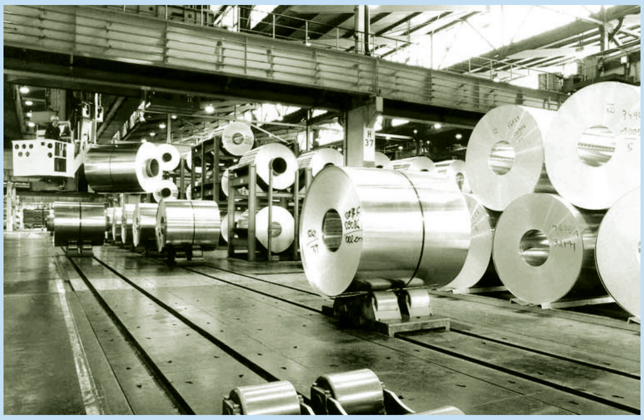
सत्यमेव जयते
Ministry of Power
Government of India

Improving Energy Efficiency in

Aluminium Sector

(Achievements and Way Forward)



Perform Achieve & Trade

September 2018

BUREAU OF ENERGY EFFICIENCY

german cooperation
DEUTSCHE ZUSAMMENARBEIT

Published by
giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Published by BEE in Partnership with GIZ

Imprint

Bureau of Energy Efficiency (BEE), Ministry of Power, Govt. of India
4th Floor, Sewa Bhawan, Sector-1, R.K. Puram
New Delhi, 110066, India

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
Registered offices: Bonn and Eschborn, Germany
Indo-German Energy Programme (IGEN)
C/o Bureau of Energy Efficiency
West Block-2, Sector-1, R.K. Puram, New Delhi, 110066, India

We acknowledge the cooperation extended by Ministry of Power, Government of India

Responsible
Winfried Damm
E: winfried.damm@giz.de

Contributing Authors
Bureau of Energy Efficiency (BEE)
Abhay Bakre, Pankaj Kumar, Ashok Kumar, Sunil Khandare, Abhishek Kumar Yadav

Indo-German Energy Programme (IGEN)
Arvind Kumar Asthana, Rita Acharya, Nitin Jain, Piyush Sharma, Ravinder Kumar

Confederation of Indian Industry (CII)
K S Venkatagiri, P V Kiran Ananth, K Muralikrishnan, Balasubramanian M B and Team

Acknowledgement
Bharat Aluminium Company Limited (BALCO), Vedanta Limited

Study by:
Confederation of Indian Industry (CII)
CII – Sohrabji Godrej Green Business Centre
Survey No. 64, Kothaguda Post, Near Hi-tech City, Hyderabad, 500084, India

Version: New Delhi, September 2018

Dr. Winfried Damm

Head of Energy, GIZ India

Aluminium is an essential part of our daily lives. It is the third most abundant element after oxygen and silicon and the most abundant metal in the crust, constituting more than 8% of the earth's crust. The production of Aluminium requires a lot of energy. As per an estimate, the embodied energy for aluminium is 211 GJ per tonne, compared to 22.7 GJ per tonne for steel. However, Aluminium is over three times lighter than steel, which means that energy savings can be made over the lifetime of the metal's use if aluminium replaces steel in some sectors such as transport. Thus, energy efficiency is utmost important in its production to reduce its embodied energy, and put an end to the debate of Aluminium over Steel.

Germany has been playing a very active role in promoting energy efficiency in not only its own land, but also supporting the other countries to adopt the same. Germany has been supporting India in various fields since last 60 years, with an aim of promoting cooperation and involving public-private sectors of both sides in the areas of energy, environment and sustainable economic development. The Indo-German Energy Programme (IGEN), works as a partner of Bureau of Energy Efficiency (BEE) in supporting policies and programmes envisaged under the Energy Conservation Act, 2001.

It has been a privilege to work with BEE, the organization spearheading activities on energy efficiency in India. IGEN has been involved with BEE in the Perform Achieve and Trade since its inception, and hence it is blissful to know that the outcome of this scheme led to a huge savings in terms of CO_2 emission reduction and coal.

However, the real outcome of PAT scheme is not only the savings in terms of toe and CO_2, but it is the change in behavior towards energy efficiency. It is astonishing to see the amount of resources and concepts the industries have put together in achieving the target. Some state-of-the-art projects implemented in PAT cycle-I are cross cutting and could have significant potential across the sectors. Some of the positive outcomes of this scheme were the utilization of waste heat in generation of steam and power, adoption of cogeneration, use of alternate fuel and raw material, etc. This report analyses the outcome of PAT scheme in Aluminium sector in multidimensional ways and forecasts the future savings along with innovative case studies having high replication potential. The estimate suggests the cumulative energy savings from the sector till 2030 to be 27.89 million TOE, which is quite impressive.

We are delighted to be a part of this historic journey where India has been a forerunner in implementing an exceptional scheme, customized to the benefit of the industries as well as the nation. I personally feel that the deepening of this scheme in Aluminium sectors including SME would prove a game changer in the times to come. This scheme has tremendous opportunities for regional synergies and its adaptation by other countries could lead to address the global climate issues.

Dr. Winfried Damm

अभय बाकरे, आईआरएसईई
महानिदेशक
ABHAY BAKRE, IRSEE
Director General

सत्यमेव जयते

ENERGY IS LIFE
CONSERVE IT
ऊर्जा दक्षता ब्यूरो
(भारत सरकार, विद्युत मंत्रालय)
BUREAU OF ENERGY EFFICIENCY
(Government of India, Ministry of Power)

FOREWORD

As we are embarking an ambitious path to provide electricity to all and raise the level of energy availability to the population across the country with limited resources at disposal; efficient use of primary energy resources is absolutely necessary.

Bureau of Energy Efficiency, under the Ministry of Power has been spearheading the promotion of energy efficiency in various aspects of the country's energy landscape, through programs such as Standards & Labelling for appliances, Energy Conservation Building Code (ECBC) for buildings and Demand Side Management (DSM) program for Agriculture and Municipality sectors.

One such flagship program for energy intensive industries namely Perform, Achieve and Trade (PAT) was launched under the National Mission for Enhanced Energy Efficiency (NMEEE). This scheme has demonstrated its value in its first cycle, in which 478 Designated Consumers have achieved 8.67 MTOE of energy savings against the target of 6.68 MTOE, exceeding by about 30 %.

With an objective to have further insight on the actions taken and other notable effects taken by these designated units in achieving the excellent results, a study has been taken up by BEE in partnership with GIZ. The report gives an in-depth analysis of the achievements, projections and success stories across various sectors covered in the first cycle of PAT scheme.

With the continued guidance of Ministry of Power, the Bureau of Energy Efficiency expresses its gratitude towards all the industries, associations and other stakeholders for their significant contribution to achieve the task of saving energy and adoption of energy efficiency measures. BEE intends to convey our congratulations to all who joined us on our collective endeavour of improving energy efficiency in the country.

Abhay Bakre.
(Abhay Bakre)

New Delhi: 19.09.2018

स्वहित एवं राष्ट्रहित में ऊर्जा बचाएँ Save Energy for Benefit of Self and Nation

चौथा तल, सेवा भवन, आर.के.पुरम, नई दिल्ली–110 066 / 4th Floor, Sewa Bhawan, R.K. Puram, New Delhi-110 066
टेली / Tel.: 91 (11) 26178316 (सीधा / Direct) 26179699 (5 Lines) फैक्स / Fax: 91 (11) 26178328
ई–मेल / E-mail : dg-bee@nic.in, abhay.bakre@nic.in, वेबसाईट / Website : www.beeindia.gov.in

Sectoral Expert Committee Members			
S. No.	Name	Designation	Organization
ALUMINIUM			
1	Shri. V Balasubramanyam	Director (production)	NALCO
2	Shri. Sadguru Kulkarni	Jt. President (Technology)	HINDALCO
3	Shri. Debashish Ghosh	General Manager (Energy)	HINDALCO
4	Shri. Deepak Prasad	VP & Head Operation	BALCO
5	Shri. Dayanidhi Behra	VP & Head Operation	Sesa Sterlite Ltd.
6	Shri. Anupam Agnihotri	Director	JNARDDC

Content

List of Figures

List of Tables

1.0 Executive Summary

In a bid to combat increasing energy consumption and related carbon emissions, the Government of India released the National Action Plan on Climate Change (NAPCC) in 2008 to promote and enable sustainable development of the country by promoting a low carbon and high resilience development path. Under the NAPCC, eight national missions were framed to focus on various aspects related to water, solar energy, sustainable habitat, agricultural, energy efficiency, ecosystems, etc. Perform Achieve and Trade scheme (PAT) is a component of the National Mission for Enhanced Energy Efficiency (NMEEE) which is one of the eight missions under the NAPCC.

PAT is a regulatory instrument to reduce specific energy consumption (SEC) in energy intensive industries, with an associated market-based mechanism to enhance cost effectiveness through certification of excess energy savings, which could be traded. Energy Savings Certificate (ESCerts) are issued to the industries which reduce their SEC beyond their target. Those companies which fail to achieve their target are required to purchase ESCerts for compliance, or are liable to be penalised. Trading of ESCerts are conducted on existing power exchanges.

PAT Cycle - I, which was operationalized in April 2012, included 478 units, known as "Designated Consumers" (DCs), from eight energy-intensive sectors viz. Aluminium, Cement, Chlor- Alkali, Fertilizer, Iron &Steel, Pulp & Paper, Thermal Power Plant and Textile. The annual energy consumption of these DCs in eight sectors was around 164 million TOE. The overall SEC reduction target in the eight sectors was about 4.05% with an expected energy saving of 6.68 million TOE by the end of 2014-15.

With the completion of the PAT Cycle - I in 2015, the reported overall achievement was 8.67 million TOE, exceeding the target for Cycle - I by almost 30%. The total energy saving of 8.67 million TOE is equivalent to saving of about 20 million tonnes of coal and avoided emissions of about 31 million tonnes of CO_2. In terms of monetary value, saving in energy consumption corresponds to Rs. 95,000 million.

