Journey of Hindalco Renukoot - An Integrated Aluminium Producer in India

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Abstract

Hindalco, Renukoot, is one of the largest integrated primary producers of aluminium in Asia, with a pan-Indian presence encompassing the entire gamut of operations, from bauxite mining and alumina refining to aluminium smelting and downstream processes such as rolling, wire rod production, and extrusions. Our journey began in 1958 in Renukoot, Uttar Pradesh, as the first integrated aluminium plant in independent India. The plant received bauxite from the Lohardaga mines and hydropower from G. B. Pant Sagar Dam project to produce 40 kt/a of alumina and 20 kt/a of aluminium, initially with entirely manual operations. Over the years, through successive organic expansions, the Renukoot Aluminium Complex has reached a production capacity of 410 kt/a of aluminium. To operate this integrated plant, approximately 830 MW of power is sourced from our Renusagar Captive Power Plant, located about 45 kilometres from Renukoot.

Alumina Refinery: It was commissioned in 1962 through technical collaboration with Kaiser Aluminum, USA, with an initial production capacity of 40 kt/a of alumina. This capacity has since increased to 720 kt/a. To enhance energy efficiency and production capacity, the plant has been expanded in phases, implementing new technologies over time. It employs the Bayer process, and its major raw materials include bauxite, steam, caustic soda, and furnace oil.

Aluminium Smelter: The aluminium smelter was also established in partnership with Kaiser Aluminum in 1962. Currently, it operates 11 potlines with a total of 2138 pots. Aluminium smelting is an energy-intensive process, with energy accounting for approximately 35 % of the total production cost. The company's efforts towards energy conservation have been consistently recognized by the relevant authorities. Over the past years, the company has implemented more than 500 energy-saving projects (both small and large) to improve energy efficiency, resulting in a reduction of specific energy consumption from 16 500 to 13 800 kWh/t Al. With the addition of a gas treatment centre, alumina feeders, pot controllers, dynamic feeding control, in-house lining design, and partial automation in the potroom, the smelter has managed to sustain its operations and remain competitive in the current market.

Fabrication Plant (Value Added Products): The Fabrication Plant began operations in 1965 with Bliss cold and hot mills and expanded in 1993 with the addition of a Davy cold mill. Starting with two US-made presses (Baldwin Lima Hamilton and Farrel) in 1965, the extrusion plant has expanded to eight presses from SMS Germany in 2021. The Fabrication Plant at Renukoot comprises four main product streams: ingots (50 %), wire rods (20 %), flat-rolled products (20 %), and extrusions (10 %). The transformation in value-added products has shown a significant shift from conventional direct chill casting to the latest state-of-the-art Wagstaff air slip casting, incorporating modern facilities such as inline degassing and over-the-top (OTT) coiling.

As the mother plant of Hindalco's Metal Business, the Renukoot complex has consistently facilitated and motivated our other upstream and downstream operations across Hindalco. This journey has been made possible through a continuous focus on the adoption of new technologies

and ongoing improvements in automation, resulting in performance and efficiencies that are comparable to newer generation plants.

As a responsible manufacturing unit, we place a special focus on sustainability, with targets of 100 % utilization of bauxite residue, net-zero liquid discharge as well as landfill and emissions by 2050. Various technological initiatives, such as the generation and storage of renewable energy, 100 % utilization of bauxite residue, and fly ash, and decarbonization, are in different stages of implementation. Simultaneously, to maintain competitiveness, several initiatives have been undertaken for specific energy reduction, loss minimization, and efficiency improvement.

To continue the proud legacy of excellence and future readiness, the Cultural & Business Transformation journey - "Parivartan RKT 2.0" - is underway. This marks a pivotal shift in the 60-year-old aluminium manufacturing unit, transitioning from a traditional functional structure to a dynamic, process-based organizational model. This realignment cultivates a culture of ownership, innovation, and resilience, positioning the organization to tackle evolving challenges while sustaining legacy strengths in a competitive landscape.

Keywords: Manufacturing, Sustainability, Cultural transformation.

1. Introduction

Hindalco Industries started its journey early in 1958. Mr. G D Birla had a vision to contribute best to Indian industries, and he successfully established India's first integrated aluminium industry at Renukoot, Sonebhadra district, in the state of Uttar Pradesh. In 1967, this aluminium plant was fused up with a thermal power plant which is situated at Renusagar. The integrated plant offers significant advantages by encompassing the entire value chain from alumina refinery to the production of finished aluminium products within a single complex. This approach leads to substantial cost efficiencies through reduced transportation expenses of raw materials and intermediate products such as alumina, primary aluminium etc. Furthermore, it allows for better control over the entire production process, ensuring consistent quality and enabling quicker identification and resolution of issues.

