UK Government

Accelerating Smart Power & Renewable Energy in India (ASPIRE) Programme

iDeeksha Newsletter

Industrial Energy Efficiency/ Decarbonisation Outlook

Case studies on select global technologies and best practices

iDeeksha

Industrial Decarbonization and Energy Efficiency Knowledge Sharing Platform

March 2023

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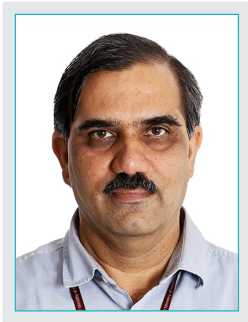


Director General, Bureau of Energy Efficiency

Warm greetings to industry friends and colleagues.

India has demonstrated climate leadership and a firm commitment for achieving the clean energy transition. At the COP27 in Egypt, India submitted its Long-Term Low Emissions Growth Strategy indicating low carbon transition pathways in key economic sectors. Earlier, at COP26 in Glasgow, the Prime Minister of India announced the five nectar elements or 'Panchamrit' of India's climate action to achieve net-zero target by 2070. In August 2022, India updated its Nationally Determined Contributions and has embarked on far-reaching new initiatives in renewable energy, e-mobility, ethanol blended fuels, and green hydrogen as an alternate energy source.

Industrial sector (including MSMEs) offers potential of upto ~55% of the total energy savings and ~42% of total emissions reduction in India by 2031, as per Bureau of Energy Efficiency's (BEE) "Unlocking National Energy Efficiency Potential" (UNNATEE) report, 2019. Thus, in order to enable our country to achieve its target to become net-zero by 2070. It is essential to decarbonize the industrial sectors, particularly, the 'hard to abate sectors' such as Cement, Iron & Steel, Aluminium, Chemicals etc.

BEE is implementing the Perform, Achieve and Trade (PAT) scheme with the objective of enhancing EE measures focusing on large energy intensive industries covering thirteen sectors. With seven PAT Cycles rolled out, these industries have adopted various low hanging energy efficiency (EE) measures to achieve energy saving targets. Now, the next set of opportunities for incremental savings and decarbonisation would require adoption of emerging low-technologies.

As the industry strives to achieve the targets given under the PAT scheme, there will be a need to enhance knowledge and access to new and innovative technologies & services. To enable industries in their efforts to decarbonise, this year the Knowledge Exchange Platform (KEP) has been rejuvenated with the support of Government of UK in association with the Ministry of Power and Ministry of New and Renewable Energy, Government of India. The rejuvenated KEP is being launched as 'iDEEKSHA – Industrial Decarbonisation and Energy Efficiency Knowledge Sharing Platform'. The iDEEKSHA would be a one-stop shop for all needs of Indian energy intensive industries including database of proven and emerging technologies and their providers available globally. The iDEEKSHA would thus facilitate exchange of knowledge and information to enhance peer-to-peer learning, access to best practices across sectors, energy management tools, technologies, links to data sources and knowledge repositories, enable knowledge and commercial partnerships.

I am happy to share that Knowledge Sharing Platform has released the, first of a series of newsletter covering international case studies on key technologies, best practices and expert views. I hope this newsletter will enable energy intensive industries to benefit from the information and explore further possibilities for adoption.

I would also like to appreciate the industry's initiative and support in working with the Knowledge Sharing Platform and ASPIRE team to promote peer-to-peer learning through various sectoral workshops. I urge industry stakeholders to intensify their efforts by offering comments to inputs on new innovative technologies, methods. Energy conservation is a national movement, and we must all work together to make India an energy-efficient economy and society to compete not only on our domestic market but also on the global stage.

Message from Alex Ellis

British High Commissioner to the Republic of India

Climate change is an existential challenge for our race and planet. Increasing numbers of extreme weather events around the world show the risks to our livelihoods, jobs and the natural environment.

So we need to act together if we are avert the worst impacts of climate change. At COP26 in Glasgow, we did just that. Almost 200 countries came together to sign the Glasgow Climate Pact which strengthens our resilience to climate change, to cut greenhouse gas emissions and to provide finance for the green transition. Prime Minister Modi proposed ambitious new targets for 2030 and pledged India would have net zero emissions by 2070. A year later, at COP 27, the Government of India published a Long-Term Strategy, setting out how India will achieve these targets.

To go further down the path of decarbonisation requires renewed focus on the industrial sector. Industries are one of the most significant contributors to emissions in India - around 25% of total emissions, second only to power generation. India's Long-Term Strategy sets out how it might develop an efficient and innovative low-emission industrial system. It highlights the opportunities to improve energy and resource efficiency, material efficiency and recycling, to strengthen the circular economy and to promote emerging technologies such as green hydrogen and carbon capture and storage technologies.

The UK must act as well, so it recently established the Energy Efficiency Taskforce to reduce energy demand through promoting energy efficiency across the economy. The taskforce will work to reduce total UK energy demand by 15% from 2021 levels by 2030, across domestic and commercial buildings and industrial processes.