PAT Cycle - I has witnessed an exceptional performance from all the sectors in terms of reducing their energy consumption. The DCs have made commendable efforts to achieve energy efficiency targets by adopting various improvement measures in technology, operational and maintenance practices, and application of management techniques.

The Aluminium sector in India is one of the major contributors for economic growth of the country as Aluminium finds its application in all the key sectors such as energy, construction and transportation. For the PAT scheme, the Aluminium manufacturing industries (Refinery and Smelters) having annual energy consumption greater than 7,500 million TOE were included under PAT Cycle - II. Based on the threshold defined, 10 number of Aluminium plants were included as DCs and their cumulative energy consumption was 7.71 million TOE. Based on their specific energy consumption level, these DCs were given SEC target reduction of an average 5.91%, resulting in 0.456 million TOE energy consumption reduction in absolute terms. The Aluminium sector constituted 6.82% of the overall energy saving target under PAT Cycle - I. A brief achievement by the aluminium sector at a glance is mentioned in Table 1.

Parameter	Units	Values
Number of DCs in the sector	nos	10
Total energy consumption of DCs in the sector	Million TOE	7.71
Total energy saving target for the Aluminium in PAT Cycle - I		0.456
Total energy savings achieved by Aluminium sector in PAT Cycle - I		0.73
Energy savings achieved in excess of the target		0.27
Reduction in GHG Emissions in PAT Cycle - I	million T CO_2	3.1
Cumulative energy savings with impact of PAT till 2030 over BAU[1]	Million TOE	27.89

Table 1: Aluminium sectoral achievement in PAT Cycle - I & Projection till 2030

The key focus of Aluminium sectoral report involves comparison of PAT to Business as Usual scenario (BAU) and this involves comparison of PAT and BAU scenario projected till the year 2030 projecting PAT impact on assessing sectoral energy consumption by the year 2030. The report also covers impact of PAT on energy intensity of the country, sector specific data analysis, process trends, sectoral benchmarking of specific energy consumption, success stories implemented in plants, and list of key technologies which can be implemented in the sector.

1. Difference of energy consumption between PAT and Business as Usual scenario (BAU)

2.0 Aluminium sector in India

The metals sector is an important contributor to economy contributing directly and indirectly to various activities such as industry, food processing, construction, energy and transportation. Among various metals, the most significant are Iron, Copper and Aluminium. With growing importance of Aluminium usage in various application, the Aluminium sector is growing very fast and the current market is estimated to be more than USD 90 billion globally[3]. India is richly endowed with large bauxite resources which is a basic ore for producing Aluminium metal. The Aluminium metal is produced in three stages – Mining of alumina, refining of alumina and smelting of alumina into Aluminium. The process of refining and smelting is highly energy intensive and demands large amount of electrical energy. From a material consumption perspective, production of 1 tonne of aluminium requires 2 tonnes of alumina while production of 1 tonne of alumina requires 2 to 3 tonnes of bauxite. Thus, indicating that the process of producing Aluminium is highly energy and material intensive. The Aluminium sector in India is concentrated among three players viz. National Aluminium Company Limited (NALCO), HINDALCO Industries and the Sesa Sterlite Group, having total installed smelting capacity of about 4.1 million tonnes. India's share in world aluminium is about 3%. The total Aluminium production in the year 2013-14 was about 1.75 million tonnes and 3.95 million tonnes in 2014-15. The production has almost doubled as compared to the production level in 2003-04 which was around 0.718 million tonnes. The installed capacity for alumina plants was around 65 lakhs of alumina per annum. The main output of Aluminium sector is Aluminium Metal which is then converted and used in various sectors such as electrical, packaging, automobile, building & construction, etc. The Aluminium production in India has grown by an average of 20% and alumina production has grown by 4.5% in last four years. The details are provided in Table 2 below.

HIGHLIGHTS OF ALUMINIUM SECTOR IN INDIA

SECTOR HIGHLIGHTS......

- India contributes to 3% share of global aluminium capacity
- The annual production of aluminium was 2.88 million tonnes in 2016-17
- Increase in demand from key sectors becoming the key drivers for aluminium market
- Dominated by three key market players – NALCO, HINDALCO and Sterlite (BALCO)
- Per capita aluminium consumption is around 2.4 kg while world average is 8 kg

Sr. No	Company	2013-14		2014-15		2015-16		2016-17 (p)	
		Alumina	Aluminium	Alumina	Aluminium	Alumina	Aluminium	Alumina	Aluminium
1	NALCO	1.91	0.31	1.82	0.32	1.91	0.37	2.02	0.38
2	HINDALCO	1.32	0.55	1.2	0.83	1.28	1.13	1.29	1.25
3	Vedanta	0.52	0.79	0.97	0.86	0.97	0.84	0.97	1.24
Total		3.75	1.65	3.99	2.02	4.16	2.34	4.28	2.88
Growth Rate (%)				6.3	21.6	4.3	15.8	2.9	22.9
Average Growth Rate				Alumina	4.5		Aluminium		20.1

Table 2: Aluminium and Alumina Sector – Production and Growth (million tonnes)[4]

3. http://www.visualcapitalist.com/size-oil-market/ (accessed on 18 July 2018)
4. Review on Metals & Alloys – Indian Minerals Year Book, Indian Bureau of Mines

India is still a net exporter of Aluminium metal. In the year 2012-13 and 2013-14 the domestic sales accounted for 80% of overall sales for the manufacturing companies. Following Table 3 provides the company wise production and domestic sales data for 2012-13 and 2013-14.

Production and Sales in Million Tonnes					
Sr. No	Company	2012-13		2013-14	
		Production	Domestic Sales	Production	Domestic Sales
1	NALCO	0.4	0.25	0.31	0.21
2	HINDALCO	0.54	0.45	0.6	0.47
3	Sterlite	0.77	0.66	0.79	0.547
Total		1.71	1.36	1.7	1.22

Table 3: Aluminium Production and Sales[5]

2.1 Sectoral Contribution to Country's Economic Value

Indian Aluminium sector's contribution to the overall economic growth is critical as it is used directly in many of the other sectors such as construction, transport, energy, etc. Over the past few years there has been significant capacity addition for Aluminium and positive growth is expected in coming years due to increased use of Aluminium metal in various applications. The refining sector and Aluminium production (smelter) witnessed Compound Annual Growth Rate (CAGR) of 3.68% and 8.75% respectively from the production data of the last eight years.

For estimating the production for alumina and Aluminium till 2030, the CAGR for last 8 years from FY2009 to FY 2016 has been considered and thus Alumina has been projected with a CAGR of 3.68% whereas Aluminium has been projected with a CAGR of 8.75% annually. The expected production of aluminium and alumina till 2030 is shown in Table 4. This increase is approximately 1.8 times the current production in the refinery sector and 3.75 times the current production in smelter.

Sub Sector	Baseline	FY14	FY17	FY20	FY23	FY26	FY30
Alumina	2.84	3.36	3.74	4.17	4.64	5.17	5.97
Smelter	1.06	1.31	1.68	2.16	2.78	3.58	5.00
Integrated	0.40	0.42	0.54	0.70	0.90	1.15	1.61

Table 4: Production Projection – 2030 (million Tonnes)

The Energy Intensity of the country is shown in Table 5, and is on the basis of primary energy consumption.

The sectoral energy intensity for aluminium sector DCs in PAT is mentioned in the Table 6.

5. NITI Aayog

Financial Year	Total Energy Consumption of India	GDP	Energy Intensity
	million TOE	Billion USD	TOE/ million USD
2008	427	1,187	360
2009	453	1,324	342
2010	512	1,657	309
Average Baseline	**464**	1,389	334
2015	**659**	2,102[7]	313
2020	**1018[8]**	3,018	337
2025	**1211[9]**	4,233	286
2030	**1440[7]**	5,937[11]	243

Table 5: India's energy intensity

Financial Year	Total Production[12]	Total Energy Consumption	GDP	Energy Intensity
	million tonnes	Million TOE	Billion USD	TOE/ million USD
Avg. Baseline	4.34	7.71	1,389	6.22
2015	5.13	9.37	2,102	4.46
2020	7.03	14.27	3,018	4.72
2025	9.34	20.12	4,233	4.75
2030	12.59	28.66	5,937	4.82

Table 6: Aluminium sectoral energy intensity

The contribution of DCs to overall energy intensity of India is 1.66% for the baseline year (2007 – 08 to 2009 -10). Aluminium sector has achieved 0.73 million MTOE savings under PAT cycle – I and the energy intensity for sector was 1.42%.

Aluminium sector Energy intensity contribution in baseline year and assessment year was 1.66 % and 1.42% respectively.

6. BP Statistical Review of World Energy 2016
7. GDP from World Bank GDP for India – Upto 2015
8. India Energy Outlook, Year 2015 - IEA
9. Estimated by calculating CAGR for 2020 and 2040 in India Energy Outlook, Year 2015 - IEA
11. GDP values calculated based on CAGR value of 7.5% till 2020 and 7% between 2020 and 2030. Same assumptions have been considered in India Energy Outlook, Year 2015 - IEA
12. Based on equivalent production (For Baseline and Assessment based on proforma and for 2020-2030 based on CAGR of 2008-2017)

3.0 Process, Technologies and Energy consumption trend of the sector

Aluminium production after bauxite extraction consists of four sub processes namely alumina production, anode manufacture, aluminium smelting and ingot casting. The description of each of these processes is described below. A schematic of the aluminium process with Bayer process for alumina production and Hall Heroult process for production of aluminium is mentioned in Figure 1 below.

