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GOVERNMENT OF INDIA
MINISTRY OF POWER

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

iDeeksha

Industrial Decarbonisation and
Energy Efficiency
Knowledge Sharing Platform

AUGUST 2024

CONTENTS

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.

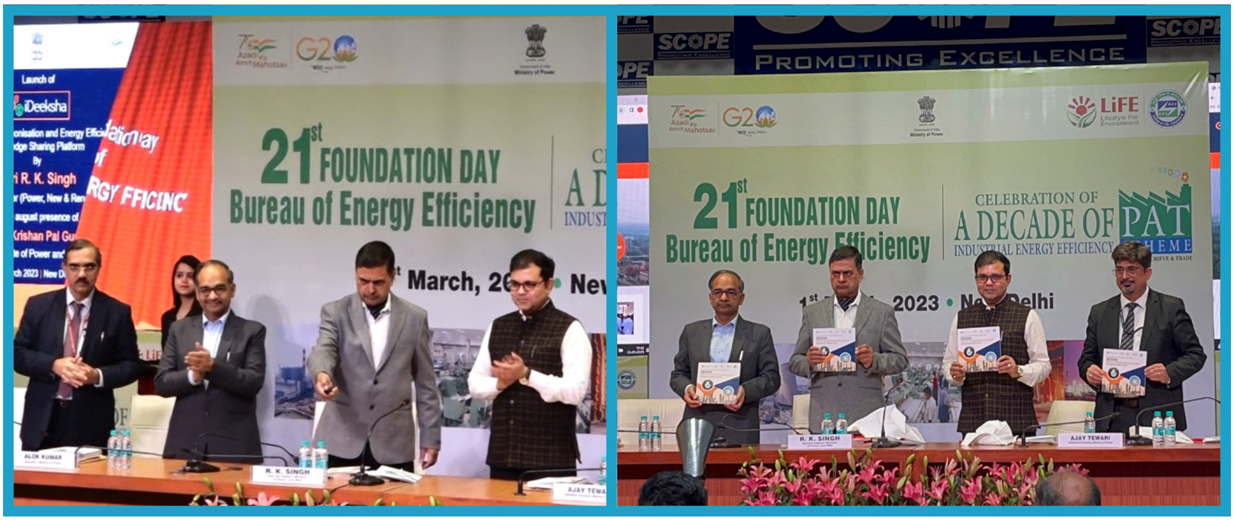
INTRODUCTION

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.

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

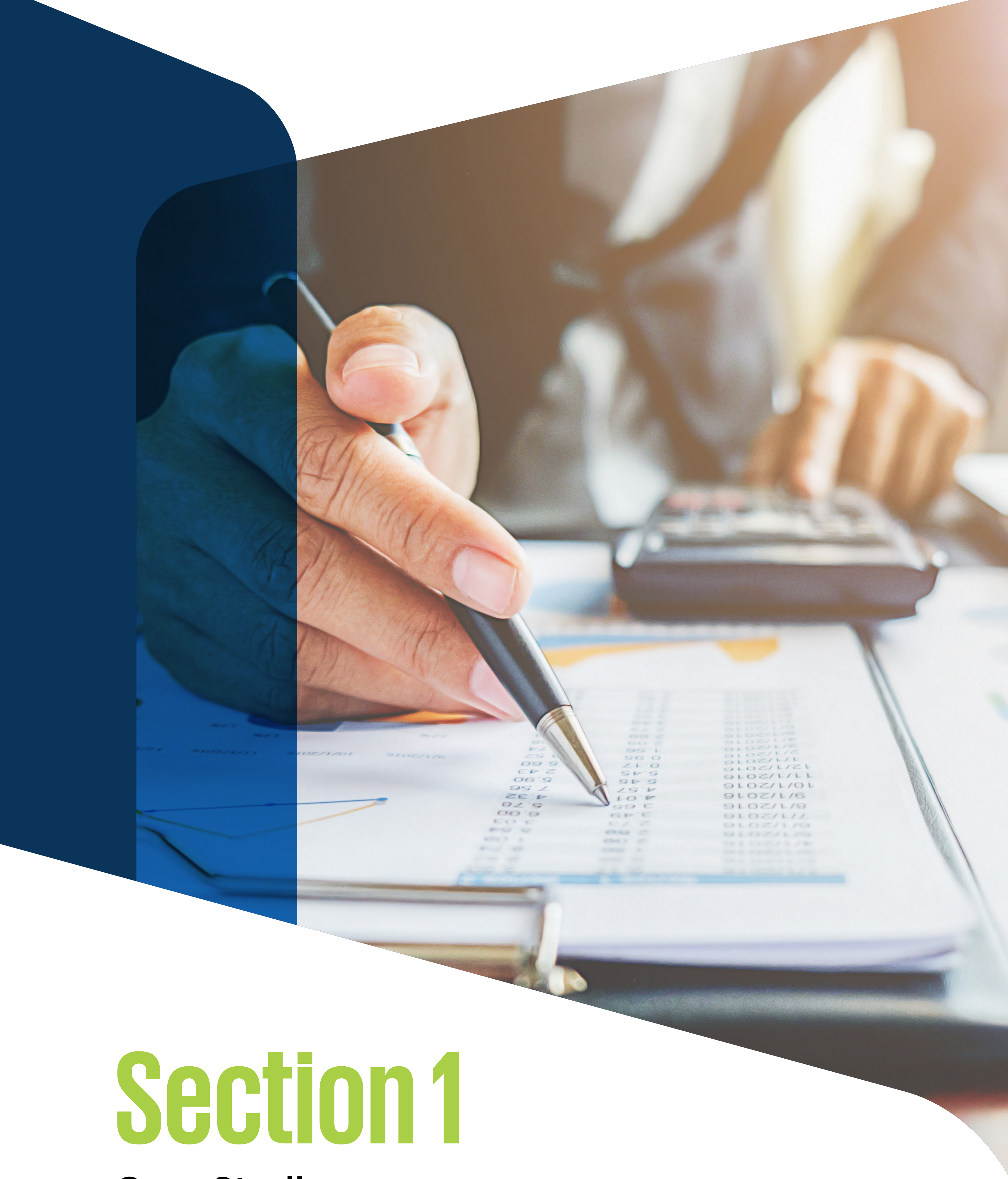
The IDEEKSHA platform is a one-stop shop for all energy efficiency/ decarbonisation needs of large industries covered/ expected to be covered under BEE's Perform Achieve and Trade (PAT) Scheme. The IDEEKSHA platform would thus facilitate:

