British
High Commission
New Delhi

GOVERNMENT OF INDIA
MINISTRY OF POWER

BEST PRACTICES COMPENDIUM

Industrial Energy Efficiency/ Decarbonisation Outlook

Case Studies on Select Global Technologies and Best Practice

ACCELERATING SMART POWER & RENEWABLE ENERGY IN INDIA (ASPIRE) PROGRAMME

iDeeksha

Industrial Decarbonisation and Energy Efficiency Knowledge Sharing Platform

Contents

Introduction **05**

About ASPIRE Programme 05

About IDEEKSHA (Rejuvenated Knowledge Exchange Platform) 05

Section 1 – Aluminium Sector **06**

1.1 Driving Sustainability Across UK Aluminium Sector 07

1.2 UK Aluminium Sector: Industry Best Practices 10

1.3 Importance of Inert Anode Technology for Aluminium Sector 14

1.4 Copper Insert Collector Bar for Energy Reduction in Hindalco Smelter 17

1.5 Indian Aluminium Sector: Energy Analytic Platform using Power BI with AI – Aditya Aluminium (Hindalco Industries Limited) 19

Section 2 – Cement Sector **23**

2.1 Cement Sector: Low Carbon Multi-Component Cements for UK Concrete Applications 24

2.2 Cambridge Electric Cement: A Zero-Emissions Breakthrough 28

2.3 Decarbonising Cement Production: Carbon Re's AI-based Delta Zero Cement Platform 31

2.4 Waste Heat Recovery from Kiln And Cooler Stacks At Hanson Cement Plant, UK 34

2.5 Superlative Utilisation of Green Energy in Cement Production 35

2.6 Carbon Capture Technology Decarbonising the Cement Industry: Carbon8, Vicat Case Study 39

2.7 Co-processing of Spent Pot Lining (SPL) Mixed Fines in Cement Plants 42

Section 3: Textile Sector **46**

3.1 Textile Sector: Waterless Smart Dyeing Technology 47

3.1.1 Alchemie EndeavourTM - Technology Description 47

3.1.2 Alchemie NovaraTM - Technology Description 48

3.2 Energy Savings & Greenhouse Gases Mitigation to Manage Climate Change- Raymond Ltd, Vapi 50

Section 4 – Cross Sectoral **55**

4.1 Industry 4.0 Wireless Energy Solutions for Net Zero and Energy Productivity 56

4.2 Semi-Modular Cdrmax Technology for Carbon Capture 59

4.3 Waste Heat Powered Treatment Of Industrial Wastewaters – LAT Water 62

4.4 Unlocking Energy Efficiency Through Industrial Intelligence: Smartia 65

Conclusion **68**


USE
CROSSWALK

INTRODUCTION

About ASPIRE Programme

The UK and India share a key strategic partnership, which has strengthened over the years with growing cooperation and bilateral engagements across multiple fields including the industrial energy efficiency and decarbonisation sector. To take forward this partnership to support sustainable development and inclusive growth, the UK-India bilateral Technical Assistance Programme, on **“Accelerating Smart Power and Renewable Energy in India” (ASPIRE)** was launched in October 2021. ASPIRE is being implemented by the Foreign Commonwealth and Development Office, Government of UK in association with the Ministry of Power and Ministry of New and Renewable Energy, Government of India. The objective of ASPIRE is to catalyse increased investment in industrial energy efficiency and decarbonisation (IEED), renewable energy, storage deployment, and electricity distribution in India. The programme aims to catalyse increased investment that supports sustained & inclusive economic growth, low carbon and leads to poverty reduction including through the promotion and empowerment of women and other socially weaker groups.

About IDEEKSHA (Rejuvenated Knowledge Exchange Platform)

Under the ASPIRE Programme, a rejuvenated Knowledge Exchange Platform (KEP) – **‘IDEEKSHA: Industrial Decarbonisation and Energy Efficiency Knowledge Sharing Platform’** has been developed in collaboration with the Bureau of Energy Efficiency (BEE) to promote and share best practices and energy-efficient technologies among largescale industries. The IDEEKSHA platform was launched by Mr. R.K. Singh, Hon’ble Cabinet Minister for Power and New and Renewable Energy, Government of India during the 21st Foundation Day Event of BEE on March 01, 2023, in Delhi

The IDEEKSHA platform is a one-stop shop for all energy efficiency/ decarbonisation needs of large industries covered/ expected to be covered under BEE’s PAT Scheme. The IDEEKSHA platform would thus facilitate:

- Exchange of knowledge and information to enhance peer to peer learning.
- Designated Consumers (DCs) in adoption of new and emerging IEED tools & technologies by facilitating access to Indian and global (including from the UK) technology suppliers.
- Access to a database of financial institutions.
- Access to IEED tools, technologies & technology providers available in India and globally.
- Access to data sources and knowledge repositories to support knowledge translation.
- Sector/ industry specific workshops/ seminars to enhance Energy Efficiency (EE) measures.
- Knowledge and commercial partnerships.

The platform acts as a hub for knowledge exchange and collaboration between industries and technology suppliers across eight hard-to-abate sectors (**Cement**, **Aluminium**, **Iron & Steel**, **Textile**, **Fertiliser**, **Chlor-Alkali**, **Pulp & Paper**, and **Refinery**), all covered under BEE’s Perform Achieve and Trade (PAT) scheme. The Platform provides support by granting access to a global database of Industrial Energy Efficiency & Decarbonisation (IEED) technologies, newsletters, organising capacity-building workshops, study tours, and more.

The **Best Practices Compendium** is a consortium of case studies developed over the life of ASPIRE programme based on our extensive research and discussions. This Compendium developed by the ASPIRE team, consolidating national and international case studies on Industrial Energy Efficiency and Decarbonisation (IEED), will serve the purpose of providing a comprehensive guide.

SECTION 1
ALUMINIUM SECTOR

ALUMINIUM SECTOR

1.1 Driving Sustainability Across UK Aluminium Sector

Introduction

The aluminium industry is a vital part of the UK manufacturing sector and an essential component of the modern UK economy. The UK aluminium sector contributes around 10 billion pounds annually to UK's economy and employs more than 39,000 people nationwide[1]. It plays a significant role in the supply chains of high-value sectors like aerospace, automotive, rail and construction and mass packaging markets. As a lightweight and highly recyclable material, aluminium is a key contributor to the UK's low-carbon economy. Its strategic importance is increasing as contributes towards the Government's green growth ambitions and 2050 net-zero targets.

The Aluminium Federation (ALFED) is the trade association representing a wide spectrum of the UK aluminium value chain including primary and secondary producers, extruders, finishers, distributors, recyclers, aluminium casting, packaging, transport, and architecture & structures producers. The UK aluminium industry including 200+ members and partners of ALFED is committed to sustainability and has set a target of becoming net zero by 2050.

UK Aluminium Sustainability Roadmap to 2050

ALFED has outlined a roadmap for boosting sustainability within the UK aluminium sector focusing on 3 pillars – a) Decarbonisation, b) Sustainable Sourcing and c) the circular economy. Under each of these pillars, ALFED has outlined key goals and action items for the sector. The following figure summarises key action items under each of these pillars.

3 Pillars of UK Aluminium Sector Sustainability Roadmap		
Decarbonisation	**Sustainable Sourcing**	**Circular Economy**
• **R&D acceleration**: work with government knowledge partners & innovators • **Capex support**: Financial support and tax breaks need to enable investment in low-carbo, energy and water-efficient, UK-based manufacturing facilities	• **Traceability**: Best practice standards • **Domestic supply chain development** • **Skills development**: work with industry, universities and other knowledge partners • **Diversity and inclusion**: boosting the proportion of women in the sector • **Social Engagement:** for driving CSR and voluntary initiatives	• **Closed-loop supply chain development**: drive alloy innovation and domestic capacity • **Whole-life design innovation**: recycling into the whole-life design • **National recycling strategy**: Support national reuse, remanufacturing and recycling strategy

Figure 1: Pillars of UK Aluminium Sustainability Roadmap

Decarbonisation

In the UK, there is minimal primary aluminium production. Nearly all primary aluminium is imported, and the minimal domestic production already uses hydroelectric power. As a result, the UK aluminium

1 The Aluminium Industry in the UK Report 2022 (ALFED)

sector is already carbon and resource efficient. Additionally, no hazardous waste is currently being sent to landfill. Drosses and slags are reduced to pure salts, which are used in melting furnaces, and potash (used as fertiliser) and aluminium is returned for recycling. Therefore, the UK Aluminium sector focused on decarbonising through a) importing the lowest-carbon primary aluminium and, b) maximising the use of end-of-life aluminium.

Key actions for decarbonisation:

- R&D acceleration: To develop policies and programmes that support the transformation of end-of-life aluminium into semi-fabricated and finished products in the UK, including investment in R&D to evolve additive manufacture, develop recycling-friendly alloys and design sensing and sorting systems that segregate alloys from mixed scrap.
- Capex support: Work with Government and knowledge partners to develop the financial support and tax breaks needed to enable investment in low-carbon, energy- and water-efficient, UK-based manufacturing facilities.

Sustainable Sourcing

Brexit and the COVID pandemic have given the UK aluminium sector a unique opportunity to restructure and rebuild key supply chains. This presents a chance to prioritise the sustainable sourcing of primary aluminium and semi-fabricated goods currently imported by the UK. ALFED aims to help the aluminium sector capitalise on this opportunity by providing frameworks and support to simplify processes, foster collaboration across the value chain, close skills gaps and increase workforce diversity.

Key actions for sustainable sourcing:

- Traceability: Support members with implementing best-practice traceability standards relating to environmental and social issues, like the Aluminium Stewardship Initiative (ASI) and Chain of Custody Standards.
- Domestic supply chain development: Encourage ongoing development of the UK aluminium value chain, working with other trade associations like Make UK and the Society of Motor Manufacturers and Traders.
- Skills development: Work with industry, universities, and other knowledge partners to develop programmes that expand the UK's skills base for expanding domestic capabilities across the aluminium value chain.
- Diversity and inclusion: Collaborate with knowledge partners and industry to foster diversity within the aluminium workforce, including boosting the proportion of women in the aluminium sector.
- Social engagement: Develop a best practice framework for driving Corporate Social Responsibility (CSR) and voluntary initiatives that help members contribute to more socially conscious supply chains.

Circular Economy

75% of all aluminium ever produced is still in use in some form, and it takes 95% less energy to produce recycled aluminium than primary aluminium[2]. The UK is a global leader when it comes to aluminium recycling, generating an estimated 1.4 million tonnes of aluminium scrap per year. 500,000 tonnes of that scrap are currently exported. ALFED aims to maximise the use of recycled aluminium in the industry and supply chains, reducing scrap exports by 50,000 tons annually and achieving a 90% increase in the domestic use of recycled aluminium.

2 European Aluminium Vision 2050

Key actions for the circular economy:

- Closed-loop supply chain development: Work with the sector and knowledge partners to drive alloy innovation and grow domestic capacity in re-processing and semi-finishing.
- Whole-life design innovation: Collaborate with knowledge partners and application-specific stakeholders to embed aluminium recycling into the whole-life design process. This includes embedding aluminium recycling into the design, replacing difficult-to-recycle materials, and enhancing product recyclability through upgrades and re-use.
- National recycling strategy: Support the Government in developing a national reuse, remanufacturing, and recycling strategy to reduce aluminium scrap exports and boost domestic use of recycled aluminium.

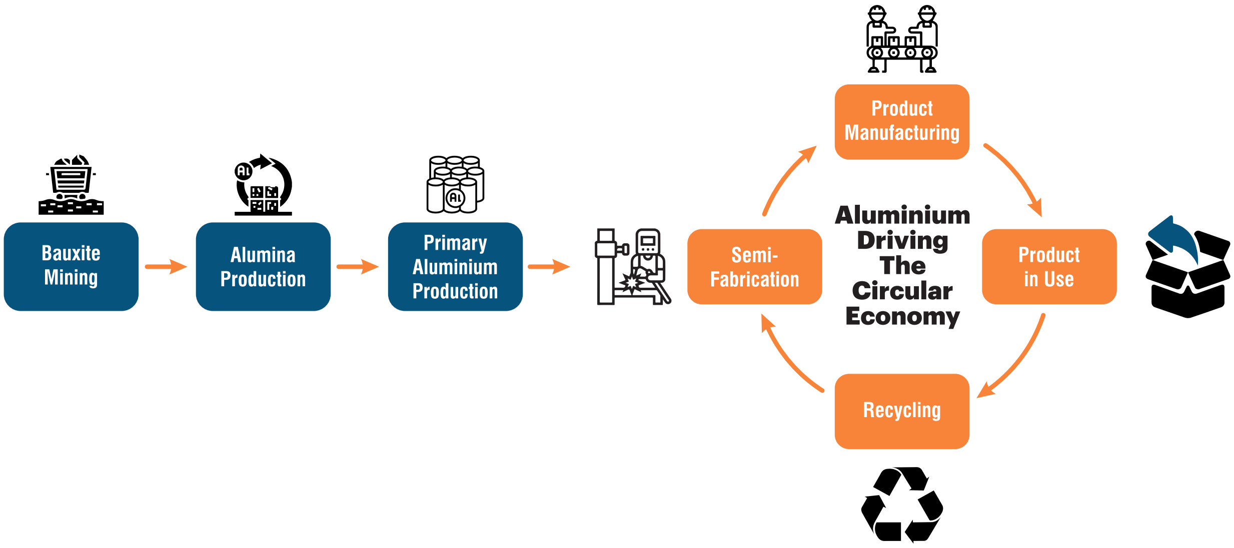


Figure 2: Circular Economy in UK Aluminium Sector

Conclusion

Embracing sustainability practices, such as decarbonisation, sustainable sourcing, and a circular economy, can enhance the Indian aluminium industry's environmental credentials and contribute to achieving national sustainability goals. By fostering collaboration with government, knowledge partners, and emphasising innovation, the industry can position itself as a key player in India's green growth agenda, promoting economic resilience and diversity while setting a benchmark for responsible manufacturing and resource management.

1.2 UK Aluminium Sector: Industry Best Practices

Introduction

The UK's aluminium sector creates an estimated £10 billion annually for the country's economy, whilst employing more than 20,000 people. Aluminium production and supply in the UK are orientated towards the supply chains of high-value sectors, such as aerospace, automotive, rail and construction, as well as mass markets for packaging. There is minimal primary aluminium production in the UK and the majority of emissions are a result of the electricity source used in electrolytic reduction. Globally, there are a number of key opportunity areas for energy efficiency in primary aluminium production, including furnaces and heating, electrolysis, and recycling.

Furnaces and heating

Heat use is abundant across multiple processes in the aluminium industry. The excess heat from the exhaust gas from electrolysis cells that is likely to be the easiest to recover as its already captured and managed through piping, ductwork, and chimneys. Recovery through heat exchanges can be utilised for various purposes, including space heating within the production site, or pre-heating/drying of raw materials.

Within furnaces, heat loss reduction is a key energy efficiency opportunity for aluminium production. This can be achieved through better refractory lining and insulating materials as well as through the use of appropriate wall thicknesses and by covering open wells. Furnaces can utilise regenerative burner and recuperator-based heat exchange systems. An estimated 20-25% fuel savings can be achieved through use exhaust gas heat exchangers, whilst up to 5% energy reduction can be realised through improved insulation materials and between 10-30% saving can be achieved through preheating of combustion air with heat recovered from exhaust gases.

The recovered heat from aluminium casting can be used for drying of raw materials, preheating scrap or metal charge, hot water, space heating, and other uses such as electricity generation and absorption refrigeration. Heat loss from the anodising process can also be reduced to improve energy efficiency, by reducing the amount of warm air lost through approaches such as the use of lids on the anodising tanks. Immersion heaters present a significant energy efficiency opportunity compared to other furnaces options such as open fire burner furnaces. Efficiency improvements of 2-3 times higher due to improved heat transfer to the metal can be realised. Immersion heating technology provides precise temperature control thanks to direct heating of the metal and saves time and energy due to reduced cleaning needs. Non-stationary flame burners can also increase the efficiency of heat transfer, through directing of the flame to preferred areas of the furnace and increasing firing rates in areas with a higher concentration of metal charge. Continued movement of the flame after the metal has been melted also ensures uniform heat transfer in a highly efficient manner. Yield is also increased through reduced problems arising from hot spots occurring on the metal. Heat recovery and, sizeable energy savings from furnace use can also be made through the implementation of simple operational improvements such as a reduction in door opening, and holding, times.

Electrolysis; process improvements

Electricity, through electrolysis, is the major component of primary aluminium production, constituting around 85% of a plant's energy requirements. Within electrolysis cells, process control improvements offer an opportunity for improved energy efficiency and cost savings. Conventional control systems work to achieve and maintain smelter target settings through adjustment of process parameters to compensate for changes in inputs, operations, and special causes of variation. The second generation of process controls, which do not have widespread use, are designed to diagnose abnormalities, and employ corrective actions through manual processes, to avoid compensatory measures used in the first-generation systems. The third generation uses a more sophisticated control system to diagnose underlying variation at the cell, cell group, and entire plotline level. Energy and mass balancing strategies along with advanced multivariate technologies are used to diagnose and address root causes and prevent the cell from going out of control.

Electrolysis; Inert anodes

Graphite anodes are currently used universally for primary aluminium production. There is significant research effort underway globally into the replacement of carbon anodes with inert materials that do not produce CO_2 emissions. As well as the eliminated carbon emissions, inert anodes also provide the opportunity for production of oxygen gas as a valued added by product. Inert anodes remain at the pilot stage of development. Inert anode development has proven a challenging target for the aluminium industry globally. Elysis, a Canadian joint venture between Rio Tinto and Alcoa, is currently leading work in the development of cell technology based on inert anodes. The company successfully produced its first batch of aluminium using inert anodes in 2019 and has ambitions for a full-scale commercial demonstration by 2023, before making the technology available globally by 2024, which if realised will mark a major step towards widespread low carbon aluminium production.

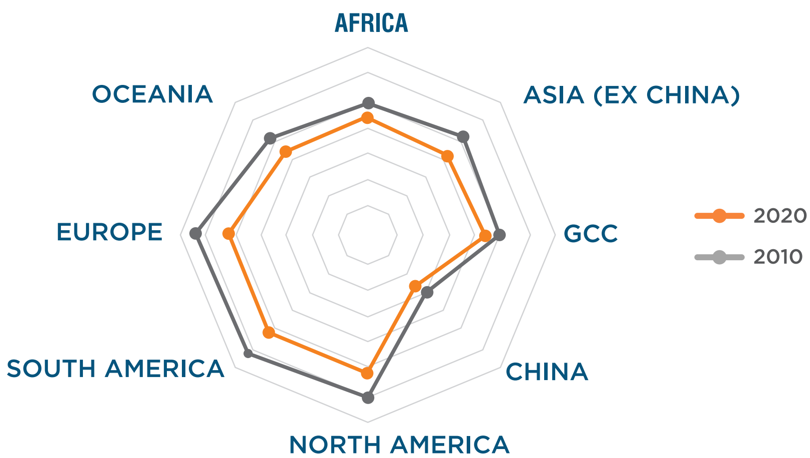


Figure 3: Global smelter electrolysis efficiency improvements over a decade

Recycling

Recycling aluminium metal saves around 92% of the energy required to create the same amount of aluminium from scratch, making recycling one of the highest impact energy efficiency opportunities within the industry. For recycling, different scrap types have different considerations relating to the melting process and selecting appropriate melting furnaces and feed material according to input scrap material, its size, oxide content and degree of contamination can be key to energy efficient aluminium recycling as energy demands for can vary significantly depending on the melting technology used. Tilting rotary furnaces are frequently used in aluminium recycling to remove impurities and ensure adequate cover of the melt with less salt. The volume of salt needed in a tilted furnace is significantly lower than conventional options, which in turn enables the sizeable reduction in energy usage and emissions associated with the waste treatment of salt slag by products. As well as optimal furnace selection, and use of tilting rotary furnaces, a third key energy efficiency option for aluminium recycling is through the melting of cleaned scrap, that is free from contaminants. This can significantly reduce energy use skmmings/ dross generation, and in some cases can also result in higher melting rates and reduced emissions.