The UK and India are also working together on the green transition and industrial energy efficiency. In October 2021, we launched a new UK-India bilateral programme: "Accelerating Smart Power and Renewable Energy" (ASPIRE) which aims to work with India to reach India's 2030 targets.

I am delighted to announce that under ASPIRE, 'iDEEKSHA: Industrial Decarbonisation and Energy Efficiency Knowledge Sharing Platform' has been developed in collaboration with the Bureau of Energy Efficiency (BEE). The iDEEKSHA platform will share best practices and Industrial Energy Efficiency and Decarbonisation (IEED) technologies among energy intensive industries. Along with the iDEESKHA platform, we are releasing the first set of newsletters which will provide case studies on new and emerging low-carbon technologies and industry best practices. I hope that the information in these will help industries in reducing their energy and carbon consumption, contributing to India's efforts to achieve its climate goals.

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" (ASPIRE)** was launched in October 2021. ASPIRE is being implemented[1] by Foreign Commonwealth and Development Office, Government of UK in association with 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

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 large-scale industries. The 'iDeeksha' portal is a one-stop shop for all energy efficiency needs of large industries covered under BEE's PAT Scheme.

The 'iDeeksha' portal would thus facilitate:

- Exchange of knowledge, information and best practices on energy management to enhance peer to peer learning
- Enable Designated Consumers (DCs) in adopting new and emerging IEED technologies offered by Indian and global technology suppliers including from the UK
- Access to database of financial institutions, policy
- Access to IEED tools, technologies & technology providers available in India and globally
- Access to data sources and knowledge repositories to support knowledge translation
- Organise sector/ industry specific workshops/ seminars to enhance EE measures
- Enable knowledge and commercial partnerships

This is the first of a series of newsletters that are being developed under the above initiative of ASPIRE programme for the 'iDeeksha' portal and the Bureau of Energy Efficiency.

[1] KPMG is the lead delivery partner for the ASPIRE programme. Idam Infrastructure Advisory Private Limited (India) and Carbon Trust (UK) are the key consortium members.

SECTION 1

CASE STUDIES - GLOBAL IEED TECHNOLOGIES

1.1 Textile Sector: UK's 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 CO2 emissions and over 20% of global water pollution. At current consumption growth rates, textile dyeing could be responsible for 10% of global CO2 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.

Alchemie Endeavour™ - Technology description

Figure 1: Alchemie's Endeavour™ Technology

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.

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.

Technical Specifications - Endeavour™	
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	12.6m x 6.3m x 3.5m
Power requirements	415V 3 phase 50/60 Hz electrical supply

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 utilizes 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.

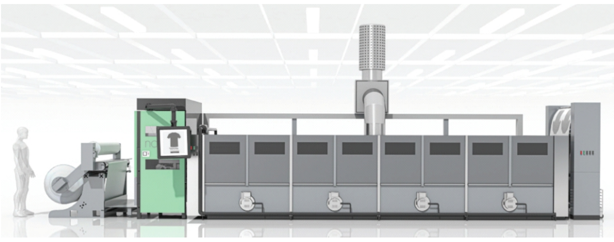


Figure 2: Alchemie NovaraTM system

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.

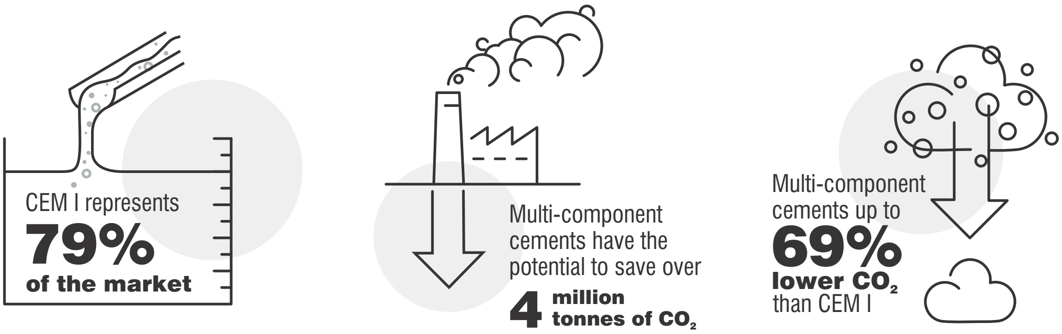
Novara™ system is fully connected and automated, enabling Industry 4.0 manufacturing platforms to be delivered. The system can be connected to MES/MRP systems, delivering unparalleled supply chain agility and flexibility. The Novara™ system can be implemented into existing production lines and capital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

Technical specifications - Novara™	
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

1.2 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), the UK trade body for the mineral product industry 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. As per expert analysis, a clinker-GGBS-limestone cement could potentially help in achieving up to 60% reduction in carbon footprint as compared to Portland cement-CEM I. If fully deployed, this would result in a reduction in direct emissions from cement production of over 4 million tonnes of CO2 every year (Figure 3). In this project, MPA 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.