During these 67 years of operation, Hindalco has evolved into one of Asia's largest primary aluminium producers. In India, Hindalco's operations are spread across key locations including Renukoot, Hirakud, Mahan, Aditya, and Utkal, among others. Hindalco's smelters and refineries are supported by captive power plants, ensuring energy security and cost efficiency, which are critical in the energy-intensive aluminium industry. From bauxite mining to alumina refining, aluminium smelting, and subsequent rolling and extrusions, Hindalco operates an end-to-end production process that allows it to serve diverse sectors. Hindalco is also a major player in the copper sector, with its facility in Dahej, Gujarat being among the largest single-location copper smelters in the world. Its copper business, based in India, includes smelting, refining, and the production of continuous cast copper rods and precious metals. A significant transformation came in 2007 when Hindalco acquired Novelis Inc., a global leader in aluminium rolled products and the world's largest recycler of aluminium. The acquisition strategically transformed Hindalco into a global leader in aluminium rolling, significantly boosting its international footprint, especially across North America, South America, Europe, and Asia. Hindalco's customer-centric approach and diversified product portfolio make it a key supplier to industries such as automotive, construction, packaging, electrical, and consumer durables. Through Novelis, the company has also become a major supplier to the global beverage can and automotive sectors, both of which are increasingly prioritizing sustainability and lightweighting.

The company places a strong emphasis on innovation, sustainability, and operational excellence. Hindalco has embraced sustainable practices across its operations, including significant

investments in renewable energy, zero-liquid discharge systems, and circular economy initiatives. It has committed to reducing its carbon footprint and increasing its share of green aluminium, in line with global ESG (Environmental, Social, and Governance) expectations. The company's commitment to sustainability and innovation has earned its recognition as one of the world's most sustainable aluminium companies by the Dow Jones Sustainability Indices consistently from 2020 to 2024.

2. Journey of Hindalco Renukoot

Commissioned in 1962, Hindalco's Renukoot plant in Uttar Pradesh marked the company's foray into aluminium production. Starting with a single potline and a smelting capacity of 20 kt/a, the plant has undergone significant expansions to achieve a current smelting capacity of 410 kt/a [1–5]. The integrated facility includes an alumina refinery, aluminium smelter, and downstream units with major raw material from bauxite mines of Lohardaga and captive power from Renusagar. Hindalco established the Renu Sagar Power Plant in 1967, India's first captive power plant for the aluminium industry. Located approximately 45 kilometers from Renukoot, this coal-based thermal power plant has an installed capacity of around 800 MW, ensuring a stable and continuous power supply for the smelter and other operations. Hindalco's Renukoot plant has embraced technological innovations to enhance efficiency and product quality. The major expansion projects of the Renukoot complex are presented in Figure 1. As one of the largest industrial employers in the region, it contributes significantly to the local economy and runs several corporate social responsibility (CSR) initiatives. These include healthcare services, education programs, infrastructure development, and women's empowerment projects in surrounding villages. Through these initiatives, Hindalco Renukoot fosters strong community relationships and supports inclusive development.

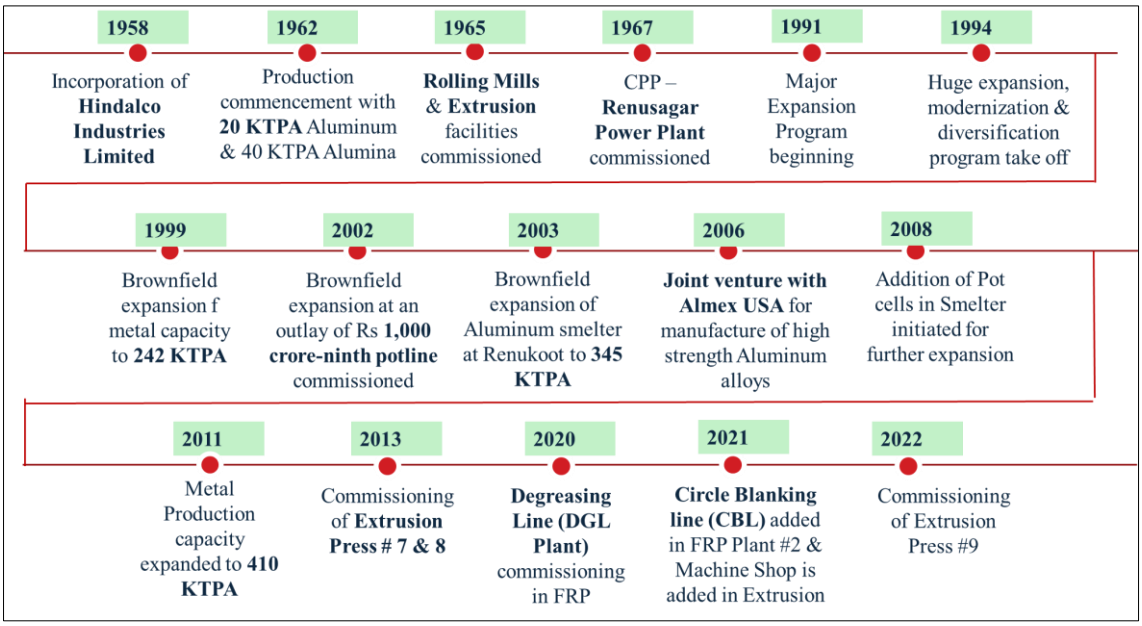

Figure 1. Major expansion projects of Hindalco Renukoot Complex.