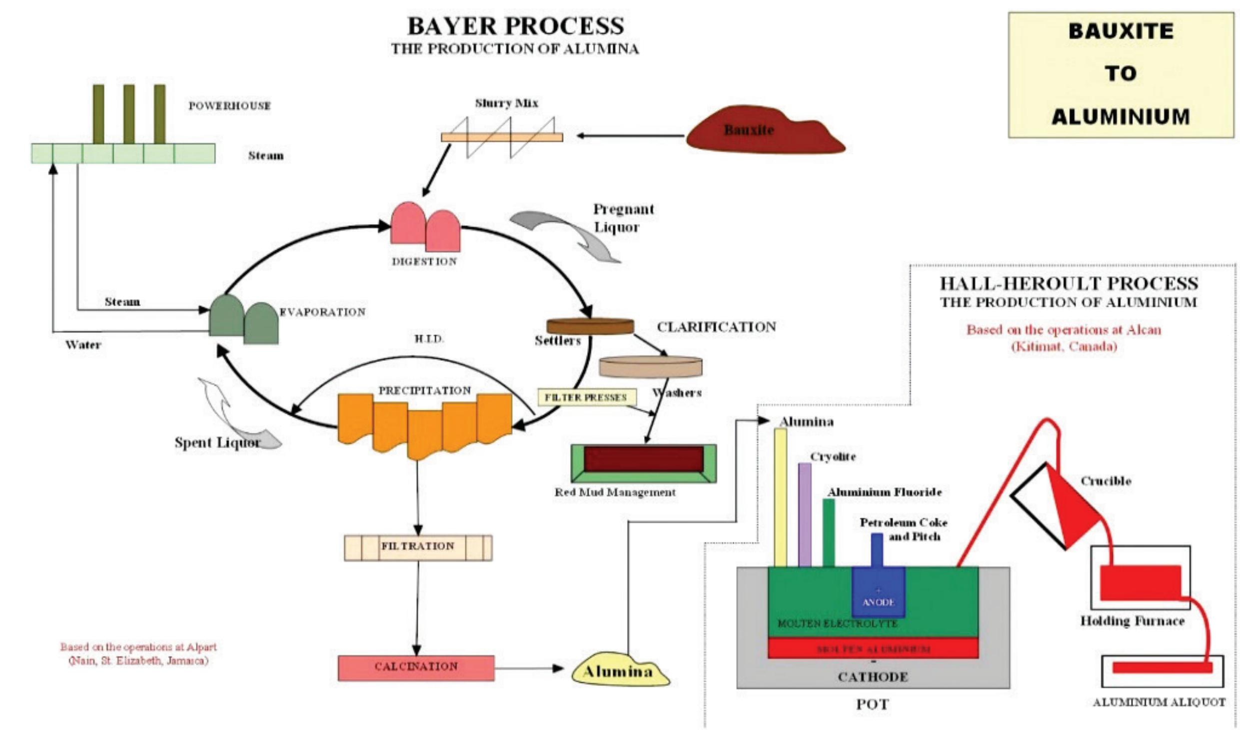


Figure 1: Alumina Production Bayer Process

Alumina production (Bayer process)

Bauxite ore is converted to alumina through Bayer process. The ore is dissolved in a solution of sodium hydroxide separating the aluminium oxide from Bauxite. The aluminium bearing minerals Gibbsite, Böhmite and Diaspore are selectively extracted from the insoluble components. Iron oxides and other oxides are separated as insoluble "red mud" and the solution is precipitated and calcined to produce anhydrous alumina. Bayer process is energy intensive in digestion and calcination process. Calcination may be done in rotary or stationary kilns. The resulting alumina is cooled in a rotary cooler or fluidized bed coolers. Bayer process approximately consumes 85% of its energy in fuel consumption.

Anode manufacturing

The efficient aluminium process uses prebaked anodes. The other process which is now obsolete and not used in production of aluminium is the Soderberg process. Soderberg technology uses a continuous anode which is delivered to the cell in the form of a paste and which bakes in the cell itself.

Prebaked anodes are produced by heating ground and pressed tar pitch or coke from refineries at high temperatures in a gas heated furnace. Centre worked pre-bake anode is the best practice and has very low fugitive emissions.

Aluminium smelting (Electrolysis)

Commercial aluminium is produced by Hall Heroult electrolysis process (Figure 2). A direct current is passed through a solution of alumina dissolved in cryolite. This enables process to occur at a lower temperature. In this process molten alumina is collected at the bottom on graphite cathode. The prebaked anode can be brought closer to the molten alumina and reduce the resistance which cannot be done in a Soderberg process. The molten aluminium formed is removed by siphoning, which avoids the use of high temperature valves and pipeline required.

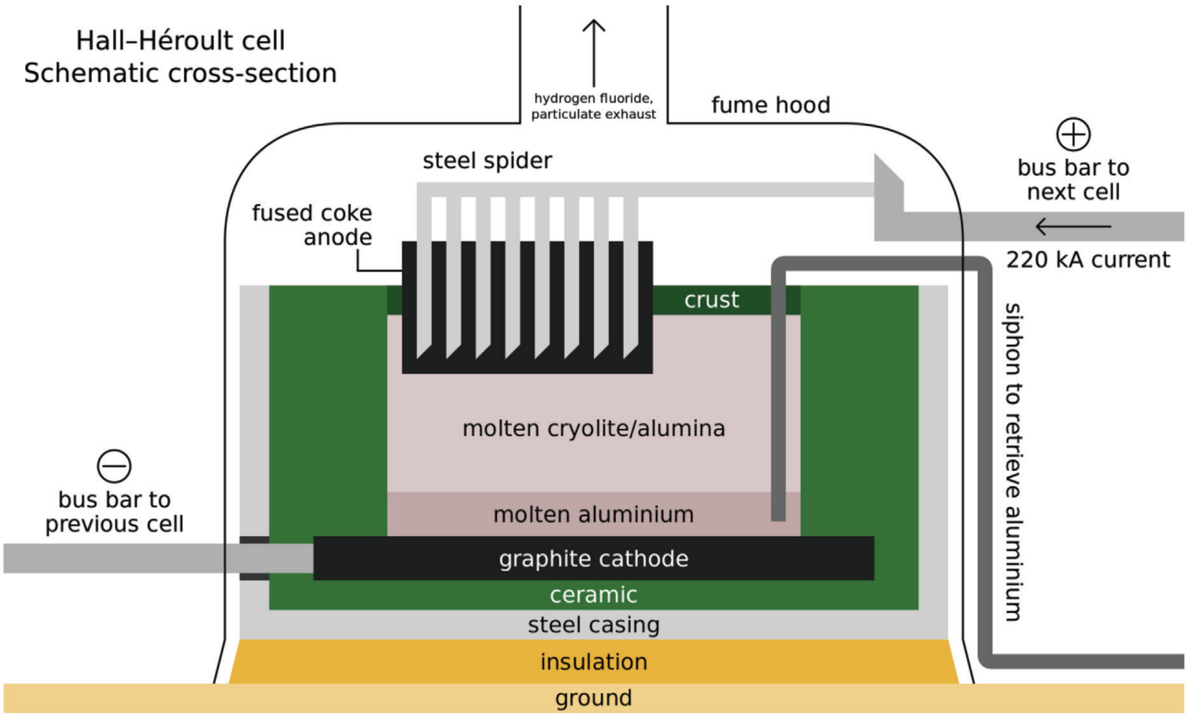


Figure 2: Hall Heroult Cell Schematic

Ingot casting

In the ingot casting aluminium is poured into separate molds until the metal solidifies into ingots. The molten aluminium is cast into ingots. Ingot casting allows the aluminium to be alloyed with other metals. Ingots can also be made into various shapes such as slabs, rolls, bars and blocks. The end user may process the ingots based on the requirement of casting and rolling.

The manufacturing process of Aluminium is considered an energy intensive process and in the recent years has witnessed the more development in the technology and resulting in specific energy consumption around 13,500 –14,500 kWh/MT[13].

13. International Aluminium Institute (2017)

4.0 Methodology adopted for the project

The activities were initiated with the collection of sector specific data from Bureau of Energy Efficiency (BEE). In addition, data was also collected through secondary research. Data analysis was conducted to assess the impact of PAT Cycle – I on energy intensity in the BAU v/s PAT scenario, GDP of the country, trend analysis for energy efficiency, quantification of energy saving in terms of TOE and coal saving. Feedback was also collected from DCs on benefits and the challenges experienced through the PAT scheme.

