coke and pitch is strongly heated causing the pitch to bind the coke particles together.
- Both types are made from the same basic materials i.e., Petroleum Coke and react in the same way.
- Anodes used in potlines are produced in house in a separate anode plant by pre-baked technology from a mixture of petroleum coke and coal tar pitch (acting as a binder).

6.5.1 Methodology:

In Smelter plant of Aluminum industries carbon anode is produced and consumed for producing the Molten Aluminum. Considering this fact it may happen that carbon anode product...
which they produce in the baseline year may be changed in the assessment year. Also due to market demand of molten aluminium, they export their carbon anode to the market/stock. This import and export may deviate the SEC of the plant in the assessment year.

- In Pre-bake technology, anode blocks are produced separately in anode baking ovens. The additional thermal energy required for anode baking is met by Furnace Oil.

- Normalization due to Anode import/export is applicable if the Baseline and Assessment year scenarios are different.

- The import/export of carbon anode will be treated as Intermediary product normalization.

- In case a DC exports anodes in target year, the energy for the same shall be excluded while calculating SEC in assessment year.

- Similarly in case a DC imports anodes in addition to own production then energy consumption for the imported anodes shall be factored in Gate to Gate energy calculated based on own anode production SEC.

- Normalization due to Anode import/export is applicable if the Baseline and Assessment year scenarios are different.

6.5.2 Need for Normalization

Import of carbon anode for production of Molten aluminium is common practice in Aluminum industry along with export of carbon anode also undertaken as per molten aluminium production. The change in the proportion of import or export during baseline year to target year may affect the SEC of the plant.

For carbon anode production change in assessment year with respect to Baseline year, there is a need to develop and impose proper Normalization factors, so that any change in the product mix could be nullified and the concerned plant should not suffer/or gain advantage due to this change only.

Carbon Anode import by the plant (for which part of the energy is not required to be used by the plant) and Carbon Anode export from the plant for which energy has been used but it is not taken into account in the Molten Aluminum production.

6.5.3 Normalization Methodology

- In case of import of carbon anode product, if import of that product was not present in the baseline year then the amount of product which is being imported in the assessment year will be taken and accordingly the energy consumption for producing the said amount of carbon anode product shall be calculated with the help of SEC of carbon anode product. This energy shall be added to the total energy of the plant. The rationale behind this is the energy consumption for producing imported carbon anode product if carbon anode would have produced within the plant itself.

- In case of export of carbon anode produce: The production and energy consumption for producing that much of amount of product shall be subtracted from the total energy and total production of the plant respectively.

Note: The stock is also considered as export of carbon anode production.
Normalization Calculation:

- **Stock in BY & AY = Carbon anode**
  - Closing Stock in BY & AY - Carbon anode
  - Opening Stock in BY & AY

- **Total Carbon anode Export**
  1. **In Baseline Year**
     a. If, Stock in BY > 0, Total Carbon anode export in BY = Export Carbon anode in BY + Stock in BY
     b. If, Stock in BY < 0, Total Carbon anode export in BY = Export Carbon anode in BY
  2. **In Assessment Year**
     a. If, Stock in AY > 0, Total Carbon anode export in AY = Export Carbon anode in AY + Stock in AY
     b. If, Stock in AY < 0, Total Carbon anode export in AY = Export Carbon anode in AY

- **Total Carbon anode import**
  1. **In Baseline Year**
     a. If, Stock in BY < 0, Total Carbon anode import in BY = import Carbon anode in BY - Stock in BY
     b. If, Stock in BY > 0, Total Carbon anode import in BY = import Carbon anode in BY
  2. **In Assessment Year**
     a. If, Stock in AY > 0, Total Carbon anode import in AY = import Carbon anode in AY + Stock in AY
     b. If, Stock in AY < 0, Total Carbon anode import in AY = import Carbon anode in AY

- **Notional energy for carbon anode exported**
  1. **In Baseline Year**
     a. Notional energy for carbon anode exported in BY = SEC of carbon anode production in BY X Total Carbon anode exported in BY
  2. **In Assessment Year**
     b. Notional energy for carbon anode exported in AY = SEC of carbon anode production in AY X Total Carbon anode exported in AY