About the innovation

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 4). Cement compositions 19- 22 (designated CEM VI) were calculated to have 60% less embodied carbon compared with Portland cement CEM I.

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)

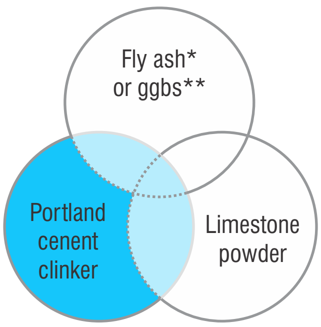


Figure 4: Design concept for low-carbon multi-component cements

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[2]

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).

Figure 5: Sequence of backfilling retaining walls with sulphated soil (clockwise from top left)

Five of the 22 cements were selected to produce five reinforced concrete retaining wall elements (Figure 5). 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.

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

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 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% as compared to Portland cement CEM I, the current market leader (Figure 6). Calculations are based on the established values of embodied carbon for each of the multi-component ingredients.

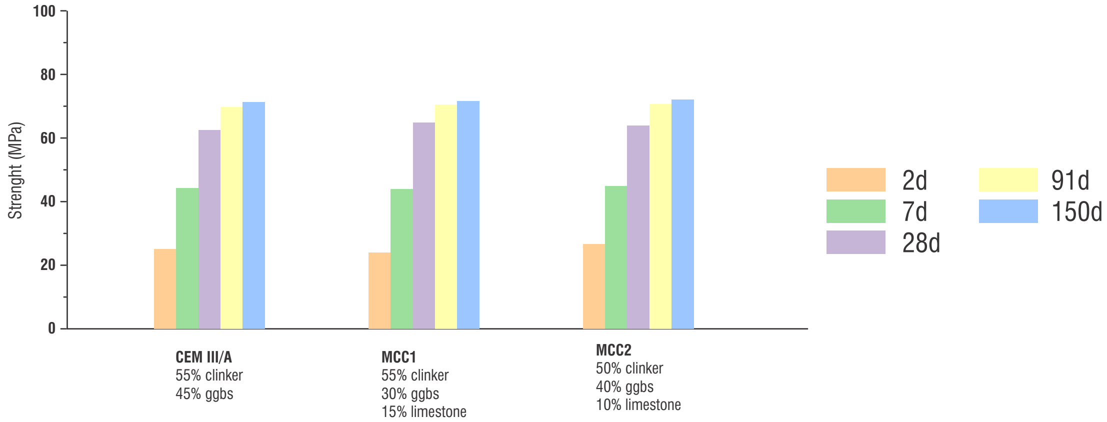


Figure 6: Compressive strength test data for multi-component cement concretes vs the reference CEM III/A

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, India's cement manufacturing capacity stands at 500 million tonnes per annum (MTPA) producing 298 MTPA. Considering the growth in infrastructure, cement production in India is expected to be 800 MTPA by the year 2030[3]. The cement industry has voluntarily devised a Low Carbon Technology Roadmap aimed at reducing its direct CO2 emission intensity by 45% by 2050 (baseline-2010). 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[4]. Similar low-carbon multi-component cement products offer significant potential for the Indian cement industry to reduce the CO2 intensity of cement production.

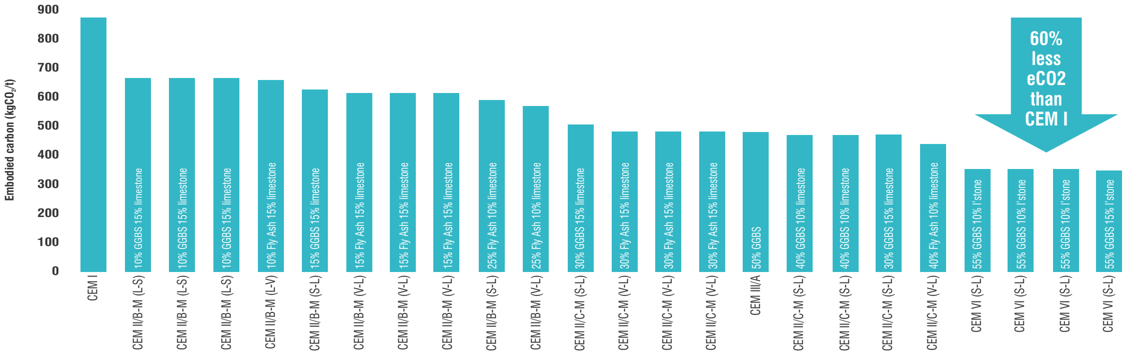


Figure 7: Embodied CO_2 of the tested cements versus Portland cement CEM I

[3] Cement | Bureau of Energy Efficiency (beeindia.gov.in)
[4] Energy Technology Perspectives 2017 – Analysis - IEA

1.3 Industry 4.0 Wireless Energy Solutions for Net Zero and Energy Productivity from UK

Centrica brings patented **Industry 4.0 Wireless Energy** solution to India which drives **Net Zero** and **Energy productivity** across the organization. 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 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 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 CO2e 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 emissions 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 8: Net Zero Solution Journey

Centrica offers end to end solution, 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.