2.1 Alumina Refinery

The Alumina Refinery, located in the same Renukoot Complex, is a critical component of Hindalco Industries Limited's integrated aluminium operations. Commissioned in 1962, it was one of the earliest alumina refineries in India and has played a foundational role in establishing Hindalco's self-reliant value chain in aluminium production. The Renukoot Alumina Refinery

processes bauxite ore into metallurgical-grade alumina, which serves as the primary raw material for aluminium smelting. The bauxite is primarily sourced from captive mines located in the state of Jharkhand, ensuring steady raw material supply and cost efficiency. The Bayer process is used to extract alumina from bauxite, involving high-temperature digestion, clarification, precipitation, and calcination. The facility has undergone several modernization and capacity enhancement programs over the decades to improve operational efficiency, reduce environmental impact, and meet the increasing demand for high-purity alumina. The captive power plant at Renusagar supplies electricity to both the refinery and smelter, further improving energy security and cost effectiveness. Sustainability and environmental responsibility are central to the refinery's operations. The Renukoot Refinery facility has adopted advanced effluent treatment systems, red mud management practices, and energy-efficient technologies. Efforts are continuously made to reduce water and energy consumption per tonne of alumina produced.

2.2 Aluminium Smelter

The smelter uses the Hall-Héroult process to convert alumina into primary aluminium. The original technology provider of the smelter plant is Kaiser Aluminum Corporation Ltd of USA. Over the years, the facility has undergone several phases of technological upgrades and modernization to improve operating performance as well as productivity. The smelter plant consists of 11 potlines having 2 138 operating pots. The potlines are being supported by a carbon plant for an uninterrupted supply of anode and Rectifier units for DC power supply. In due course of time, the smelter plant has adopted various initiatives for productivity enhancement, substituting manual jobs with semi-automatic tools, etc. From a strategic business standpoint, the smelter supports downstream operations at Renukoot itself by supplying the majority of the primary metal for a wide range of products.

2.3 Fabrication Plant (Value Added Products):

To utilise the primary metal produced from the Smelter plant, there is a full-fledged fabrication plant that lies within the same Renukoot complex. The fabrication plant includes FRP (Flat Rolled Product) unit, cast house, and Extrusion plants with the product portfolio shown in Figure 2.

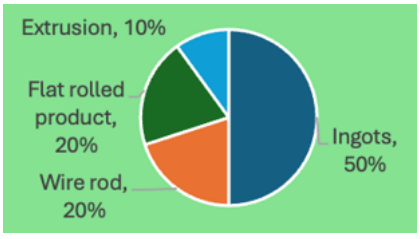

Figure 2. Product portfolio distribution in fabrication plant.

The Fabrication Plant started operations in 1965 with Bliss cold and hot mills and expanded in 1993 with the addition of a Davy cold mill. Starting with two US-made presses (Baldwin Lima Hamilton and Farrel) in 1965, the extrusion plant has expanded to eight presses from SMS Germany in 2021. The transformation in value-added products has shown a significant shift from conventional direct chill casting to the latest state-of-the-art Wagstaff air slip casting, incorporating modern facilities such as inline degassing and over-the-top (OTT) coiling.

3. Journey of Technological and Productivity Enhancement

3.1 Alumina Refinery

The production of the integrated aluminium complex of Renukoot starts from the processing of bauxite ore to alumina using the Bayer process, as illustrated in Figure 3.

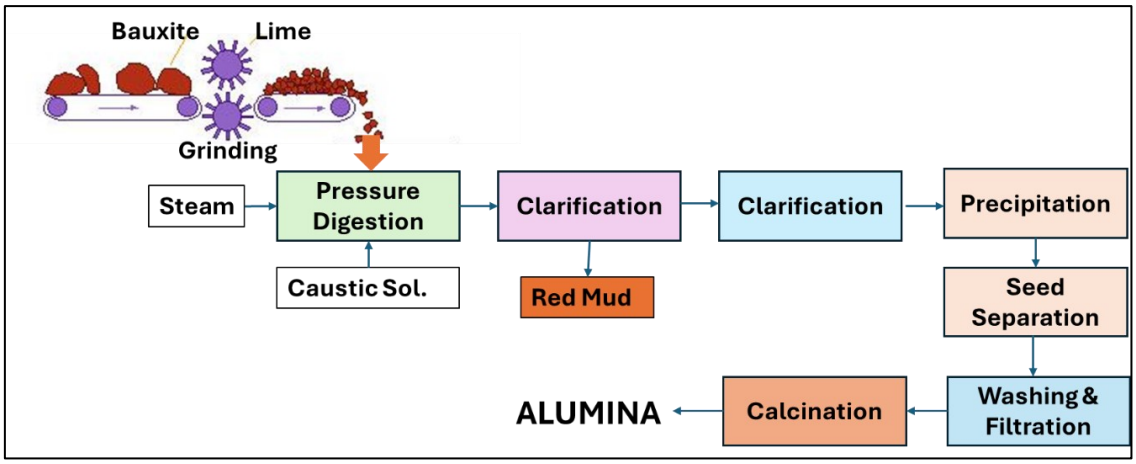

Figure 3. Renukoot Alumina Refinery process flow.