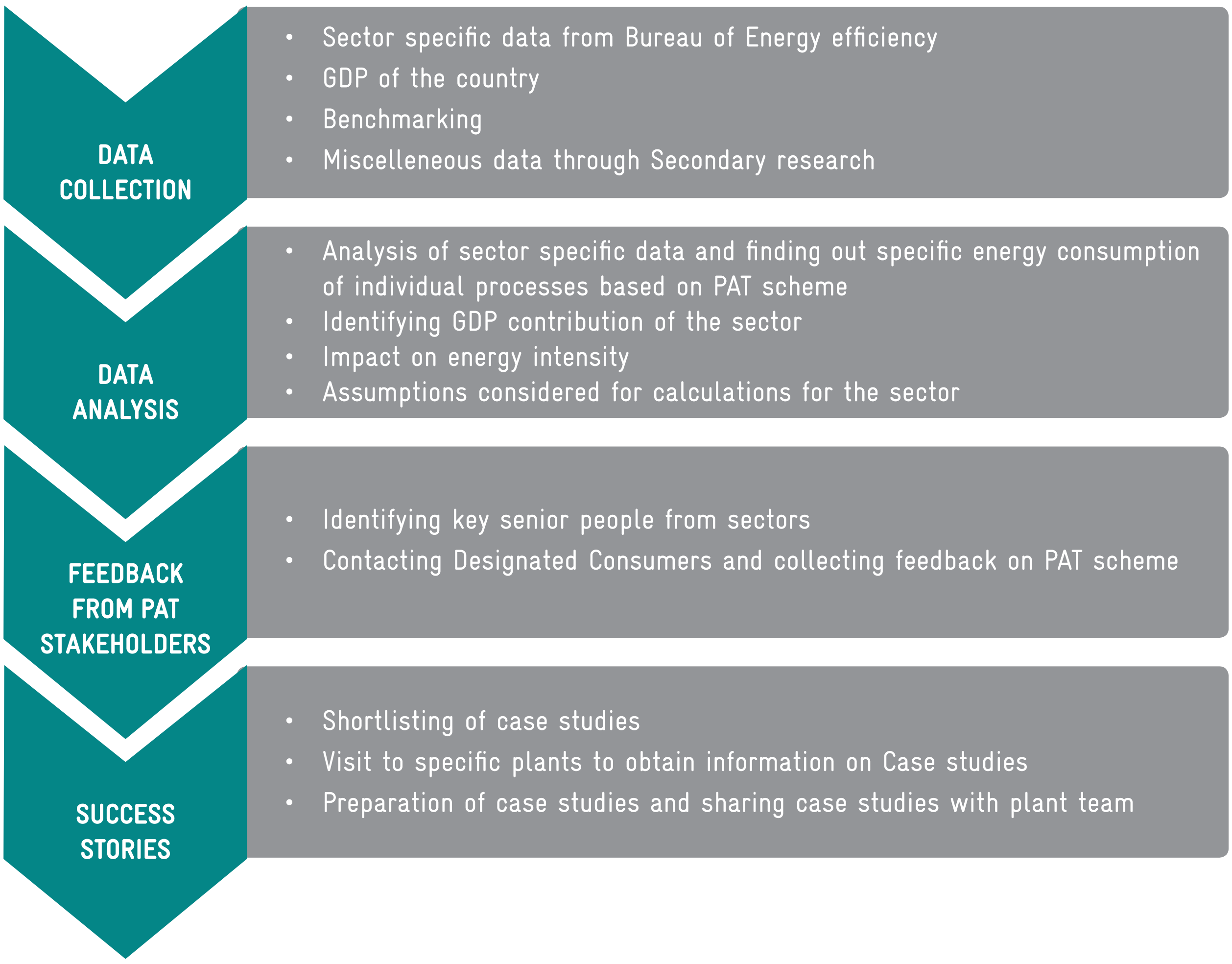


Figure 3: Methodology followed for Impact assessment of PAT Cycle – 1

The case studies were shortlisted based on higher savings, low cost implementation, innovative projects and high replication potential across the sector. With the assistance of BEE and GIZ, various plant visits were scheduled and conducted across various sectors to study the technical benefits and challenges faced by designated consumers in implementing their projects. Based on the feedback from the respective plants, success stories were developed on the same.

5.0 PAT Cycle-I and its impact on Aluminium Sector

PAT scheme's primary goal is to reduce energy consumption by assigning time bound targets to the Designated Consumers. Any gain or shortfall in meeting the target is traded by using ESCerts, where 1 ESCert is equivalent to 1 MTOE of energy saving. This scheme is regulated by Bureau of Energy Efficiency (BEE). The existing power exchange platforms facilitate trading of ESCerts among the DCs. The cycle started from 2012, while the baseline considered was from financial years 2007 – 08 to 2009-10. The average value of specific energy consumed by the plant was taken for three years. The minimum threshold considered for becoming a designated consumer of PAT varied based on sectors.

For declaring a plant as a DC in the aluminium sector, the threshold level was 7500 TOE and above. The total reported energy consumption of DC was about 7.71 million TOE. These DCs were given a target of 0.456 million TOE as energy consumption reduction and they achieved 0.73 million TOE, which was around 8.42% of the total energy saving achieved (8.67 million TOE) under PAT Cycle – I. Subsequently, after the completion of PAT Cycle - I, 12 units for Aluminium sector were notified as DCs with their overall energy consumption 10.56 million TOE in cycle 2 with target energy savings of 0.5 million TOE. In PAT Cycle 3, only one unit was notified as DC with energy saving target of 0.06 million TOE and in PAT cycle 4 there are no DCs from aluminium sector.

5.1 Impact of PAT Cycle-I

Aluminium sector has achieved reduction of 0.73 million TOE in comparison to the target of 0.456 million TOE. This achievement has resulted in estimated GHG emission reduction of 3.1 million tonnes of CO_2 equivalent exceeding the targeted emission reduction of 1.13 million tonnes of CO_2 equivalent. The results of PAT Cycle – I is summarised in Figure 4.

Energy Savings 0.73 million TOE

1.65 million tonnes of coal

3.1 million tonnes of CO_2 equivalent

Savings 7.52 billion INR

Reported Investment 0.9 billion INR

Figure 4: Savings achieved by Aluminium Sector under PAT Cycle - I

The savings are attributed to a number of measures adopted by the DCs. Where some of the DCs implemented short term measures with minimal investment, others opted for medium and long-term measures requiring considerable investment. The investment for energy efficiency measures were reported by 90% of the DCs in the sector for PAT Cycle - I.

The emissions reduction for the sector due to energy savings achieved under PAT Cycle – I and contribution of these emissions to overall GHG reduction achieved are mentioned in Table 7. The emission reduction due to reduction in fossil fuel consumption is considered for reduction in GHG emissions.

Parameter	Value
Reduction of CO_2 emission due to implementation of PAT Cycle – I(All sectors)	31 million Tonnes of CO_2 equivalent
Reduction of CO_2 emission due to of PAT Cycle – I in Aluminium Sector	3.1 million Tonnes of CO_2 equivalent
Contribution to CO_2 emission reduction in overall PAT Cycle-I	10%

Table 7: Reduction in CO_2 emissions from the PAT cycle

5.2 Energy Scenario at Business as usual (BAU) Vs PAT

The section describes the impact of PAT and comparison with BAU scenario. A summary of performance of the sector and its projection for 2030 is mentioned in Table 8. The impact of PAT has been assessed for PAT Cycle – I and with the current trend, the energy reduction potential has been estimated for the year 2030.

Particulars	Unit	Value
Number of plants in the sector	Nos.	10
Baseline Energy Consumption in PAT Cycle – I	million TOE	7.71
Energy reduction target for the Aluminium sector	million TOE	0.456
Energy Savings achieved in PAT Cycle – I	million TOE	0.73
Energy savings achieved in excess of target	million TOE	0.274
Reduction in GHG Emissions in Cycle – I	million T CO_2	3.1
Total energy savings with impact of PAT till 2030 over BAU[14]	million TOE	27.89

Table 8: Achievements of Aluminium Sector in PAT Cycle – I and Projections till 2030

The energy saving of 8.67 million TOE declared for PAT Cycle – I has been calculated based on notified production for the baseline period, whereas the actual energy saving obtained will be higher while considering the subsequent production of individual sectors for subsequent years. The methodology of calculation involves SEC consumption of individual years and the achieved energy savings till 2030.

PAT Cycle – I witnessed large investments towards implementation of energy efficient projects. These projects enabled the plants to reduce the overall energy consumption and thus specific energy consumption of the industry. Therefore, a comparison of annual energy consumption of the sector with and without the Business as Usual scenario would illustrate the impact of implementation of the PAT scheme and project the same for the future demand requirement for the industrial sector.

To understand the possible impact the PAT scheme can have on energy consumption of the sector, the comparison of SEC reduction under Business as Usual and PAT scheme has been compared. The impact of PAT has been assessed for PAT Cycle – I and with the current trend for energy reduction has been estimated till the year 2030.

The reduction in specific energy consumption in the baseline year from 2007 – 08, 2008 – 09 and 2009 – 10, has been calculated and considered as Business as Usual scenario (BAU). This reduction in specific

14. Difference of energy consumption between PAT and Business as Usual scenario (BAU)
15. Difference of GHG reductions between PAT and Business as Usual scenario (BAU)

energy consumption is used to project the reduction in specific energy consumption by the sector till 2030 under BAU. The graphs in this section show specific energy consumption, energy consumption for business as usual and impact of PAT, projected till 2030. The reduction from baseline to assessment year of PAT is the reduction in specific energy consumption for PAT Cycle – I. The different sub sectors in aluminium sector has been considered individually for comparing business as usual and PAT impact scenarios.

The specific energy consumption trend business as usual versus PAT for the sub sectors – refinery, smelter and integrated are shown in Figure 5, Figure 6 and Figure 7 respectively. The overall energy consumption trend for the sectors are shown in Figure 8.

For the refinery sub-sector, the SEC under BAU vs PAT would be 0.296 TOE/Tonne of product and 0.265 TOE/Tonne of product respectively. Thus by 2030, the sector would further be able to reduce their SEC by 10% over BAU. The following Figure 5 highlights the SEC trend for the refinery sector under subsequent cycles for BAU and PAT :

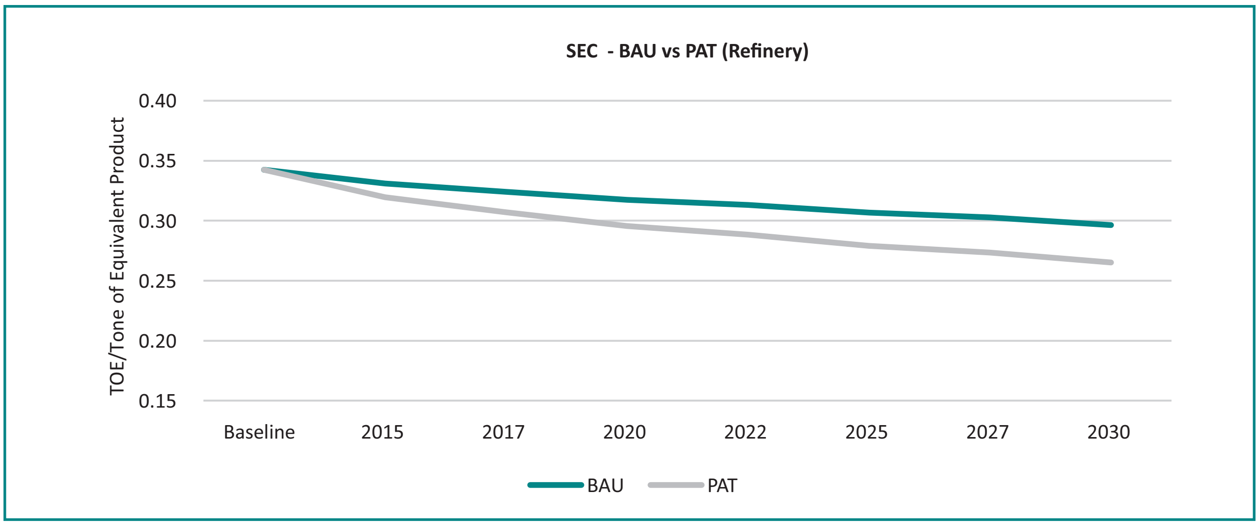


Figure 5: SEC Trend for Refinery

For smelter sub-sector, the SEC under BAU and with PAT would be 4.485 TOE/Tonne and 4.013 TOE/Tonne of product respectively. Thus by 2030, the sector would be able to further reduce their SEC by 10% over BAU. Similarly, for integrated also the impact would be 13.6% for SEC. Following Figure 6 and Figure 7 highlight the SEC trend for smelter and integrated sub-sector under subsequent cycles for BAU and PAT[9]:

