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ASPIRE Programme

Accelerating Smart Power & Renewable Energy in India

IDEEKSHA NEWSLETTER

INDUSTRIAL ENERGY EFFICIENCY/ DECARBONISATION OUTLOOK

CASE STUDIES ON SELECT GLOBAL TECHNOLOGIES AND BEST PRACTICES

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Industrial Decarbonisation and Energy Efficiency Knowledge Sharing Platform

MARCH 2024

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Message from Mr. Srikant Nagulapalli, IAS

Director General, Bureau of Energy Efficiency

As our nation's economy continues to thrive, energy demand has grown substantially. However, the heightened energy intensity in specific sectors raises concerns about sustainability. In this context, the efficient use of energy resources and their conservation becomes pivotal for curbing wasteful consumption and ensuring sustainable development. Recognising that efficient energy use and conservation are the most cost-effective solutions to address the escalating energy demand, the Bureau of Energy Efficiency (BEE) has introduced the Perform, Achieve, and Trade (PAT) scheme, now in its eighth cycle.

The PAT scheme, a cornerstone of our efforts, has played a pivotal role in driving the adoption of various energy efficiency measures by large energy-intensive industries in thirteen sectors, with plans to include more sectors soon. As we strive towards the PAT scheme targets, incorporating emerging low-carbon technologies becomes imperative for unlocking the next level of incremental savings and achieving decarbonisation.

To support industries in their journey towards decarbonisation, I am pleased to introduce the IDEEKSHA platform which was launched by the Hon'ble Cabinet Minister for Power and New and Renewable Energy, at the 21st Foundation Day of BEE and a Decade of PAT Scheme event on March 01, 2023. The platform has been developed by the Accelerating Smart Power and Renewable Energy in India (ASPIRE) programme in collaboration with the Bureau of Energy Efficiency (BEE). ASPIRE is a bilateral programme implemented by the Foreign, Commonwealth and Development Office, Government of UK and Ministry of Power, Government of India.

The IDEEKSHA platform serves as a central hub for knowledge exchange and collaboration between industries and technology suppliers across eight challenging sectors, all covered under BEE's Perform Achieve and Trade (PAT) scheme. It provides comprehensive support to these sectors, fostering access to a global database of Industrial Energy Efficiency & Decarbonisation (IEED) technologies, newsletters, capacity-building workshops, study tours, and more. As part of our commitment to continuous improvement, we are now extending technical assistance support through the IDEEKSHA platform to four new industrial sectors: Pulp & Paper, Chlor-Alkali, Sugar and Tyre Manufacturers

As we embark on this extension, I am delighted to announce the launch of the first newsletter by the IDEEKSHA Platform. This edition showcases national and international case studies on IEED technologies, specifically focusing on the Pulp & Paper, Chlor-Alkali, Tyre, and Aluminium sectors.

Heartfelt congratulations to the authors of this newsletter. I trust that the information presented will prove invaluable to our stakeholders, contributing to the continued success and sustainability of our endeavours.

Message from Lindy Cameron

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. Prime Minister Modi proposed ambitious new targets for 2030, and pledged India would have net zero emissions by 2070. At G20 New Delhi, India encouraged the global leaders for tripling of renewable energy capacity and doubling of energy efficiency by 2030. The UK being a global leader in the fight against climate change, supported this initiative along with other world leaders.

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, submitted to UNFCCC during COP27, 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 is acting as well – we are committed to delivering clean power by 2030 and accelerating to net zero. The UK government has committed £3.9 billion in financial year 2025-26 for the first carbon capture utilisation and storage (CCUS) clusters in the UK to decarbonise industry, support flexible power generation and capitalise on the UK's geographic and technical strengths. We have also launched the Great British Energy to invest in home-grown, clean energy, and are establishing a new National Wealth Fund to supercharge growth in clean energy industries.

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.

Under ASPIRE, the 'IDEEKSHA: Industrial Decarbonisation and Energy Efficiency Knowledge Sharing Platform' has been developed in collaboration with the Bureau of Energy Efficiency (BEE), Ministry of Power. The IDEEKSHA platform has shared best practices and Industrial Energy Efficiency and Decarbonisation (IEED) technologies among energy intensive industries. The newsletter provides case studies on new and emerging low-carbon technologies and industry best practices. I hope that the information in it will help industries in reducing their energy and carbon consumption, contributing to India's efforts to achieve its climate goals.