Aluminium technology case study

Hot form quenching for aluminium forming within high value vehicle manufacturing, originally published as a White Paper by Impression Technologies, UK

UK based Impression Technologies, was spun out of Imperial college London, and builds upon 13 years of advanced metallurgic and process research. The company is leading aluminium lightweighting solution provider. In 2021, the company announced a highly efficient new patented lightweighting technology known as the Hot Form Quench (HFQ). The process was developed to offer step change in aluminium forming across multiple industries that stand to benefit from lightweighting through increased aluminium use. The HFQ process establishes a new international standard for lightweighting in automotive applications through the use of high-strength aluminium as a cost-effective alternative to steel or low-strength aluminium. HFQ is a multi-stage process that begins with a standard heat-treatable grade of aluminium sheet that is heated in a furnace to its solutionising temperature (typically around 550°C) depending on the alloy grade. Next, an automated process is used to transfer the blank to a press where it is formed between a die tool and cold punch, with rapid cooling of the formed part for 5-10 seconds until quenched. The aluminium microstructure is frozen through the quenching process in a supersaturated solid solution state. The forming process removes cold working of the aluminium alloy and eliminates the need for complicated spring back compensation in the part. The quenching method can also enable a reduction in the time needed (down to just over two hours for aluminium grade AA6082 from the standard nine-hour ageing time using current hot rolling methods), for artificial ageing to further increase the strength of the pressing, should a heat treatable aluminium alloy be used. Reduced ageing times are a result of the dislocations developed during the forming stage providing nucleation sites for precipitates, which is the mechanism by which maximum strength is achieved. Final artificial ageing times required to achieve peak strength are dependent upon the strain during the forming process, and the thermo-mechanical processing cycle of the HFQ Technology has been developed to enable full alloy strength without compromising desired design elements of the part. Partial artificial ageing can also be achieved using the process, followed by full ageing once the part has been assembled into the vehicle structure.

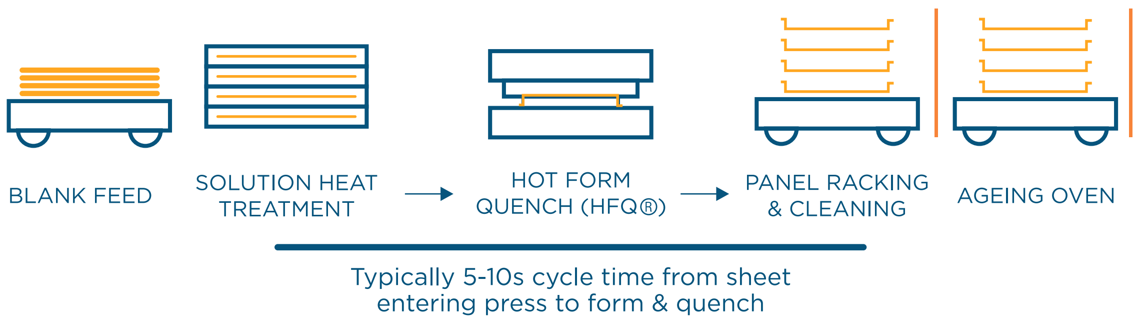


Figure 4: Process steps in the innovative low carbon Hot Form Quenching solution from Impression Technologies

As shown in figure 5, a full comparison between HFQ Technology and cold-rolled forming for deep-draw complex pressings, the complete forming of the parts was achieved using HFQ Technology (left image), whereas producing the same parts using cold forming (right image) was not feasible, with splitting of the alloy sheet in deeper-drawn sections. These failures of aluminium at room temperature are characteristic and occur even during the early stages of forming. The improvement in aluminium formability achieved by the HFQ process broadens the scope for aluminium use in automotive applications, offering greater design freedom, process optimisation and attainment of higher strength and stiffness levels with a reduced bill of materials.

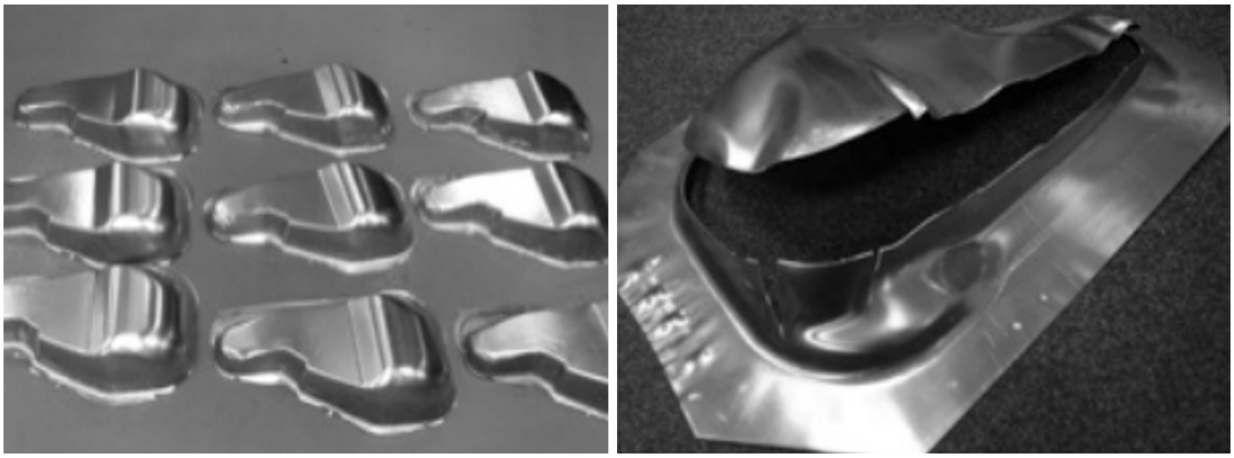


Figure 5: (left) Selection of successfully pressed parts with HFQ Technology (right) same material shown to sheer when pressed at room temperature using conventional cold methods.

Conclusion

Adopting energy-efficient technologies in furnaces, inert anodes, and recycling processes aligns with India's commitment to sustainability, offering the Indian aluminium industry a pathway to substantial emission reductions. Embracing innovations like Impression Technologies' Hot Form Quenching (HFQ) can enhance India's pursuit of low-carbon aluminium production, fostering eco-friendly practices and contributing to the nation's environmental goals while maintaining focus on high-value sectors in the economy.

1.3 Importance of Inert Anode Technology for Aluminium Sector - *By Dr. Anupam Agnihotri, Director, JNARDDC, Nagpur*

Introduction

An inert anode is a non-consumable anode that is insoluble in the electrolyte under the conditions obtained in electrolysis. Using inert anodes in the aluminium smelting process is a breakthrough technology revolutionising the industry. Unlike carbon anodes, inert anodes are not corroded during the aluminium reduction process and do not release CO_2 but rather pure oxygen. Material for inert anodes is physically stable at the operating temperature and resistant to the molten electrolyte, oxygen & thermal shock at 960℃ (materials such as ceramics, cermets, and metals). It is electrochemically stable, electronically conducting, mechanically robust, and easy to deploy (for instance, electrical connections to the bus, startup, and power interruptions).

Hall-Heroult Process:

$$\frac{1}{2}Al_2O_3 + \frac{3}{4x}C \xrightarrow[960]{} Al + \frac{3}{4}\left(2 - \frac{1}{x}\right)CO_2 + \frac{3}{2}\left(\frac{1}{x} - 1\right)CO$$

where x=current efficiency

The total theoretical minimum energy requirement for the Hall-Heroult process is 6.34 kWh/ (kg Al) based on the reactants' enthalpy formation at ambient temperature and for products at the reaction temperature.

Theoretically, at 100% efficiency, from the above equation, ½ unit of alumina and ¾ unit of carbon is consumed to produce one unit of aluminium. These values are equivalent to 1.89 kg of alumina and 0.33 kg of carbon per kg of aluminium. Also, the reduction is associated with ¾ unit of carbon dioxide for each unit of aluminium produced, corresponding to 1.22 kg of CO_2 per kg of aluminium.

The actual electrical consumption (EC) of the Hall-Heroult reduction process, EC, can be determined by

$$EC_{\frac{kWh}{kg}Al} = \frac{298.06 \times V_{cell}}{x}$$

Where V_{cell} is the total voltage per cell in Volts.

The current Hall-Heroult cell's total voltage is about 4.2 - 4.5V, and the current efficiency is around 90 - 96%. Therefore, the average electrical consumption (DC) of the Hall-Heroult cell is about 13 - 15 kWh/ (kg Al).

The energy efficiency, Hall–Heroult, can be estimated as

$$= \frac{Theoretical\ Energy\ Requirment}{Actual\ Energy\ Requirment} = \frac{0.482 + 1.65x}{V_{cell}}$$

Which varies from 42 - 47% depending upon cell voltage and current efficiency.

1.93 kg of alumina is required instead of 1.89 for each kg of aluminium produced, depending on the purity of alumina powder.

Two primary sources responsible for CO_2 emissions from the reduction process are:

- the reduction reaction
- carbon anode oxidation (due to high operating temperature).

As mentioned earlier, theoretically, 0.33 kg of carbon anode is consumed to produce 1 kg of aluminium; however, 0.40-0.45 kg of carbon anode is consumed in the actual process (not a 100% efficient process). Most excess carbon is oxidised from the high-temperature anode surface, and some excess carbon is used to protect the iron electrical connections in the anode.

The excess carbon is assumed to be fully oxidised:

$$C + O_2 = CO_2$$

One unit of CO_2 (44 kg) is produced from the oxidation of 1 unit of carbon (12 kg), and 0.12 kg of carbon will produce 0.44 kg of CO_2. Therefore, the actual CO_2 emissions are 1.66 kg/ (kg Al).

For Inert Anode:

$$\frac{1}{2} Al_2O_3 \underset{960}{\longrightarrow} Al + \frac{3}{4} O_2$$

The total theoretical minimum energy requirement for the Inert Anode process is 9.184 kWh/kg Al based on the reactants' enthalpy formation at ambient temperature and products at the reaction temperature. This technology requires the same theoretical quantity of alumina; however, no carbon is consumed in this process, so there are no carbon dioxide emissions.

- Carbon anodes are consumed in the conventional Hall–Heroult process; however, introducing inert anodes into the Hall–Heroult process will eliminate the problem of consumable anodes.
- The reactions occurring at the anode create localised conditions that add around 0.6 V to the overall cell voltage, known as anode overpotential. Since there are no reactions at the inert anode, the polarisation voltage or anode overpotential is reduced to about 0.15 V.

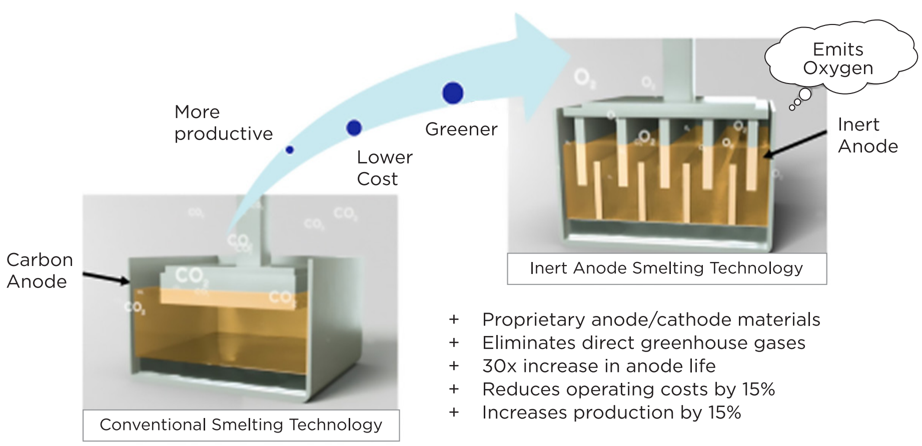


Figure 6: A breakthrough aluminium smelting technology

- In the conventional Hall–Heroult cell, the energy required by the cell is partly provided by the oxidation of the carbon anode, which is not the case for inert anodes. As described earlier, the theoretical energy requirement for an inert anode is higher than that for the conventional Hall–Heroult process by around 2.95 kWh/ (kg Al).
- Thus, for the minimum energy requirement for alumina reduction in an inert anode system, the voltage required should be increased by 0.89-0.95 V as per the calculations mentioned earlier and depending on current efficiency.

Combining both effects (reduced anode over potential and increased reaction voltage) will result in a voltage increase of about 0.45V voltage. The total voltage required for the inert anode technology will be around 5V, which corresponds to a minimum of 15-16 kWh/ (kg Al) depending on the cells' current efficiency. Since no changes to the alumina feeding system occur, the actual alumina consumption is assumed to be the same as for the conventional Hall–Heroult process. However, **no carbon anode** is **consumed**, and hence, **no carbon dioxide emission** in this technology.

Conclusion

The adoption of inert anodes in the aluminium smelting process presents a transformative breakthrough, eliminating carbon anode consumption and associated CO2 emissions. This revolutionary technology not only enhances environmental sustainability by mitigating carbon-related impacts but also offers operational advantages, such as reduced anode overpotential, contributing to a more energy-efficient and eco-friendly aluminium production industry in India. However, there is also increase in energy consumption than that for the conventional Hall–Heroult process by around 2.95 kWh/ (kg Al)

1.4 Copper Insert Collector Bar for Energy Reduction in Hindalco Smelter

Hindalco is working towards achieving an ambitious Net-Zero CO_2 emission target by 2050. Also, ever-increasing energy prices have forced the aluminium industry to reduce specific energy consumption by various means. Mahan smelter of Hindalco embraces AP36 cell technology operating at about 366 kA with specific energy consumption of 13.5 DC kWh/kg of Al. Hindalco smelters work closely with Aditya Birla Science & Technology Centre (ABSTC), the corporate R&D Centre of Aditya Birla Group, to improve the energy efficiency & productivity of their smelters.

Figure 7: Copper Insert Collector Bar

Copper-insert Collector Bar (CuCB) has been of the recent focus areas for energy reduction in aluminium smelters worldwide. CuCB reduces the cathode voltage drop along with a significant reduction in horizontal currents, a key factor of MHD stability in the cells. Intuitively CuCB becomes a preferred choice for high kA cells, which are known as heat-dissipating cells, however long power outage scenario can be detrimental for the cell.

Mathematical models have demonstrated their capability in addressing most of these challenges in the design stage of a cell. ABSTC team had developed & extensively validated 3D models for a multi-physical aspect of the smelter. These were utilised to predict and analyse the thermal profile, voltage & current distribution, magnetic field, and molten fluid flow for existing cells as well as cells with CuCB. The CuCB offers a reasonable reduction in cathode voltage drop as compared to normally used steel collector bars at constant line amperage. The presence of copper increases the electrical conductivity of the collector bar, leading to a reduction in horizontal current in the molten metal. This improves the magnetohydrodynamic (MHD) stability of the cell as well as the reduction of overall flow velocity in molten aluminium, positively affecting the current efficiency. Increased MHD stability provides good potential to squeeze the inter-electrode gap without loss in current efficiency. The cell lining was also modified to ensure the temperature isotherms and freeze profile at reduced heat generation and to have a similar performance during power outages.

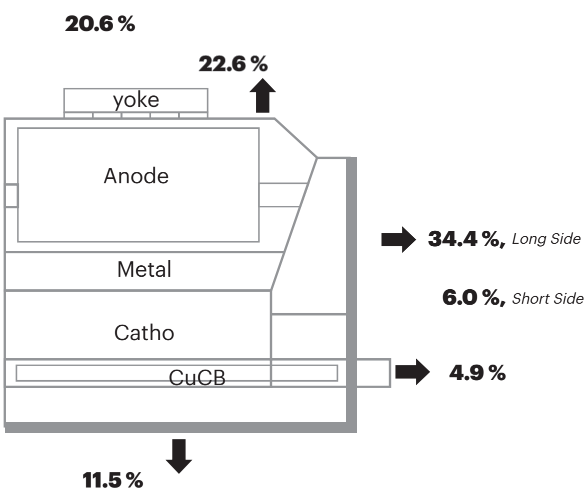


Figure 8: Scientific Diagram of CuCB

Based on the design one pilot cell was started in 2018, which offered excellent performance w.r.t. reduction in specific energy consumption by 300 kWh/ton. Also, the cell performed acceptably well during a zero-power situation of 4 hours. Based on this excellent performance, it is under implementation in all the cells of Mahan as well as Aditya smelter of Hindalco.

Conclusion

Overall, there is a significant scope of upscaling the use of Copper-insert Collector Bar (CuCB) in Indian Aluminium industry offering significant reduction in specific energy consumption and enhancing Magneto Hydro Dynamic (MHD) stability. The technology could help other Indian aluminium industries in improving efficiency, enhancing product quality, reducing maintenance cost, optimising energy usage, and provide competitive edge.

1.5 Indian Aluminium Sector: Energy Analytic Platform using Power BI with AI – Aditya Aluminium (Hindalco Industries Limited)

Introduction

Aditya Aluminium Smelter is a flagship unit of Hindalco located at Lapanga, Sambalpur, Odisha, with a capacity of 380000 TPA and a 900 MW captive power plant (CPP). The Smelter plant is put up with AP-36S technology (RTA) from Aluminium Pechiney, France involving numerous processes, quality parameters, and safety aspects at different levels. The process is quite intricate in nature as it handles very high current to the tune of 368 kA and new generation controls. Aditya Aluminium outstands amongst all twenty-two, AP-36 smelters across the Globe in terms of metal quality producing the best grades of Aluminium i.e. P0404, P0405 & P0406. Aditya Aluminium's product is recognised as 'Good Western Metal' among global customers.

Aditya Aluminium has become the market leader in terms of productivity amongst all smelters operating below 370kA. The key challenges lie in sustaining as a premium quality primary aluminium producer along with quality, cost, energy efficiency and sustainable operations.

The Innovation

It is evident that electrical energy is a key input to produce Aluminium and the process requires extensive and flawless monitoring to minimise consumption, reduce wastage and achieve operational efficiencies both in smelter as well as CPP. Both processes require monitoring and analysis of consumption data at the substation, feeders and at the equipment level with demand and consumption analysis. One of the bottlenecks that Aditya Aluminium faced is that, as the quantity of data grew larger the monitoring of energy consumption and other process parameters became cumbersome. This called for a process innovation not only to handle large sets of data but also to model and generate useful insights in a short period of time for timely decision making.

To achieve this goal in a cost-effective manner, Microsoft Power BI with AI platform was employed. Smart meters capable of transferring data on real time basis were installed across substations at the Power Control Centre (PCC) and Motor Control Centre (MCC) levels and integrated with the energy server. This data so derived was loaded to Microsoft Power BI to get deeper insights with AI analytics for sustainable decision making. A similar approach also was initiated for monitoring data related to PHR, GCV, Boiler efficiency with drill down analysis for proactive decision making. This process innovation has resulted in the transformation of the reactive decision to predictive and preventive strategies in managing energy consumption of critical equipment of Smelter.

1. Difficulties in managing and processing bulk energy data
2. Inefficiencies due to lack of proper decision making
3. Lack of awareness led to energy wastage
4. Higher Energy impacting the overall cost of Metal
5. Future readiness for capacity enhancement for increasing productivity (Current Ramp up)

Figure 9: Challenges Faced

To achieve the above-mentioned objectives and to mitigate the problem of handling huge data, a dedicated team was constituted, and a four-pronged approach was taken to address the problem:

- Smart energy meters with 0.2s class accuracy were installed across different substations.
- Meters were connected through a fibre-optic network.
- Meters were connected to the server for data pulling with an Energy Management System (EMS) software from Schneider Electric.
- Microsoft Power BI with AI was used for deep data analytics.

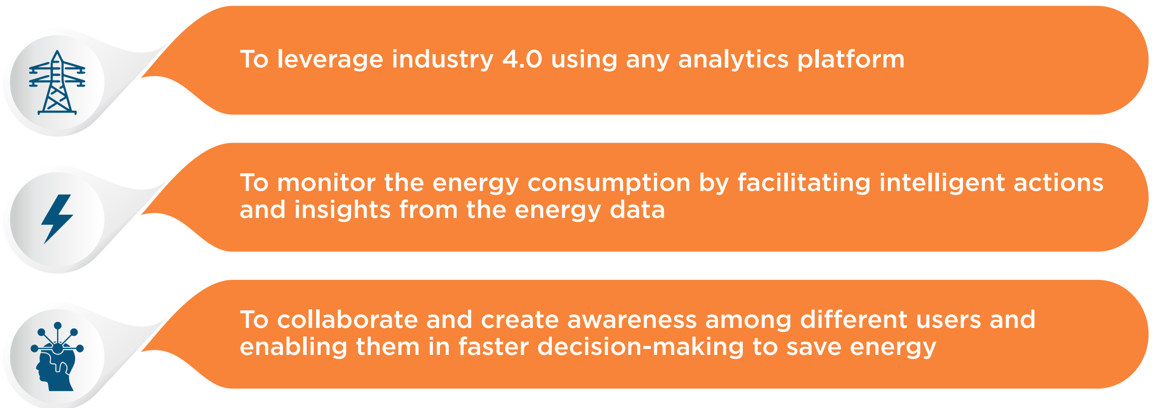


Figure 10: Approach

The uniqueness of the project was Microsoft Power BI with AI tool. The complete configuration was conceived and developed in-house in three stages.