- **Notional energy for carbon anode imported**
  1. **In Baseline Year**
     a. Notional energy for carbon anode imported in BY = SEC of carbon anode production in BY X Total Carbon anode imported in BY
  2. **In Assessment Year**
     b. Notional energy for carbon anode imported in AY = SEC of carbon anode production in AY X Total Carbon anode imported in AY

- **Net energy for carbon anode export and import**
  1. **In Baseline Year**
     a. Net energy for carbon anode export and import in BY = Notional energy for carbon anode exported in BY - Notional energy for carbon anode imported in BY
  2. **In Assessment Year**
     b. Net energy for carbon anode export and import in AY = Notional energy for carbon anode exported in AY - Notional energy for carbon anode imported in AY
Normalization Methodology for Aluminium Sector

6.5.5 Documentation

- Purchase and sell document of carbon Anode
- Carbon Anode production documents of Smelter plant
- Carbon Anode – Excise Documents

6.6 Power Mix

6.6.1 Baseline Year Methodology:

In GtG methodology, the heat rate of power source considered as per following factors

- Electricity Imported from grid @ 860 kcal/kWh
- CPP generated Electricity @ Actual CPP Heat Rate
- DG generated Electricity @ Actual DG Heat Rate
- Electricity Exported to grid @ 2717 kcal/kWh

6.6.2 Need for Normalization

Power Sources and Import: The ratio of electricity import/export may change in the assessment year w.r.t. the baseline year. In specific energy consumption calculation, the Electricity import from Grid is taken @ 860 kcal/ kWh, whereas heat rate of self- generation could be in the range of 2200-4000 kcal/kWh. Hence, the heat rate of self-generated electricity impact 3-4 times than the Grid Electricity in SEC calculation.

There is a possibility that a plant, by increasing the import from grid to meet plant’s electricity demand can show savings because of decrease in its own captive power consumption, which has a higher heat rate.

Power Export: The heat rate of power export from Plant having CPP as one of the power source has been taken as 2717 kcal/kwh (national average heat rate of all power plants) in the baseline year, while the heat rate of self-generation from CPP stands at 3200-4000 kcal/kwh. Hence, the plant exporting power higher or lower in the assessment year w.r.t. the baseline year will gain or loss in terms of Energy Consumption in the plant.

Therefore, this advantage/disadvantage attracts Normalization Factors

6.6.3 Power Mix Normalization methodology

6.6.3.1 Power Sources and Import

- The baseline year power mix ratio will be maintained for Assessment year for Power Source and import
- The Normalised weighted heat rate calculated from the baseline year Power mix ratio will be compared with the assessment year Weighted Heat Rate and the Notional energy will be deducted from the Total energy assessed
- The Thermal Energy difference of electricity consumed in plant in baseline year and electricity consumed in plant during assessment year shall be subtracted from the total energy, considering the same % of power sources consumed in the baseline year.
- However, any efficiency increase (i.e. reduction in Heat Rate) in Assessment year in any of the power sources will give benefit to the plant
6.6.3.2 Power Sources and Export

- In case of Power export, the plant will be given disadvantage of advantage by comparing the assessment year heat rate of CPP with the baseline year heat rate of CPP and deduct the same by taking the heat rate of 2717 kcal/kwh.
- CPP Actual Net Heat Rate will be considered for the net increase in the export electricity from the baseline.

6.6.4 Power Mix Normalization Calculation

6.6.4.1 Normalization for Power Sources

Normalized Weighted Heat Rate for Assessment year (kcal/kwh):

\[ J = A \times \left( \frac{D}{G} \right) + B \times \left( \frac{E}{G} \right) + C \times \left( \frac{F}{G} \right) \]

Where

A: Grid Heat Rate for Assessment year (AY) in kcal/kwh.
B: CPP Heat Rate for AY in kcal/kwh.
C: DG Heat Rate for AY in kcal/kwh.
D: Grid Energy consumption for Base Line Year (BY) in Million kwh.
E: CPP Energy consumption for BY in Million kwh.
F: DG Energy consumption for BY in Million kwh.
G: Energy Consumed from all Power sources (Grid, CPP, DG) for BY in Million kwh.

(Note: Any addition in the power source will attract the same fraction to be included in the above equation as \( PS_{iHR_{AY}} \times \left( PS_{iEC_{BY}} / TEC_{BY} \right) \))

6.6.5 Normalization for Power Export

Net Heat Rate of CPP to be considered for export of Power from CPP instead of 2717 kCal/kWh.