Introduction

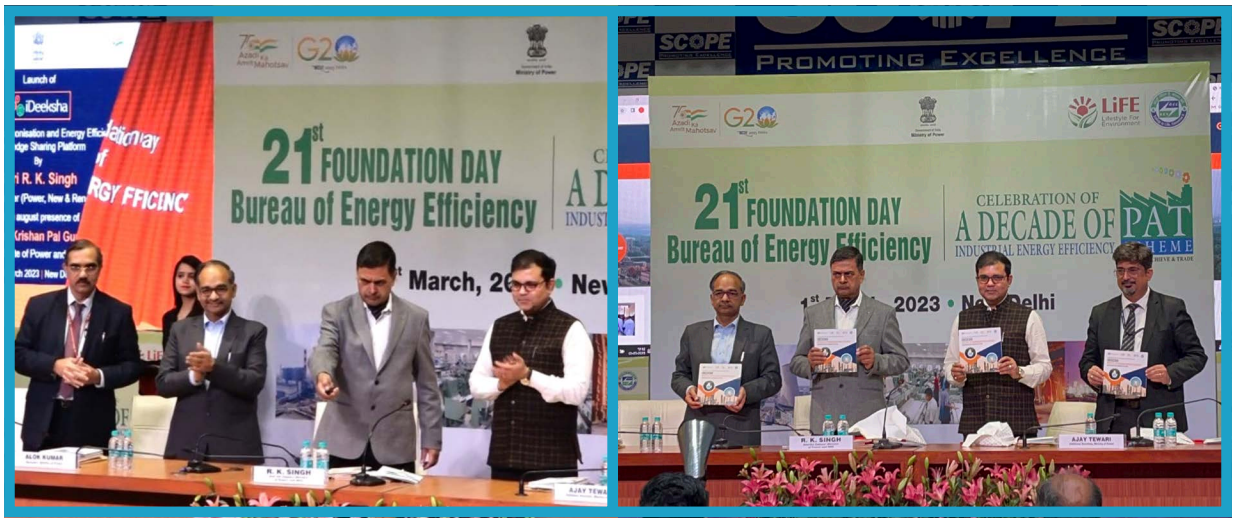
1.1 About ASPIRE Programme

Accelerating Smart Power and Renewable Energy (ASPIRE) is a bilateral technical assistance programme being implemented by the Foreign, Commonwealth and Development Office (FCDO), Government of UK in association with the Ministry of Power and Ministry of New and Renewable Energy, Government of India (GOI). Key objective of the ASPIRE Programme is to facilitate India's transition towards a sustainable, low carbon energy ecosystem to fulfill its net-zero commitments. KPMG is the implementation advisor to FCDO in relation to the ASPIRE programme and Idam Infrastructure Advisory Private Limited (India) is a key consortium member.

Industrial energy efficiency and decarbonisation (IEED) is a key thematic area of support under the ASPIRE programme which is being implemented in association with Bureau of Energy Efficiency (BEE), GoI.

1.2 About IDEEKSHA Platform

The Industrial Decarbonisation and Energy Efficiency Knowledge Sharing (IDEEKSHA) Platform has been developed under the ASPIRE Programme in collaboration with the BEE to promote and share best practices and energy-efficient technologies among large-scale 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 1st March 2023, in Delhi.



Snapshots from IDEEKSHA Platform and Newsletter launch during BEE's Foundation Day Event

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 EE measures.
- Knowledge and commercial partnerships

The IDEEKSHA platform facilitates knowledge exchange and partnerships among industry and technology suppliers for 8 hard-to-abate industrial sectors (Cement, Aluminium, Iron & Steel and Textile, Fertiliser, Chlor-Alkali, Pulp & Paper, and Refinery) which are also covered under BEE's Perform Achieve and Trade (PAT) scheme. Under the IDEEKSHA Platform, support was extended to four (4) energy-intensive industrial sectors (Cement, Aluminium, Iron & Steel and Textile) in terms of providing access to database of global industrial energy efficiency & decarbonisation (IEED) technologies, organising capacity building workshops and study trips, etc. Four sectoral workshops and study trips were organised in 2022 and 2023, each focusing on key industries: Aluminium, Textile, Cement, and Iron & Steel. These events are aimed at understanding industry-specific challenges, opportunities, and identifying strategies for sustainable development. The details of the events, including background notes, presentations, event summary reports, etc., can be accessed through the IDEEKSHA Platform (https://www.ideeksha.in/) under 'Past Events' tab.

Now, the ASPIRE Programme in consultation with the Bureau of Energy Efficiency is extending the technical assistance support through IDEEKSHA platform to four (4) new industrial sectors namely, Pulp & Paper, Chlor-Alkali, Tyre manufacturers and Sugar. As part of the support, ASPIRE Programme team is organising workshops and plant study trips for the above 4 new focus sectors to enhance energy efficiency measures and enable decarbonisation in the industrial sectors. Further, the platform would also host a technology compendium encompassing IEED technologies available in India and globally (including from the UK and newsletters showcasing case studies on leading IEED best practises adopted by the Indian and International players (including from the UK), along with innovative low – carbon technologies/ solutions and their suppliers tailored for the above sectors.

This is the fifth of a series of newsletters that are being developed under the above initiative of ASPIRE programme for the 'IDEEKSHA Platform" and the Bureau of Energy Efficiency.

Section 1

Case Studies on International IEED Technologies

1.1 INEOS's Bichlor™ Bipolar Membrane Electrolyser for Chlor-Alkali Sector

Introduction

BICHLOR™ is a technological solution offered by INEOS Electrochemical Solutions, UK. This technological solution introduces a modular design in electrolyser construction, allowing for streamlined maintenance and reduced plant downtime. Each module, comprising an anode, membrane, and cathode, can be independently removed, is maintained in a controlled workshop environment, and replaced without disrupting the system's operation.

The BICHLOR™ Electrolyser features several innovative technologies that contribute to its efficiency and performance. Some of these are as follows:

1. A bipolar design allows for the use of a thicker membrane, which reduces power consumption.
2. A proprietary CHLORCOAT™ coating on the electrodes which reduces corrosion and increases lifespan.
3. A modular design that simplifies maintenance and minimises plant downtime.