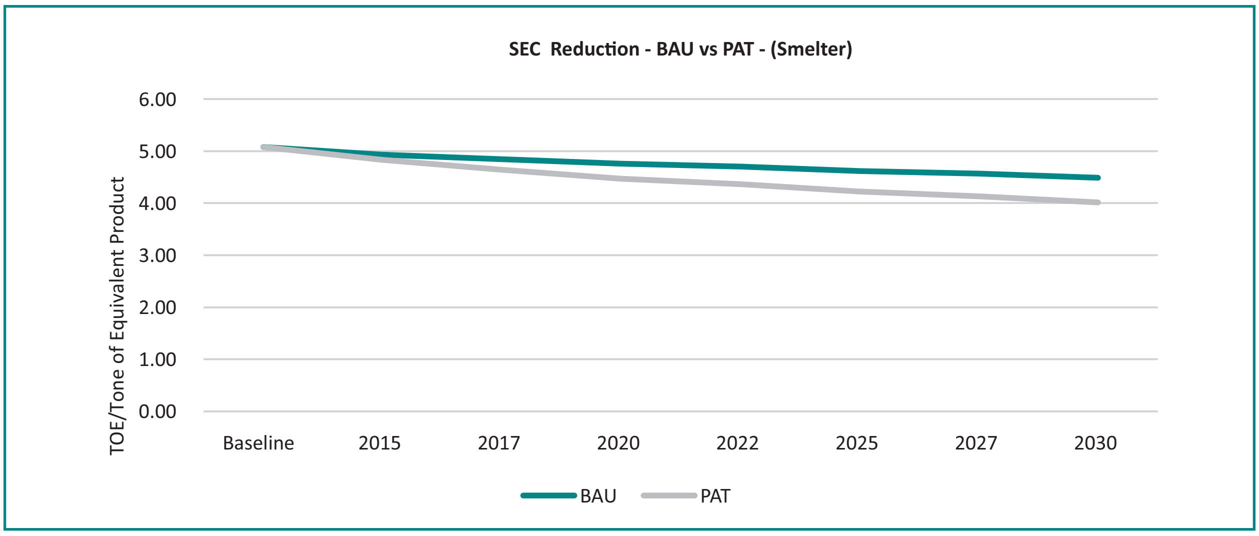


Figure 6: SEC Trend for Smelter

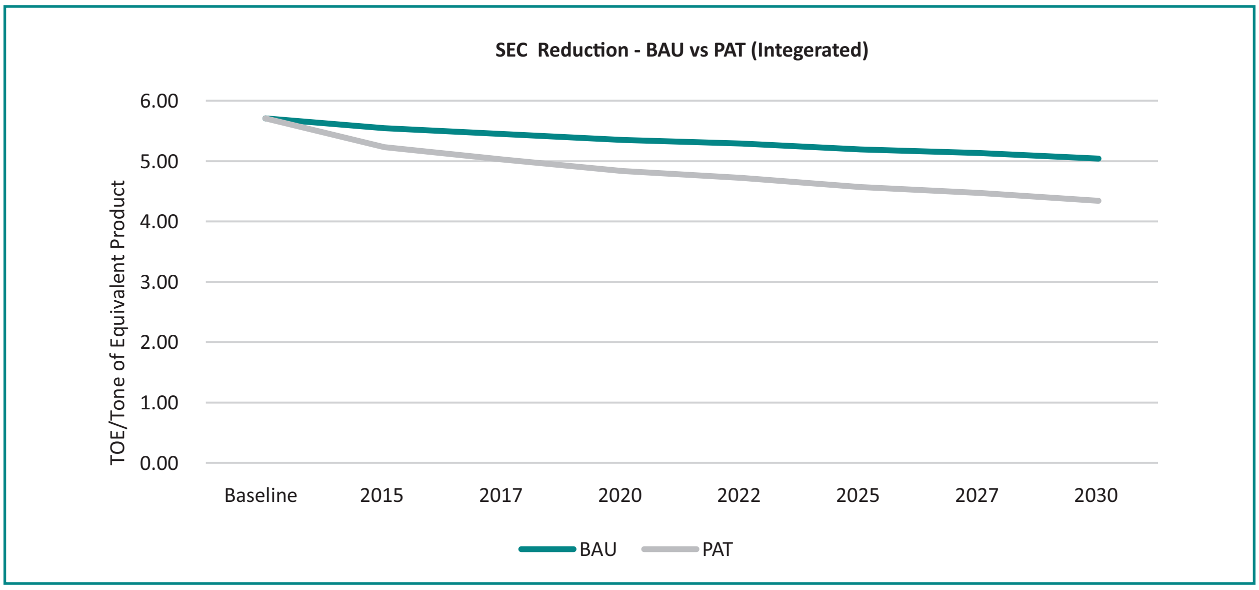


Figure 7: SEC Trend for Integrated Plants

The estimation for 2030 energy reduction has been calculated based on the estimated production and estimated SEC under BAU and PAT scheme.

Following Figure 8 indicates the impact of PAT scheme on overall energy consumption of the sector:

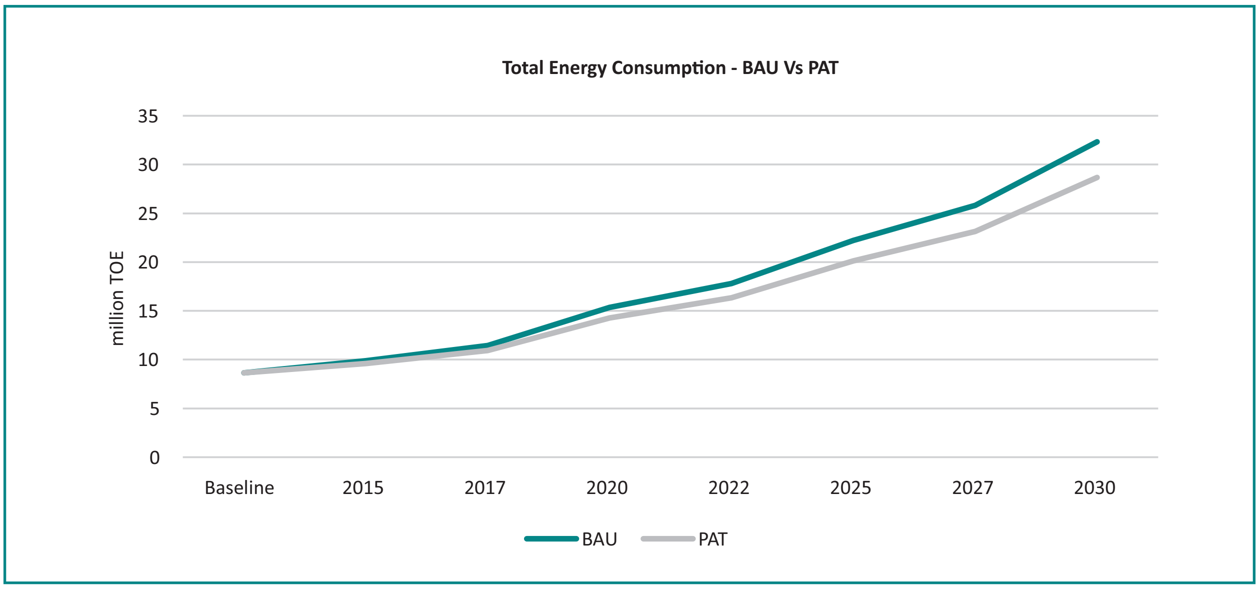


Figure 8: Total Energy Consumption for overall sector

Thus, above figure indicates that the PAT scheme would have positive impact on the sector and would help in reducing the energy consumption additionally by 3.68 million TOE over the BAU in 2030 and collective energy benefits for all years (2015-2030) would be 27.89 million TOE .

The total energy consumption for Aluminium sector in the year 2030 without the impact of PAT is estimated to be **32.34 million TOE**, which may reduce to **28.66 million TOE** considering the impact of PAT.

Figure 9: A view of Aluminium plant

Table 9 below shows the energy for the sector. The increase in energy after 2020 is due to relatively lesser growth rate in GDP than the sector growth.

Year	GDP	Business as usual	With PAT
	Billion USD	Energy Intensity TOE/million USD	Energy Intensity TOE/million USD
Baseline	1389	6.22	6.22
2015	2102	4.70	4.56
2020	3018	5.08	4.72
2025	4233	5.25	4.75
2030	5937	5.44	4.82

Table 9: Energy intensity with PAT and BAU for Aluminium Sector

Assumptions considered for BAU Vs PAT calculation till 2030

Specific Energy Consumption

- The SEC of the sector has been calculated considering the total equivalent production of the subsector and the total energy consumption in the sub sector, and hence may not represent the actual SEC of any particular product/ process.