The Renukoot Alumina Refinery started production in the year 1962 with Kaiser Aluminum, USA Technology having an annual production of 40 kt. The initial Kaiser technology was energy intensive and designed for lower liquor concentration and yield. So, to reduce the energy consumption of the process as well as to improve productivity, several technological upgrades were carried out with the support of global technology providers. As a result, today the alumina refinery produces 720 kt/a of alumina by processing around 4500 t of bauxite every day. In the present scenario, the Renukoot alumina refinery is a technological amalgamation of various world-class technologies like Kaiser Aluminum (USA), Alcan, FLS, FCB, and Algroup Alusuisse. The productivity growth of the refinery is summarized in Figure 4. The timeline chart shows the growth in alumina production capacity from 1962 to 2012. This chart highlights key milestones and optimization projects that have contributed to the increase in production capacity. The initial production capacity was established in 1962 with the opening of the first digestion unit by Kaiser. This marked the beginning of alumina production at Renukoot Alumina Refinery. In 1967 the production capacity was further enhanced with the introduction of the second digestion unit by Kaiser which contributed production volume increase from 40 kt to 150 kt. In 1969 through in-house process optimization, the production capacity increased to 190 kt, showcasing the company's commitment to continuous improvement. During 1986 the introduction of the third digestion unit by Reynolds for digestion significantly boosted production capacity to 300 kt. Alcan's involvement in the optimization projects contributed to further growth in production capacity in 1994. Followed by the introduction of the fourth digestion unit by Reynolds in 1997, marking another milestone in the production enhancement journey. In 2001, Alusuisse's optimization projects played a crucial role in increasing production capacity up to 660 kt which was further supported by the introduction of PGL Flashing Unit during 2005. The production capacity reached 720 000 t/a in 2009, reflecting the cumulative efforts of various optimization projects and technological advancements. From 2012 onwards the production capacity remained at 720 000 t/a, indicating sustained efforts to maintain and optimize production processes.

The growth in alumina production capacity is a testament to the company's commitment to continuous improvement and innovation in the production process. Similarly, in terms of in-house development, some of the key innovations in industrial processes have contributed to energy efficiency and improved safety. These innovations include:

1. Calciners in place of Rotary Kilns: This innovation has led to significant energy savings and improved process efficiency.

2. Mixing Tee: The introduction of the Mixing Tee has enhanced the mixing process, resulting in better product quality and reduced energy consumption.
3. Double Digestion: This process innovation has improved the efficiency of the digestion process, leading to higher yields and reduced waste.
4. Slurry Geho Pump: The use of the Slurry Geho Pump has improved the handling of slurry, reduced maintenance costs and improving overall process efficiency.

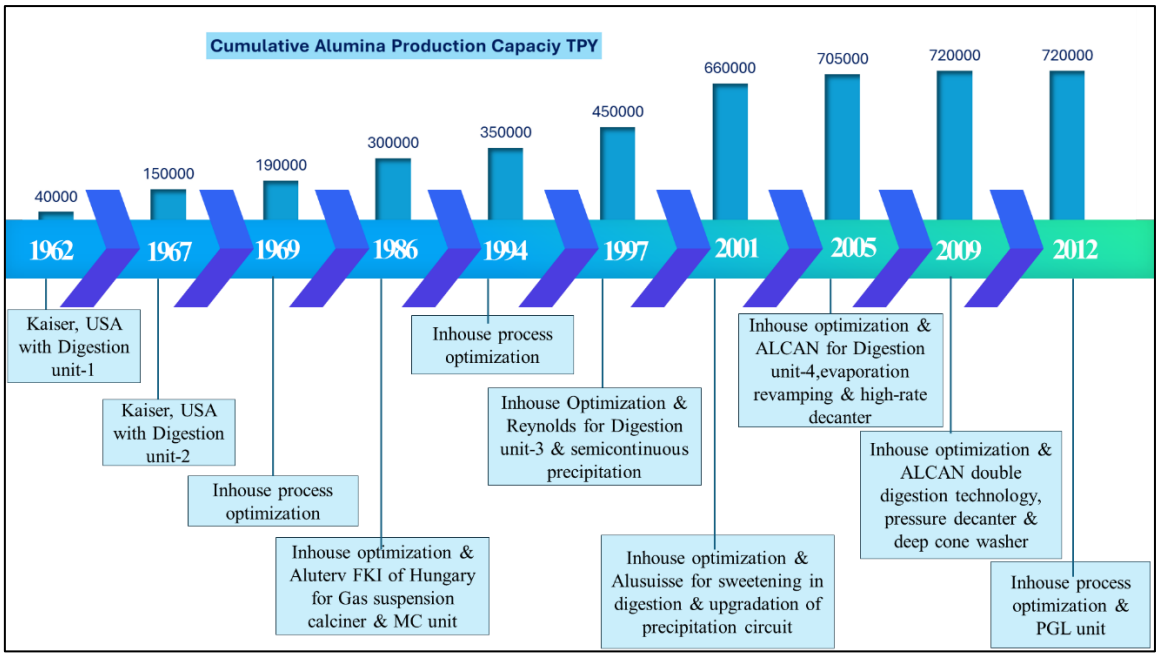

Figure 4. Alumina refinery production enhancement with technology upgrade.