Centrica's End to End Coverage of Carbon Footprint

End to End coverage of **Carbon footprint** by Centrica's Wireless sensors **across Energy sources**

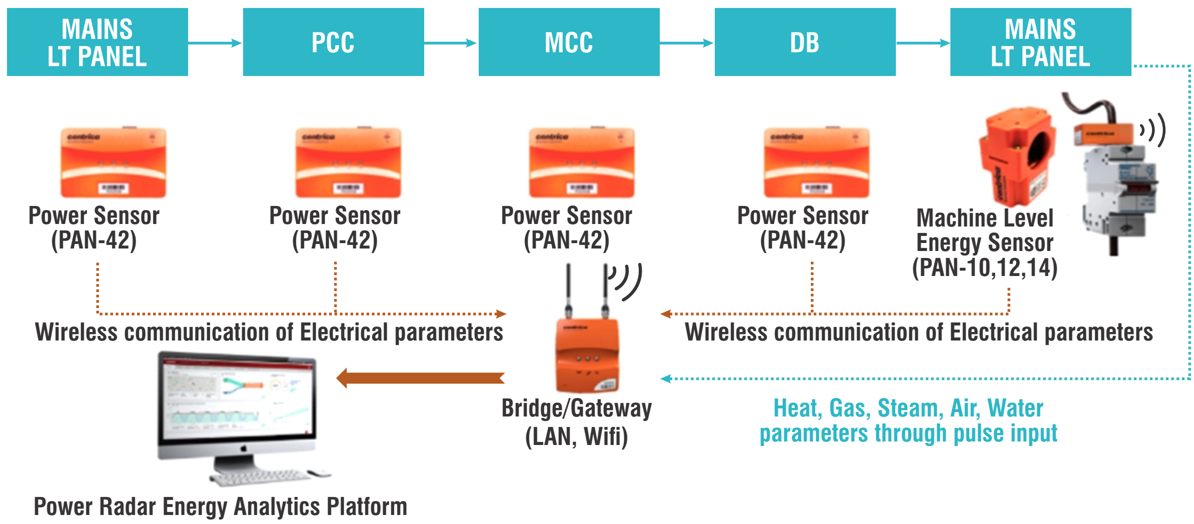


Figure 9: System Architecture

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 **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 **prioritizing** and **sequencing** of energy efficient machines which drives efficient **production-planning**.

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 the 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).

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**

Wireless Sensors - no wiring cost	Maintenance free
Self-powered	Granular "Machine level" Intelligence
Non-invasive	Real time data transmitted every 10 seconds
Stores data during power failure	Temperature & Fire safe (Flammability rating UL94 V-0)
Humidity safe Humidity range (5%-95% non-condensing)	International certifications (USA, Europe, AUS, RUS, JAPAN)
No Disruption in Production	Cost-effective
Miniature & Quick installation	Patented Technology with no Competition
Real-time alerts for equipment failure	Reports for Management review meetings

Figure 10: Key Features

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 IIoT energy management, IIoT solutioning & Green strategy company and works with organizations to drive their production efficiency and energy productivity by leveraging digitalization & automation.

1.4 Pulp & Paper Sector: Novel dewatering solutions within corrugated case medium manufacture

Background and technology introduction

The UK paper-based industry has developed a 2050 Decarbonisation Roadmap with the Government and between 1990 and 2019, emissions of fossil CO_2 from UK paper mills fell from 6.6 million to 1.8 million tonnes – a total reduction of 72%. Building on these efforts, DS Smith and RISE Innventia targeted improvements in water cleanliness and dewatering during formation and pressing giving a 2.5% increase in sheet dryness after pressing and a reduction in drying energy consumption by 10%. To test and optimize dewatering at scale, the demonstration was carried out between 2020-2022 on Paper Machine 4 (PM4) at DS Smith Kemsley Mill in the Southeast of England. Three areas of technology improvement were targeted; improving process water cleanliness with the aim of reducing conductivity and cationic demand by 20%, optimisation of dewatering chemicals, and finding the best floc size and formation for increased press section dewatering.

The current process and improvement

Dewatering starts in the wire forming section where water is removed first by gravity and later by applying vacuum in suction boxes. The drying section accounts for ~**75%** of the total energy consumption on the paper machine. Increasing the dryness of the paper web after pressing by one percent could reduce the drying energy consumption by 4%.