Production

- For the Aluminium sector, the production for alumina and aluminium sector till 2030 has been calculated considering the CAGR arrived for production from 2008-2017.

Business as usual scenario:

- The plant would have undertaken activities on energy efficiency on its own, even without the intervention of PAT scheme.
- The reduction in specific energy consumption in the baseline year from 2007 – 08, 2008 – 09 and 2009 – 10, has been calculated and the same reduction is projected till the year 2030 to establish the BAU scenario. (Sub sector wise SEC reduction is considered)

With PAT scenario:

- The actual energy saving achieved in the PAT Cycle – I is taken for the assessment year 2014 – 15.
- It has been assumed that the plants meet the target allotted to them till the years 2030.
- The target for the subsequent PAT cycles is calculated based on the current trend of reduction in target between PAT Cycle – I and II.
- It has been considered that the target will go on decreasing in the subsequent cycles owing to the diminishing potential in the plant as they go on implementing projects on energy efficiency.
- It has also been considered that some breakthrough technological advancement might provide further reduction potential in the sector.

5.3 Aluminium sector specific data analysis of PAT Cycle – 1

The following section contain the details on the various aspects of energy efficiency in Aluminium sectors based on the data submitted by the Designated Consumers under the PAT Scheme. The total numbers of Aluminium plant in PAT Cycle – II were 10 and summary of sub sectors is indicated in Table 10 below.

Sub Sector	Refinery	Smelter	Integerated	Cold Sheet
No. of Plants	4	4	1	1
CPP	0	4 (Total : 3692 MW)	1 (Total: 801 MW)	0

Table 10: Sector – Sub Sector Classification

Utilisation Factor

The average utilization factor for the calcined and hydrate alumina was lower for both baseline and assessment as the market conditions were the major reason for lower utilization. However, the energy efficiency achievement would have been better if the capacity utilization was optimal. The average capacity utilization for refinery and smelter is shown in the Table 11 and Table 12 below:

Refinery	Baseline		Assessment	
	Hydrate Alumina	Calcined Alumina	Hydrate Alumina	Calcined Alumina
Plant 1	50	64	69.0	66.0
Plant 2	100	99	81.0	80.0
Plant 3	103	62	72.4	0.0
Plant 4	75	76	100.0	97.0

Table 11: Capacity Utilization of Refineries – Aluminium (%)

Smelter	Baseline		Assessment	
	Molten Aluminium	Cast House	Molten Aluminium	Cast House
Plant 1	93.67	113.00	78.37	64.56
Plant 2	102.94	52.23	104.70	49.64
Plant 3	94.51	95.50	70.60	71.10
Plant 4	56.01	48.04	100.8	93.46
Plant 5	112.00	85.61	118.75	109.68

Table 12: Capacity Utilization for Smelter – Aluminium (%)

The thermal specific energy consumption for alumina/refinery is mentioned in Table 13:

Plant	Thermal SEC Baseline (million kCal/Tonne)		SEC Assessment (million kCal/Tonne)		Improvement (%)	
	Calcined Alumina	Hydrate Alumina	Calcined Alumina	Hydrate Alumina	Calcined Alumina	Hydrate Alumina
Plant 1	5.39	4.56	4.06	3.22	24.66	29.39
Plant 2	3.19	2.40	3.24	2.44	-1.50	-1.64
Plant 3	2.43	1.40	NA	1.34	NA	4.30
Plant 4	3.12	2.19	3.09	2.27	0.81	-3.43
Best Number			3.09	1.34		

Table 13: Thermal Specific Energy Consumption - Refinery

The specific energy consumption for molten Aluminium is mentioned in Table 14

Plant	SEC for Molten Aluminium Baseline		SEC for Molten Aluminium (Assessment)		Improvement	
	SEC (m kCal/Tonnes)	SEC (kWh/ Tonnes)	SEC (m kCal/ Tonnes)	SEC (kWh/ Tonnes)	%	%
Plant 1	39.64	14541.00	42.08	14894.00	-6.16	-2.43
Plant 2	42.04	14549.65	37.11	14361.98	11.72	1.29
Plant 3	47.55	14573.47	44.62	14575.64	6.16	-0.01
Plant 4	43.74	15848.78	35.08	14383.00	19.80	9.25
Best Number			35.08	14575.64		

Table 14: Specific Energy Consumption - Smelter

In addition to the process, the improvement in energy efficiency for power plant is also critical for the sector as most of the smelters and integrated plants have installed Captive Power Plant (CPP) for meeting their power requirements.

The following Table 15 indicates the parameters for the captive power plants - Heat Rate and Unit Load Factor (ULF) at various smelters in Aluminium Sector

Plant	Baseline Year		Assessment Year	
	Heat Rate (kCal/ kWh)	ULF (%)	Heat Rate (kCal/ kWh)	ULF (%)
Plant 1	2747	78.65	2852	78.65
Plant 2	2899	89.6	2909	71.12
Plant 3	3275	76.22	3037	61.71
Plant 4	2730	43.09	2447	83.58
Plant 5	2909	98.18	2676	96.16

Table 15: CPP Heat Rates & ULF - Aluminium Sector

6.0 Benchmarking in Aluminium Sector

Benchmarking is an important tool to establish how a plant is performing and what avenues can be adopted to achieve the highest level in energy efficiency. Following section provides the comparison of India's Aluminium sector performance with the best efficiency levels in the world.

The best specific energy consumption figures for different process paths are mentioned in the table below. The specific energy consumption values mentioned below by considering the best practices implemented in that process are mentioned per tonne of product in order to compare with various processes.

Following Table 16 the benchmarking data for the Aluminium Sector :

Production	Global Best10	Global Average	India Average	India Best Numbers11	Unit
Alumina Refinery	0.20	0.267	0.33	0.23	TOE/Tonne of Alumina
Aluminium Smelting	13599	14145	14361	14558	kWh/Tonne of Molten Aluminium

Table 16: International Benchmarking – Aluminium Sector

Process	Section wise	Unit	India Best Numbers (Gcal/t)11	Average number (Gcal/t)11
Anode Manufacturing (Carbon)	Fuel	GCal/T	0.49	0.63
	Electricity	kWh/T	0.12	0.16
Ingot casting	Electricity	kWh/T	0.09	0.15

Table 17 Indian Benchmarking in other areas

From the above table it can be seen that there is a significant potential for energy efficiency improvement for –refineries and Aluminium smelting in India.

16. Energy Statistics World Aluminium– International Aluminium Institute (2017)
17. Based on assessment year data PAT Cycle – I

7.0 List of major energy saving opportunities in the sector

A list of major energy saving opportunities in the sector have been identified and listed Table 18. The projects are listed based on readiness level, co – benefits obtained by installing the system and based on expected payback range by implementing the project.

Technology Readiness Level (TRL):	Co-Benefits: PQCDSME	Payback Horizon (PB)
TRL 1 – Research (Basic or Advanced)	Productivity (P)	PB 1 - less than 1 year
TRL 2- Proof of concept	Quality (Q)	PB 3 – 1 year to 3 years
TRL 3- Demonstration(Pilot)	Cost(C)	PB 5 – 3 to under 5 years
TRL 4- First of a Kind	Delivery (D)	PB 8 – 5 to under 8 years
TRL 5- Fully Commercial	Safety (S)	Safety (S)
	Moral (M)	PB >12 – over 12 years
	Ethics, Environment (E)	

S No	Technology	Co-Benefits (P, Q, C, D, S, M, E)	Readiness Level (TRL-1, TRL-2 .....TRL5)
	Refinery		
1	Multi-variable predictive control technology (RMPCT) for digestion	P, C, E	TRL 4
2	Installation of VFD for Pumps	P, C, E	TRL 5
3	Installation of VFD for Centrifugal Fans	P, C, E	TRL 5
4	Fuel Switch	P, C, E	TRL 5
5	Proper descaling of flash tank		TRL 5
6	Maintaining level controllers and last flash temperature for efficient heat recovery from flashing	P, C, E	TRL 5
7	Installation of PHE for heat exchanger	P, C, E, S	TRL 5
8	Double Digestion	P, C, E,	TRL 5
9	Optimise Temperature and residence time of second stage digestion	P, C, E	TRL 5
10	Installation of Falling Film Evaporator	P, C, E	TRL 5
11	Maximizing hot condensate recovery from digester-flashing system	P, C, E, M	TRL 5
12	Proper maintenance and cleaning of calendaria/evaporator tubes	P, C, E, M	TRL 5
13	Energy Efficiency in Grinding	P, C, E	TRL 5
	Smelter		
14	Increase in anode length to optimize current density.	P, C, E	TRL-4
15	Increase in anode ring bus size to reduce voltage drop.	P, C, E	TRL-4
16	Installation of state-of-the-art cathode block pre-heater to reduce resistance by eliminating uneven heating before putting into new pots.	P, C, E	TRL-4

17	Point feeding for proper distribution of alumina in the electrolyte	P, C, E	TRL-4
18	Electronic pot controller to reduce DC power consumption in Söderberg alumina electrolysis	P, C, E	TRL-4
19	Introduction of slotted anodes in pot lines for reducing the pot voltage	P, C, E	TRL-4
20	Installation of 100% graphite Cathodes	P, C, E	TRL-5
21	Installation of air cooled cathode tabs in collector bar	P, C, E	TRL-5
22	Condition based planned cut out of pots.	P, C, E	TRL-5
23	Adoption of New technology of Cell lining	P, C, E	TRL-3
24	Online Compensating Busbar Welding	P, C, E	TRL-4
25	Online Repair of DC Isolator	P, C, E	TRL-4
26	High Efficiency Rectifiers	P, C, E	TRL-5
27	Eco-contact to reduce voltage drop at conductor joints	P,C,E	TRL-4
28	Reduction in Stub to carbon voltage drop	P, C, E	TRL-5
29	Cold Sealing paste in potline	P, C, E, M	TRL-4
30	Wetted, drained cathode technology	P, C, E, M	TRL 1
31	Alternate cell concepts (inert anodes + wetted + drained cathodes)	P, C, E, M	TRL 1
32	Carbothermic Reduction	P, C, E, M	TRL 2
33	Tib2 - Carbon Coating in Drained Cells	P, C, E	TRL 2
34	TINOR Coating and Novanor Inert Anode – MOLTECH	P, C, E	TRL 2
35	Single Beam implementation in Pot line	P, C, E	TRL 4