- Data Acquisition and cleansing.
- Data Modelling.
- Data visualisation and analysis using Data Analysis Expressions (DAX).

Demonstration

The foremost step was to create a blueprint of the action to be taken. A digital stack consisting of digital threads or subunits was arranged in an orderly manner that would replicate the sequences of steps to be taken (Figure 11). The outcome of the stack was to concisely develop indicators for monitoring and decision-making. The outcome of such an exercise led to the generation of pre-processed data in a systematic manner which was then ready for further action. The acquisition of energy and process data so derived was loaded in Power BI for data modelling.

The use of Data Analysis Expressions (DAX) helps in creating new parameters within the dataset for ease of visualisation. Ultimately with Power BI's dynamic charts and other visualisation tools, data can be observed in a clean manner with drill-down options, allowing the user to gain deeper insights. The software also has a powerful AI tool that works like Google, providing easy answers to specific questions about the data (E.g. Total consumption in a particular section, date, etc).

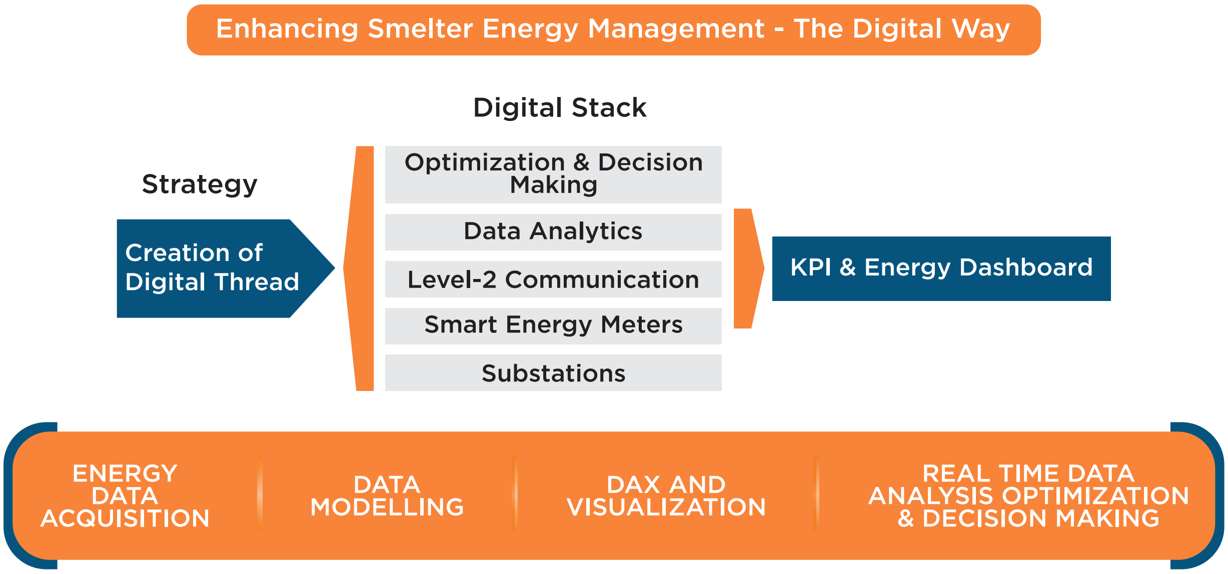


Figure 11: Solution

Results

After the implementation of Power BI in data analytics, the inefficiencies mentioned above were successfully mitigated. There was a reduction in auxiliary energy consumption in the smelter to the tune of 11.07 kWh/T in the Gas Treatment Centre ID Fan (depicted in Figure 12). Apart from this, there is a reduction in energy consumption in the areas of the compressed air system.

- BI helped in predicting the excess energy usage among the running ID fans with different combinations (3 W + 1 S)
- Insights helped in saving Auxiliary energy consumption in GTC – 10 kWh/t*

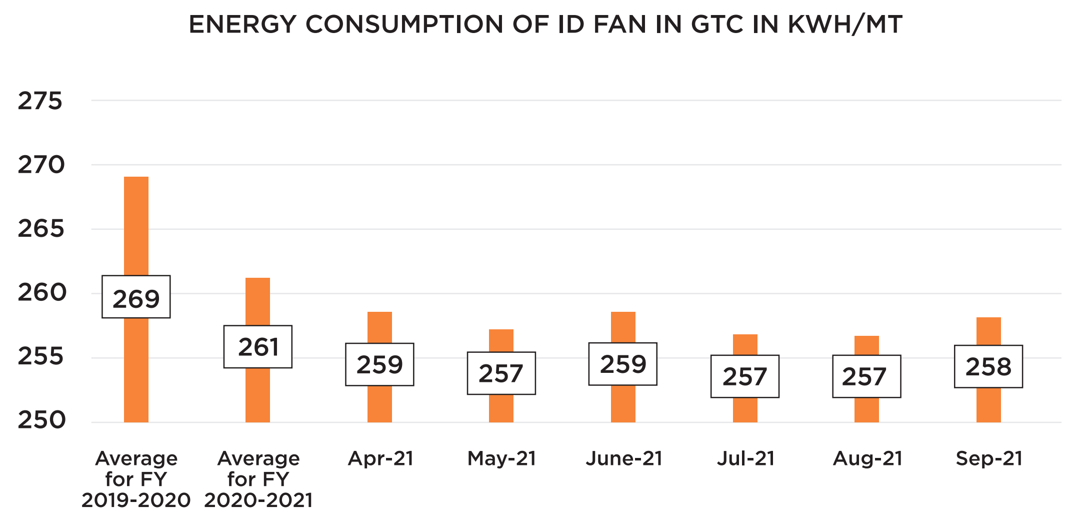


Figure 12: Energy Savings

Potential Opportunity for India

The Indian Aluminium industry **is the second largest producer** in the world with a share of ~**5.3%** of the global output. Indian aluminium industry is thriving at an enviable growth rate of **7%** per annum, which is one of the highest in the world. The Aluminium sector is one of the designated sectors covered under Bureau of Energy Efficiency's (BEE) Perform, Achieve, Trade (PAT) scheme. The fourteen industries from aluminium sector, covered under the PAT scheme, cumulatively consume **10.85 MTOE** and emit **37.13 $MTCO_2e$** annually. These industries offer an energy saving potential of **1.06 MTOE** and decarbonisation potential of **3.63 $MTCO_2e$**.

Aditya Aluminium demonstrated how utilisation of energy analytics platform based on power BI and AI helped in identifying inefficiencies in their energy usage and take corrective action to reduce consumption and cost associated with it. The use of Power BI enabled them to gather and analyse data from various sources, including energy usage data from meters, sensors, and other devices. This also allowed them to monitor energy consumption in real-time and identify patterns and trends that would have been difficult to detect otherwise.

Other Aluminium industries in India may also consider implementation of energy analytics platform for real time monitoring to minimise consumption, reduce wastage and achieve operational efficiencies. Implementation of such innovative measures not only helps the organisation in improving their bottom line, but also helped to reduce their carbon footprint and contribute to a more sustainable future.

Conclusion

Leveraging the integration of Microsoft Power BI with AI for energy analytics holds the potential for substantial cuts in auxiliary energy consumption, providing a scalable and replicable solution applicable across the entire Indian aluminium industry. By leveraging data-driven insights, Aluminium manufacturers can improve their competitiveness, sustainability, and resilience in an increasingly challenging market landscape.

SECTION 2
CEMENT SECTOR

CEMENT SECTOR

2.1 Cement Sector: Low Carbon Multi-Component Cements for UK Concrete Applications

Introduction

In the UK, Portland cement CEM I is utilised in either its pure form or blended with secondary materials to produce low carbon cements. CEM I consists mostly of Portland cement clinker, which is high in embodied carbon. The Mineral Products Association (MPA) identified that limestone remains underutilised in the UK and could be combined with ground granulated blast furnace slag (GGBS) or fly ash in new low carbon multi-component cements. The use of limestone in these cements would lessen the burden on supplies of fly ash and GGBS without compromising performance. It has been calculated that a clinker-GGBS-limestone cement could potentially achieve a reduction in carbon of up to 60% vs Portland cement CEM I[3]. If fully deployed this would result in a reduction in direct emissions from cement production of over 4 million tonnes of CO_2 every year. In this project, MPA[4] and project partners developed, manufactured, and demonstrated 22 new clinker-fly ash-limestone and clinker-GGBS-limestone cements. All cements completed rigorous laboratory testing in concrete and five cements were selected for a precast concrete manufacturing trial and installation. Following this, a proposal to revise the British standard for concrete (BS 8500) was made to the British Standards Institution and accepted.

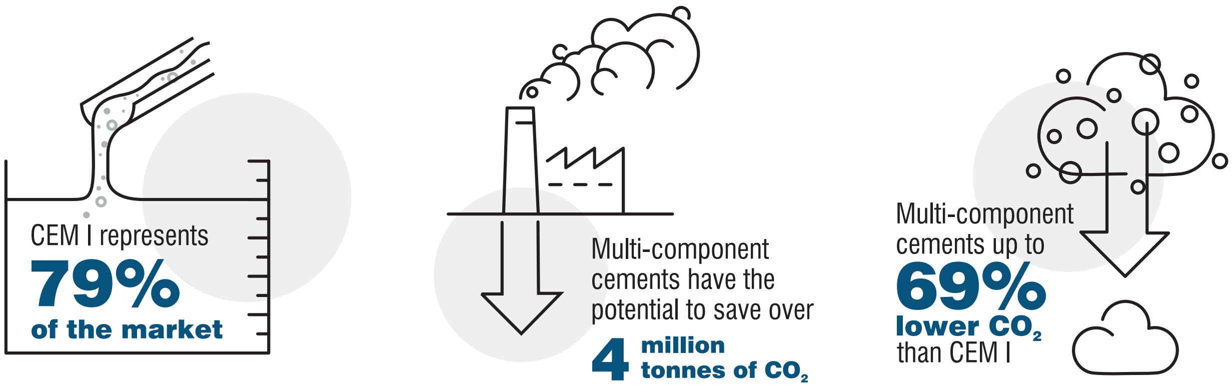


Figure 13: CEM I production and potential CO_2 savings with multi-component cements

About the innovation

Multi-component cement is defined as cements containing more than one secondary ingredient. In this project, focus was given to two main groups of multi-component cements: clinker-GGBS-limestone and clinker-fly ash & limestone. To optimise multi-component cements, attention needs to be paid to the grinding of the individual components as well as the proportions of components in the blend. This was investigated for both clinker-GGBS-limestone and clinker-fly ash limestone (Figure 13). Cement compositions 19 - 22 (designated CEM VI) were calculated to have 60% less embodied carbon compared with Portland cement CEM I.

3 UK: cement manufacture CO2 emissions | Statista
4 MPA-UKC Roadmap to Beyond Net Zero: 2020

To influence the relevant standards and guidance, demonstration of 'fitness for purpose' of any non-traditional material is necessary usually through rigorous testing or industry trials. While testing in a laboratory may provide sufficient evidence for the revision of standards, additional evidence from manufacturing trials may be key for increasing confidence amongst designers, specifiers, and clients. In addition to a laboratory test programme, it was proposed to carry out a full-scale manufacturing trial of precast concrete elements and to install in a challenging exposure environment (i.e., soil containing high levels of sulphates).

To examine possible variations in performance from different constituent materials, several candidate cements were replicated but with varied constituents. These were:

Group A	(different sources of fly ash)
Group B	(varying fineness of limestone)
Group C	(different sources of CEM I)
Group D	(different sources of GGBS)
Group E	(different sources of limestone)

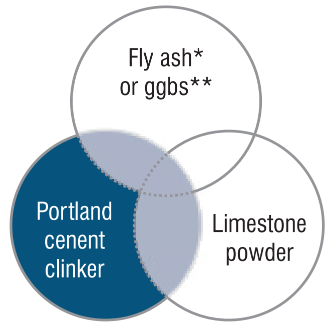


Figure 14: Design concept for low-carbon multi-component cements

The cements were proportioned and produced at Hanson Cement's laboratory in Scunthorpe UK using a large-scale laboratory blender, to produce approximately 50 kg of each cement. The effect of different source materials was studied by testing the compressive strength of standard mortar prisms manufactured using the relevant cements from each group where proportions were fixed, but source materials were changed.

The Demonstration

A series of trial concrete mixes were carried out at the Building Research Establishment (BRE) laboratory using each of the new cements to meet the minimum requirements for two generic concretes – one normal strength and one high strength. These two concrete mixes also used parameters that met the minimum BS 8500 requirements for Design Chemical Classes 2 and 4 (DC-2 and DC-4) for established cements CEM II/B-V + SR and CEM III/A + SR at the recommended consistence class S3. In addition to compressive strength, a suite of durability tests were carried out which include: dimensional stability (BRE in-house prism method), natural carbonation resistance, sheltered exposure (BS EN 12390-10:2018), accelerated carbonation resistance (prEN 12390-12), sulfate resistance (BRE in-house method), chloride migration (prEN 12390-18), accelerated freeze-thaw resistance (scaling test) (PD CEN/TS EN 12390-9:2016) and alkali silica reaction (amended version of BS 812-123:1999).

Five of the 22 cements were selected to produce five reinforced concrete retaining wall elements (Figure 14-15). An additional three reference retaining walls were produced with the three reference cements (CEM I, CEM II/B-V + SR and CEM III/A + SR). Eight precast concrete retaining walls with overall dimensions 1m (w) x 1m (d) x 2m (h) were designed and manufactured for installation on concrete blinding with restraint brackets used to join the units. The retaining wall units were backfilled with sulphated soil. Brief access to the site has been arranged every 3-5 years to extract small samples (cores) from the concrete units for chemical analysis. The data obtained from the demonstration phase will be compared with the laboratory programme to further validate the performance of the new multi-component cements for UK concrete applications.

Figure 15: Sequence of backfilling retaining walls with sulphated soil (clockwise from top left)

Results

All new cements successfully demonstrated that they meet the minimum strength requirement of 20 MPa at 28 days for normal strength concrete and 40 MPa at 28 days for high strength concrete. The durability performance of the new cements in generic BRE concrete mixes was successfully characterised and understood. A good relationship between compressive strength and carbonation depth was observed, in keeping with the relationship already established for traditional UK cements. All cements, except for one outlier, have shown excellent resistance to chlorides, freeze-thaw, and alkali-silica reaction. The compressive strength for MCC1 demonstrated was identical to the reference (CEM III/A). This demonstrates clearly that limestone powder saves on ggbs without any compromise in performance. MCC2 demonstrates material efficiency at work whereby performance is slightly improved with less clinker in the cement. MPA has verified that multi-component cements can reduce the embodied carbon of concrete by up to 60% vs. Portland cement CEM I, the current market leader (Fig 16). Calculations are based on the established values of embodied carbon for each of the multi-component ingredients.

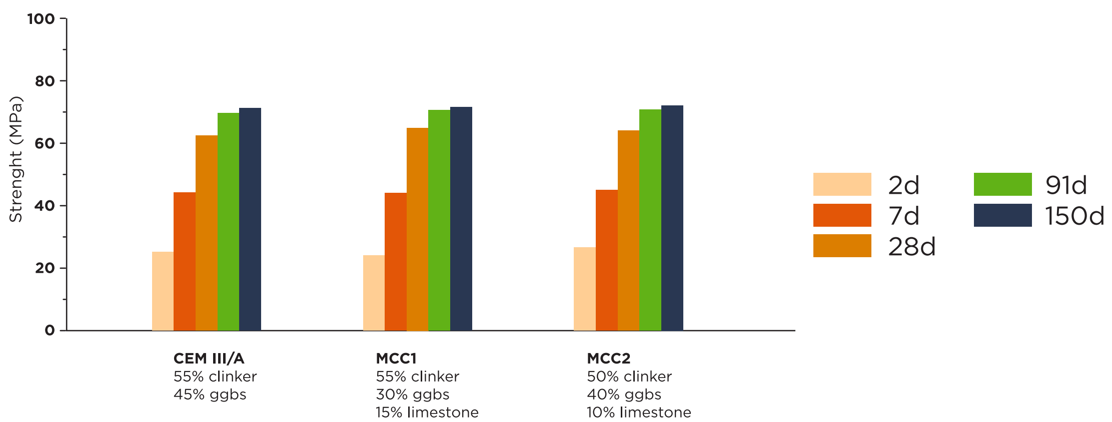
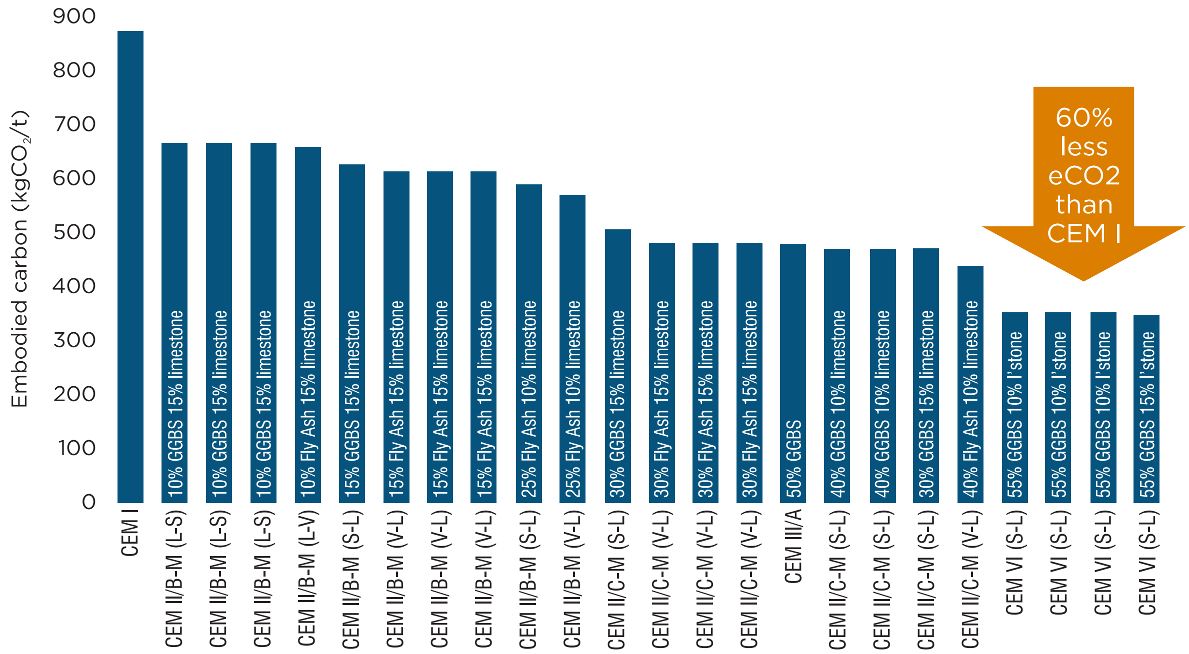


Figure 16: Compressive strength test data for multi-component cement concretes vs. the reference CEM III/A



[MPA Cement Factsheet 18,2019]

Figure 17: Figure 17: Embodied CO_2 of the tested cements versus Portland cement CEM I

Potential Opportunity for India

India is the second largest producer of cement in the world, accounting for more than 7% of global installed capacity. Currently, the Installed Capacity of Cement in India is 500 MTPA producing 298 million Tonnes per annum. Considering the increase in the growth of infrastructure, cement production in India is expected to be 500 million Tonnes by the year 2020 and 800 million Tonnes by 2030[5]. The cement industry has voluntarily devised a Low Carbon Technology Roadmap aimed at reducing its direct CO_2 emission intensity by 45% by 2050 from a 2010 baseline. The International Energy Agency (IEA) estimates that around 3.7 GJ energy and 0.83 tonnes of CO_2 can be saved per tonne of clinker displaced[6]. Comparable low-carbon multi-component cement products developed for Indian production present a significant opportunity for the Indian cement industry to reduce the CO_2 intensity of cement production.