- 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 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 has organised workshops and industry study trips for the above 4 new focus sectors to enhance energy efficiency measures and enable decarbonisation in the industrial sectors. Eight (8) sectoral workshops and Seven (7) study trips were organised between 2022 and 2024, each focusing on key industries: Aluminium, Textile, Cement, Iron & Steel, Pulp & Paper, Chlor-Alkali, Sugar, Tyre manufacturers sectors. The platform would also host a technology compendium encompassing IEED technologies available in India and globally (including from the UK) along with newsletters showcasing case studies on leading IEED best practises practices adopted by the Indian and international players (including from the UK). Further, the platform would also provide energy intensive Indian industries access to innovative low-carbon technologies/ solutions and their suppliers tailored for the above sectors.

This is the seventh 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 Utililisation of Solenis' Barrier Coatings Technologies for Enhancing Sustainability in the Pulp & Paper Sector

Background

Solenis is a leading producer of specialty chemicals for water-intensive industries. The company provides a wide range of innovative solutions for water treatment, process improvements, and sustainability across various sectors, including paper and packaging, water treatment, oil and gas, chemical processing, and mining. Solenis focuses on enhancing productivity, reducing environmental impact, and optimising resource use for its customers. Through its advanced products and technologies, the company supports industries in improving efficiency, maintaining regulatory compliance, and achieving sustainability goals.

About the technology

The demand for sustainable paper and paperboard packaging has increased dramatically in recent years because consumers have become more mindful of the effects their buying choices have on the environment. This trend has put significant pressure on paper and paperboard packaging producers to eliminate their use of barrier coatings that employ polyethylene, paraffin-based waxes, silicones and fluorochemicals and to switch to using more environmentally friendly barrier coatings, especially in food and beverage packaging applications.

Solenis' portfolio of barrier coatings for paper and board includes a range of products that repel water and water vapor, hot and cold liquids, and oils and greases. These barrier coatings are available as either water-based polymer emulsions or solid bio waxes and are produced using the highest level of renewable raw material content currently feasible. Most importantly, paper and board coated with these barrier coatings typically are repulpable, recyclable, compostable and biodegradeable, thereby offering paper and paperboard packaging producers a way to improve their sustainability credentials with brand owners, retailers, and consumers.