The Export power normalization would be

- Actual CPP heat rate would be considered for the net increase in the export of power from the baseline.
- The exported Energy will be normalized in the assessment year as following calculation.

The energy to be subtracted in the assessment year in Mkcal:

\[ = (EXP_{AY} - EXP_{BY}) \times ((GHR_{AY}/(1-APC_{AY}/100)) - 2717) \]
GHR_{AY}: CPP Gross Heat Rate for AY in kcal/kwh
EXP_{AY}: Exported Electrical Energy in AY in Million kwh
EXP_{BY}: Exported Electrical Energy in BY in Million kwh
APC_{AY}: Auxiliary Power Consumption for AY in %

6.6.6 Documentation

A. Electricity Bills from Grid
B. Energy generation Report from CPP/DG/WHR/CoGen
C. Power Export Bills from Grid and ABT meter reading
D. Fuel consumption Report [DPR, MPR, Lab Report]
E. Fuel GCV test report- Internal and external [As received or As fired basis as per baseline methodology]

6.7 Product Mix

Production quantity is an important relevant variable, but is often difficult to determine; especially for an organization producing various products, since the quantity unit and SEC differs between products.

Annual Sales differs in the Assessment years compared to the Baseline Year due to many external factors such as Market Demand, Socio Economic Condition, Government Policy etc. Such external factors sometimes affect the production quantity ratio of the organization.

A designated consumer (DC) may have different product mix and the ratio of product mix may vary from baseline period to target year. Hence there has to be right comparison of product mix between base line period and target year. Some product may be more energy intensive and product yield and scrap rate may vary from product to product depending on the finished product.

In product mix (Refinery and Smelter) the baseline year product energy factor (Energy Factor) will be maintained for equivalent major product in the assessment year.
6.7.1 Common Methodology

- The Specific Energy Consumption (SEC) should be known for each product
- The methodology will be used for Parallel and Series line production
- One major product to be chosen among the products for parallel line production, the product which is sold out will be included after conversion into the equivalent product
- For Series production major product is fixed, all the products or value added product will be converted to the major product with the help of specific energy consumption (SEC) factor
- The Energy factor of baseline will be used to convert other products to the major product in the Assessment Year
- The Major product will be kept same in the Assessment Year as of Baseline Year
- In the Refinery sub-sector, plant may have different product mix based on process like Standard hydrate or special alumina apart from calcined alumina
- Hence, different types of products needs to be converted in to equivalent major product produced by that plant with the help of energy factor, based on the SEC of the product.

6.7.2 Normalization Calculation

(i) Equivalent production (In Major Product) in the Baseline Year (BY) will be

\[ EqMP_{BY} = PP_{1BY} + (PP_{2BY} \times EFP_{2BY}) + (PP_{3BY} \times EFP_{3BY}) \]

Major Product: Product 1 in the baseline year (Tonnes)

Where

\[ EqMP_{BY} = \text{Total equivalent product in Major Product} \]

Product in BY (Tonne)

\[ PP_{1BY} = \text{Total Product 1 production in BY (Tonne)} \]
\[ PP_{2BY} = \text{Total Product 2 production in BY (Tonne)} \]
\[ EFP_{2BY} = \text{Product 2 energy factor with respect to Product 1 in BY} \]
\[ PP_{3BY} = \text{Total Product 3 production in BY (Tonne)} \]
\[ EFP_{3BY} = \text{Product 3 energy factor with respect to Product 1 in BY} \]

\[ BY = \text{Baseline Year} \]

(Note: Any addition in series or parallel product will attract the same fraction and to be included)
in the above equation as \( P_{i_{\text{BY}}} \times E_{FP_{i_{\text{BY}}}} \)

The Energy factor for the baseline will be calculated as

\[
E_{FP_{2_{\text{BY}}}} = \frac{SECP_{2_{\text{BY}}}}{SECP_{1_{\text{BY}}}}
\]
\[
E_{FP_{3_{\text{BY}}}} = \frac{SECP_{3_{\text{BY}}}}{SECP_{1_{\text{BY}}}}
\]
\[\ldots\]
\[
E_{FP_{i_{\text{BY}}}} = \frac{SECP_{i_{\text{BY}}}}{SECP_{1_{\text{BY}}}}
\]