Table 18: List of key technologies in the sector

8.0 Success stories – Case Studies in Aluminium Sector

8.1 Case Study No. 1 : Single Beam Implementation in Potline

Introduction

At BALCO, Aluminium metal production is done using the Hall-Heroult process. Following are some of the salient features of BLACO potline:

1. It works on the Prebaked GAMI technology.
2. A total of 288 electrolyte cells are installed with a designed current of 320 kA.
3. All 288 pots are connected in series circuit.
4. Design capacity of pot line is 245 ktpa

Following are some of the main processes which are carried out in the potline:

- Anode Change - Prebaked anodes have to be replaced at regular intervals, when they have reacted down to one third or one fourth of their original size.
- Metal Tapping - The molten Aluminium is siphoned from the bottom of the cell in a process called tapping (done by rotation every 24 hours) and transported to dedicated casting operations where it is alloyed; then cast into ingots, billets and other products.
- Beam Raising - Raising the anode beam to the top position using Anode Jacking Frame (done by rotation in every 18 days).

Problem Identification:

As per the GAMI design, the beam is a split beam type. There are two separate anode suspension mechanism which allow normal pot operations, that is, the raising and lowering of anodes clamped on to an Aluminium busbar/beam. Due to difference in inertia of the two-suspension mechanism there is always a difference between the levels of the two beams and hence the anodes, which results in an overall variation in the hydro magneto dynamics of the pot and leads to voltage fluctuation and increase in noise.

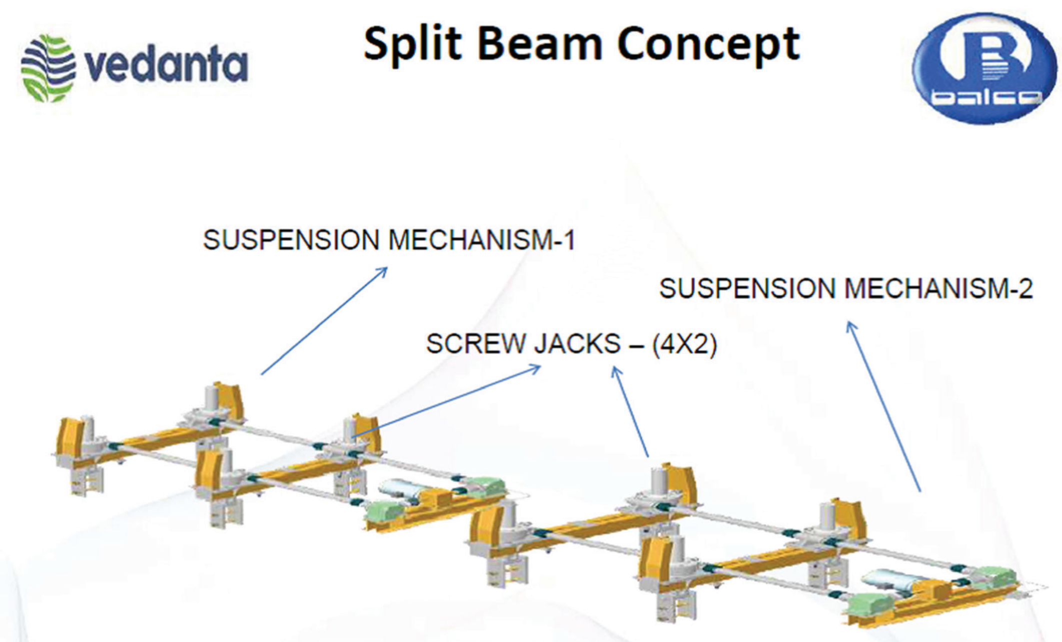


Figure 10: Split Beam Concept

Description of the project

In a split beam design the two-suspension mechanism work independently and hence difference in beams create disturbances in magneto hydro dynamics of molten metal, if both the suspension mechanisms are synchronized or differences are minimized, better current efficiency can be achieved.

BALCO developed technology in-house, with which it was possible to convert the split beams to a single beam using a floating shaft. This technology upgradation was critical in reducing production losses due to voltage fluctuations, and disturbances to the operating pots. The plant has successfully implemented this technology in the pot room and it is now standard procedure for mitigating the risk from the split beam. The impacts are manifested in increased production, energy savings and stability of operating pots.

Methodology Adopted

Initially, the use of an electro mechanical clutch mechanism on each pot was proposed, keeping the anode jacking frames untouched. This involved developing a mechanism to facilitate engagement of the two suspension assemblies during normal operation and disengagement while raising the bus bar. However, this proposal was rejected because it was technically complicated and expensive. Further discussions drew out the fact that the beam differences could be eliminated by connecting both suspension mechanisms by two floating shafts to overcome the adverse effects of split beams; trials carried out in about ten pots proved to be successful.

The one difficulty in using this method was that both the floating shafts had to be removed from the system during beam raising, and then restored. This difficulty was overcome by joining the two anode jacking frames (AJF) to make one AJF capable of handling 40 anodes together. Now anode raising can be performed in one go thereby eliminating the process of anode raising in parts. An added benefit of this method was that the beam raising time per pot came down from 40-45 minutes to 20-25 minutes. To the best of plant's knowledge, such a conversion of split beam pots to a single beam has been accomplished for the first time in the world, in a running smelter.

Implementation Strategy

A Risk Assessment exercise was carried out before the innovation was implemented with necessary approvals taken and drawings prepared, including drawings for the pot and pot controller system. The modification was implemented in the following steps:

1. **Step 1:** An arrangement to shift AJFs was required to facilitate beam raising in all sections while the AJFs were refurbished/ modified; to this end a special trailer was prepared, tried and deployed on the field.

2. **Step 2:** Since the number of AJFs in the potline was going to be reduced, they would need to be more reliable and hence they were taken up for refurbishment.

3. **Step 3:** Once the refurbished AJFs were made available, two of them were joined together so as to enhance their capability from handling 20 anodes to handling 40 anodes at a time. Floating shafts were installed and changes made to the pot-controller hardware with all necessary interlocks/instruction displays taken up in each pot (room-wise). Modifications were made in steps to allow pilot runs, during which the performance was assessed, and then later, pots were modified in entire potline. Around ten pots were identified in Section 8 for trial. Floating shafts were installed in these pots and the following changes were made to the pot-controller system: the beam raising operation included A.ABR and all the functions related to B.ABR would be disabled. All 40 anodes were to be unclamped in one go and beam raising would be completed after giving the A.ABR command as done earlier, without needing to give the B.ABR command.

4. **Step 4:** The first trial was made on Pot No. 806 and pot parameters were assessed for control. The only observation during the first trial was that the crane (PTM) hoist speed was a bit higher than normal and a risk of mishandling the AJF existed. The crane hoist speed was

later reduced after getting MOC (Management of Change) approval.

5. **Step 5:** The same changes were implemented in the other room.

Trial and Implementation period: During the trial phase, about 30 days in 16 pots of the potline, it was found that all pot parameters were improving. These parameters were:

- Noise – reduction from 30.5 mV to 22.2 mV
- Average voltage of pot cell – 4.298 V to 4.238 V
- Number of cover collapses in pot
- Average voltage fluctuation

Upon the trial's success, an action plan and target dates were prepared for putting the single beam into operation in the potline.

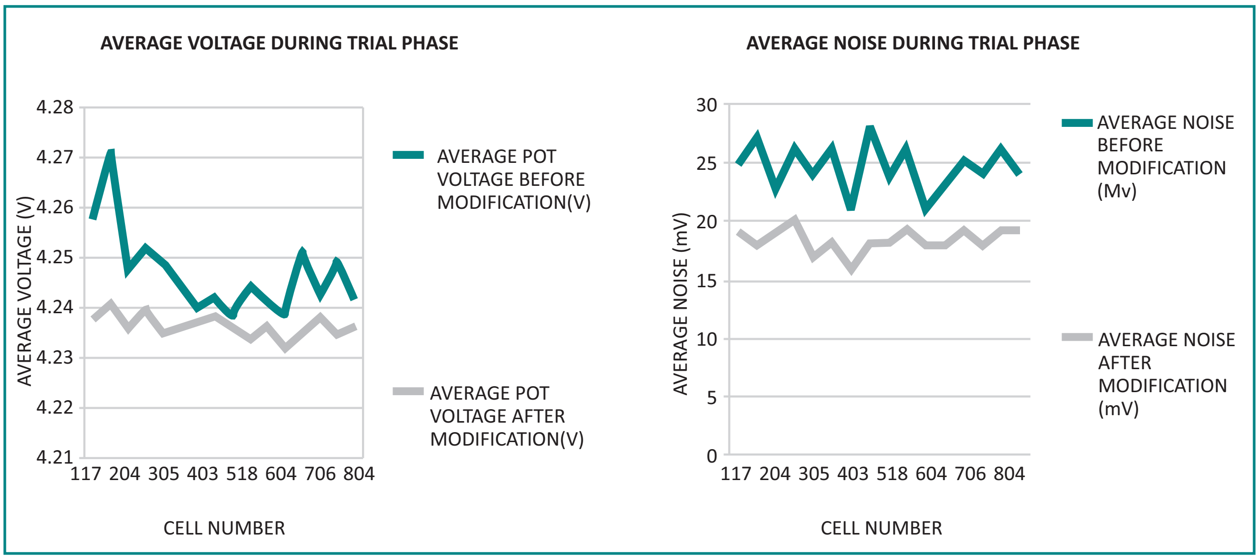


Figure 11: Impact - Voltage

Impacts and Benefits realized:

- Energy savings: 20 mV voltage reduction in potline and increase in current efficiency with reduction in pot parameter fluctuation after anode change.
- Financial implications: The total amount of money invested in the project was about Rs. 6.82 million in FY 2014-15. The monetary benefits achieved were Rs. 130 million in FY 2014-15.