Conclusion

Embracing the innovation of low-carbon multi-component cement, as successfully demonstrated in the UK, presents a pivotal opportunity for the Indian cement industry. By aligning with India's Low Carbon Technology Roadmap, the adoption of such advancements can propel the sector towards achieving substantial carbon reductions, reinforcing its commitment to global initiatives aimed at mitigating the environmental impact of cement production.

(Note: The demonstration project was funded by the UK Department of Business Energy and Industrial Strategy (BEIS) through the Industrial Energy Efficiency Accelerator Programme.)

5 Cement | Bureau of Energy Efficiency (beeindia.gov.in)
6 Energy Technology Perspectives 2017 – Analysis - IEA

2.2 Cambridge Electric Cement: A Zero-Emissions Breakthrough

Introduction

Concrete is the most widely used material on earth, after water, and it is fundamental to our way of life, our economy and shaping our world. However, the chemical and thermal combustion processes involved in the production of cement are a significant source of carbon dioxide (CO_2) emissions – with more than four billion tonnes of cement produced each year, accounting for around seven per cent of global CO_2 emissions, according to the Global Cement and Concrete Association (GCCA)[7]. Replacing today's cement is one of the hardest challenges on the journey to a safe climate with zero emissions. There are many options to make cement with reduced emissions, mainly based on mixing new reactive cement (clinker) with other supplementary materials. However, until now, it has not been possible to make the reactive component of cement without emissions. Recently three engineers at the University of Cambridge, Dr Cyrille Dunant, Dr Pippa Horton and Professor Julian Allwood, have filed a patent and been awarded new research funding for their invention of the world's first emissions-free route to recycle Portland cement.

Created at the University of Cambridge, Cambridge Electric Cement is the world's first truly zero-emissions Portland cement. The inspiration for Cambridge Electric Cement struck inventors when they noticed that the chemistry of used cement is virtually identical to that of the lime flux used in conventional steel recycling processes. The new cement is therefore made in a virtuous recycling loop, that not only eliminates the emissions of cement production, but also saves raw materials, and even reduces the emissions required in making lime-flux.

The product

The Cambridge Electric Cement process begins with concrete waste from demolition of old buildings. This is crushed, to separate the stones and sand that form concrete from the mixture of cement powder and water that bind them together. The old cement powder is then used instead of lime-flux in steel recycling. As the steel melts, the flux forms a slag that floats on the liquid steel, to protect it from oxygen in the air. After the recycled steel is tapped off, the liquid slag is cooled rapidly in air, and ground up into a powder which is virtually identical to the clinker which is the basis of new Portland cement. In pilot-scale trials of the new process, the Cambridge team demonstrated this combined recycling process, and the results show that it has the chemical composition of a clinker made with today's process.

Figure 18: Electric Arc Furnace (EAF) steel recycling process. For the Cambridge Electric Cement process, this material will be cooled to make Portland Cement clinker

7 The Global Cement and Concrete Association (GCCA)

A problem of scale

Any solution needs to not only work, but it needs to also be scalable with a reasonable expectation of the speed of deployment and expansion. Having demonstrated that the product works and performs as well as Portland cement, it is now being trailed at the industrial scale in the Cement2Zero project. Around £6.5m of Innovate UK funding has been awarded to trial the Cambridge Electric Cement product at the industrial scale with a consortium of leading industry partners from across the sector. Led by the Materials Processing Institute, supported by the University of Cambridge (UoC), and in collaboration with key players in the supply chain, Cement2Zero is the first collaborative trial of its kind, to address the global construction industry's biggest challenge of decarbonisation, in response to the climate emergency (Figure 19).

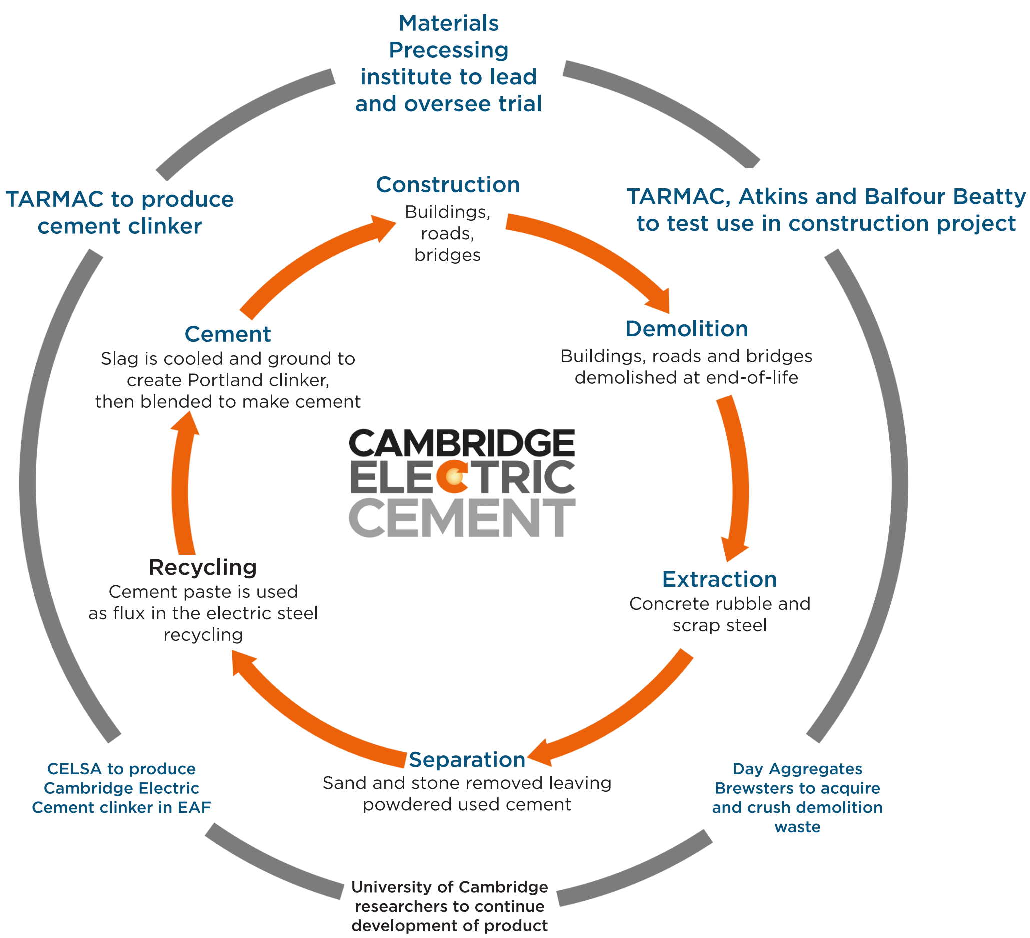


Figure 19: The Cement2Zero project

Industrial Trial

The Cement2Zero project will investigate both the technical and commercial aspects of upscaling Cambridge Electric Cement (CEC) production to produce 20 tonnes of the world's first zero-emissions cement. The first phase of trial melts is being carried out by the Materials Processing Institute, initially in an 800kg induction furnace, before being scaled up to 6T in an Electric Arc Furnace (EAF). Once the process has been substantially trialled, developed and de-risked effectively, industrial-scale melts will follow in CELSA's EAF in Cardiff.

The two-year industrial trial will test each stage of the production process and brings together the expertise of the Materials Processing Institute, the University of Cambridge and key supply chain partners – Atkins, Balfour Beatty, CELSA, Day Aggregates and Tarmac – before using the innovative product in a live UK construction project. The strength of the first cement produced by the project is currently being tested and results will be shared shortly. The success of this project can not only further advance the cement, steel, and construction industries, but influence how we recycle, construct, and maintain our built environment and transport infrastructure, shaping the future of towns and cities, whilst simultaneously boosting economic development, and most importantly, reducing CO_2 emissions to help tackle global warming. The adoption of Cambridge Electric Cement can have a significant impact on the country's carbon emissions. In addition to reducing emissions, it will also help to conserve resource and reduces the need for virgin materials.

Cambridge Electric Cement is a collaboration between the Universities of Cambridge, Warwick and Imperial College London and is funded by EPSRC. Cement2Zero is led by the Materials Processing Institute, supported by the University of Cambridge (UoC), in collaboration with Atkins, Balfour Beatty, Celsa, Day Group and Tarmac, and is funded by Innovate UK and UKRI.

Conclusion

Cambridge Electric Cement paves the way for mitigating the environmental impact of cement production by offering a zero-emissions alternative, driven by efficient recycling processes. The ongoing industrial-scale trials within the Cement2Zero project hold significant promise for the Indian Cement Industry, providing a valuable opportunity to embrace sustainable practices and contribute to a greener future.

2.3 Decarbonising Cement Production: Carbon Re's AI-based Delta Zero Cement Platform

Introduction

Carbon Re is an AI for materials company on a mission to reduce carbon emissions by gigatonnes every year through the use of AI technology. A joint spin-out of Cambridge University and University College London (UCL), it is focusing on decarbonizing cement and other foundational materials (such as steel and glass). Carbon Re's first product, Delta Zero Cement applies the latest advances in artificial intelligence (AI) and machine learning (ML) to optimise fuel use and quality in cement production. Key features and functions of Delta Zero (Figure 20) include:

- Open and closed loop - Delta Zero provides specific and quantified recommendations and predictions that can be fed directly to the expert system or advanced process control (APC) system with no action required by the control room. For clients with manual kilns, a "human-in-the-loop" system is used, where the control room operator manages the optimisation recommendations.
- API layer data integration – Delta Zero connects directly to the plant via a secure API interface, providing the AI agents with access to the live status and data of the plant.
- Digital twin – Using the plant's existing data, Delta Zero software creates and maintains an accurate model specific and bespoke to the plant.
- Recommendation engine – Delta Zero provides specific and quantified setpoint recommendations. Example recommended settings include kiln feed rate (tonnes/hour), fan speed (rpm) and Preheater Cyclones (PC) temperature (ºC) (Figure 21).

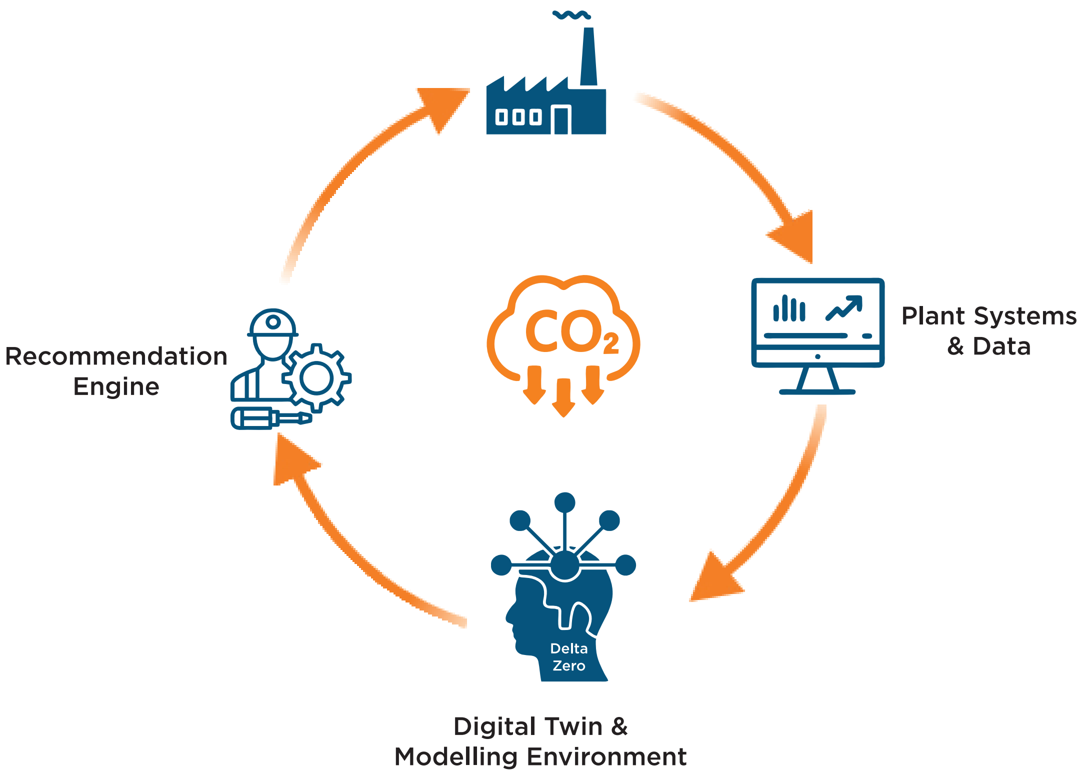


Figure 20: Key features and functions of Delta Zero

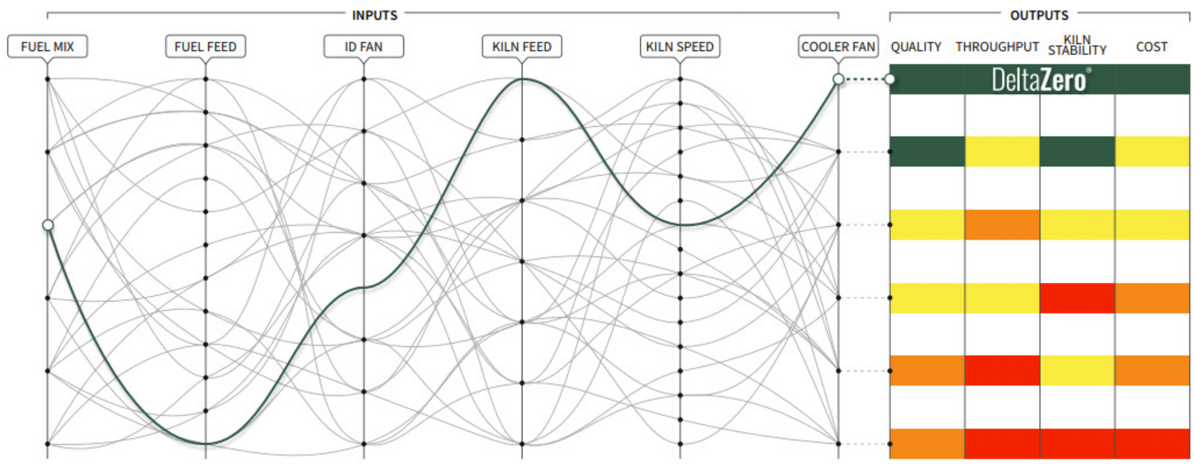


Figure 21: Illustrative input and output parameters for recommendation

Delta Zero for Cement Sector

Cement production is a remarkably complex process with ever-changing inputs (fuels, raw materials), conditions (state of equipment, shift changes), and competing priorities (throughput, control limits). Carbon Re's Delta Zero Cement (AI and ML-based software platform) simulates the chemical and physical processes in a plant, enabling AI agents to find solutions tailored to each plant. The software analyses feed rates, sensor data and control parameters to provide clear quantified recommendations to reduce the mass of CO_2 emitted per useful heating value ($kgCO_2$/UHV). Delta Zero Cement (AI and ML-based software platform) enables lower fuel costs and lower emissions.

Delta Zero Cement is powered by Deep Learning, a powerful branch of artificial intelligence that can efficiently handle complex relationships and provide effective pathways for process optimisation. This brings advanced AI tools to cement plant operations, enabling significant efficiencies, cost savings and emissions reduction, without CAPEX. Delta Zero Cement is being deployed with customers across Europe and the Americas.

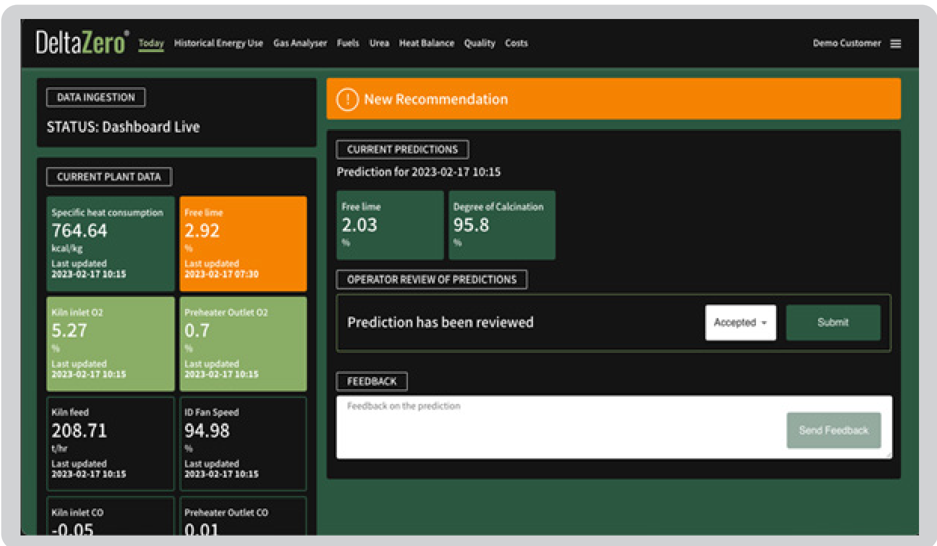


Figure 22: Illustrative Dashboard for Delta Zero

The Key Features of Delta Zero Cement Include:

- Live forecast and quality metric predictions from the current operating parameters such as Free Lime % and heat balance
- Adaptable outcomes to customer market conditions: Recommendations and predictions work on a live or daily basis, using the latest operating data. They are customisable to current priorities whether that is maintaining throughput or maximising cost savings.
- Regular insight into the trends and performance of plant from detailed analysis of the operating data
- Plant controls: Ability to set control limits to keep parameters such as kiln torque and NOx emissions within desired parameters, improving kiln stability.
- Data visualisation: The platform analyses and visualises key operational data for the cement plant including Clinker production (tonnes), Specific Heat Consumption (kcal per kg clinker), Kiln Torque, actual Torque limits exceeded (%), NOx Emissions (actual), NOx limits exceeded (%), Raw Mill Chemistry, Clinker Quality, Recommendation tracking actual selections vs recommendations (Figure 22).

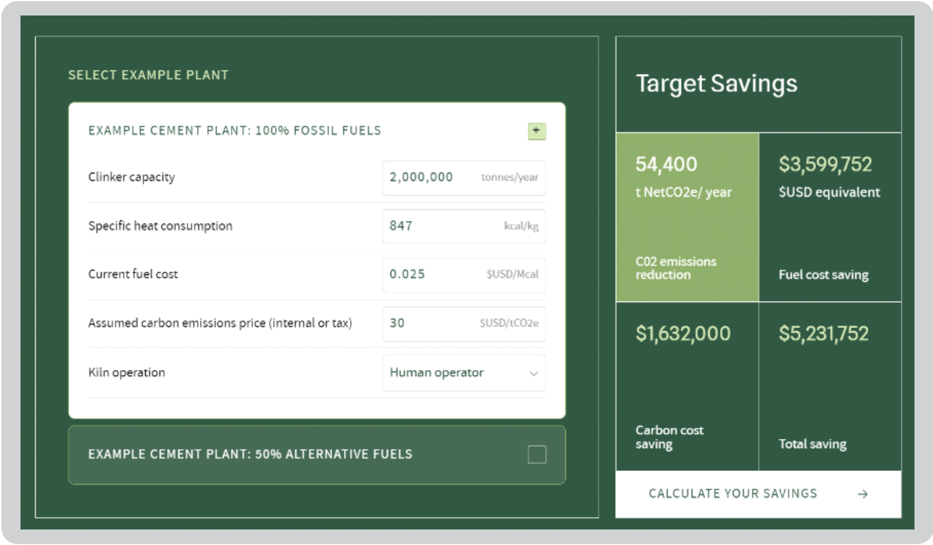


Figure 23: Delta Zero Savings Calculator

Delta Zero Cement is fast and easy to deploy, with no capital/ hardware instalments. As a cloud-based platform, it can easily integrate with an existing distributed control system or an 'Expert System' to set optimum efficiency parameters. Deployment of Delta Zero Cement can deliver potential benefits like **a) up to 5% reduction in carbon emissions through optimisation of fuel usage, b) $3-10M savings per kiln line per year, c) up to 5% reduction in fuel costs, and d) break even on investments within year one and up to 4x returns by year 3 and beyond**. Cement companies can also get a customised calculation of the potential savings in their plant through a savings calculator developed by Carbon Re (Figure 23).

For more information: Cement Decarbonization & Sustainable Alternatives - Carbon Re

Conclusion

The seamless integration of this technology in the Indian Cement Industry not only fosters efficiency but also aligns with the industry's pursuit of a net-zero target, showcasing a transformative approach towards sustainable and cost-effective cement production. By leveraging the technology, cement manufacturers can reduce overall cost, enhance their product quality, and derive innovation thereby strengthening their competitive position in the market and contributing to the industry's long-term growth and sustainability.