Where

\( E_{FP_{2_{\text{BY}}}} \) = Product 2 energy factor with respect to Product 1 in BY

\( E_{FP_{3_{\text{BY}}}} \) = Product 3 energy factor with respect to Product 1 in BY

\( E_{FP_{i_{\text{BY}}}} \) = Product \( i \)th energy factor with respect to Product 1 in BY

\( SECP_{1_{\text{BY}}} \) = Specific Energy Consumption of Product 1 in BY

\( SECP_{2_{\text{BY}}} \) = Specific Energy Consumption of Product 2 in BY

\( SECP_{3_{\text{BY}}} \) = Specific Energy Consumption of Product 3 in BY

\( SECP_{i_{\text{BY}}} \) = Specific Energy Consumption of Product \( i \)th in BY

(ii) Condition 1, No new product is introduced in the assessment year i.e., if \( P_{i_{\text{BY}}} = 0 \) and \( P_{i_{\text{AY}}} \neq 0 \) then

Equivalent production (In Major Product) in the Assessment Year (AY) will be

\[
E_{QMP_{\text{AY}}} = P_{1_{\text{AY}}} + (P_{2_{\text{AY}}} \times E_{FP_{2_{\text{BY}}}}) + (P_{3_{\text{AY}}} \times E_{FP_{3_{\text{BY}}}})
\]

Major Product: Product 1 in the baseline year (Tonnes) and will remain same in the assessment year

Where

\( E_{QMP_{\text{AY}}} \) = Total equivalent product in Major Product in AY (Tonne)

\( P_{1_{\text{AY}}} \) = Total Product 1 production in AY (Tonne)

\( P_{2_{\text{AY}}} \) = Total Product 2 production in AY (Tonne)

\( E_{FP_{2_{\text{BY}}}} \) = Product 2 energy factor with respect to Product 1 in BY

\( P_{3_{\text{AY}}} \) = Total Product 3 production in AY (Tonne)

\( E_{FP_{3_{\text{BY}}}} \) = Product 3 energy factor with respect to Product 1 in BY

\( AY \) = Assessment Year

(iii) Condition 2, Due to introduction of new product in the assessment year, the production of new introduced product in the baseline year will be 0 i.e., if \( P_{i_{\text{BY}}} = 0 \) and \( P_{i_{\text{AY}}} \neq 0 \) then

Equivalent production (In Major Product) in the Assessment Year (AY) with 4th new introduced product will be

\[
E_{QMP_{\text{AY}}} = P_{1_{\text{AY}}} + (P_{2_{\text{AY}}} \times E_{FP_{2_{\text{BY}}}}) + (P_{3_{\text{AY}}} \times E_{FP_{3_{\text{BY}}}}) + (P_{4_{\text{AY}}} \times E_{FP_{4_{\text{AY}}}})
\]

Major Product: Product 1 in the baseline year (Tonnes) and will remain same in the assessment year

Where

\( P_{4_{\text{AY}}} \) = Total Product 4 production in AY (Tonne)

\( E_{FP_{4_{\text{AY}}}} \) = Product 4 energy factor with respect to Product 1 in AY

\( E_{QMP_{\text{AY}}} = \frac{SECP_{4_{\text{AY}}}}{SECP_{1_{\text{BY}}}}
\]

\( AY \) = Assessment Year
6.7.3 Refinery Process

In Refinery Industries, many plants do the work of value addition in Calcined Alumina/Hydrate Alumina due to demand of their customers or by their own. These value additions are of different type and sometimes increase the quality of the products. The impact of value addition results increase in the SEC of the plant. A typical Production process of plant is shown below.

6.7.3.1 Baseline Year Methodology:

In the refinery plants of aluminium sector there are wide variety of value added products are produced after hydrate alumina/Calcined alumina production. In baseline year, Calcined alumina was considered as major product and the production of value added products were not converted into equivalent major product.

6.7.3.2 Need for Normalization

Product mix (some products consume higher energy whereas other consume comparatively less) may change in Assessment year w.r.t. baseline year.

- For all the Product mix change in assessment year with respect to Baseline year, there is a need to develop and impose proper Normalization factors, so that any change in the product mix could be nullified and the concerned plant should not suffer / or gain advantage due to this change only.

Partially processed product import by the plant (for which part of the energy is not required to be used by the plant) and export from the plant for which energy has been used but it is not taken into account in the final product.