3.2 Aluminium Smelter

Hindalco's Smelter plant was established in 1962 with a single potline and a smelter that had a capacity of 20 kt/a. Over the years, the plant has expanded its smelting capacity to 410 kt/a. The aluminium metal production increase with the addition of pots is summarized in Figure 5. The Hindalco Renukoot Aluminium smelter has undergone significant technological evolution to enhance operational efficiency and sustainability. Initially, the pots operated at approximately 58–60 kA and 4.8 V, yielding an average pot life of 800 days, current efficiency of 87 %, and high specific energy consumption exceeding 16 000 DC kWh/t Al. This early phase was characterized by substantial consumption of aluminium fluoride (30 kg/t) and net carbon (over 500 kg/t), exacerbated by manual control systems. Issues included sudden pot cooling and sludge formation from manual alumina feeding, energy losses and disturbed side ledges due to manual voltage adjustment, higher current density from smaller anodes, and poor performance of monolithic cathode linings (high bath absorption, high electrical resistance, and reduced pot life). The lack of pot covers further contributed to fluoride and heat loss, poor working conditions, and environmental impact. To address these challenges and remain competitive, Renukoot implemented a series of technological modernizations. These included the adoption of prebake cathode blocks with improved insulation and thermal design, and redesigned anodes to reduce air burning and heat loss while lowering current density, anode resistance, and carbon consumption through increased size and optimized stub hole geometry. Microprocessor-based pot controllers were retrofitted to automate alumina feeding, voltage regulation, and other critical parameters, integrating advanced control strategies for automated voltage control, demand feeding, noise control, and anode effect termination. The bath chemistry was optimized for higher excess AlF_3 and lower spar percentage, along with low alumina concentration. Furthermore, upgraded pot

cover materials, a comprehensive pot hooding system with dry scrubbing for emission control and fluoride recycling, and a hyper-dense phase system for dust-free alumina transfer were introduced. Upgrades to operational equipment (such as scoopers, crust breakers) also contributed to the overall improvement. Some of the key technological advancement initiatives executed during this long journey of Renukoot potroom are shown in Figures 6 and 8. The carbon plant executed production enhancement through anode size increase at the Green Anode Plant, installing new modern baking furnaces, and equipment upgrade at the Anode Rodding shop. The Green Anode Plant installed modern equipment like a vibro-compactor in place of press unit and vacuum system to ensure high-quality productivity. Similarly, the number of baking furnaces has been increased from 1 to 6 numbers, out of which, 3 are upgraded with automatic modern firing system (refer to Figure 7 for baking furnace modernization). These enhancements have demonstrably improved current efficiency to over 94 % and reduced specific energy consumption to 13 800 DC kWh/t Al. Looking to future requirements, Renukoot has installed booster sections to test cell designs capable of operating at 78 and 90 kA, targeting specific energy consumption below 13 400 DC kWh/t Al.

To drive digitalization transformation several digital initiatives have been implemented towards Data capturing, storage, and inferencing. One such case is to streamline the complex sample management process. To address these challenges, the Laboratory Information Management System (LIMS) has been implemented that is lightweight and easy to adopt. This system ensures data integrity and reduces redundancies across multiple systems, facilitates data transfer within the laboratory, and supports information sharing across all stakeholders. This LIMS system helped in increasing productivity through efficient management of analytical data and resource planning.

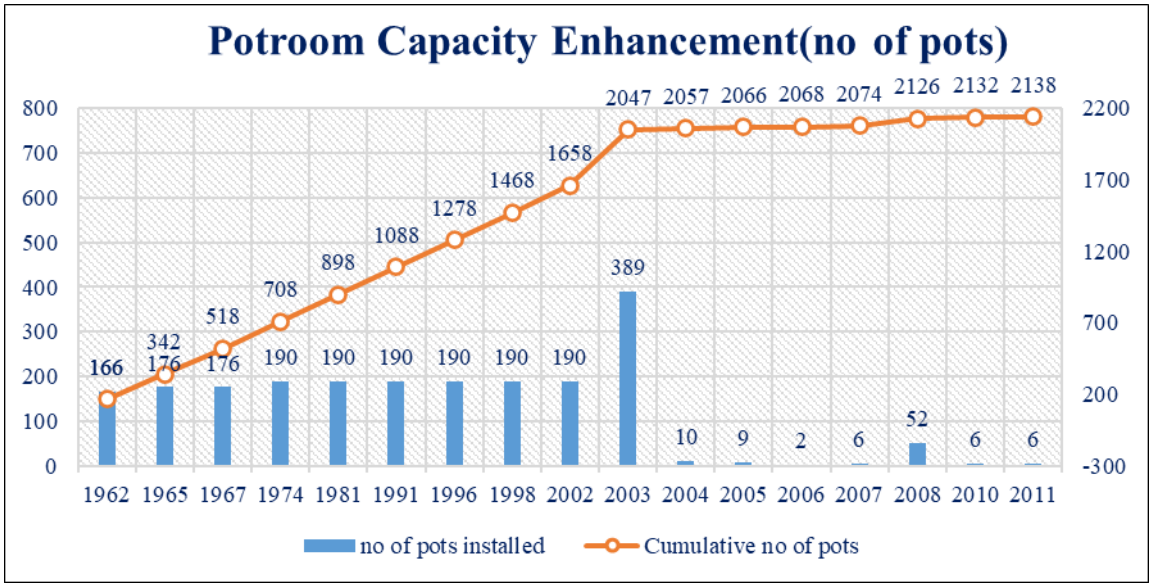

Figure 5. Pot room productivity increases by new pot additions over time.