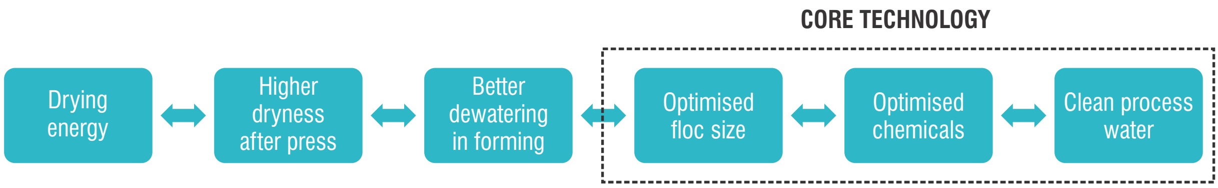


Figure 11: The Link Between Dewatering, Drying and Process Water Quality

The demonstration[5] within RISE Innventia's semi-industrial FEX plant included installing a Focused Beam Reflectance Measurement (FBRM) device (Mettler-Toledo Particle Track E25) to assess if such a technique could measure floc formation 'real time' and allow the control of process chemical addition to increase dewatering. The FBRM device was installed at DS Smith and water clean-up and dewatering trials were carried out at full scale over six days of operation.

Improving process water quality

The critical areas to improve water quality were identified (Figure 12) and following measures were undertaken at each of the critical areas identified:

1. Treatment of pulp before the thickener to fix anionic trash to fibre and improve process water cleanliness. This in turn improved flocculation and dewatering thereby reducing the amount of water carried over to PM4.
2. A consequence of reducing high cationic demand filtrate solids from the thickener, meant that 30% less cationic polymer was required to be added to the Save All. This in turn improved retention aid efficacy and dewatering on PM4.
3. Further fixation of anionic trash to the pulp after the blend chest improved water quality leading to further improvement in dewatering.
4. Optimising the retention system chemicals to that improved pulp enabled the control of the floc size in the headbox and delivered the required dewatering improvement.

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

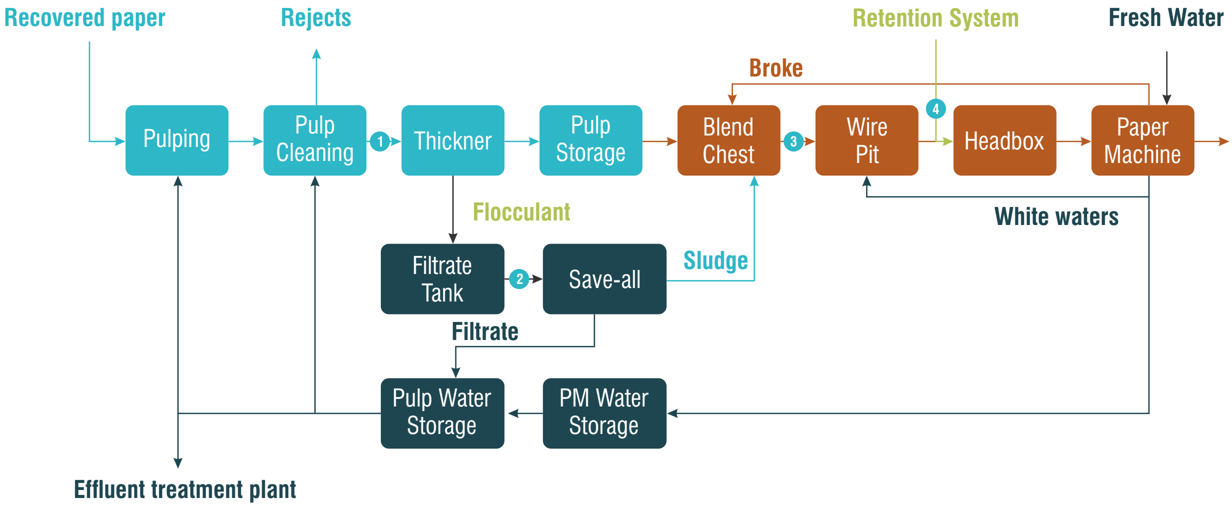


Figure 12: Critical Areas to Improve Process Water Quality

Dewatering and drying

The FBRM was installed in the approach flow to PM4 to monitor flocculation by measuring the number of fibre flocs in the pulp suspension and their chord length (Figure 13). The FBRM provided, for the first time, real-time information on floc formation to allow the control of process chemicals to optimise floc size for dewatering and higher dryness after press.