2.4 Waste Heat Recovery from Kiln and Cooler Stacks At Hanson Cement Plant, UK

Introduction

Hanson Cement is a UK-based cement production company, owned by Heidelberg Cement. The Padeswood Kiln (owned and operated by Hanson) was commissioned in 2005 and was uniquely designed to burn alternative fuels for the clinker production process making it one of the most modern Kilns in the UK. The Kiln has the capacity to produce 2,650 tonnes per day of cement clinker and consumes an average of 10 MWh per hour of electricity. Due to the modern design, the plant currently recovers surplus heat to dry the coal used to fire the kiln and preheat the raw meal mix.

Waste heat recovery feasibility study

Through UK government funding programme support, a feasibility study for waste heat recovery was undertaken. The study findings verified that a larger amount of heat could be recovered for onsite electricity generation. With the potential to reduce the site's electrical load from the grid by 45 % and associated CO_2e savings of 11,341 Tonnes per year, Hanson Cement intends to progress to the next stage of preliminary engineering with continued support under the UK government program.

Impacts and benefits realised

At the outset of the project, it was expected that the existing equipment would be replaced with a more modern thermal oxidiser, which would be coupled with a heat recovery solution, evaluated through this feasibility project. As work proceeded, it has become apparent that an alternate technology, namely solvent recovery equipment driven by a small-scale Combined Heat and Power (CHP) plant, has the potential to further reduce the environmental footprint and provide an improved commercial proposition compared to all the thermal oxidiser/heat recovery options. Such potential could not be ignored and so, alongside regenerative thermal oxidation and heat capture, Hanson evaluated the technology in parallel and it has become the anticipated preferred option at the conclusion of the feasibility study.

Figure 24: Padeswood Kiln and Cement Plant

Conclusion

This technology holds the potential to significantly reduce onsite electricity reliance on the grid, making it a viable option for Indian industries to curtail their carbon footprint. It offers win-win solution for cement plants offering economic, environmental, and operational benefits that contribute to more sustainable and competitive landscape. As Indian cement manufacturers continue to prioritise energy efficiency and sustainability, waste heat recovery will play an increasingly vital role in shaping the future of cement production.

Note: This best practice overview has been adapted from the UK Department for Business, Energy, and Industrial Strategy's (BEIS) Industrial Heat Recovery Support (IHRS) programme.

2.5 Superlative Utilisation of Green Energy in Cement Production

Introduction

Udaipur Cement Works Limited (UCWL), is a Public Limited Company, incorporated on 15th March 1993. Its Registered Office is situated in Udaipur, Rajasthan. The Company is a subsidiary of JK Lakshmi Cement Limited (JKLC), a renowned name in the Indian Cement Industry for about four decades having an annual Turnover of about Rs.5100 Crore during Financial Year 2021-22.

The Company's philosophy is based on sustainable growth and a developmental framework that works for a better tomorrow. The Company has an integrated Cement Manufacturing unit with an installed cement production capacity of 2.2 million tons per annum (MTPA). The company has ingrained "Sustainable Development" as one of the key ethos of its daily business activity, led by the Integrated Sustainable Development Policy for its System structures.

In line with the agenda of Climate change and the COP26 commitments made by the nation, today the Company meets more than 45% of its total electricity requirement from green renewable sources, i.e., Solar and WHRS. During FY 2021-22, the Company ramped up its solar power generation capacity by 4.35 MW, in addition to the existing 10.1 MW, further totalling it to 14.45 MW. The Company has also consumed about 100,000 MWh of green energy that has mitigated around 85,000 tons of CO_2 emissions, which is equivalent to 34 Lakh trees mitigating CO_2 emissions/year, during the last 2 fiscal years. Being a resource-responsible corporate, the Company has done considerable work in water conservation and stands around 2 times water positive and has saved about 3.6 lakh tons of virgin-natural resources by replacing them with waste-derived raw materials in the process.

Major milestones achieved and planned by the Company are depicted in Figure 25 that follows:

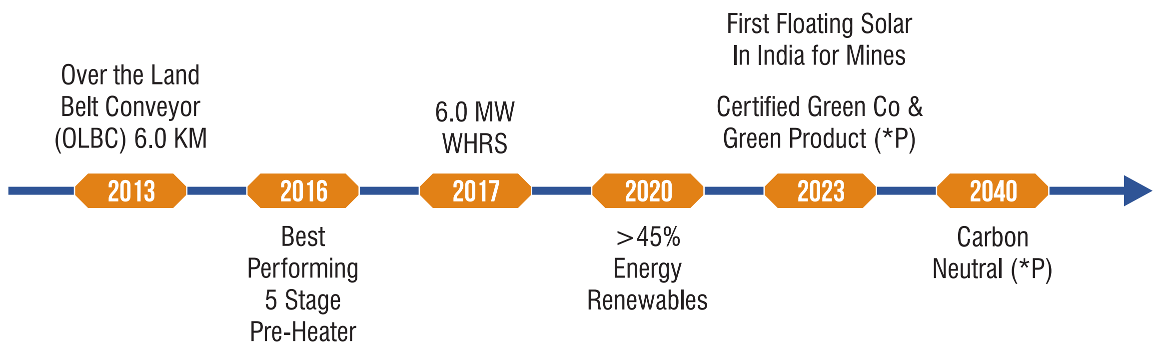
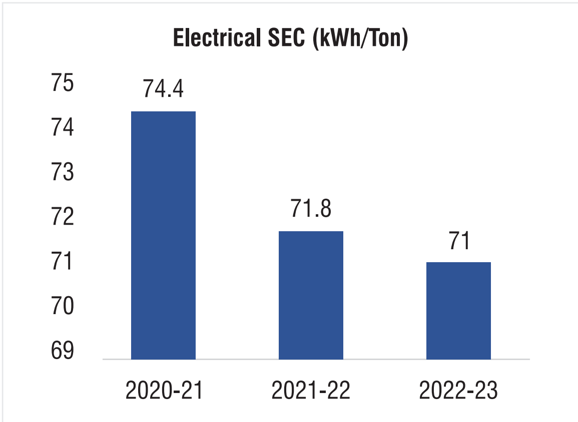


Figure 25: Milestones Achieved

Specific Energy Consumption

There has been a significant energy consumption reduction over the last three years (2020-23) due to the various energy efficiency improvement initiatives taken by the plant:



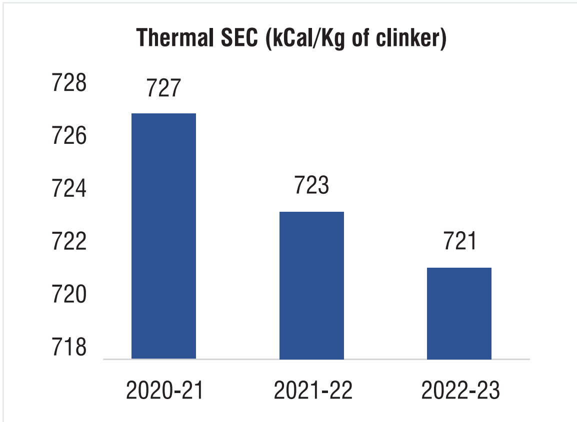


Figure 26: UCWL Energy Intensity (YoY)

Shift from Grid Electricity to Renewable Energy

The electrical energy contributes to 15% of the total energy requirement, UCWL was dependent on the grid supply. To become green and reduce dependency on the grid supply, plant made a strategy to reduce its dependency on Grid Electrical Power up to 50 % of total consumption by Installation of WHRS and Solar PV.

UCWL has enhanced Renewable Energy Resources to increase green power contribution by more than 50%. The current Capacity of WHRS and Solar are 6 MW & 15.45 MW respectively.

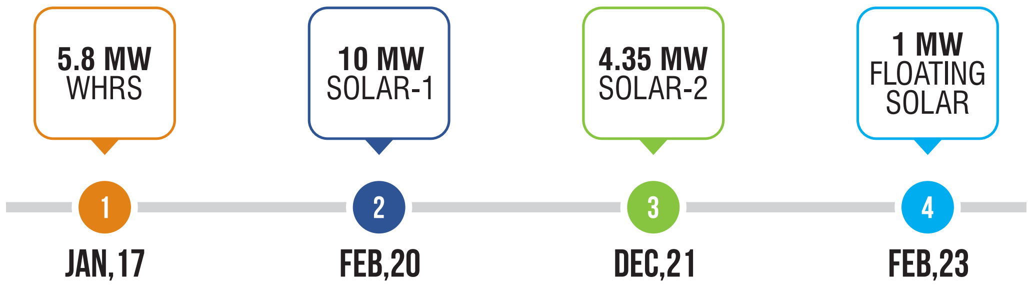


Figure 27: Progressive Journey (Green Energy)

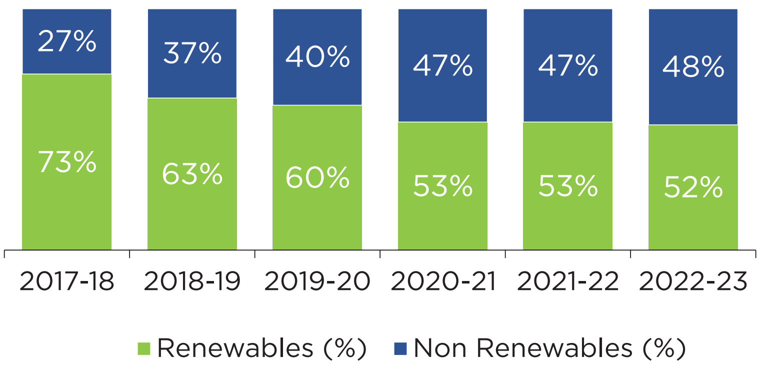


Figure 28: Energy Trend

To make full utilisation of WHRS capacity following modification and improvement jobs were carried out:

- AQC Boiler O/L Duct Pressure Drop Reduction.
- Increase in Pressure and Flow in AQC boiler by controlling Cooler Fans RPM by cascading PID loops with Boiler I/L Temperature.
- Kiln Feed Stage Change from 5th Stage Feeding to 4th Stage Feeding using Splitter Damper in Air Slide.
- Reduced Auxiliary Consumption below 4%.

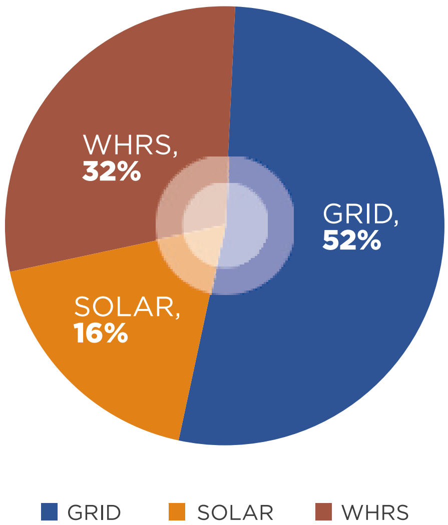


Figure 29: Electrical Energy Mix (%)

Further process Operation is optimised to utilise max Power of Solar in daytime, keeping night hours for maintenance.

Floating Solar Grid

In way forward Floating Solar grid is also Installed in Mines pits to further increase renewable energy share. And this floating solar is 1st of its kind in Indian Cement Industry with approval from Directorate General of Mines Safety (DGMS) and 1st floating solar in Rajasthan.

Scope	Advantages
Environmental savings in terms of water evaporation (Approx)	8000 m^3/Yr
Environmental savings in terms of carbon savings (Approx)	1000 Ton/Yr
Land area savings (Approx)	7200 Sq.mtr
Equivalent Trees savings (Approx)	1.5 Lakhs/Yr
Financial savings (Approx) Rs 25 Cr (25 Yrs)	Rs 25 Cr (25 Yrs)

Figure 30: Solar Energy (Key Highlights)

Use of Emerging Technologies

UCWL has been always taking several initiatives in adopting new and emerging decarbonisation technologies. Few of such technologies deployed by the plant are shown in the Fig.31

Latest Technology developments	Feedback
IOT Sensors for realtime condition monitoring of equipment's	Implemented, Getting alerts
Real-time beltscanning system in OLBC	Implemented, Getting alerts
Online Particle Size Distribution system formills	Implemented Getting feedback of product quality
AI-based "Advanced Process Control Suite" for kiln & mills optimization	Implemented Getting feedback to produce desired production quality
Use of AI-ML enabled Maintenance & Equipment Feedback	Being explored

Figure 31: Emerging Technologies adopted by the plant

Mitigating Climate Change-Carbon Emissions

The impact of various initiatives taken by the plant management has resulted in the reduction of GHG emissions from 593 to 562 kg CO_2/ Tonne Cement equivalent during the 2018-21 period. This has been achieved by increasing blended cement by 20%, increasing RE share and improving energy efficiency and increasing the use of Alternate Fuel and reducing 15 % coal consumption.

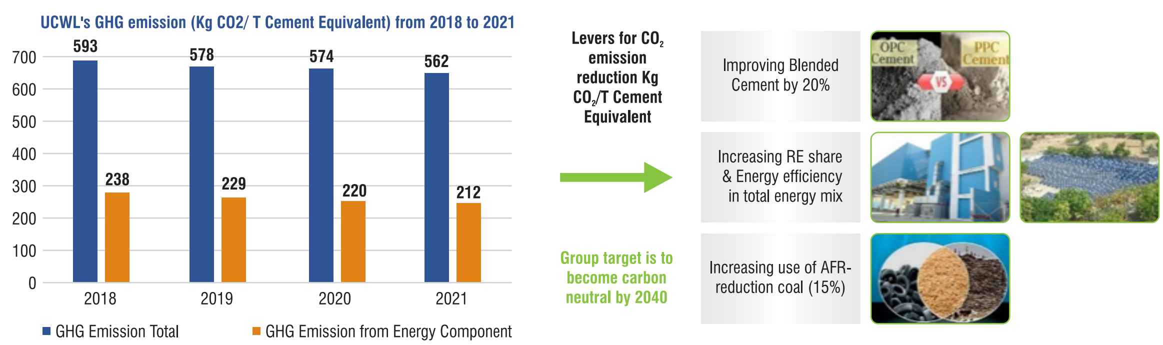


Figure 32: Mitigating GHG Emissions

Conclusion

Green energy initiatives, such as floating solar, presents a forward-thinking and environmentally responsible solution for the Indian cement industry, offering economic, environmental, and social benefits. As Indian cement industry continues to prioritise responsible manufacturing to reduce its carbon footprint, floating solar emerges as a viable and impactful strategy for deriving the positive change.

2.6 Carbon Capture Technology Decarbonising the Cement Industry: Carbon8, Vicat Case Study

Introduction

In 2020 Carbon8 deployed its first commercial CO_2ntainer to the Vicat Group cement plant in Montalieu, France. Carbon8 is a UK-based cleantech company with a carbon capture technology that can help the global cement industry and other heavy industries to decarbonise, using industrial residues produced onsite as inputs into the process. The outcome is a permanent carbon capture, utilisation and storage (CCUS) technology that provides a circular solution to industrial wastes while helping hard-to-abate industries reach Net Zero and achieve their Zero Waste ambitions.

Carbon8's award-winning technology solution is the outcome of over 25 years of research, turning captured carbon and industrial residues into new materials for the construction industry. The technology is housed in the CO_2ntainer, two 40ft shipping containers that are retrofitted into industrial sites. The CO_2ntainer provided Vicat with a solution to their increasing quantity of cement bypass dust (CBD) while contributing to the decarbonisation of their operation and manufacturing a sustainable aggregate that can be directly integrated into their concrete production.

> **"With the CO2ntainer system, Vicat kills two birds with one stone. At the Montalieu-Vercieu cement plant, we are now able to upcycle chlorinated dust, with some of the CO2 emitted during the manufacture of cement, by turning it into a new construction material."**
>
> **- Laury Barnes-Davin, Scientific and R&D Director Vicat Group.**

The Challenge

Vicat is a French multinational company that manufactures cement, concrete, and aggregates, headquartered in France with operations in over 12 countries. Vicat Group aims to be climate neutral by 2050, which includes using 100% Alternative Fuels. The Alternative Fuel sources being considered are a precise mix of Refuse Derived Fuel (RDF), sewage sludge, wood, and polyurethane (PU) foam waste. The use of Alternative Fuels was accompanied by rising levels of chloride, which required a bypass system, producing CBD. Vicat Group needed a solution for the CBD by-product that would help them move to a more sustainable operation and reach their climate targets.

Carbon8 Solution

The CO_2ntainer is the realisation of Carbon8's award-winning Accelerated Carbonation Technology (ACT) as a compact, mobile CCUS solution. Its innovative Plug 'n Play system allows for seamless integration and transportation across the globe in two 40FT CO_2ntainers. The CO_2ntainer captures CO_2 at the source, which becomes an ingredient to carbonate industrial residues destined for landfill. The solution is able to treat up to 12,000 tonnes of residues annually in the process. Housed inside the CO_2ntainer, ACT enables the production of carbonated products for the construction industry. This includes carbon-negative aggregate, which has a variety of applications including in cement blocks, road fillers and green roofing substrates.

Figure 33: CO_2ntainer at Vicat

Deployment at Vicat Group cement plant in Montalieu France

Two stacked 40ft containers at Montalieu house (Figure 33) the Accelerated Carbonation Technology (ACT), which uses CO_2 taken directly from the plant's flue gas and its CBD as feedstock to manufacture CircaBuild products directly onsite. CircaBuild are a carbon-negative alternative to virgin aggregate with various applications in construction. Carbon8 is providing Vicat with an economic and circular solution to CBD while acting as a decarbonisation lever.

How does it work?

Flue gas is extracted from the main flue stack, cooled, and passed through the processing equipment in the CO_2ntainer. The concentration of CO_2 in the flue gas is typically 10 - 20%, which is sufficient for the technology. The solution can operate using flue gas-derived CO_2 (as at Vicat) or by using bottled pure CO_2. At Montalieu, the CBD is transported to the CO_2ntainer by truck, where it is first stored in a silo for batch processing. The two waste streams are treated within the CO_2ntainer, where the carbonation process takes 15-20 minutes. The conveyer belt at the rear transports the carbonated products – CircaBuild - out of the system and directly onto trucks for transportation.

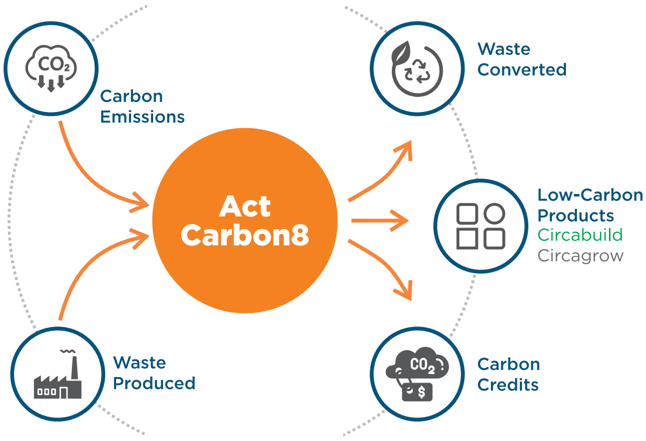


Figure 34: Input and output process for ACT Carbon8

The CO_2ntainer Overview:

Carbon capture	**Direct carbon capture from flue stack, 1,500 tonnes- 4,000 tonnes CO_2 annually**
Cloud-connected	Industry 4.0 capability
Waste utilised	Treats and utilises up to 12,000 tonnes of residue annually
Output	Manufacture up to 16,000 tonnes of CircaBuild carbon-negative aggregate annually
Integration	Seamless installation, retrofittable with minimal downtime

The Outcomes

Following the deployment of the CO_2ntainer, Vicat Group became an investor in Carbon8 in 2022. Together with EDF Group and its corporate venture capital arm, EDF Pulse Ventures, they co-invested £4m. The commercial deployment of Carbon8's CO_2ntainer at Montalieu is a demonstration of Vicat Group's commitment to achieving carbon neutrality by 2050 across its value chain, and the technology is seen by Vicat Group as a key enabler to reducing carbon emissions.

Following the deployment, Carbon8 and FLSmidth, the Danish OEM, signed an exclusive partnership to deploy the solution to the global cement industry, to accelerate the adoption of our technology, furthering the transition to a greener cement industry. Through establishing a close working relationship, Vicat Group and Carbon8 are unlocking the increased use of alternative fuels by providing a sustainable solution to CBD, whilst decarbonising and enabling circularity in Vicat Group's operations. The two companies have set a benchmark for the cement and construction industries.