Figure 6. A few of the technological advances in potroom.

Figure 7. Anode Baking Furnace modernization.

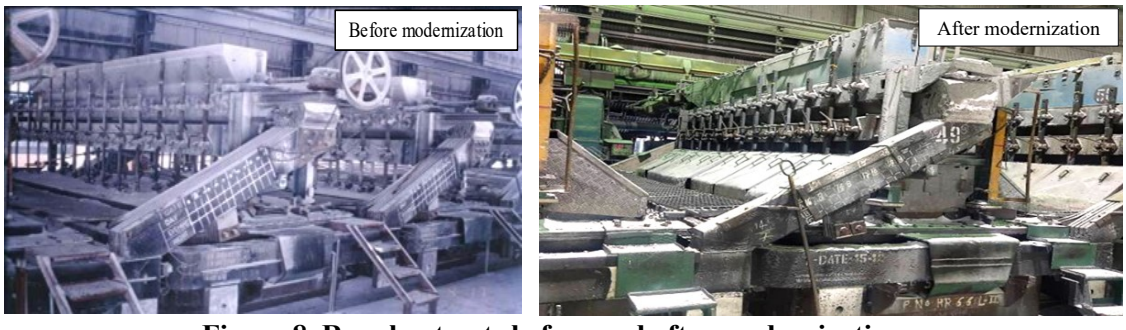

Figure 8. Renukoot pots before and after modernization.

3.3 Fabrication Plant

The Hindalco Renukoot Fabrication Plant has undergone a significant historical evolution, transforming from its initial capabilities to a sophisticated manufacturing facility. Initially established to process the primary aluminium produced by the smelter into basic rolled or extruded products, the plant's early operations utilized conventional technologies for sheet and foil production. Over time, driven by evolving market demands for higher quality, specialized products, and increased efficiency, the facility embarked on a series of strategic technological upgrades. These advancements included the integration of advanced rolling mills, enhanced annealing furnaces, and sophisticated finishing lines, enabling the production of a diversified portfolio of value-added products. During the past year, the fabrication plant has upgraded its productivity as well as added several new product segments. The cast house, extrusion plant, and rolling mills are catering the requirements of sectors like electrical, transportation, rail wagons, packaging, cookware, defence, construction, and architectural with a variety of products as shown in Figure 9.

Hindalco Renukoot's extrusion facilities are equipped with state-of-the-art technology to ensure high-quality billet production and efficient extrusion processes. Billet casting utilizes advanced Wagstaff Air-slip technology, featuring inline degassing and filtration, all controlled by a Programmable Logic Controller (PLC) system, achieving a capacity of 37 500 tonnes per annum. The in-house die shop is highly capable, leveraging Computer-Aided Design/ Computer-Aided Manufacturing (CAD/CAM) and advanced Computer Numerical Control (CNC) machines, including wire Electrical Discharge Machining (EDM) and machining centers, to develop over 1000 specialized dies. The extrusion presses themselves incorporate sophisticated controls for precise press operation and billet temperature management, further supported by efficient downline equipment such as pullers and aging furnaces to optimize product quality and throughput. The plant features a diverse extrusion facility with a capacity of around 50 000 t/a, including a Balwin Lima Hamilton press installed in 1965 and upgraded in 2010 with a Granco Clark downline. The plant also has seven additional presses supplied by Farrel, SMS Sutton, Clecim, Shinjye, Gia, Hydraulik Duisburg, and SMS Group, which are utilized for producing critical architectural profiles, building applications, machine and automotive components, and defense sector.