Figure 13: Installed FBRM

Results

- Most striking results obtained through application of a fixative to the pulp after the blend chest to improve water quality
- 3-5% lower couch vacuum and 10% reduction in steam consumption across six different grades made over a 6-day period
- Improvements seen in Figure 14 were linked to improved flocculation in the headbox (Figure 15)
- Better dewatering at higher amount of fixative, even without the addition of Cationic Starch (CS)
- Linear correlation observed between the number of particles measured (counts) and the dryness in the wire section (referred as couch vacuum), enabling the possibility for online control and development of dewatering soft sensors based on the FBRM
- Estimated costs, energy savings, and payback are depicted in Figure 16

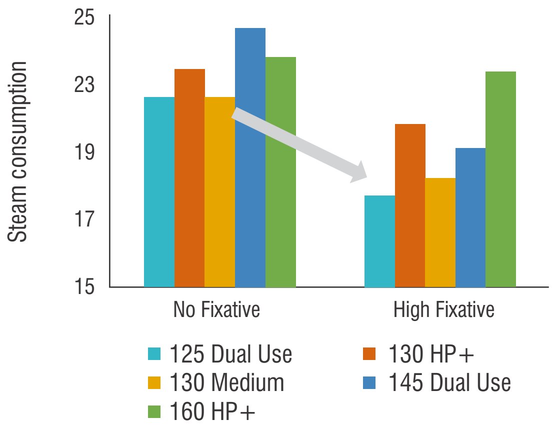


Figure 14: Steam consumption with and without fixative for different paper grades

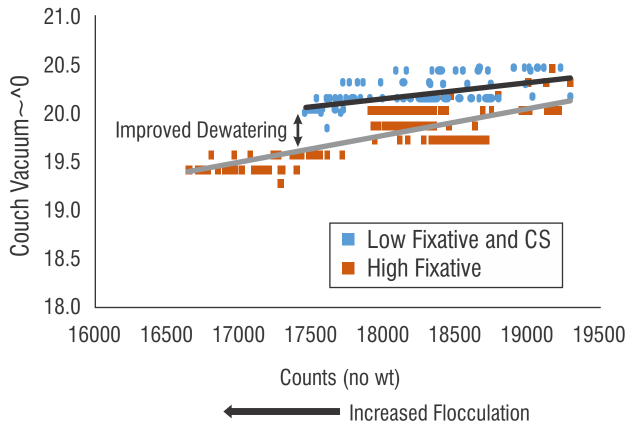


Figure 15: The couch vacuum vs flocculation at different addition levels of fixative and cationic starch

Description	Cost Estimates (£)
Total Capital Cost	645,000
Additional Chem Spend	459,000
Depreciation	64,500
Total Annual Cost	523,000
Annual Saving	877,500
Net Annual Saving	354,000
Capex Payback	1.82

Figure 16: Estimate of costs, energy savings, and payback

Potential Opportunity for India

The Indian paper industry accounts for about 5% of the world's paper production, with more than 900 mills and estimated turnover of INR 74,000 Crores (£ 7.4 billion).

The specific energy consumption of the typical paper industry in India was evaluated as 34.3 GJ per ton of paper (including energy consumption for wood chipping and pulping) and specific CO2e emissions as 3.4 tons CO2 per ton of paper. An integrated wood/ agro-based paper mill with a conventional recovery system in India is estimated to use 12.7- 16.5 tons of steam per ton of paper produced. The use of novel dewatering solutions presents a significant opportunity to reduce steam consumption up to **10%**, resulting in substantial energy and carbon savings.

SECTION 2

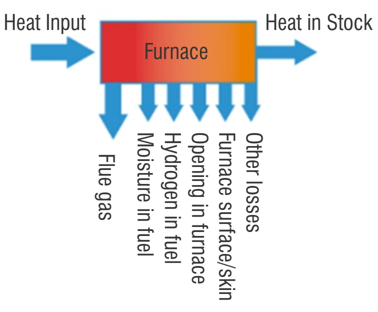
INTERNATIONAL BEST PRACTICES IN IEED

Global Aluminium Sector: Industry Best Practices

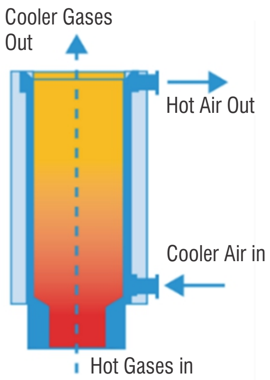
The UK's aluminium sector creates an estimated £10 billion annually for the country's economy, whilst employing more than 20,000 people. Aluminium production and supply in the UK is orientated towards the supply chains of high-value sectors, such as aerospace, automotive, rail and construction, as well 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

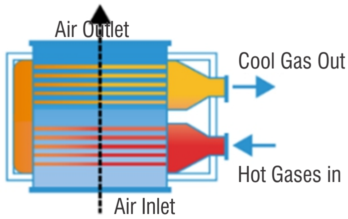
Heat use is abundant across multiple processes in the aluminium industry. The excess heat from exhaust gas of electrolysis cells can easily be recovered through heat exchangers. Similarly heat loss in aluminum furnaces presents a key energy efficiency opportunity. This can achieved in multiple ways like, better refractory lining and insulating materials, use of appropriate wall thicknesses, covering open wells and use of regenerative burner and recuperator-based heat exchange systems. An estimated 20-25% fuel savings can be achieved through use of exhaust gas heat exchangers, whilst up to 5% energy reduction can be realized through improved insulation materials and between 10-30% saving can be achieved through preheating of combustion air with heat recovered from exhaust gases.