Figure 1: BICHLOR™ Electrolysers[1]

Benefits of BICHLOR™ Electrolysers

Key benefits of the BICHLOR™ Electrolyser include the following:

1. Significant energy savings with very low power consumption of 1,990[2] kilowatt hour/ tonne (kWhr/te) Sodium Hydroxide (NaOH) @ 6 kiloampere/ square meter (kA/m^2)
2. Class leading output of 52,000 million tonnes per annum (MTPA) of NaOH per electrolyser[3] Robust, safe construction with superior strength and resistance to damage and distortion
3. Largest effective working area of 3.4m^2 per module requiring fewer modules per tonne of NaOH

1 Home | INEOS Electrochemical Solutions
2 Expected value @ 385 mbarg, 90°C and 32 wt% NaOH, subject to coating selection
3 Based on 350 days operation and 7 kA/m^2
4 en_ineos-bichlor-electrolyser.pdf

	BICHLOR™	Closest alternative technology performance
Active unit Area, m²	**3.4**	**2.7 – 3.27**
Pressure range, mbarg	**0 - 400**	**0 - 400**
Cathode coating life, years	**8**	**8**
Anode coating life, years	**8 - 12**	**8 - 10**
Max current density, kA/m²	**7**	**7**
Expected life of units, years	**30+**	**20**
In-Pan recoating	**Yes**	**Yes**
Access to electrode pool	**Yes**	**Sometimes**
Pan wall thickness, mm	**1**	**0.8**

Figure 2: BICHLOR's performance against the closest alternative technology[4]

Key features of the technology

1. Zero-gap technology delivers full use of the membrane area and extends the membrane's life
2. Offers widest operational pressure range, and hence all operator requirements can be met
3. Modular design enables pre-installation pressure testing, simpler and safer maintenance, and offline preparation for rapid electrolyser turnaround
4. Fully wetted membrane design and external header helps protect against explosions and membrane damage
5. Open mesh cathode structure reduces localised heating and concentration high spots that can cause membrane damage
6. Advanced module sealing reduces the risk of leakage and corrosion
7. Long-lasting electrode coatings enhance the efficiency of the electrolysis process by lowering the overpotential needed to drive the reaction. This reduction in overpotential leads to decreased energy input, resulting in lower power consumption and other production- and energy-related greenhouse gas emissions in caustic soda production.

Case Study: Caustic Soda Production by INEOS's BICHLOR™ Electrolyser at Xinpu Chemical Co Ltd, China[5]

Background

Xinpu Chemical Co., Ltd., a leading chemical manufacturer in China, the company primarily produces and supplies various industrial chemicals including biomedical chemicals, food additives, textile chemicals etc. The company wanted to optimise their caustic soda production process, with specific focus on reducing energy consumption, enhancing safety, and improving overall efficiency. To achieve these goals, the company invested in the acquisition of BICHLOR™ Electrolyser for caustic soda production.

Implementation

Xinpu Chemical's strategic investment involved incorporating a new INEOS Electrolyser into its production line, which produces approximately 150,000 tonnes of caustic soda annually. This addition contributes to the company's total annual production of nearly 750,000 tonnes.

Results

After just 120 days of operation, the new INEOS Electrolyser achieved an impressive production rate of over 540 tonnes per day. This significant improvement not only met but exceeded the company's initial expectations.

5 ***Disclaimer:*** *The ASPIRE Programme does not endorse or support any specific company or information contained within the case study. The information provided in the case studies of this newsletter are based on the information available on the websites of the respective technology providers.* ***Source:*** *Case Studies | INEOS Electrochemical Solutions*

Benefits

One of the most notable advantages of the INEOS technology was the high degree of automation it offered. This advanced system allowed Xinpu Chemical's staff, many of whom were recent university graduates with limited experience, to quickly become proficient in managing the cellroom. The automation enabled seamless control of gas-switching, air-purging, and flow adjustment, streamlining the training process and enhancing operational efficiency.

Potential opportunity for India

1. The BICHLOR™ Electrolyser technology by INOES enables substantial energy savings and enhanced energy efficiency through several key features. Firstly, its innovative cell design reduces the energy required for the electrolysis process. Secondly, the use of advanced materials and coatings minimises energy losses and improves overall efficiency. Additionally, the system's modular architecture allows for optimised operation and reduced maintenance, further contributing to energy savings.
2. The solution ensures long-lasting performance over the lifetime of chlor-alkali production due to its robust design and the use of high-quality materials. The electrolyser's modular construction enables easy maintenance and replacement of individual components, extending its operational life and maintaining consistent performance.
3. It prioritises safety in chlor-alkali production. It incorporates advanced safety features and control systems to minimise risks associated with the handling of hazardous materials. The modular design allows for safe and efficient maintenance, reducing the potential for accidents and ensuring a secure operating environment.

Latest updates on technology collaboration in India

INEOS Electrochemical Solutions will be deploying BICHLOR™ bipolar membrane electrolysers in the Chemfab Alkalis Karaikal Limited's (CAKL) production facility in Karaikal, South India.[6] The initial caustic soda capacity of 250 tonnes per day (TPD) will expand to 1,000 TPD in phases. The first phase will commission in mid-2024.

6 INEOS BICHLOR™ electrolysers selected by Chemfab Alkalis

1.2 Distributed Boiler Control System for Pulp and Paper Sector

Introduction

A distributed boiler control system (DBCS) is a type of industrial control system that is used to monitor and control boilers used in various sectors including the pulp & paper industry.

Refiners rank among the top energy consumers in the pulp and paper industry, alongside boilers, steam generation systems, compressed air, and hydraulic systems. The significant amount of waste heat generated underscores the importance of implementing heat recovery systems, such as economisers and heat exchangers. Additionally, the byproduct of biomass anaerobic digestion, which produces biogas, holds considerable potential for onsite green energy generation.