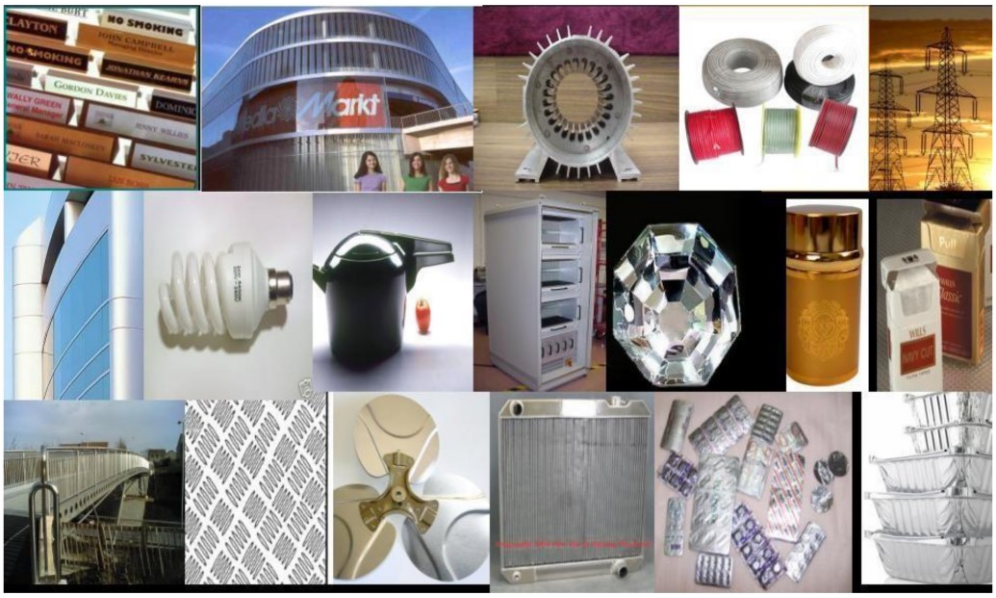

Figure 9. Fabrication plant products for various sectors.

Technological innovation and digitalization are being gradually incorporated into operations at all the facilities of Renukoot. From process automation and real-time data monitoring to predictive maintenance and digital quality control systems, the facility is aligning with Industry 4.0 standards to enhance productivity and reduce downtime.

4. Journey of Sustainability

The integrated facility at Renukoot includes an alumina refinery and smelter, as well as production capabilities for semi-fabricated products such as conductor redraw rods, sheets, and extrusions. Renukoot has obtained the Integrated Management System (IMS) certification, combining quality, environmental, and occupational health and safety standards into a comprehensive business framework. The unit has also received several national and international awards for its achievements in quality, environmental management, and energy conservation (Figure 10).

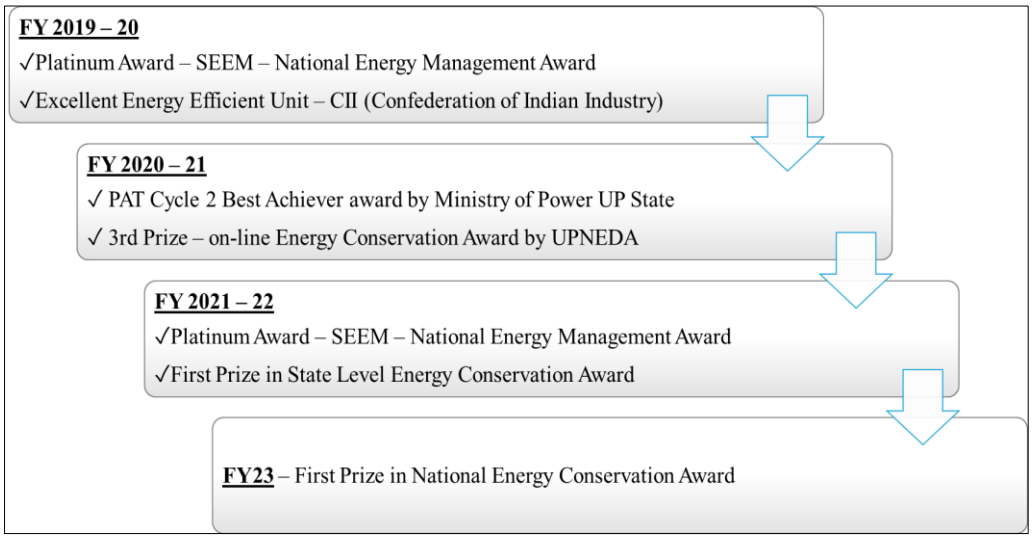

Figure 10. Various awards for sustainability initiatives.

Several initiatives have been taken towards reduction in specific energy consumption in operational activities, adopting energy efficient technologies/equipment for all new projects, replacing old equipment and technologies with the latest, creating awareness amongst employees and society, and with periodic management review mechanisms. Few of such high impacting energy saving projects are like use of cold ramming paste in pots, use of solid busbar in pot, use of Cu insert collector bars, installation of fan less cooling towers, replacement of old non-energy efficient motors with new energy efficient motors, improvement in liquor productivity in Alumina Refinery, installation of On-delay timers on Sump Pumps, installation of medium voltage (MV) drive in FLS induced draft (ID) fans and automatic controlling equipment ideal running hours. Other initiatives like the use of copper insert collector bars in pots are under progress aiming for further reduction in specific energy consumption per tonne of metal produced. Apart from this the team of Renukoot is proactively working and maintaining secured handling/storage/disposal of the hazardous materials generated from the Smelter plant. The red mud generated during the alumina refining process is sent to cement plants (100 %). During the transportation of red mud through railway wagons, proper control measures are being taken to avoid spillage/dusting by proper covering. All three plants are well equipped with dust collection and bag filter systems associated with stacks to ensure clean gas to the environment. With its DNA embedded in the Company's purpose statement that reads— "We manufacture materials that make the world Greener—Stronger—Smarter", Hindalco Renukoot is always working towards becoming Hindalco, the world's most sustainable aluminium company in the Dow Jones Sustainability Indices (DJSI).