Typical heat flow and losses in a furnace



A cross-section of a double shell radiation recuperator



Two-step convection heat exchanger in parallel flows

Figure 17: Typical heat losses and recuperator for waste heat recovery

The recovered heat from aluminum 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. Similarly heat loss from anodizing process can be reduced by use of lids on the anodizing tanks. Immersion heaters also 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 and saves time and energy via reduced cleaning needs. Non-stationary flame burners can also increase the efficiency of heat transfer, by directing the flame to preferred areas of the furnace and increasing firing rates in areas with a higher concentration of metal charge. 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

Electrolysis in primary aluminium production is around 85% of plant's energy requirement. The process control improvement in electrolysis cells offers an opportunity for energy efficiency. Conventional control systems work to achieve smelter target settings through adjustment of process parameters to compensate for changes in inputs and operations. The second generation of process controls 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 CO2 emissions and 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 aluminum industry globally. Elysis, a Canadian company is leading work in the development of cell technology based on inert anodes. The company produced the first batch of aluminium using inert anodes in 2019 and has ambitions for a full-scale commercial demonstration by 2023.

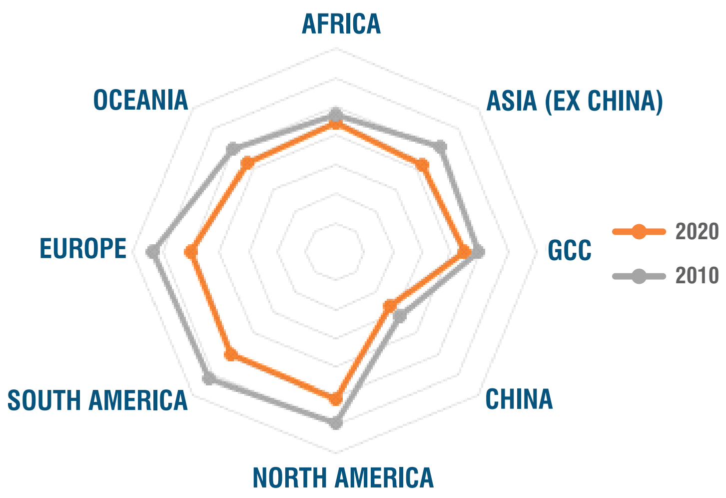


Figure 18: Global smelter electrolysis efficiency improvement over the decade

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, 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. 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, is leading aluminum 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.

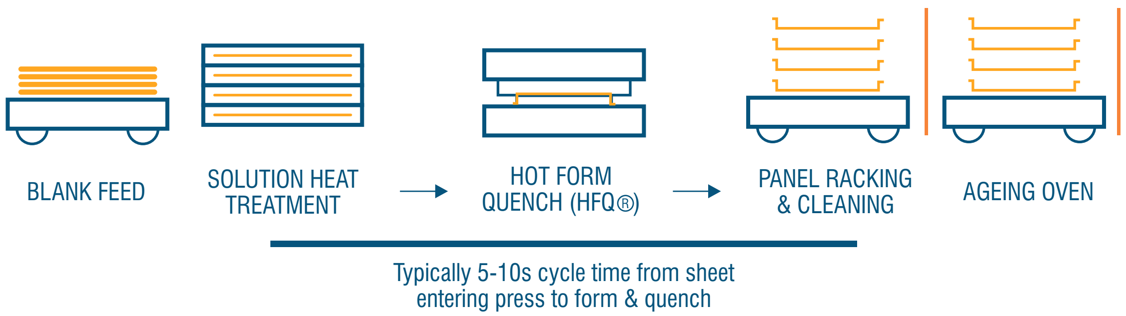


Figure 19: Process steps in low carbon Hot Form Quenching solution from Impression Technologies

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 springback 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.

As shown in Figure 20, 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. The improvement in aluminium formability achieved by the HFQ process broadens the scope for aluminium use in automotive applications, offering greater design freedom, process optimization, and attainment of higher strength and stiffness levels with a reduced bill of materials.