DBCSs are typically composed of a series of networked controllers that are responsible for monitoring and controlling different aspects of the boiler, such as the fuel feed, combustion, steam pressure, and temperature. DBCSs are used to control a variety of boilers, such as firetube boilers, water tube boilers, & recovery boilers.[7]

Use of DBCS in Pulp & Paper Industry

DBCSs are used in the pulp & paper industry for monitoring and controlling the following:

1. **Fuel feed rate:** DBCSs can be used to monitor the fuel feed rate to the boiler and adjust the same as needed to maintain a desired combustion temperature which improves efficiency and reduces emissions.
2. **Air flow:** DBCSs can be used to monitor the air flow to the boiler and adjust the same as needed to maintain a desired combustion efficiency which improve efficiency and reduce emissions.
3. **Combustion temperature and pressure:** DBCSs can be used to monitor the combustion temperature and pressure in the boiler and adjust the same as needed to maintain a desired temperature thereby improving the quality of the steam that is produced and reducing the risk of damage to the boiler.
4. **Alarms:** DBCSs can be used to monitor and alert the operator in case of irregularities.

Benefits of DBCS technology

1. **Improved efficiency:** improved boiler efficiency through optimisation of fuel combustion and steam distribution resulting in significant cost savings in terms of fuel and energy consumption.
2. **Reduced emissions:** reduced emissions through combustion optimisation and real-time feedback on emissions levels.
3. **Enhanced safety:** enhanced safety through real-time monitoring and control of boiler operations. Thus aiding in prevention of accidents and injuries.
4. **Increased uptime:** increased uptime by providing early warning of potential problems and by providing remote access for troubleshooting. This can help to reduce unplanned downtime and improve production efficiency.
5. **Simplified operations:** simplified operations by providing a single, integrated platform for monitoring and controlling boiler operations. This can make it easier for operators to manage boiler operations and can free up their time for other tasks.

7 https://www.researchgate.net/publication/286317538_Automatic_control_of_boiler_system_using_distributed_control_system

About Yokogawa's OpreX Control – Distributed Control System (DCS)[8]

A distributed control system (dcs) is a platform for automated control and operation of a plant or industrial process. A DCS combines the following into a single automated system: human machine interface (HMI), logic solvers, historian, common database, alarm management, and a common engineering suite.

Yokogawa's DCS provides field-proven system availability, enterprise-wide interoperability, extensive advanced solutions portfolio, and third party-certified defence-in-depth cybersecurity to increase productivity and improve plant operations. DCS has applications across several manufacturing sectors with processes that are continuous or batch- oriented including pulp & paper mills, chemical and petrochemical industries, nuclear power plants, water and sewage treatment plants, fertiliser industries, automobile manufacturing, sugar refining plants, etc.

Application of the technology in pulp & paper production

Yokogawa helps the pulp and paper productions plants through comprehensive automation solutions that enable plant-wide integration and lifecycle optimisation. With regards to boilers, Yokogawa offers ABC Control, charbet level control, black out monitor and emissions control recovery boilers.[9]

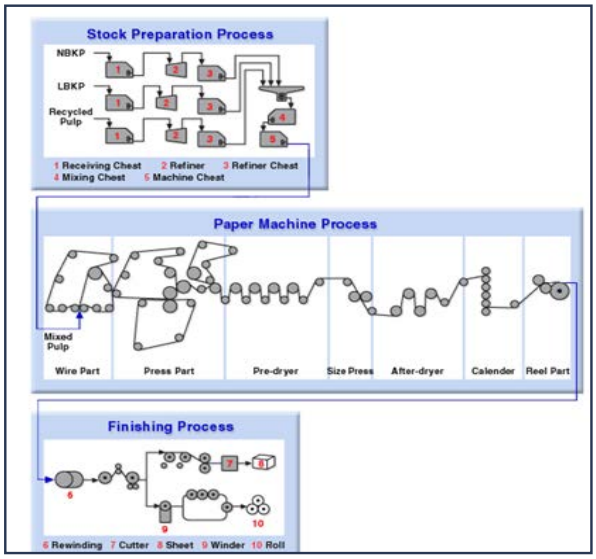


Figure 3: Diagrammatic representation of Pulp Production Process

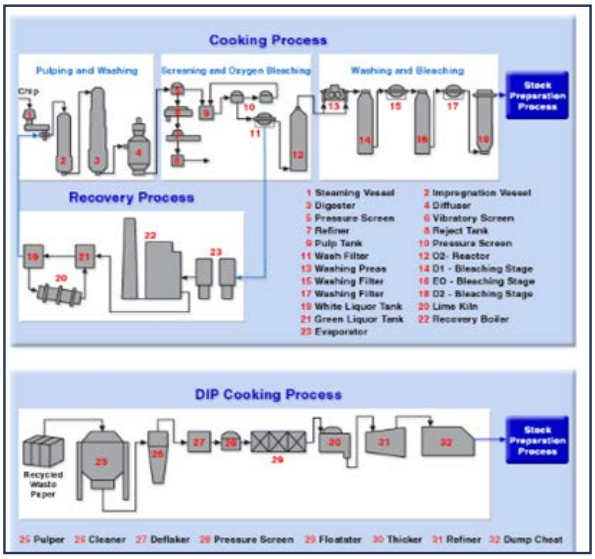


Figure 4: Diagrammatic representation of Paper Making Process

Case Study: Yokagawa's Installation of Quality Control System integrated with Distributed Control System at Chung Hwa Pulp Corporation, Taiwan[10]

Background:

Chung Hwa Pulp Corporation (CHP) is a prominent paper manufacturing company in Taiwan. With the goal of enhancing paper quality and improving operational efficiency, CHP decided to upgrade the control systems of its paper machine. The aim was to achieve better weight consistency, caliper, and moisture profile control while optimising machine speed.