Potential Opportunity for India

India is the second largest producer of cement in the world, with an installed capacity of 500+ million metric tons per annum (MTPA). Carbon8's technology can help the Indian cement industry to reduce its emissions and decarbonise. The technology can be used to capture carbon dioxide from the flue gas of cement plants and then use it to produce sustainable materials for the construction industry. This would help the Indian cement industry to meet its environmental goals and contribute to India's efforts to combat climate change.

Conclusion

The journey towards carbon capture in the cement industry requires collaboration, innovation, and commitment from all stakeholders involved – from policymakers to industry leaders, researchers, and civil society groups. All the stakeholders must work together to overcome technical and financial barriers to implement and create an enabling environment for carbon capture projects to thrive.

2.7 Co-processing of Spent Pot Lining (SPL) Mixed Fines in Cement Plants - A Sustainable Solution – By Dr. Alka Mishra, Rajiv Sadavarti and G V Ramakrishna, Dalmia Cement (Bharat) Limited, New Delhi

Introduction

The disposal of waste is an expensive and painstaking process. One of the major challenges in the present scenario is to utilise hazardous wastes judiciously that are being generated during the production process in Iron and Steel, Petroleum, Aluminium, Power, and other sectors.

Dalmia Bharat Group follows the business philosophy of 'Clean & Green is Profitable and Sustainable' to create positive environmental and social impacts, by replacing conventional fuels and raw materials with alternative solutions. It engages with the Iron and Steel, Petroleum, Aluminium, Power, and other sectors to utilise their wastes. Aluminium smelting is the second most important metallurgical industry in India, which generates hazardous waste, identified as Spent Pot Lining Mixed Fines (SPL-MF) in the primary Aluminium smelting industries.

Dalmia Cement (Bharat) Limited was granted permission from SPCB-Odisha to receive SPL-MF from one of the largest Aluminium Industries in Odisha, for co-processing in the Cement kiln of the Clinkerisation Unit in Odisha . A Trial run was conducted to co-process SPL-MF in a cement plant, as per the guidelines of SPCB-Odisha. Environmental monitoring was carried out by a team of a NABL-accredited lab during the trial run.

The Innovation

One of the major challenges in the Aluminium Industry today is to utilise hazardous waste that is generated during the production of Primary Aluminium from the Alumina Smelting Industries, by segregation of fines from lumps of carbon and refractory portion of Spent Pot Lining (SPL). These fines are referred to as SPL Mixed Fines (SPL-MF) that are categorised as Hazardous waste (S. No. 11.2 of Schedule-I of Hazardous Waste Management (HOWM) Rules 2016) and are required to be disposed of in an authorised disposal facility in accordance with authorisation condition, when not utilised as energy/ resource recovery. It has no energy value but contains a few very valuable components and can be used for specific purposes.

Dalmia Cement (Bharat) Limited Odisha Unit is the first Cement Plant in India to conduct a trial run to co-process SPL-MF, as per the guidelines of the Central Pollution Control Board (CPCB) and State Pollution Control Board (SPCB)-Odisha.

The trial run has been conducted successfully and has resulted in up to 1.0% absorption of SPL-MF in clinker production. However, proper pre-processing of SPL-MF is a must prior to co-processing in a cement kiln. Co-processing needs a separate controlled feeding system to feed into the kiln inlet while maintaining clinker quality and rated production was a challenging task.

Demonstration

Generation: SPL-MF is a waste generated in the primary aluminium smelting industries by the segregation of fines from lumps of carbon and refractory portion of Spent Pot Lining (SPL). Ideally, the generation of SPL-MF is about 16 -18 kg/ MT of Aluminium metal. During pot operation, carbon lining gradually deteriorates with slow penetration of molten melt and the continued operation of the cells/ pots demands the replacement of pot-lining. This replaced pot lining is termed SPL and during the de-lining of pots, fines are generated mixed with lumps of both carbon and refractory portion. These fines are referred to as SPL-MF which is categorised as Hazardous waste and is required to be disposed of in an authorised disposal facility in accordance with authorisation conditions, when not utilised as energy/ resource recovery.

Storage and Handling: Dedicated and authorised vehicle is required to transport SPL-MF from the generator (Aluminium Industry) to the co-processor (Cement Plant). Vehicles must be in completely covered (tarpaulin) condition with requisite safeguards. This arrangement ensured no spillage of waste in accordance with provisions stipulated under Hazardous and Other Wastes (Management & Transboundary Movement) Rules, 2016.

The storage facilities from both ends should be well-ventilated covered sheds having impervious Reinforced Cement Concrete (RCC) flooring within the premises to eliminate rainwater intrusion. There should be garland drains all around the storage shed and the same to be connected to the Effluent Treatment Plant (ETP) for further treatment and recycling.

As per guidelines of HWM Rules-2016, Dalmia Cement (Bharat) Limited, Odisha Unit has a storage facility, and Aluminium Industry in Odisha has the facilities for storage and handling of SPL-MF.

Testing: Multiple samples of SPL-MF were tested in Dalmia Cement lab in Odisha, received from the Aluminium Industry of Odisha. All samples were checked systematically with sophisticated equipment available in the plant laboratory. It has a wide variation in major components. Storage condition and range of chemical composition of SPL-MF are depicted in Table-1.

Table-1 Chemical composition of SPL-MF		
Storage Condition	**Chemical Composition**	
	LOI [%]	10 – 12
	SiO_2 [%]	**30 - 50**
	Al_2O_3 [%]	**20 - 35**
	Fe_2O_3 [%]	2 - 5
	CaO [%]	2 - 6
	MgO [%]	3 - 6
	K_2O [%]	1 - 4
	Na_2O [%]	2 - 6
	SO_3 [%]	0.20 -1.0

As per CPCB guidelines, SPL-MF must meet the concentration limits of Cyanide based on Toxicity Characteristic Leaching Procedure (TCLP) and Fluoride based on Soluble Threshold Limit Concentration (STLC), as specified in Schedule II of HOWM Rules, 2016. Both tests of the composite samples have been conducted in National Accreditation Board for Testing and Calibration Laboratories (NABL) accredited lab and test results are well within the recommended limit (Refer Table-2).

Table-2 Mandatory test results - CPCB March 2021			
Mandatory Requirement (mg/l)		Value	Method of Analysis
Cyanide (TCPL)	20 (max)	< 3.5 mg/l	EPA 1311, APHA 23 Rd edn. 4500-CN: C/D
Fluoride (STLC)	180 (max)	< 5.5 mg/l	EPA 1311, APHA 23 Rd edn. 4500, F:D

Result – Plant Trial

Utilisation of industrial waste to partially replace raw material is one of the solutions to protect the environment and enhance clinker production in the cement manufacturing process. Aluminium Industry has enough quantity of waste materials in their plant located in Odisha and wants to dispose of it. Dalmia Cement found the usability of SPL-MF to utilise its valuable components in clinkerisation.

Methodology: SPL-MF was used mainly to compensate for the silica and alumina deficiency in the cement raw mix. As a raw mix component, better control can be expected due to improved homogenisation and more dilution. However, SPL-MF was not allowed to grind in a raw mill, due to its characteristics, and a separate controlled feeding system was used to feed into the kiln inlet.

The addition of SPL-MF started from 0.25% with gradual addition up to 1.5%. The kiln performance was challenging to maintain clinker quality and rated production, due to larger size and wide variation in the composition of SPL-MF.

Environmental monitoring was carried out as per Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2018 to OSPCB/ PCC guidelines w.r.t Cement co-processing by a team of NABL- accredited lab during the trial run. Compliance to standards at the stack (connected to rotary kiln followed by Bag filter) and at the work zone was found well within the specified limit (Refer Table-3).

Table-3 Compliance to Standards - CPCB March 2021		
Fugitive Emission in the Work Zone		
Mandatory Requirement (mg/l)		Value
PM10	5.0 mg/m³ TWA (Note-1)	<5 mg/m³ TWA
Cyanide as CN	5.0 mg/m³ TWA	<5 mg/m³ TWA
Fluoride as F	2.5 mg/m³ TWA	<2.5 mg/m³ TWA
Ammonia	25 ppm (18 mg/m³) TWA	< 25 ppm TWA
	35 ppm (27 mg/m³) STEL (Note-2)	< 35 ppm STEL
Emission from Stack connected to Rotary kiln followed by Bag filter		
PM	50 mg/Nm³	< 50 mg/Nm³
Total Fluoride	25 mg/Nm³	< 25 mg/Nm³
Hydrogen Fluoride	4 mg/Nm³	< 4 mg/Nm³
Ammonia	75 mg/Nm³	< 75 mg/Nm³
Hydrogen Cyanide	10 mg/Nm³	< 10 mg/Nm³
Note-1 TWA = Time Weighted Average (8 hours, Max)		
Note-2 STEL = Short-Term Exposure Limit (15 minutes, Max)		
Reference: Occupational Safety and Health Standard 1910: 1000		

Challenges and Mitigation: SPL-MF is categorised as Hazardous waste at S. No. 11.2 of Schedule-I of HOWM Rules, 2016, operational challenges are quite normal to co-process SPL-MF in cement kiln.

Major challenges were:

- Failure of the grinding process in the Raw Mill,
- Restriction in production, due to larger size and wide variation in the composition of SPL-MF.

The Prime requirement to mitigate the challenges:

- Proper pre-processing of SPL-MF to segregate contaminants and to reduce size <10 mm,
- Separate feeding system with controlled dosing at kiln inlet,
- Appropriate sampling of SPL-MF during operation,
- Additional requirement of additives to maintain clinker quality,
- Replacement of existing Hazardous Waste to maintain the mandatory Norms specified by SPCB / CPCB.

Potential Opportunity for India

The Circular economy is a new pathway to sustainability when hazardous waste can be consumed cautiously into a useful product.

Aluminium smelting is the second most important metallurgical industry in India, similarly, India is the world's second-largest cement producer. Hence, it's an opportunity for both sectors to promote the Circular economy.

Judicious usage of SPL-MF to co-process in cement kiln as a raw mix component is possible provided it should be used as per the guidelines of CPCB/ SPCB and to fulfil the prime requirements to mitigate challenges.

Conclusion

Through strategic utilisation of hazardous waste in cement kilns, both the Indian Aluminium and Cement sectors can actively contribute to sustainability, complying with environmental regulations and promoting effective waste management practices. By harnessing the synergies between industry and waste management sector, we can transform hazardous waste into valuable resource, protect environment, and promote sustainable development.

SECTION 3
TEXTILE SECTOR

TEXTILE SECTOR

3.1 Textile Sector: Waterless Smart Dyeing Technology

Introduction

Textile dyeing and finishing processes are some of the most polluting manufacturing processes on the planet and are responsible for over 3% of global CO_2 emissions and over 20% of global water pollution. At current consumption growth rates, textile dyeing could be responsible for 10% of global CO_2 emissions by 2050. To address this urgent issue, Alchemie Technologies (Alchemie) has developed breakthrough digital dyeing and finishing technologies that deliver a dramatic reduction in energy consumption and eliminate contaminated wastewater emissions. Alchemie is a UK-based technology company with a mission to transform the textile industry with clean-tech digital manufacturing solutions that eliminate the environmental impact of polluting processes. Alchemie's digital approach to textile dyeing and finishing enables a step-change in the sustainability of textile dyeing: eliminating wastewater emissions and reduction of energy consumption by over 85%. The company has developed two core products based upon this technology: Alchemie Endeavour™ for Waterless Smart Dyeing, and Alchemie Novara™ for Digital Textile Finishing.

3.1.1 Alchemie Endeavour™ - Technology Description

Figure 35: Alchemie Endeavour™

Endeavour™ is the world's first digital dyeing process. It utilises advanced digital manufacturing technology to deliver a breakthrough in the cost structure, supply chain capability and sustainability of fabric colouration**.** As a digital on-demand process, it reduces minimum run lengths and enables rapid changeovers between colours and fabrics. The process enables a step-change in the sustainability of textile dyeing by eliminating wastewater emissions and reducing carbon footprint by over 85%. Due to the elimination of wastewater, the Endeavour™ system can be installed in water-poor regions and enables on-demand dyeing in garment manufacturers. Endeavour™ process can reduces operational costs by over 50%, with typical capital payback period of 12 months.

Technical specifications	
Throughput (15 m/min)	>1500 m2/hr
Maximum web width	1.8m
Substrate basis weight	50 - 500gsm
Substrate	Polyester, cotton, polycotton, nylon
Changeover time	< 15 mins
Dimensions	12.6 m x 6.3 m x 3.5 m
Power requirements	415V 3 phase 50/60 Hz electrical supply

Endeavour™ process can also Integrates with supply chain management tools to reduce supply chain waste and retail discounting. Endeavour™ utilises an advanced digital colourant application and fixation technology to deliver single pass roll-to-roll solid colours to fabrics. The Endeavour™ digital dye applicator applies liquid colourants to fabrics using a unique non-contact high-energy jetting of nanodroplets, delivering exceptionally homogeneous colour throughout the fabric. The Endeavour process is designed to be compatible with all colourant chemistries used in traditional dyeing. The system can also be used with reactive, acid dyes, Vat dyes and a range of speciality colourants to enable digital dyeing with a wide range of substrate types.

The Endeavour process utilises advanced digital technology for colour matching and is capable of precision colour matching, shade control and can be used with a wide range of fabrics. Alchemie have also developed the ColourHit™ technique for rapid digital colour matching using a proprietary software platform that utilises a database of colour matches. The machines are fully software controlled and connected to enable integration with automated supply chain systems and advanced Industry 4.0 production facilities.

3.1.2 Alchemie Novara™ - Technology Description

Novara™ digital textile finishing technology delivers sustainability with a precision digital application of functional finishes to textiles. Novara™ is a non-contact technique, that utilises an array of digitally controlled nozzles to deliver precisely defined finishing to the fabric. Delivering finishing only where it is needed, with precision 2D digital patterning and registered two-sided coating. The key benefits of technology include cost reduction, chemistry savings, and energy reduction. The Novara™ precision digital finishing system can deliver cost reductions of over 30% vs pad coating due to the significant reductions in energy and chemistry consumption. Cost saving in excess of 50% can also be achieved in applications where the finish is only required on one side of the fabric.

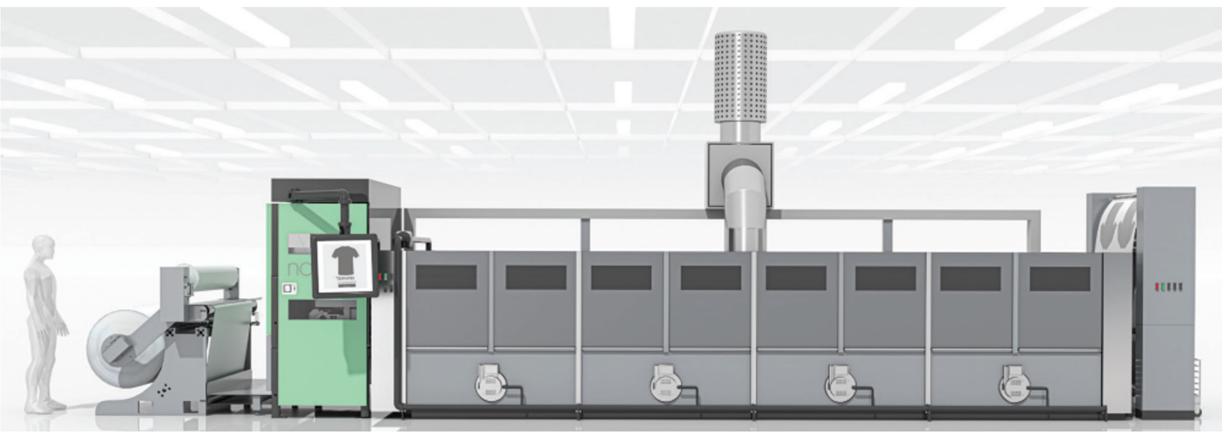


Figure 36: Alchemie Novara™ system

Technical specifications	
Throughput	Up to 100m/min
Web width	1.8m and 3.6m
2D pattern resolution	~1mm
Side application	Single or duplex application
Finishing chemistries	Up to 50 cPoise, water-based, up to 50C
Multi-functionality	2D and/or sided patterning of up to two functionalities
Substrate basis weight	50 - 1000gsm
Substrate	Polyester, Nylon, Cotton, Wool, Blends
Changeover time	< 15 mins automated
Dimensions	2 x 2.5 x 2.5 m
In-line drying	IR in-line (optional)
Connectivity	Ready for Industry 4.0
Power requirements	415V 3 phase 50/60 Hz electrical supply

The Novara™ digital finishing process can reduce energy consumption by over 85% vs traditional padding processes. By delivering finishing chemistry at higher concentrations, targeted to the areas needed, the technology demonstrated that durable water-repellent (DWR) finishes can be delivered to fabric substrates with 85% less energy and 25% less chemistry than pad coating. This technology has demonstrated a wide range of finish functionalities like waterproof, stain resistant, self-cooling, fire-retardant, metallics / visual effects, anti-viral, anti-bacterial, anti-odor, and UV-Protection.

Novara™ system is fully connected and automated, enabling Industry 4.0 manufacturing platforms to be delivered. The system can be connected to Manufacturing Execution System (MES)/ Material Requirements Planning (MRP) systems, delivering unparalleled supply chain agility and flexibility. The Novara™ system can be implemented into existing production lines and capital investment payback is typically achieved in less than 12 months.

Conclusion

Embracing these technologies in the Indian textile sector not only amplifies operational efficiency but also presents a significant opportunity to mitigate environmental impact. Addressing the pressing challenges of rising global CO2 emissions and water pollution, these technologies align with sustainability goals and play a pivotal role in shaping a cleaner and greener future.

3.2 Energy Savings & Greenhouse Gases Mitigation to Manage Climate Change- Raymond Ltd, Vapi

Introduction

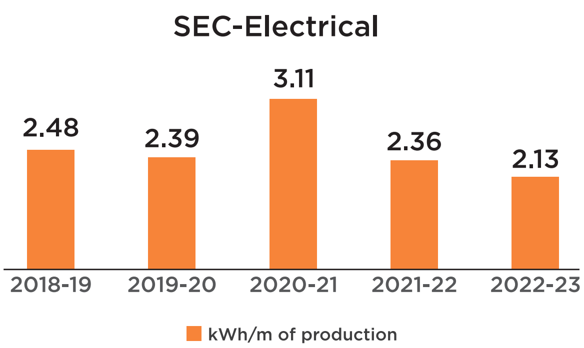
Raymond Ltd, Vapi Unit is one of the three manufacturing units of worsted suiting fabrics in the Textile Division of the organisation. The plant is well-equipped with modern machinery, ensuring high efficiency and productivity. The workforce is highly skilled, well- trained, and competent. The unit became operational in 2006.

The need to save energy is the need of the hour. Being one of the most recognised brands in the country, Raymond Limited takes immense pride in implementing projects to achieve the goals of sustainability and greenhouse gas mitigation. The plant has successfully implemented an EMS that meets all the requirements of ISO 50001..

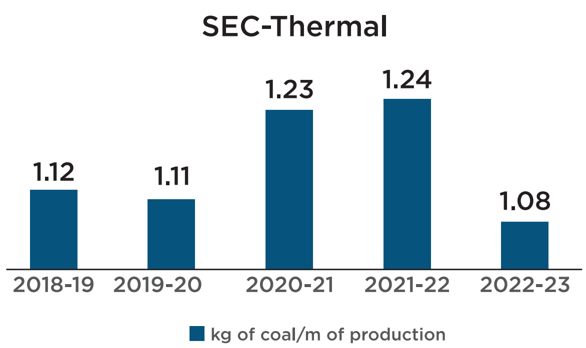
Raymond Ltd, Vapi has received numerous awards for its work towards environment and energy management. Some of the awards include the prestigious National Energy Conservation Award (NECA) Certificate of Merit, 2019, Apex India Green Leaf Platinum Award 2021 for Energy Efficiency and the Green Gujarat Award 2023 by News18 Network.