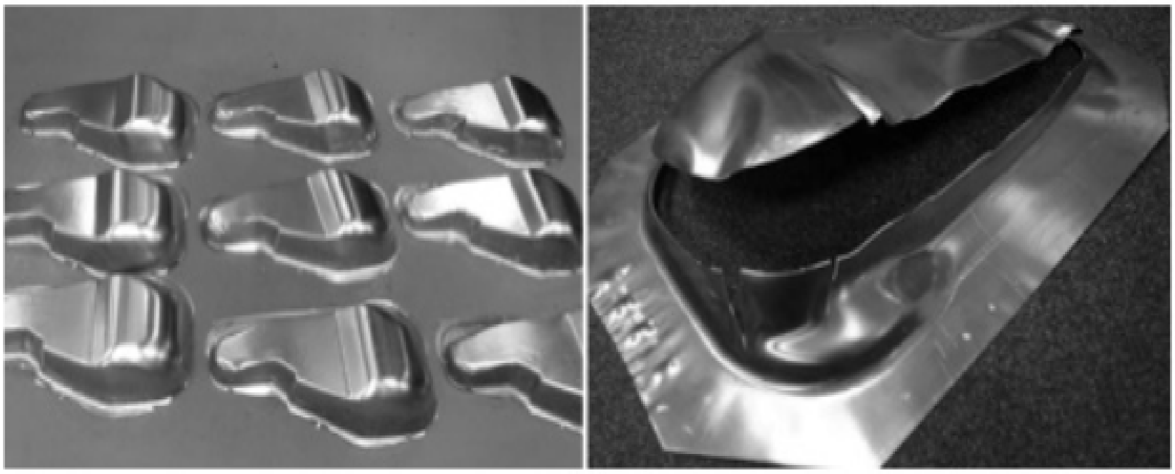


Figure 20:(left) Selection of successfully pressed parts with HFQ Technology (right) same material shown to sheer when pressed at room temperature using conventional cold methods

SECTION 3

EXPERT VIEWS ON EMERGING LOW-CARBON IEED TECHNOLOGIES

"Importance of Inert Anode technology for the Aluminium Sector" – by Dr. Anupam Agnihotri, Director, JNARDC, Nagpur

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 revolutionizing the industry. Unlike carbon anodes, inert anodes are not corroded during the aluminium reduction process and do not release CO2 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:

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

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 CO2 per kg of aluminium.

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

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

Where Vcell 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 oxidized 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 oxidized:

$$C + O_2 = CO_2$$

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).

Inert Anode process:

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

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 localized 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 polarization voltage or anode overpotential is reduced to about 0.15 V.
- 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.

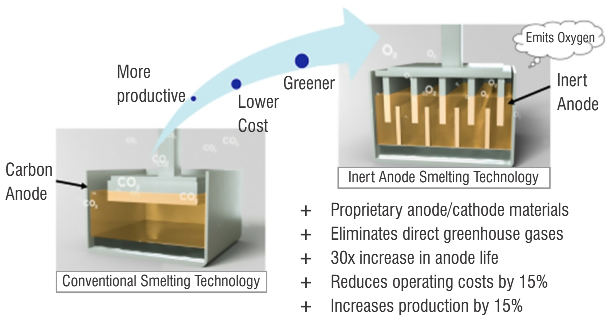


Figure 21: A breakthrough aluminium smelting technology

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.

SECTION 4

INITIATIVES BY INDUSTRIES TO PROMOTE GESI (GENDER EQUALITY & SOCIAL INCLUSION)

Initiatives by UK industries

Renishaw, UK

- Formed an employee led, UK Diversity and Inclusion Group, in 2020, to establish a more inclusive culture and diverse workforce
- Conducted awareness campaigns on various topics such as racism, LGBTQIA+, gender, cultural awareness, disabilities, etc.
- Forged partnerships with several organisations including – (a) The Employers Network for Equality & Inclusion (enei); (b) Disability Confident – Are you disability confident?; (c) Empowered Employers

Make UK – The Manufacturers' Organisation

- Make UK has set out the following guiding principles to encourage its 20,000+ member manufacturers to commit to a more diverse and inclusive manufacturing workforce:
    - Define an EDI ambition and publish it through an EDI statement owned and championed by senior leaders form the company
    - Create a truly inclusive culture by building a workforce reflective of the working population, and the local community
    - Share best practices with peers and learning from those who have made positive change
- Women make up ~**18%** of company boards and ~**29%** of manufacturing workforce in member manufacturers

Initiatives by Indian industries

Vardhman Fabrics, Budhni

- Organises workshops on women empowerment in nearby villages
- Policy of “Equal work equal remuneration”
- Social skill development programs for women workers like "PACE" (Personal Advancement and Carrier Enhancement)
- Women workers representing the organisation at various international events

Vedanta Ltd., Lanjigarh

- Inclusion of women employees in important managerial decision-making bodies (at present up to 30%)
- Target to deploy 30% of women employees on the shop floor
- Hiring from the LGBTQ community and conducting sensitisation training of all employees
- Implemented project ‘Sakhi’ with the objective to make women aware of their socio-economic and cultural status in society and help them avail their rights and privileges

Trident Group

- ‘Asmita’ initiative to spread awareness among women regarding empowerment, general health and hygiene through interactive audio/visual presentations and seminars
- ‘Saksham’ initiative to provide employment for differently abled people to ensure inclusion with mainstream society
- ‘Shisha Protsahan’ initiative aimed at increasing the literacy & development level of the girl child of families living in tribal and remote areas of Sehore district, Madhya Pradesh

Women employees of Aditya Aluminium Plant (Odisha, India) during the Aluminium Sector Study Tour orgranised under ASPIRE Programme (November 2022)

NOTES

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