5. Journey of Cultural and Business Transformation

Cultural and Business Transformation at Renukoot involves a deep and intentional shift in the organization's values, beliefs, and behaviours to align with Hindalco's strategic goals of becoming High Performing Contemporary Organization. Hindalco's cultural transformation framework named as "Shillim" initiative, aims to transform the company culture by creating an agile, inclusive, and collaborative work environment. The goal is to evolve from a raw materials supplier to a solutions-driven provider, promoting employee empowerment and innovation. In line with this objective, to build on a proud 60-year legacy of excellence and to ensure future readiness, the Cultural and Business Transformation initiative – "Parivartan RKT 2.0" – has been launched. This transformative journey signifies a major shift from a traditional functional structure to a dynamic, process-driven organizational model. The realignment aims to foster a culture of ownership, innovation, and resilience, empowering the organization to navigate emerging challenges while preserving its core strengths in an increasingly competitive environment. In addition to this, a structured working model has been developed and successfully implemented to mitigate the risks related to old technology, depleting skilled manpower, safety concerns linked with manual jobs, and congestion inside the plant to sustain profitability. The working philosophy of this Parivartan RKT 2.0 is explained in Figure 11.

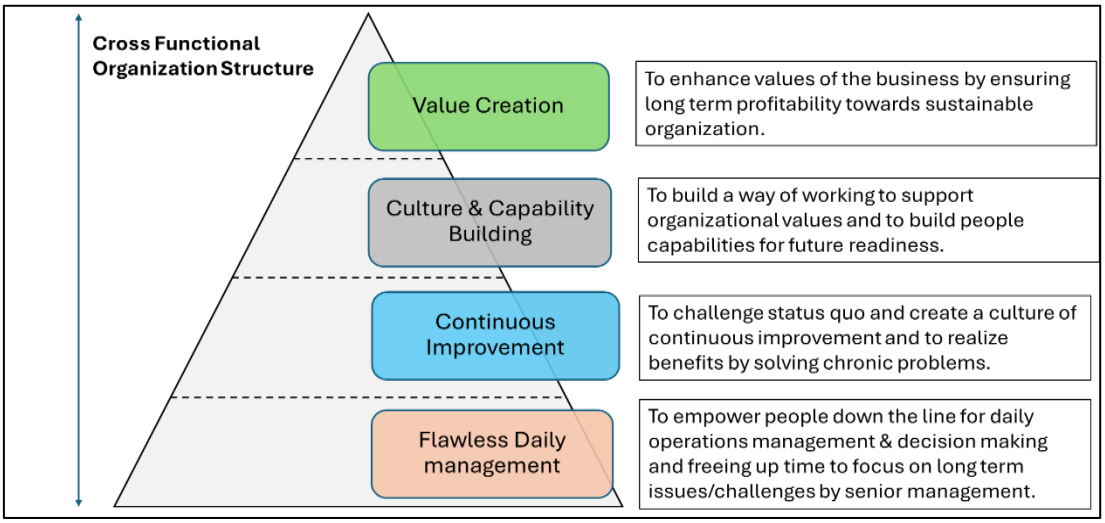

Figure 11. Working model of business transformation journey.

After the launching of this transformation drive "Parivartan RKT 2.0", the acceptance, participation, and learning agility level of employees has gone up significantly. Over the past years, the team has been involved in continuous improvement projects to eliminate chronic issues, contributing to overall profitability as well as making the plant competitive with new-age aluminium plants. The ownership culture has developed the workplace significantly (Figure 12).

Figure 12. Transformation in overall plant look and feel.

6. Summary

Hindalco's Renukoot complex, established in 1962 as India's first integrated aluminium plant, is one of Asia's largest primary aluminium producers, managing operations from bauxite mining to refined aluminium and various downstream products. Starting with an initial capacity of 40 kt/a alumina and 20 kt/a aluminium, it has expanded to 410 kt/a aluminium production, powered by its Renusagar Captive Power Plant. The Alumina Refinery, commissioned in 1962, has increased its capacity to 720 kt/a through technological advancements and uses the Bayer process. The Aluminium Smelter, also from 1962, has undergone significant energy conservation efforts, reducing specific energy consumption from 16 500 to 13 800 kWh/t Al through over 500 projects and partial automation. The Fabrication Plant, evolving since 1965, now produces ingots, wire rods, flat-rolled products, and extrusions, incorporating advanced casting technologies. As Hindalco's "mother plant," Renukoot drives company-wide improvements through continuous technology adoption and automation. The complex is deeply committed to sustainability, aiming for 100 % bauxite residue utilization, net-zero liquid discharge, and landfill and emissions by 2050, alongside ongoing energy reduction and efficiency initiatives. To maintain its competitive edge and secure its future, Renukoot is undergoing a "Parivartan RKT 2.0" transformation, shifting to a dynamic, process-based organizational model that fosters ownership, innovation, and resilience. Hindalco Renukoot being an integrated aluminium complex, transforms the aluminium value chain into a high-efficiency ecosystem, offering reduced costs, energy savings, operational control, and sustainability—all of which are critical for long-term competitiveness and profitability in the aluminium industry.

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