8 Distributed Control System (DCS) | Yokogawa United Kingdom Ltd.
9 Pulp & Paper | Yokogawa United Kingdom Ltd.
10 Disclaimer: The ASPIRE Programme does not endorse or support any specific company or information contained within the case study. The information provided in the case studies of this newsletter are based on the information available on the websites of the respective technology providers. Source: Yokogawa Installation of Integrated Quality Control System Improves Product Quality and Efficiency at Pulp & Paper Mill | Yokogawa India

Implementation:

To achieve this, CHP acquired Yokogawa's B/M9000CS quality control system, which includes high-resolution sampling and display capabilities for managing weight consistency, caliper, and moisture profiles. The system's adaptive control with artificial intelligence techniques allowed for automatic tuning, while the virtual actuator zone averaging method provided improved cross-direction (CD) control.

Additionally, a finite time setting response method was employed to realise stable and high-speed control. The new system was also integrated with the company's existing CENTUM CS 3000 distributed control system, allowing seamless operation of the stock preparation, additive, and screening processes. A plant-wide Ethernet network was established to link the control room with the main office, enabling real-time monitoring and modifications.

Results:

The upgrade led to significant improvements in paper quality and machine speed. Notable results include:

- **30% Improvement in Paper Quality:** Enhanced CD control improved paper fiber orientation, reducing sheet breaks on the rotary press and printing displacement in multi-color printing. This also decreased curling defects and the likelihood of paper jams in photocopiers.
- **10% Increase in Machine Speed:** The efficient control system allowed the paper machine to operate at higher speeds, leading to increased productivity.
- **30% Reduction in Steam Consumption:** The CD moisture control significantly reduced steam usage, resulting in energy savings.

Potential opportunity for India

The Indian pulp and paper industry can leverage **distributed boiler control system** to address several challenges such as high energy consumption, low productivity, increasing emissions, safety apprehensions etc. The distributed boiler control system, currently employed in the UK paper industry, enables energy efficiency, improves productivity, helps in reducing emissions, enhances product quality and plant safety.

1.3 Carbon nanotubes for Tyre Sector

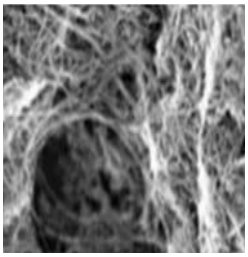
Introduction

Carbon nanotubes (CNTs) are a type of nanomaterial which is used to improve the tensile strength and tear resistance of tyres and make them more durable as well as less likely to puncture.

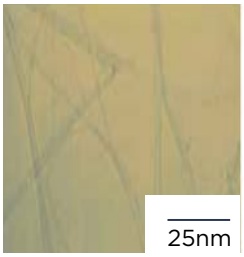
CNTs can be used in tyres to improve several properties, including:

1. **Rolling resistance:** CNTs can help to reduce rolling resistance, which can improve fuel efficiency and lower CO_2 emissions.
2. **Wet grip:** CNTs can help to improve wet grip, which can reduce the risk of hydroplaning.
3. **Abrasion resistance:** CNTs can help to improve abrasion resistance, which can extend the life of the tyre.
4. **Heat dissipation:** CNTs can help to dissipate heat, which can improve the performance of the tyre.
5. **Improved tyre durability:** CNTs can enhance the durability and longevity of tyres. This means that tyres made with CNTs can last longer, reducing the need for frequent tyre replacements and the associated environmental impact of tyre production and disposal.

Test	Elicarb SW	Elicarb SW Low Residue
Inorganic ash% w/w	4.0	1.9
Fe residue % w/w	1.0	1.2
TGA inorganic ash % w/w	4.2	1.8
BET surface area/ m2g-1	>700	>800
Raman G/D ratio	>22	>22



SEM image of **Elicarb® Sw**.



TEM image of **Elicarb® SW**.

Typical test data on **Elicrab® SW and Elicarb® Sw Residue**.

Figure 5: Details of CNTs by Thomas Swan | Source: Thomas Swan, UK

Decarbonisation in tyre manufacturing using CNTs

The use of CNTs in tyre manufacturing can enable decarbonisation of the tyre sector by reducing fuel consumption and improving tyre durability. CNTs are a sustainable material as they require less product per volume of rubber in tyre manufacturing.

Application of CNT technology and impact in tyre manufacturing

Molecular Rebar Design, Austin, USA

Molecular Rebar Design has successfully developed new rubber composites with individualised carbon nanotubes under the Molecular Rebar (MR) brand name improving tyre tread compound performance for use with EVs.

The new MR material is a chemically functionalised, discrete multi-wall carbon nanotube that binds into the rubber compound using silane technology. This Molecular Rebar-based tyre tread material drastically improves abrasion resistance by more than **25%** (correlating to improved tyre life), reduces tread weight by **6-7%,** and reduces rolling resistance by more than **20%** (correlating to improved energy efficiency), as compared to an in use, state-of-the-art, silica-silane tread compound.

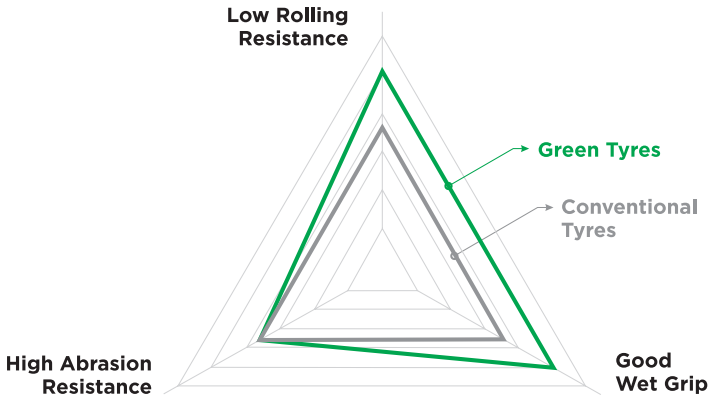


Figure 6: Graphical representation of three tyre properties as altered from a carbon-filled tyre compound to a silica-filled green tyre compound

Utilisation of MR in tyre rubber composites changes the paradigm of tyre compounds that have been used for decades, with the most recent shift being the adoption of silica bound by silane. With MR, particularly an organo-silane functionalised version that covalently binds to the rubber composite structure, new rubber compounds can be designed to improve energy efficiency, lower tyre weight, and improve lifetime of tyres for electric vehicles. Over time, these improved composites will be used in various types of tyres, regardless of power train source (internal combustion engine or electric vehicles).[11]

Process

In situ polymerisation is one of the most popular methods to incorporate CNTs into a polymer matrix.

Basic method to introduce CNT in tyre rubber:

1. Raw materials - natural rubber and chemicals
2. Compounding and Mixing: operation of bringing together natural rubber, process oil, CNT, accelerator, and other additives, each of which contributes certain properties to what is called a 'compound'. To obtain a homogeneous mixture, they are mixed at high temperatures.
3. Component Preparation:
    - Extrusion – Process of applying heat and pressure on the compound and additional mixing of the compound.
    - Calendaring – Process of squeezing the compound into a thin sheet.
4. Tyre building: As per standard method
5. Curing: As per standard method

Chemical method to introduce CNT into Natural Rubber (NR):

1. Soaking of NR in the Tetrahydrofuran (THF) for 6-8 hours
2. Separately disperse the CNT 2-3% into the solvent (THF)
3. Add dispersed CNT in the above-mentioned solution of THF and NR
4. Mechanical stirring for about 2-3 hours
5. Probe sonicate the solution for 10-20 minutes
6. Dry at room temperature after which it could be added into the extrusion process

11 RPN_20230501_tech_notebook.pdf (rubbernews.com)

Costs

One of the key motivations to utilise CNTs in tyre manufacturing has been reduction in cost of producing industrial quantities of CNT's. Compared with other methods, chemical vapor deposition (CVD) is the most effective method that has broad prospects for large-scale control of CNTs in recent years due to its simple equipment, simple operation, and lower cost. This method has enabled ~**66%** reduction in CNT production cost.

Benefits of the technology

1. **Lower rolling resistance:** Rolling resistance is the force that opposes the rolling motion of a tyre. Lower rolling resistance results in lower energy consumption to move the tyre, which leads to improved fuel efficiency. CNTs can help to lower rolling resistance by increasing the stiffness of the tyre and reducing the amount of energy lost due to friction.
2. **Lighter weight:** CNTs are very strong and lightweight, which can help to reduce the weight of a tyre. This can improve fuel efficiency and handling.
3. **Improved wet grip:** CNTs can help to improve the wet grip of a tyre by providing an even distribution of pressure across the tread. This can help to prevent hydroplaning and improve safety in wet conditions.
4. **Increased durability:** CNTs can help to increase resistant to wear and tear resulting in increased durability. This can extend the lifespan of the tyre and reduce the frequency of replacements.
5. **Reduced heat build-up:** CNTs can help to reduce heat build-up in a tyre by improving the thermal conductivity of the rubber. This can help to prevent the tyre from overheating, which can lead to premature failure.

Thomas Swan Advanced Materials CNT Technology, UK

Thomas Swan & Co. is a global leader in the production of advanced materials, with a focus on graphene and other 2D materials. Based in the UK, the company specialises in research, development, and commercialisation of innovative materials for a wide range of industries, including electronics, energy, aerospace, and more. They offer a variety of high-quality products and services, such as graphene powders, dispersions, and composites, to meet the needs of their customers worldwide. Thomas Swan & Co. also offers carbon nanotube (CNT) products alongside their graphene offerings, including:

1. Elicarb® SW (single-walled carbon nanotubes)
2. Elicarb® SW Low Residue

Potential opportunity for India

Carbon nanotubes (CNTs) have the potential to revolutionise the tyre industry in India due to their exceptional properties such as high strength, low weight, and excellent electrical and thermal conductivity. Some potential opportunities for using CNTs in the Indian tyre industry include:

1. Reinforcement of tyre rubber.
2. Improved tread wear.
3. Enhanced grip and traction.
4. Reduced rolling resistance.
5. Sensing and monitoring.

Overall, use of CNTs in the Indian tyre industry has the potential to enhance tyre performance, reduce costs, improve safety, and contribute to a more sustainable transportation sector.

Sources:

1. *Elicarb-SW-Products-Advanced-Materials-LR.pdf (thomas-swan.co.uk)*
2. *Nanomaterials used in Tyre (Tire) Manufacturing - INSCX*
3. *TUBALL: Revolutionary Carbon Nanotubes for the Tyre Industry (ocsial.com)*
4. *Nanotube Technology Set to Replace Carbon Black in Tire Production (teamtrade.cz)*

Section 2

National Case Studies on Leading IEED Practises

2.1 Reducing Environmental Footprint And Enabling Decarbonisation Of Lanjigarh Refinery

By Mr. Sanjaya Kumar Jena,
General Manager, Vedanta Ltd. - Lanjigarh Alumina Refinery

Introduction

Vedanta is the largest producer of aluminium in India. The company has carved a niche for itself in the global aluminium industry with its superior product quality based on state-of-the-art technology. Vedanta Limited operates a **2** million tons per annum (MTPA) capacity alumina refinery in Lanjigarh (Odisha), India since 2007 and an associated **90** megawatt (MW) captive power plant. The refinery feeds Vedanta's aluminium smelters at Jharsuguda in Odisha and at BALCO in Korba, Chhattisgarh. Lanjigarh Refinery is on track to decarbonise its operations and contribute to the local community, in line with the Vedanta group strategy.

Highlights of Energy Performance

- 322 tonnes (T) of biomass successfully fired in boilers in FY2023 in a pilot project
- ~7 Million Units (MU) of green power imported in FY2023
- ~91,000 tonnes of CO_2e abated with savings of ~INR 300 per tonne achieved through various energy saving projects in FY2023
- ~31,700 tonnes of carbon oxide per tonne of CO_2e saved (INR 61 per tonne) through steam economy improvements in one turbine
- ~14,000 tonnes of CO_2e abated with savings of ~INR 27 per tonne by replacing air preheater (APH) in one boiler
- ~8,900 tonnes of CO_2e abated with savings of ~INR 46 per tonne by replacing air venturi rectification & refractory in one calciner

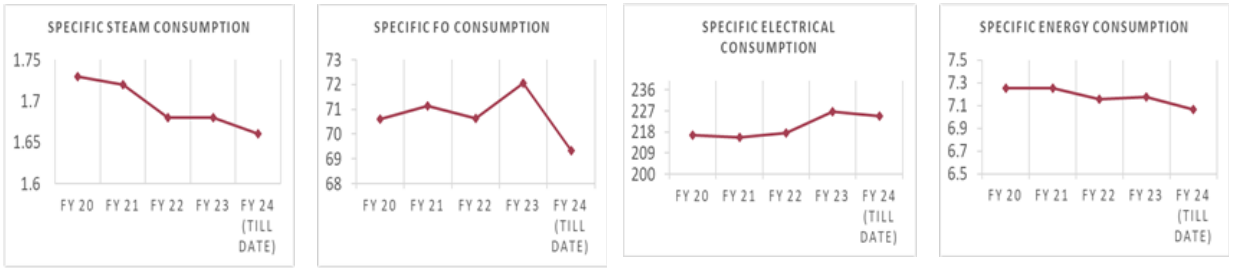


Figure 7: Energy Performance of Lanjigarh Refinery

Highlights of energy saving projects (FY 2020 – FY 2023)

Year	No. of Energy Saving Projects	Investment (in INR million)	Electrical Savings (million Kwh)	Thermal savings (GJ)	Savings (in INR Million
FY 2019-2020	4	15.5	1.2	75805.4	63.8
FY 2020-2021	7	11.2	34.2	13.4	119.7
FY 2021-2022	15	76.3	5.5	339759.3	159.2

Year	No. of Energy Saving Projects	Investment (in INR million)	Electrical Savings (million Kwh)	Thermal savings (GJ)	Savings (in INR Million
FY 2022-2023	**32**	**447.2**	**20.12**	**914709**	**615**

~30x growth in investment on energy saving projects between 2020 and 2023 to INR 447 million

Highlights of key energy saving projects completed in FY 2023

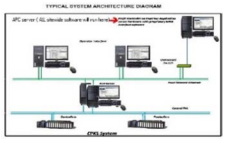
A total of 32 nos. of energy saving projects were completed in FY 2023 resulting in savings of:

- **7** kilo watt hour (kWh) per tonne of output in specific electrical energy consumption
- **0.05** tonnes of steam per tonne of output
- **1** kilogram per tonne of output .

Key projects impacting specific coal consumption and station heat rate:

	**Steam economy improvement in Turbine Generator #3:** Overhauling of the turbine rotor with repair of damaged blades. Steam economy of turbine ain steam improved by **0.2** T/MW, with energy saving of **0.37** million gigajoules (GJ) and greenhouse gas (GHG) savings of **31,735** tons of CO_2.
	**Air pre heater (APH) replacement in Boiler #2:** replacement of APH in boiler helped improve specific coal and thermal efficiency. This resulted in coal savings of **11.7** kilo tonne (kT) and energy saving of **0.15** million giga joule (GJ) and GHG savings of **14+** kilo tons of CO_2.

Key projects for improving specific steam consumption:

	**Max HT™ Chemical Dosing:** MHT™ acts as a scale growth inhibitor and helps as an anti-scalant in evaporation tubes. MHT dosing resulted in energy savings of **40,000** GJ and GHG savings of **3,564** tons of CO_2e.
	**Evaporation 1 & 2 Calandria tubes replacement:** Scaling inside calandria tubes affect specific steam consumption. Replacement of the tubes resulted in energy savings of **80,000** GJ and GHG savings of **8,134** tons of CO_2e.
	**Implementation of APC in Evaporation units:** Digitalisation of process control units by implementation of advanced process controllers. Resulting in energy saving of **40,000** GJ and GHG savings of **3,563** tons of CO2.
	**Digestion heater replacement:** this helped improve specific steam consumption resulting in energy savings of **1,20,000** GJ and GHG savings of **7,126** tons of CO_2e.

Key projects for improving specific electrical & furnace oil (FO) consumption:

	**Calciner 2 refractory and air venturi replacement:** to minimise heat loss in calciner and to arrest air ingress in furnace and improve specific Furnace Oil (FO) resulting in energy savings of **86,000** GJ and GHG savings of **5,900** tons of CO_2e.
	**HST O/F motor from DOL to VFD:** to prevent valve throttling operation resulting in energy saving of **1.3** million kWh and GHG savings of **1,014** tons of CO_2e.

Energy Week Celebration & Energy Awareness in Schools

 	• Organised energy walks with higher management during Energy Week celebration in December 2022 • Undertook various energy awareness activities such as ideation sessions, quiz session across the refinery • Awareness campaigns regarding energy related topics across two schools during the Energy Week.

Mr. Sanjeev Kumar
COO - 5 MTPA
Vedanta Lanjigarh

"Energy efficiency and renewable technology are not just buzzwords for us; they are the cornerstone of our commitment to sustainability and a greener future. By embracing these practices, we not only reduce our environmental impact but also unlock new opportunities for innovation, cost savings, and long-term success. Investing in energy efficiency and renewable technology is not only the responsible thing to do but also a strategic move that positions us as leaders in our industry".

Disclaimer: The projected or estimated saving potential or investment in case studies are as claimed by the company/author and ASPIRE Programme do not endorse it.

Section 3

From the Archives

3.1 From the Archives: timeless gems to revive your reading list!

A. Pulp & Paper Workshop & Study trip

A sectoral workshop on 'Best Practices in Energy Efficiency in Pulp & Paper sector: A Path for Decarbonisation' was organised by the ASPIRE programme in collaboration with Bureau of Energy Efficiency (BEE) on 13th February 2024 in Amritsar, Punjab.

The workshop witnessed participation from **40+** stakeholders including senior officials from the BEE, Indian Agro and Recycled Paper Mills Association, Central Pulp and Paper Research Institute (CPPRI), leading Indian pulp and paper manufacturers including – JK Paper Mills, Century Pulp and Paper, Tamil Nadu Newsprint & Aper Ltd., Bindals Papers Mills Ltd. etc. along with low-carbon and digital technology providers from India and the UK.

During the workshop, experts from UK and India presented some new emerging technologies and best practices to enhance energy efficiency (EE) and enable decarbonisation including advanced pulping methods like black liquor gasification, innovative paper forming and drying techniques, energy-efficient processes such as CHP, waste heat recovery, energy management solutions and sustainable practices like green liquor utilisation and carbon capture. The workshop also included a dedicated session on importance of Gender Equality & Social Inclusion (GESI) in the industrial sector and various GESI initiatives undertaken by Indian industries across sectors to build capacity regarding equity, diversity and inclusion.

Figure 8: Sectoral workshop on 'Best Practices in Energy Efficiency in Pulp & Paper sector: A Path for Decarbonisation' held in Amritsar on 13th February 2024

The workshop was followed by a study trip to Khanna Paper Mills in Amritsar on 14th February 2024. **~40** stakeholders (including 17% women participants) got an opportunity to develop deeper understanding of the paper making process, new and innovative IEED technologies implemented by Khanna Paper Mills, foster an ambitious, mutually beneficial, and outcome-focused relationship with other industry stakeholders.

Figure 9: IDEEKSHA sectoral study trip of Khanna Paper Mills, Amritsar on 14th February 2024

B. Chlor- Alkali Workshop & Study trip

A sectoral workshop on 'Best Practices in Energy Efficiency in Chlor-Alkali sector: A Path for Decarbonisation' was organised by the ASPIRE Programme in collaboration with BEE and with support of Gujarat Alkalies & Chemical Ltd. (GACL) on 27th February 2024 at GACL Dahej, Gujarat.

The workshop witnessed participation from **70+** stakeholders including senior officials from the BEE, GACL, DCM Shriram Alkali & Chemicals, Grasim Industries, Reliance Industries, Kutch Chemical Industries, Nirma etc. along with low carbon and digital technology providers from India and the UK. During the workshop, experts from UK and India presented new and emerging technologies & leading practices to enhance IEED of the chlor-alkali sector. Some of the key technologies included – membrane cell electrolysers, specialised electrode coatings, carbon capture, wireless energy management solutions, etc. The workshop also included a dedicated session on importance of Gender Equality & Social Inclusion (GESI) in the industrial sector and various GESI initiatives undertaken by Indian industries across sectors to build capacity regarding equity, diversity and inclusion.

Figure 10: IDEEKSHA sectoral workshop on 'Best Practices in Energy Efficiency in Chlor-Alkali sector: A Path for Decarbonisation' held at GACL Dahej Complex on 27th February 2024

The workshop was followed by a study trip of GACL Dahej Complex on 28th February 2024 wherein **25+** industry stakeholders (including 15+% women participants) got an opportunity to develop deeper understanding of the new & innovative IEED technologies implemented by GACL, foster an ambitious, mutually beneficial, & outcome-focused relationship with other industries.

Figure 11: IDEEKSHA sectoral study trip of GACL Dahej Complex, Gujarat on 28th February 2024

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