Energy Review

A textile plant is an extremely energy-driven unit. In Raymond Ltd Vapi, the energy cost comprises around 25-30% of the total production cost. With proper planning and execution of energy-saving projects, Raymond, Vapi has been able to reduce the specific energy consumption of thermal and electrical on a year-on-year basis. This is reflected in the last five years' performance of the plant in thermal and electrical as shown below:



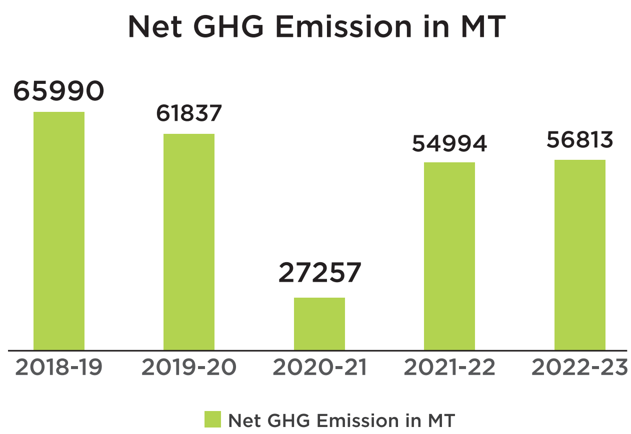
Graph 1: Specific Energy Consumption – Electrical



Graph 2: Specific Energy Consumption – Thermal

Raymond Limited, Vapi plant is a Designated Consumer (DC) as per the norms laid down by the Ministry of Power under the Perform Achieve Trade (PAT) Scheme. Under this scheme, the organisation was allotted the target to reduce its specific energy consumption by 6% in PAT cycle III. The plant was able to achieve an 11% reduction in specific energy consumption (SEC) against the target of 6%.

Currently, the plant is under PAT Cycle VII, and it has been given a target of SEC reduction of 6.8% by 2025.



Graph 3: Net GHG Emission

Apart from achieving these targets, the organisation also understands its responsibility towards the environment and hence through the implementation of energy conservation projects as well as sustainable development activities, there has been a remarkable impact on the reduction of Greenhouse gases emission and CO_2 emission reduction.

Energy Conservation Initiatives in FY22-23

The organisation identifies and classifies all energy units in the plant. With the help of the trend analysis of the energy units based on historical data, the Significant Energy User (SEUs) are defined at process, system and equipment level. After formation of baseline of these SEUs based on historical data, the impact of relevant variables is taken into consideration. Identification of opportunities for improvements and setting of respective objectives and target is done.

The organisation understands the importance of energy conservation; hence there is a huge amount of investment in these projects taking into account the payback period and overall environmental impact. The major projects related to GHG reduction are mainly classified into two parts: the use of energy-saving products and finding alternate and sustainable (renewable) sources of energy.

Figure 37: Flash Stream Recovery Pump

Energy Saving Initiatives

The top management of Raymond Limited has always accepted the notion that energy conservation is best for business and the way forward towards sustainable development. The organisation is continuously in search of advanced and modern energy-saving products. Some of the major projects are:

Low Pressure Compressor with Heat Recovery Unit

In a textile unit, the compressed air system is one of the key energy consumers, attributing 12-13% of the total plant consumption. An opportunity of energy conservation was identified through the installation of a low-pressure compressor with a heat recovery unit. The Specific power consumption of a low-pressure compressor is 0.125 kWh/cfm against 0.18 kWh/cfm of existing compressors. The heat recovery unit is used to generate hot water through waste heat recovered from the compressor oil.

With an investment of Rs 66 lakhs, this project gives an annual saving of Rs 66 lakhs. The annual electrical and thermal savings are 4.7 lakh units and 985 MT of steam respectively.

Figure 38: Centrifugal Electrical Chiller

Replacement Of TFO Chiller (Steam- Based to Electrical- Based)

The existing vapor absorption machine (VAM) chiller in Two-for-One (TFO) has been replaced with a centrifugal electrical chiller. This was done due to wear and tear of the existing TFO Chiller which was beyond repair.

Also, with the increase in coal cost from Rs 6000-7000/ MT on May-21 to Rs 13000-14000/ MT in FY 23, it was decided to replace the existing VAM- based chiller with an electrical chiller. Electrical chillers are beneficial from the environmental point of view also as their carbon emission is far less than VAM chillers as the plant VAM chiller was operational on steam generated through coal.

Figure 39: Low-Pressure Compressor

With an investment of Rs 180 lakhs, this project gives an annual saving of Rs 54 lakhs.

Flash Stream Recovery Pump

The increase in coal prices all over the world has emphasised the importance of saving thermal energy in industrial units. Raymond Ltd, Vapi plant which runs its thermal equipment on coal has implemented an energy saving initiative of flash steam recovery pump in FY 22-23 to achieve steam saving. This project served two purposes:

- Recovery of flash steam.
- Recovery of condensate at higher temperatures.

Through this initiative, the plant has been able to recover condensate at 100°C (previously, the condensate temperature was around 75°C). Also, flash steam of 5 MT per day is being recovered through this project.

The investment of this project was Rs 20 lakhs, and the annual savings is around Rs 50 lakhs which is equivalent to 2000 MT of steam.

Other Projects

Raymond has always been at the forefront when it comes to energy conservation through technology development and new energy- saving equipment. The organisation has replaced a total of 11 pumps in chillers with new energy-efficient pumps giving an annual electrical saving of 4.6 lakh kWh.

Variable frequency drives have been installed across different types of machinery like fabric dyeing machines, FM machines, and low-pressure compressors to achieve savings of close to 2 lakh units annually. In FY 22-23, cumulative savings of Rs 10 lakhs were achieved through the replacement of conventional lights with LEDs and the replacement of standard efficiency motors with IE3 motors.

Renewable Energy

The organisation understands its responsibility toward climate change. It has introduced the following initiatives in the field of renewable energy.

Solar Rooftop Power Plant

Solar energy can be used directly for heating, lighting, generating electricity, and a variety of other commercial and industrial uses. Solar power is self-sufficient and installing solar panels on roofs is a safe and easy path to contribute to a sustainable future. Raymond, Vapi looked for opportunities for the installation of the solar power plant on its roof. After analysis, the preferred roof where the maximum sunlight can be utilised was selected and a 640 kW solar rooftop power plant was proposed. The top management of Raymond Limited understands the importance of renewable energy, and with their support, a 640kWp solar rooftop power plant was installed in December 2017. The power generated through solar is directly utilised in the plant. The power plant had a huge investment of Rs. 259 lakhs with an average annual generation of 8.3 Lakh units.

Wind Energy & Hybrid Energy

Wind power offers many advantages, which explains why it's the fastest-growing energy source in the world. Raymond Ltd, Vapi has initiated two renewable energy projects through bilateral agreement projects in Virvav Gujarat. They are:

- Power through bilateral from a 3.15 MW hybrid power generator. (May-22)
- Power through bilateral from 3 MW wind turbine generator. (May-19)

Renewable Energy Portfolio (FY22-23)

With the help of the above-mentioned projects, Vapi plant has a renewable energy portfolio of 32% by the end of FY 22-23. This number will increase to 52% in the next FY.

Figure 40: 640kWp Solar Rooftop Plant

Figure 41: Wind Energy

Table-4 Renewable Energy Portfolio (FY 22-23)		
S.NO.	**Particulars**	**Units (lakh kWh)**
1	Solar	7
2	Wind	75
3	Hybrid	51
4	Renewable Total	133
5	Total Plant Consumption	413
Renewable %		**32**

Conclusion

The utilities (Power, Air, Water etc.) contribute to approx. 25 – 30% of the Plant's Budget. With the rise in global temperature and exhaustion of fossil fuels, it is high time that reputed organisations take a pledge toward renewable and sustainable development.

With a reduction in carbon emissions by 14% over the past 5 financial years, the unit pledges to contribute and achieve more and more towards energy saving and create innovations to mitigate climate change.

SECTION 4
CROSS SECTORAL

CROSS SECTORAL

4.1 Industry 4.0 Wireless Energy Solutions for Net Zero and Energy Productivity

Introduction

Centrica brings patented **Industry 4.0 Wireless Energy** solution to India which drives **Net Zero** and **Energy productivity** across the organisation. This is a comprehensive solution which not only maps and monitors the **energy** consumption and **carbon** emissions (CO_2e) in **real-time** but at the same time helps to **reduce** it.

Centrica Drives Net Zero & Energy Productivity

Centrica provides a **comprehensive** IoT 4.0 solution to **drive Net Zero & Energy productivity across your organization**

1 PLAN	2 CUT WASTAGES & EMISSIONS	3 MEASURE & TRACK IMPACT	4 DRIVE ENERGY PRODUCTIVITY	5 DIGITAL REPORTING
Draw Net Zero Baseline & Build science-based carbon reduction roadmap with Granular view of existing energy usage & Carbon emissions	Cut wastages & improve energy efficiency through Smart Energy Management with Machine-level energy insights	Masure & track impact of Energy efficiency initiatives and improvement projects	Reduce Machine breakdown through predictive maintenance & Optimize preventive maintenance	Digital Reporting: ISO 14001, ISO 50001, PAT, BRSR
Build Enterprise wide plan up to machine level through Enterprise wide granular Real-time Energy monitoring & accounting	Reduce Scope 1 & 2 emissions through Granular/Machine-level Energy reduction	Ensure consistency & stability of results by Digitally tracking CO_2e footpring & Energy usage	Drive higher Energy productivity through Machine-level SEC analysis; Real-time peak load demand - Open access bidding	
Enables Data driven Decision making for Net Zero	Ensure transparent monitoring and reduction of Scope 3 emsissions across the value chain	Measure & validate returns from capex investments	Lower the Capex - Reduce & right-size the need for RE Drive Manpower productivity & behavioural change	

NET ZERO SOLUTION JOURNEY

Figure 42: Net Zero Solution Journey

Centrica Plc is a UK based energy solutions & services MNC, FTSE 100 (London Stock Exchange), with businesses spreading across oil & gas exploration, nuclear power generation, gas and electricity distribution, energy marketing and trading and integrated energy solutions for a low carbon future.

Centrica offers end-to-end solutions, right from LT main panel up to individual machines. While Centrica's **panel-level wireless sensors** give an overview of energy consumption at the macro-level, **the circuit-level / machine-level wireless sensors** monitor energy consumption at each electrical phase (R/Y/B) of a machine.

The **machine-level intelligence** helps in pin-pointing the **energy intensive** machines and helps in focused energy reduction. This drives **Smart energy management** and reduces inefficiencies/ wastages in any system such as air compressor leakages, chiller inefficiencies, motors drawing over-current, off-hour consumption, idle hours & others. This in turn reduces **Scope 1 & 2 emissions**. When this solution is installed at vendor-sites, even **Scope 3 emissions** can be transparently monitored across the value chain. Further, backed by data, vendors can be convinced and encouraged to reduce the emissions at their sites, thereby **reducing Scope 3 emissions**.

Machine-level intelligence also helps in **reducing machine breakdowns** through **predictive maintenance**. The sensors give **real-time alerts** as soon as any **abnormal behavior** is detected. One can also **reduce the preventive maintenance costs** as maintenance can be done on **the actual running** of the machine and not as per the pre-defined timeline. Machine-level intelligence helps in **correlating production data with energy** data. This is useful for **SEC** (specific energy consumption) **analysis** which can help in **prioritising** and **sequencing** of energy efficient machines which drives efficient **production-planning**.

Centrica's Solution Addresses The Energy Challenges

Centrica's **patented technology** driven by **wireless** sensors & advanced analytics from Power radar software enables **"Circuit level"** actionable **intelligence**

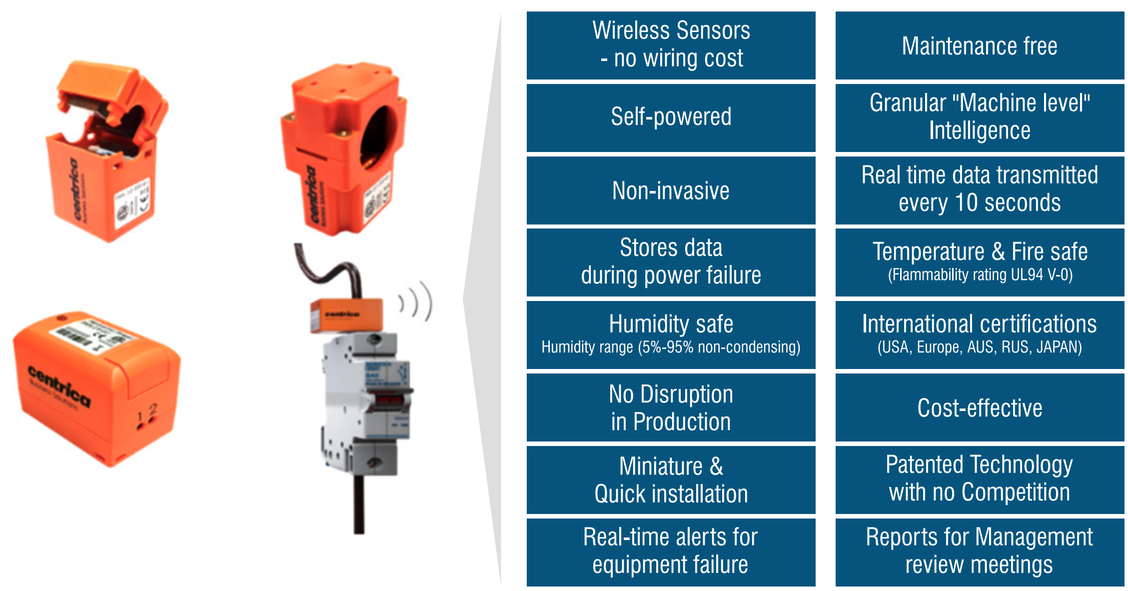


Figure 43: System Architecture

Also, this being an **Enterprise level solution** helps in **data driven planning and decision-making**, right from the enterprise level up to machine level. As a result, the granular level data can be used for fixing the **Net Zero baseline** by defining the status quo of existing energy usage and carbon emission (CO_2e). It also assists in **tracking** and validating energy efficiency initiatives and projects. One can even benchmark multiple facility as well as machines across different facilities.

The **real-time** data helps in **peak load demand estimation** for **open access** bidding. Also, various **digital reports and trends** can be generated for reporting as per different schemes (ISO 14001, ISO 50001, PAT, Business responsibility & Sustainability reporting).

As the complete solution is wireless, the **installation and software integration** are executed **within minutes** and the whole system/ facility can be **digitalised** in no time. The solution not only boasts of super-quick installation but also **reduces the high wiring costs** and hassles. The clip-on sensors are **self-powered** (no battery/ electrical source) and **maintenance-free**. It transmits data every 10 seconds and stores data during power failure. Apart from electrical & energy parameters, one can also measure **heat, gas, steam, air & water parameters** in any facility.

Centrica's granular-level Energy Solution is in wide use in more than sixty countries across the globe. To know more about the unique solution, please reach out to Hi-Tech Facility Engineers, India Partner of Centrica Energy Solutions. Hi-Tech Facility Engineers is an Industrial Internet of Things (IIoT) energy management, IIoT solutioning & Green strategy company and works with organisations to drive their production efficiency and energy productivity by leveraging digitalisation & automation.

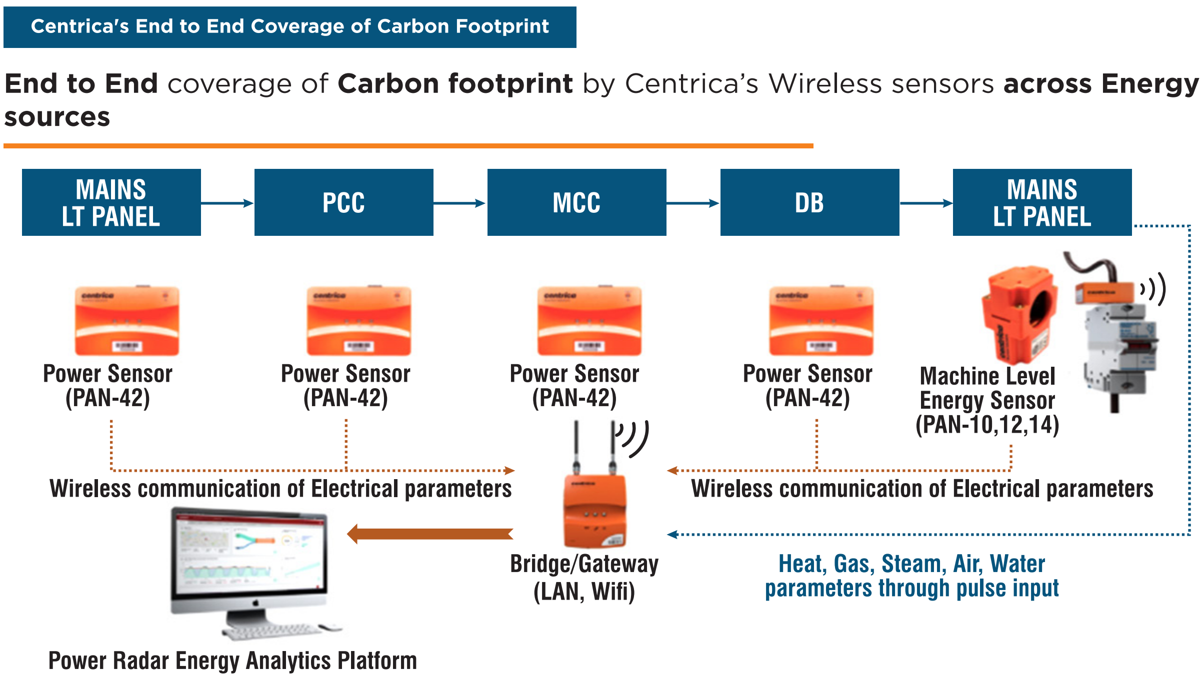


Figure 44: Centrica's Patented Technology – Wireless Sensors

Conclusion

This technology paves the way for improvement in efficiency, reduced carbon footprint, and informed decision-making, and has potential use across cross sectoral industries in India. The energy solutions discussed in this case study empower industries to take control of their energy intensity, reduce energy costs and contribute to the resilience and reliability of the overall energy system.

4.2 Semi-Modular Cdrmax Technology for Carbon Capture

Introduction

Carbon Clean patented technology significantly reduces the costs and environmental impacts of CO_2 separation, when compared to existing techniques. Headquartered in London, UK with offices in India, Spain and the US with 49 sites operating across Europe, North America and Asia capturing 1.8 million tonnes of CO_2. They global leader in cost-effective CO_2 capture technology and services for essential hard-to-abate industries such as cement, steel, oil & gas power plants, energy from waste and biogas.

carbon clean
TECHNOLOGY TO ACHIEVE 'NET ZERO'

Figure 45: Carbon Clean's CDRMaxTM semi-modular technology

The Innovation

Carbon Clean offers a range of advanced industry leading technologies and provide all the services needed to support net zero, from technology licence and solvent supply, a full process design package (PDP) and proprietary equipment to end-to end systems — including design, build, financing and operation.

- **CDRMaxTM: Semi-modular solution for Carbon Capture**

These systems modularise and containerise about 80% of a carbon capture system, giving many of the benefits of modularisation. Installation and on-site activity are dramatically

Figure 46: Carbon Clean's CDRMaxTM semi-modular technology implemented at Tata Steel, Jamshedpur, India as part of pilot demonstration

reduced compared to an open plant construction. Their semi-modular systems are proven, fully scalable solutions, currently being operated around the globe – standard sizes 10, 100, 200, 300 tonnes per day (TPD) CO_2 capture.

Some of the key benefits of their systems are mentioned below:

- Pre-fabricated semi-modular systems
- Less installation and onsite activities

Reduced project timelines

- 30% less energy consumption
- No hazardous emissions
- 50% less solvent make-up
- 20x less corrosion

Demonstration -TATA Steel Plant, Jamshedpur

Tata Steel aims to be the industry leader in sustainability by reducing its CO_2 emissions intensity and freshwater consumption, developing supply chains and contributing to the circular economy. The company wanted to implement carbon capture in order to achieve its decarbonisation goal.

Carbon Clean collaborated closely with Tata Steel to successfully design and commission a semi-modular, skid-mounted 5 (TPD) CDRMaxTM carbon capture unit for its Jamshedpur plant. Their unit is affordable and sits within the available onsite space. They also supplied our proprietary APBS-CDRMaxTM solvent.

Carbon Clean also helped in contributing to the circular Carbon Economy and creating jobs in the steel Industry.

Results

The modular skid-mounted unit captures CO_2 directly from the blast furnace gas and makes it available for onsite reuse in a variety of applications. The depleted CO_2 gas is then sent back to the gas network with an increased calorific value. The 5 TPD carbon capture plant, along with the semi-commercial use of the captured CO_2 within the steel value chain, makes the Tata Steel Jamshedpur plant the first-of-its-kind within the steel industry. “Following the successful demonstration, we plan to rapidly accelerate the number of carbon capture projects, says Aniruddha Sharma, Co-founder and CEO, Carbon Clean.