Benefits

Parameter	Units	Values
Energy savings	Rs million	130
TOE equivalent savings	TOE	13167
Investment	Rs million	6.82
Payback(months)	Months	1
Replication Potential	% of plants in the sector can opt for this technology	25%
	Reduction in TOE anticipated for the sector	55000

Table 19: Energy Savings

Contact details for the project	
Plant Name	Bharat Aluminium Company Limited
Person to be contacted	Mr. Avinash Chavan
Designation	Head - MRSDS
Contact number	9893222868
Email – ID	Avinash.Chavan@vedanta.co.in
Address for communication	Balco – Korba

Table 20: Contact Details for BALCO

8.2 Case Study No. 2: Utilisation of 50% Graphitized cathode

Introduction

Vedanta Limited is an associate company of the London Stock Exchange listed, FTSE 100 diversified resources group Vedanta Resources Plc. Originally incorporated in 2001, VL is a leading producer of metallurgical grade alumina and other aluminium products, which cater to a wide spectrum of industries. VL has carved out a niche for itself in the aluminium industry with its superior product quality based on state-of-the-art technology. The firm operates a 1 MTPA greenfield alumina refinery and an associated 75 MW captive power plant at Lanjigarh in the state of Orissa.

Description of the project

Vedanta Aluminium Limited, Jharsaguda is one of the 10 notified DCs in PAT Cycle - I. The Baseline production of Vedanta Aluminium Limited, Jharsaguda unit. Aluminium Industries have been in a constant search for low resistance material in the pot line.

Conventionally Vedanta Aluminium Limited, Jharsaguda was using 30% graphitized cathode in their pot line, which have high resistance and provides a continuous loss of energy. In a step by step manner plant team have achieved 100% graphitized solution for their cathode with least resistance. During the PAT assessment period, installation of 50% graphitized cathode with low resistance was achieved by the plant team.

The energy savings achieved by the plant team is mentioned in the table below. Vedanta Aluminium, Jharsaguda has taken immense step in replacing several of their pot line to 50% graphitized. Currently, several of the potline have been implemented with complete (100%) graphitized cathode. The energy

Figure 12: Graphtisied Cathode

saving achieved is 61 kWh/Tonne of aluminium in comparison to 30% graphitized cathode. The data mentioned below is excluding the 90day period for initial stabilization of the pot.

The difference in energy consumption of 30% and 50% graphitized cathode is depicted below:

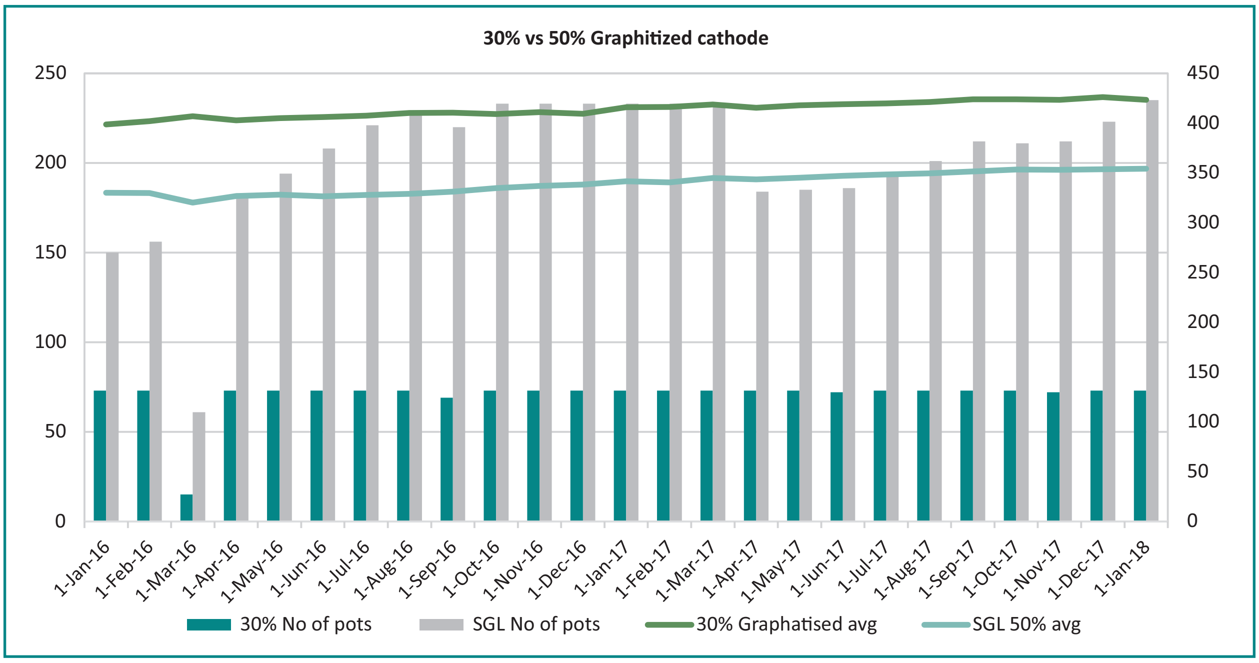


Figure 13: Energy Consumption Impact (kWh)

- Timeline for the project (project start date and end date)
  Start date: 27 April 2014, End date: 19 March 2017
- The financing was done in house by the plant team.

Benefits

50% graphitized cathode: 61 unit/ton aluminium after normalization period of pot. The normalization period of each pot considered is 90 days approximately.

Parameter	Units	Values
Energy savings	Rs million	15.00
TOE equivalent savings	TOE	252
Investment	Rs million	32
Payback(months)	Months	26
GHG reduction	Tons of CO_2	2400
Replication Potential	% of plants in the sector can opt for this technology	70%

Table 21: Energy Saving due to project

Other Benefits (Based on data available)

Increase in production by 0.3 – 0.4% was achieved by the plant team.

Contact details for the project	
Plant Name	Vedanta Limited, Jharsuguda
Person to be contacted	Mr. S S Bisen
Designation	Assistant General Manager – Process control
Contact number	9937294173
Email – ID	shailesh.bisen@vedanta.co.in
Address for communication	Vedanta Aluminium Jharsaguda, Smelter plant Bhurkamunda, Odisha 768203

Table 22: Contact Details for Vedanta

9.0 List of Technology suppliers

S No	Company Name	Technology	Website link
1	Honeywell Process Solutions	Alumina Refining Automation Solutions	https://www.honeywellprocess.com
2	Alfa Laval	Plate Heat Exchangers	https://www.alfalaval.com
3	Alfa Laval	Falling Film Evaporators	https://www.alfalaval.com
4	Forbes Marshall	Steam Distribution Systems	https://www.forbesmarshall.com/
5	Hamilton Research & Technology Pvt. Ltd.	Advanced Pot Controller for Aluminium Smelters; Heat Regulation System for Anode Baking Furnaces;	http://www.hart.co.in/
6	FL Smidth	Direct Pot Feeding System	http://www.flsmidth.com
7	Outotec	Calcination, Carbon Paste Plant, Automation, Grinding Optimisation System	http://www.outotec.com
8	SGL Carbon	Graphite Blocks, Lining, Carbon Paste	https://www.sglgroup.com
9	ABB	High Power Rectifiers, Busbar collector systems,etc	http://www.abb.com
10	Fives	Potline Systems, Anode baking, Green Anode Plant, Cast house equipment, etc	https://aluminium.fivesgroup.com
11	Lizmontagens	Potlining, Refractories, etc	https://www.lizmontagens.com

Table 23: List of key technology suppliers in Aluminium sector

Abbreviations

BAU

Business as Usual, 2, 3, 5, 15, 16, 17, 18, 19

BEE

Bureau of Energy Efficiency, 12, 13

CAGR

Compound Annual Growth Rate, 8, 9

CO_2

Carbon dioxide, 9, 12, 13, 14, 15

CPP

Captive Power Plant, 3, 21, 22

DCs

Designated Consumers, 4, 5, 8, 13, 30

ESCerts

Energy Saving Certificates, 4, 13

GDP

Gross Domestic Product, 5, 9, 12,19

GHG

Greenhouse Gas, 3, 4, 5, 9, 13, 14, 15, 16, 18, 32

IEA

International Energy Agency, 9

INR

Indian Rupee, 9,13

million TOE

million Metric Tonnes of Oil Equivalent, 4, 5, 9, 13, 15,18

NALCO

National Aluminium Company Limited, 6, 7

NAPCC

National Action Plan on Climate Change, 4

NMEEE

National Mission for Enhanced Energy Efficiency, 4

PAT

Perform Achieve and Trade, 2, 3, 4, 5,8,12, 13, 14, 15, 16, 17, 18, 19, 21, 23, 30

SEC

Specific Energy Reduction, 3, 4, 5, 16, 17, 21, 22

TOE

Tonne of oil equivalent, 9, 13

TRL

Technology Readiness Level, 24, 25

ULF

Unit Load Factor, 3, 22

Bureau of Energy Efficiency

Ministry of Power, Government of India
4th Floor, Sewa Bhawan, R. K. Puram, New Delhi – 110066 (INDIA)
T: +91 11 26766700 I F: +91 11 26178352
Email: admin@beenet.in I www.beeindia.gov.in
Follow us on @BEEIndiaDigital on Facebook & Twitter

Leading Towards Energy Efficiency Economy

Confederation of Indian Industry

german cooperation
DEUTSCHE ZUSAMMENARBEIT

Published by
giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH