# Systematic Approaches to Reduce Specific DC Power Consumption at Vedanta Jharsuguda Smelter

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**Abstract**

The aluminium industry is a very energy intensive industry. Hence, energy management and improving energy efficiency are of utmost importance for any aluminium smelter. A measure of energy efficiency is specific power consumption, i.e. – the amount of DC energy required to produce unit mass of primary aluminium.

Plant-1 of Jharsuguda smelter at Vedanta Aluminium, comprises 608 GAMI technology electrolytic cells, running at 330 kA. Over the past five years, Plant-1 adopted systematic approaches to cut down the specific DC energy consumption (SEC) while concurrently improving process control and productivity. The initiatives encompassed using graphitized cathode blocks, strategic adjustment of process parameters to minimize process variability, the introduction of copper-inserted collector bars in cathode assembly, reduction of external drops through focused improvement projects, upskilling and reskilling both direct and indirect employees in regular intervals, and promoting the concept of sustainable growth and Environment, Social and Governance (ESG) goals. These efforts yielded tangible results; the SEC of Plant-1 reduced to 12 985 kWh/t Al in financial year 2024 from 13 230 kWh/t Al in financial year 2019. The progressive measures contribute to the establishment of an energy-efficient production management system, aligning with Vedanta's commitment to "Zero Harm, Zero Discharge".

**Keywords:** Vedanta Aluminium Limited, Reduction of specific DC energy consumption, Process control, Graphitized cathode, Copper collector bar insert.

## 1. Introduction

Vedanta's Jharsuguda Smelter is India's largest single location aluminium production facility. It has produced 1.8 million tonnes of primary aluminum in financial year (FY)2024. This remarkable achievement comes as a result of the continuous efforts from the operation team and embracing technological upgradation at Jharsuguda location. Compared to FY'20, 0.245 kWh/t Al saving in SEC has been recorded in FY'24. With more than 1 900 operational cells, the journey of accomplishing lowest ever specific energy consumption at Jhasruguda smelter started with implementation of graphitic and graphitized cathodes.

The chemistry of Hall-Héroult process says, alumina, under the provision of sufficient energy, breaks down into atomic states and produces aluminium and oxygen. In Hall-Héroult cell, this "sufficient energy" is provided in the form of Joule heating and subsequent electrolysis of the alumina molecule breaks it down into aluminium cation and oxygen anion. Further, the aluminium cation migrates toward cathode and accepts electron to become aluminium-whereas, the oxygen anion moves toward carbon anode and reacts with it to form carbon dioxide.

Ionic dissociation: $2Al_2O_3 + \Delta \rightarrow 4Al^{3+} + 6O^{2-}$

Cathode reaction: $4Al^{3+} + 12e^- \rightarrow 4Al$

Anode Reaction: $3C + 6O^{2-} \rightarrow CO_2 + 12e^-$

Overall Reaction: $2Al_2O_3 + 3C + \Delta \rightarrow 4Al + 3CO_2$

This process, known as Hall-Héroult process, is aided by a constant supply of Direct Current (DC).

Despite the theoretical decomposition potential for alumina to aluminium being -2.21 V, using carbon anode aids in reducing the Gibb's free energy by almost half of the earlier case and therefore sustains with -1.18 V decomposition potential, also known as reversible cell voltage [1].

| | |
|---|---|
| $2Al_2O_3 \rightarrow 4Al + 3O_2$ | Gibb's free energy: 640 kJ/mol (1000 °C) |
| $2Al_2O_3 + 3C \rightarrow 4Al + 3CO_2$ | Gibb's free energy: 340 kJ/mol (1000 °C) |

Still, the practical considerations such as ohmic resistances necessitate operation at higher voltages, accounting for typically around 4.15–4.25 V voltage drop across a cell in a 330 kA smelter. The additional voltage drop is attributed to mainly four components:

- Anode voltage drop (0.3–0.4 V)
- Bath voltage drop (2.2–2.5 V)
- Cathode voltage drop (CVD) (0.25–0.35 V) and
- External voltage drop (0.2–0.25 V).

The specific energy consumption is one of the most important measures to perceive the efficiency of cell operation. It is influenced by the cell voltage drop and current efficiency [2], as described by the following empirical relation:

$$SEC = \frac{2.98 \times V}{CE} \quad (1)$$

where:

| | |
|---|---|
| *SEC* | Specific energy consumption, kWh/kg Al |
| *V* | Voltage drop across cell + line loss, V |
| *CE* | Current Efficiency, decimal number |

The measure of specific energy consumption not only affects the economy but also plays a crucial role in environmental sustainability and greenhouse gas (GHG) emissions. Since the Jharsuguda smelter relies on a coal-based power plant for electricity supply, reducing specific energy consumption is a priority for sustainable development as well as important from financial perspective. Over the past five years, Vedanta has undertaken various initiatives to address these opportunities, following a systematic approach to lowering specific energy consumption.

## 2. Initiative For Reducing Specific Energy Consumption

### 2.1 Graphitized Cathode Implementation

Since its inception, the Jharsuguda Smelter was equipped with cathode lining that could deliver specific energy consumption of around 13.5 kWh/kg Al. Over 12 years, the lining was progressively upgraded to higher-grade cathodes, transitioning from amorphous and semi-graphitic to graphitic and graphitized cathodes. These advancements have reduced specific energy

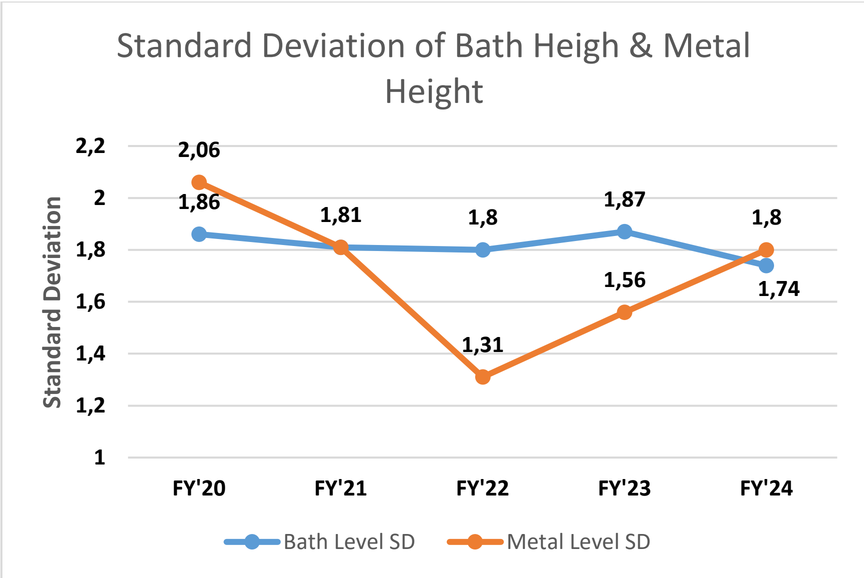


**Figure 9. Bath and metal height variability trend for Plant-1 from FY'20 to FY'24.**

## 5. Conclusions

Plant-1 of Jharsuguda Smelter started a journey of reducing specific energy consumption which once seemed to be almost impossible to achieve due to design implications. But systematic approaches taken to reduce energy consumption gradually has shown excellence of both process and operation teams which did not only break the barrier of specific energy consumption constraints, but also achieved upward trend in current efficiency. Replacing graphitic cathodes with graphitized ones have a significant role in this scenario. But process control strategy review and implementation are indispensable parts of the whole journey. Training and skill development of employees reflect a positive change in operational practices enabling employees to make knowledge-based decision making. Summing up all the efforts that were chased in the last 5 years, landed Vedanta to successfully achieve landmarks and it is continuing efforts for further reduction in specific energy consumption.

## 6. References


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