> **“The operational experience gathered from this 5 TPD CO_2 capture plant will give us the required data and confidence to establish larger carbon capture plants in future.”**
>
> **T. V. Narendram**
> CEO & MD, Tata Steel

Potential Opportunity for India

India’s power and industrial sectors (primarily steel, cement, oil & gas, refineries, chemicals and coal gasification) contributed around 1,600 million tons per annum (mtpa) of CO_2 emissions i.e., ~60% of the total emissions in 2020. Fuelled by economic growth across sectors as well as rapid urbanisation, emissions from these sectors are expected to increase to nearly 2,300 mtpa by the year 2030. These sectors are amenable for carbon capture and offer significant potential for deployment of carbon capture utilisation and storage (CCUS) technology to aid in decarbonising the hard to electrify and hard to abate industrial sectors, due to use of fossil fuels not only as a source of energy but within the core process itself.

Further, CCUS also has an important role to play in decarbonising the power sector, given India's current reliance on coal for meeting over 70% of its electricity needs. Even if the country successfully meets its target of 500 GW installed power generation capacity from renewable sources by 2030, there would still be a need to meet the base power demand from fossil fuels (most likely coal) or other dispatchable sources.

Thus new-age low carbon technologies such as CCUS would play a critical role in India's energy transition and aid in reducing CO_2 emissions by half by 2050 to achieve the net-zero target by 2070. Hence, it is important to design and develop the framework and policy instruments (including pilot demonstration projects) for CCUS to become a reality in India and contribute to the country's efforts to decarbonise.

Conclusion

CCUS technology will be useful in India's journey towards achieving its ambitious net-zero targets by 2070 and fostering sustainable industrial growth. As the technology is presently at a very nascent stage in the country, the execution of such operational clean energy projects at scale is essential to build stakeholder confidence in adoption of such technologies. Such projects will thereby facilitate in wider adoption and scalability of the technology.

4.3 Waste Heat Powered Treatment Of Industrial Wastewaters – LAT Water

Introduction

Globally up to 80% of wastewater is directed back into the ecosystem without adequate treatment. Where treatment technology is available it can be costly, inflexible, and incapable of fully treating the water, especially for highly contaminated waste streams. LAT Water's innovative solution to this problem is a bespoke engineered wastewater treatment solution, capable of treating a wider variety of input waters than traditional water treatment technologies.

LAT Water is a British company, set up to develop new approaches to wastewater treatment and desalination.Their technology has been piloted and commercialised in the UK and internationally with three commissioned treatment facilities in China.

LAT Water's patented, single-process wastewater treatment separation technology works at lower temperatures and pressures than conventional technology. Their on-site waste effluent process can operate using low-grade waste heat which has been generated from industrial processes or renewable sources. The technology allows for operational expenditure reductions due to energy savings and negates the requirement for procuring expensive structures capable of withstanding high pressures.

Figure 47: LAT Water installation at Broadpath landfill treating leachate

Low Temperature Ambient Pressure Technology (LAT™) offers high rates of water recovery and the ability to treat more complex waters than conventional systems. The process is suitable for all sectors which have highly saline effluents, and complex dissolved contaminants and currently require costly treatment schemes such as municipal waste sites, food and drink, anaerobic digestion, chemicals, pharmaceuticals, power generation, and aquaculture. By recovering both clean water and high-value minerals LAT Water offer a cost-effective solution.

The technology allows clients to reduce energy consumption and lower carbon emissions which contribute to decarbonisation goals. LAT™ is a closed system therefore, unlike conventional open-to-atmosphere evaporators, wastewater never contacts the atmosphere therefore volatile organic compounds are not released, this reduces GHG emissions and associated health and safety concerns.

The Innovation

LAT™ is a wastewater separation technology that produces clean water and a concentrated product stream. The technology differs from traditional evaporation and condensation technologies which use low pressure steam, require exotic materials, have a single point of failure, and require sophisticated pre-treatment.

LAT™ offers three solutions in a single step: reduction of high levels of ammonia, reducing dissolved salts, and reducing organics. The system has been designed for continuous operation, this enables the system to reach equilibrium and increases water recovery and thermal efficiencies.

The process uses air movement to transport water vapour from a humidification column to a dehumidification column below the boiling point of water. Medium-grade heat (70°C - 95°C) is used to evaporate and condense water in successive "stages", each stage produces freshwater and successively concentrates the feed stream. The freshwater produced can be reused and/or recycled back into the operation, whilst the product concentrate can undergo further treatment within existing discharge consents to extract added value (salt and mineral recovery) – avoiding the need for customers to apply for new consents that bring additional costs.

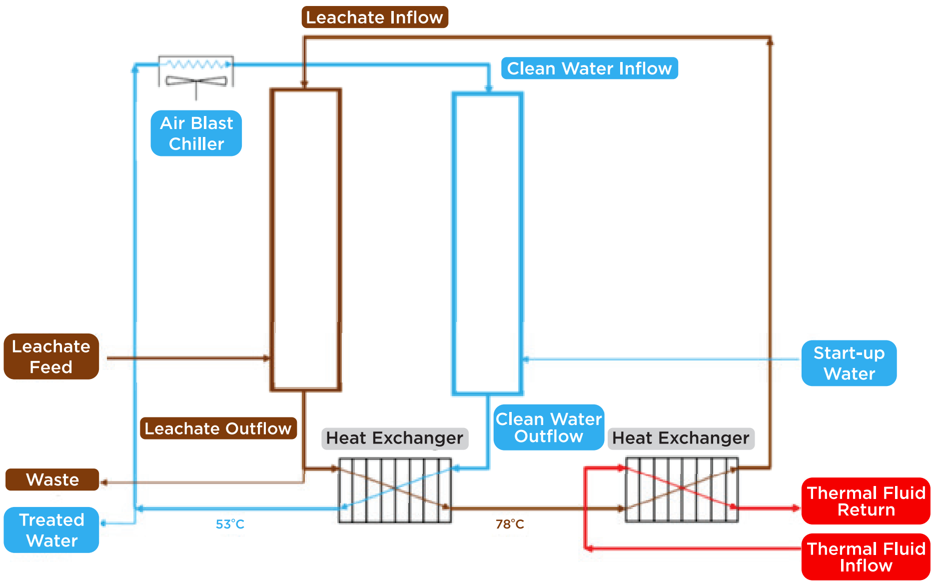


Figure 48: Simplified process flow diagram shows how LAT™ demonstrator recirculates leachate and clean water at variable temperatures to produce clean water and concentrate

Demonstration

LAT Water demonstrated the technology in the UK at Broadpath landfill site, operated by Viridor Waste Management Ltd. Prior to the installation of LAT™, Broadpath landfill had no treatment process on-site and leachate was instead collected and transported to an off-site treatment plant, at a high cost and carbon emissions. The leachate at this facility is wastewater containing high levels of ammonia, organic matter and dissolved salts. This mix of compounds provides a high level of complexity, and many traditional technologies struggle to satisfactorily treat the leachate in a commercially viable manner.

LAT Water installed a water treatment system to treat the raw leachate, and by utilising the waste heat provided on-site from bio-gas generators, LAT Water's solution provided offer an environmentally friendly and sustainable solution wastewater treatment alternative. The water treatment system was designed to treat 10m^3/day of leachate, and thermal energy was provided by a waste heat exchanger connected to the exhaust gas of a 1MW gas generator, providing ample energy to heat the LAT™ unit.

Results

Process recipes were set up for water recoveries ranging from 70% to 90%. Water quality was assessed and checked against discharge and consents/permits in place. Key parameters such as pH, TDS/EC, Ammoniacal Nitrogen, COD, Anions, and Cations were measured. Environmental performance was assessed regarding emissions to air, water, photochemical ozone creation ("POCP"), and global warming potential.

LAT Water achieved the targeted minimum clean water recovery of 70%, and a maximum of over 90% which could be safely discharged or recycled. This resulted in reduced product concentrate to be disposed which had positive implications for trucking costs and energy requirements for leachate treatment.

Table 5: Results showing characteristics of leachate, distillate and concentrate.

	Raw Leachate	Distillate	Product Concentrate
pH	8.2	9.5	9.3
Electrical Conductivity [mS/cm]	1.3	1	16
Total Dissolved Solids [mg/L]	5,510	48	29,450
Suspended Solids {mg/L}	80	<2	96
Ammoniacal Nitrogen [mg/L]	3,610	72	8,970
TOC [,g/L]z	964	21	4,700

The 10m3/day plant delivered operating costs savings of 48%, with net savings of 11% after including all capital costs. The unit operation of the LAT process achieved an electrical power reduction from 15 kWh/m3 to 8 kWh/m3 thus achieving a 48% reduction in energy use. If the unit had been sized to process *all* the leachate produced at the site, the operating cost savings would have been 64% and the net saving 41%. This includes the cost of the electrical energy requirement of 8kWh/m3 for ancillary equipment including pumps and fans for the 10m3/day unit. This is projected to fall below 5kW/m3 for larger units. Baseline annual energy savings of 125,000 kWh are achieved by implementing LAT Water system for 10m3/day unit, equivalent to 26.5 metric tonnes of CO2/yr.

Potential Opportunity for India

Increasing economic activities and declining water quantity and quality are driving the demand for water and wastewater treatment systems in India's industrial sectors. Increasing globalisation is affecting the quality of water being used in the process industries and encouraging adherence to wastewater disposal regulations. It is therefore anticipated that India's water and wastewater treatment market will grow by ~60% to GBP 1.7 billion by 2025 from GBP 1.05 billion in 2020, registering a compounded annual growth rate of ~10%[8] LAT™ is suitable for water treatment in a wide spectrum of industrial sectors in India and is particularly well-suited for sites where there is waste heat and high-water demand. The water recovery from LAT technology will create a virtuous circle of water and energy demand. Beyond landfills, these include textiles, paper, pharmaceuticals, power, mining, aquaculture, beverages, and chemicals. LAT Water offer multiple-sized solutions capable of treating inputs between 1-5,000 m^3/day, utilising a wide range of heat sources such as waste heat (hot water, hot exhaust gas), geothermal, solar, or low-pressure steam, and allowing industries to reduce energy consumption and lower carbon emissions.

Figure 49: Test samples from anaerobic digestor digestate: clean water recovered, concentrate, feed input, raw unfiltered feed

Conclusion

The need of waste heat powered treatment of industrial wastewaters is driven by water conservation, regulatory compliance, industrial growth, and technological advancements to improve energy efficiency. By incorporating such technologies, India can enhance its industrial sustainability and contribute in effectively & economically reducing the strain on freshwater sources.

Note: This demonstration project was funded through, and the case study has been adapted from, the UK BEIS (Department for Business Energy and Industrial Strategy) Industrial Energy Efficiency Accelerator Programme 2018-2021

8 Indian Water and Wastewater Treatment Industry, Frost & Sullivan 2022

4.4 Unlocking Energy Efficiency Through Industrial Intelligence: Smartia

Introduction

Manufacturing is an energy-intensive industry facing immense pressure to reduce costs and environmental impact. However, most of these industries lack the data and tools needed for intelligent energy management. Core issues include a lack of granular visibility into usage, inability to pinpoint waste, siloed data collection, complex pricing schemes, and internal skills to actively manage consumption. This hampers their ability to actively manage and improve energy consumption.

Smartia is a UK-based AI and Internet of Things (IoT) technology company that addresses these challenges through an industrial intelligence software platform combining artificial intelligence, IoT connectivity, and data analytics to help manufacturers gain transparency in their operations. Smartia captures and centralises data from across industrial assets and systems, applies machine learning to derive insights, and delivers intuitive visualisation to users. This enables detailed visibility into energy consumption, identifies optimisation opportunities, and builds capabilities for continuous efficiency gains. With the rapid deployment of non-intrusive sensors and a cloud-based solution, Smartia delivers impactful analytics and energy expertise that drive sustainability and savings.

Behind-the-Meter Energy Management

One application of Smartia's technology is Smartia Energy Analytics, which enables monitoring and analysis of energy usage down to the level of individual machines, production lines, and manufacturing cells. This gives visibility into exactly how and where energy is consumed within a facility, hence pinpointing savings opportunities. By providing a detailed breakdown of energy consumption, companies gain a multidimensional understanding of their energy use and can identify specific actions to reduce waste and costs.

Figure 50: Illustrative Dashboard for Smartia Energy Management Platform

Key features of Smartia's energy management solutions

Rapid Deployment and Non-Intrusive Sensors

As a cloud-based solution, Smartia can be deployed in a matter of weeks. Non-intrusive sensors allow quick setup without costly integration or downtime. Smartia's cloud-based technology is vendor-agnostic and can easily be scaled to a global level. Smartia uses easy-to-install, non-intrusive sensors to connect devices without disruption. For example, current transducers attached to cables measure electricity consumption without splitting lines and can start providing value within a few weeks of deployment.

Powerful Analytics

At the core of Smartia's industrial intelligence platform are advanced analytics that converts raw sensor and meter data into meaningful insights. The built-in machine learning algorithms analyse usage patterns to pinpoint waste and savings opportunities. The system correlates energy consumption with production, weather, and equipment data to reveal optimisation opportunities.

Intuitive Dashboards Tailored to All Users

Smartia Energy Analytics lets users easily see energy information specific to their needs. Operators can view the live consumption of machines they oversee. Plant managers can analyse usage for production lines. Executives can track facility-wide metrics tied to carbon and cost goals. Maintenance teams can correlate energy data with equipment telemetry to identify faults. Built-in analytics also generate reports, alerts, and recommendations that highlight areas for energy savings and efficiency gains. The intuitive dashboards make energy management accessible and actionable across the business.

The key benefits of Smartia Energy Analytics include:

- Full visibility into energy use, enabling accurate accounting of consumption by process, product, facility area, or asset.
- Ability to accurately calculate energy costs by product or batch.
- Identification of savings opportunities through meter-level monitoring and analytics pinpointing excess energy use.
- Utility bill reductions from efficiency gains, load shifting, optimal tariff selection, and other measures.
- Ranking of loads to encourage operators and managers to focus on the biggest opportunities.
- Enhanced energy management practices using data for better resource planning, target setting, and performance improvement.
- Progress towards carbon and sustainability goals by establishing energy baselines and tracking reductions.

The use of Smartia technology can also help in improving production efficiency, machine uptime, maintenance scheduling and quality control. Through previous technology deployment, Smartia has been able to help to manufacture industries identify savings of 30% on machines in regular use and almost 80% savings on machines that have sporadic usage[9].

Potential Opportunity for India

Smartia's industrial energy management solution has significant potential to help major manufacturing industries in India improve their energy efficiency and sustainability. Smartia can help Indian industries to reduce energy overhead by providing equipment-level visibility into energy usage, detecting waste from

9 For more details, please visit: https://www.smartia.tech/

idle assets, visualising peak demand, analysing production versus consumption, and optimising based on insights. The cloud-based deployment also makes adoption feasible without large capital investment. Smartia's industrial energy management solution can support Indian industries to be more globally competitive through intelligence-driven energy management.

Conclusion

Smartia's industrial energy management platform uniquely combines AI and data technologies to help collect, centralise data from industrial equipment/ assets and other organisational data sources. It provides transparency and predictability of all assets and factory operations resulting in clear insights within a collaborative and secure environment.

CONCLUSION

The ASPIRE team has developed a comprehensive compendium of best practices, acting as a valuable guide for industrial stakeholders. This compendium extensively explores both national and international (including the UK) best practices and case studies related to Industrial Energy Efficiency and Decarbonisation (IEED) identified under ASPIRE program.

Encompassing a wide range of industries, including those deemed hard-to-abate, this compilation of case studies and best practices offers practical insights to drive advancements in industrial energy efficiency and decarbonisation. Serving as a guiding light, these resources provide actionable strategies and real-world examples, empowering industries in their pursuit of net-zero targets.

Beyond serving as a resource for individual industries, these case studies and best practices also play a crucial role in bridging the gap between industries and technology providers. They foster collaboration and innovation, facilitating the development of sustainable solutions. This collaborative approach sets the stage for meaningful partnerships and contributes to creating a greener and more resilient industrial landscape.

For a deeper dive into these technologies and access to our global IEED database, please visit: https://www.ideeksha.in/

ABBREVIATIONS

Abbreviation	Definition
ACT	Accelerated Carbonation Technology
ABSTC	Aditya Birla Science & Technology Centre
APC	Advanced Process Control
ASPIRE	Accelerating Smart Power and Renewable Energy
ALFED	Aluminium Federation
ASI	Aluminium Stewardship Initiative
AI	Artificial Intelligence
BRE	Building Research Establishment
BEE	Bureau of Energy Efficiency
CCUS	Carbon Capture, Utilisation, and Storage
CEC	Cambridge Electric Cement
CPP	Captive Power Plant
CCUS	Carbon Capture, Utilisation and Storage
CO2	Carbon Dioxide
CO2e	Carbon Emission
CBD	Cement Bypass Dust
CuCB	Copper-insert Collector Bar
CPCB	Central Pollution Control Board
CHP	Combined Heat and Power
CSR	Corporate Social Responsibility
DAX	Data Analysis Expressions
DGMS	Directorate General of Mines Safety
DCs	Designated Consumers
DWR	Durable Water-Repellent
ETP	Effluent Treatment Plant
EC	Electrical Consumption
EAF	Electric Arc Furnace
EE	Energy Efficiency
EMS	Energy Management System
FCDO	Foreign, Commonwealth, and Development Office
GCCA	Global Cement & Concrete Association
GHG	Greenhouse Gases
GJ	Giga Joules
GCV	Gross Calorific Value
GGBS	Ground Granulated Blast Furnace Slag
HOWM	Hazardous Waste Management
HFQ	Hot Form Quench

Abbreviation	Definition
ID	Induced Draught
IDEEKSHA	Industrial Decarbonisation and EE Knowledge Sharing
IIoT	Industrial Internet of Things
IEED	Industrial Energy Efficiency and Decarbonisation
IEA	International Energy Agency
IoT	Internet of Things
JKCL	JK Lakshmi Cement Limited
IoT	Internet of Things
JNARDDC	Jawaharlal Nehru Aluminium Research Development and Design Centre
kWh	Kilowatt Hour
KEP	Knowledge Exchange Platform
LAT	Low Temperature Ambient Pressure Technology
ML	Machine Learning
MHD	Magnetohydrodynamic
MES	Manufacturing Execution System
MRP	Material Requirements Planning
MW	Mega Watt
MTCO2e	Metric Tons of Carbon Dioxide Equivalent
MTOE	Metric Tonne of Oil Equivalent
MTPA	Million Tonne per Annum
MPA	Mineral Products Association
MCC	Motor Control Centre
MCC1	Multi Component Cement 1
MCC2	Multi Component Cement 2
NABL	National Accreditation Board for Testing and Calibration Laboratories
NECA	National Energy Conservation Award
NOx	Nitrogen Oxides
PV	Photovoltaic
PAT	Perform, Achieve, and Trade
PC	Preheater Cyclones
CEM I	Portland Cement
PU	Polyurethane
PCC	Power Control Centre
PDP	Process Design Package
RDF	Refuse Derived Fuel
RCC	Reinforced Cement Concrete
R&D	Research and Development
RTA	Rio Tinto Aluminium
SPL	Spent Pot Lining
STLC	Soluble Threshold Limit Concentration
SEC	Specific Energy Consumption
SEU	Significant Energy User

Abbreviation	Definition
SPL-MF	Spent Pot Lining Mixed Fines
SPCB	State Pollution Control Board
TCLP	Toxicity Characteristic Leaching Procedure
TPD	Tonnes per Day
TFO	Two-for-One
UCWL	Udaipur Cement Works Limited
UKRI	UK Research and Innovation
UK	United Kingdom
UCL	University College London
UoC	University of Cambridge
VAM	Vapor Absorption Machine
WHRS	Waste Heat Recovery System

For more information please contact:

Bureau of Energy Efficiency
Ministry of Power, Govt. of India
4th Floor, Sewa Bhawan,
R. K. Puram, New Delhi - 110066 (INDIA)
Phone : 011 – 26766700
Fax: +91 11 26178352

ASPIRE Programme Team
In-fmaspire@kpmg.com

Archana Chauhan
Head, Energy Sector Reform
British High Commission
archana.chauhan@fcdo.gov.uk

Vikas Gaba
Programme Lead ASPIRE and
Partner, KPMG in India
vikasgaba@kpmg.com