Innovations for barrier coatings for paper and paperboard

- **Contour℠ PFAS-free oil & grease resistant technology**: a non- per- and polyfluoroalkyl substance (PFAS) solution that provides functional barrier properties to thermoformed moulded fibre articles. It enables the replacement of single-use plastics in food containers with sustainable moulded fibre-based solutions. Contour℠ technology can be customised depending on the type of pulp and moulding conditions to meet the desired performance in low- to mid-temperature end-use applications.
- **TopScreen™ barrier coatings for cupstock:** provides papermakers a versatile toolkit to produce the next generation of cupstock with superior liquid barrier without the use of polyethylene. These innovative PE alternatives are waterborne dispersions that can be applied using conventional coating application processes, resulting in coated board that can be converted into cups on existing cup-forming machines. Paper cups with Topscreen™ Barrier coatings are recyclable and repulpable and post single use can be utilised to produce new cups or other paper-based packaging products.
- **TopScreen™ water-resistant barrier coatings:** allows paper manufacturers to create eco-friendly paper packaging without plastic or paraffin. The formulas can be modified to offer varying levels of oil, grease resistance, and water vapor transmission rate (WVTR). The water-repellent coatings for paper are recyclable, repulpable, and more compostable than traditional coatings. The current formulations contain up to **50%** renewable content with the potential for further increase.
- **TopScreen™ biowax-based barrier coatings:** the coating contains up to 100% bio-based content derived from vegetable oils, which is free from mineral oil saturated hydrocarbons (MOSH) and mineral oil aromatic hydrocarbons (MOAH). Paper and board treated with TopScreen biowax barrier coatings are repulpabable, recyclable and compostable, making the coatings a better environmental choice than paraffin-based wax coatings.

Case Study: TopScreen™ water repellent barrier coating replaces polyethylene for ream wrapping paper[1]

Problem statement

A European producer of office paper and professional printing papers required a more sustainable, recyclable barrier solution to replace polyethylene (PE) for a ream wrapping paper application. The desired solution was to eliminate the PE extrusion converting operation and utilise the existing off-line coaters. In response to the increasing consumer demand for environmentally sustainable packaging, paper manufacturers are tasked with developing innovative barrier technologies that maintain high-performance standards.

About the innovation

Water repellent paper coatings used in food-grade paper packaging applications must provide the right amount of water resistance and water vapor transmission rate without exposing consumers to unsafe chemicals, such as per- and polyfluoroalkyl substances. TopScreen™ water repellent barrier coatings can be instrumental in helping paper and board producers strike the balance between functional performance, safety, and sustainability. These water repellent coatings for paper keep food fresh while preventing leakage in packaging applications such as wraps and folding cartons for burgers, sandwiches and other fast-food items and packaging for meat, poultry, and seafood.

Process description

TopScreen™ water repellent barrier coatings do not require installation of any specialised coating application equipment. They can be applied using a variety of standard coating equipment and methods, including metered size presses and film, rod, air knife and curtain coaters. These water repellent paper coatings also support printability, using either gravure or flexographic technologies, and can be adapted to specific requirements for water repellency, water vapor transmission rate, heat seal and application viscosity.

Key benefits

- Recyclable, sustainable replacement for fossil-based polyethylene barrier
- Functional on both food service and paper-based flexible packaging
- Suitable for printing
- Compatible with most standard coating application equipment and methods
- Heat-sealable, with non-heat-seal options available
- Recyclable and repulpable
- May be compostable, with many applications capable of achieving EN 13432 certification
- Compliant with global food contact standards

Opportunity for Indian industrial sectors

The innovative water-resistant coatings offered by Solenis offers paper industries with a pathway towards eco-friendly packaging without compromising on performance. Adoption of Top Screen™ coatings presents a compelling opportunity for Indian paper manufacturers facing the challenge of meeting consumer demand for sustainable products and reducing environmental footprint. Indian paper manufacturers can also leverage Solenis' technology to develop customised paper packaging materials to better cater to consumer preferences prevalent in the Indian market to ensure that the adopted solutions align closely with local needs and regulatory standards resulting in enhanced market acceptance and competitiveness.

1 Recyclable Barrier Coating Replaces Polyethylene For Ream Wrapping Paper (solenis.com)

1.2 INEOS's CHLORCOAT™ Electrode Coatings for Chlor-Alkali Sector

Introduction

INEOS Electrochemical Solutions (UK) is a division of INEOS, a global chemical company. INEOS Electrochemical Solutions specialises in the production of chlorine, caustic soda, and other electrochemical products. These products are used in a variety of industries, including water treatment, food production, pharmaceuticals, and the manufacture of other chemicals.

INEOS offers a range of proprietary titanium and nickel anode and cathode coatings under the brand name CHLORCOAT™ to satisfy the demands of today's chloralkali industry. CHLORCOAT™ coatings are available for membrane electrolyser cells.[2]

About the innovation/ technology[3]

CHLORCOAT™ electrode coatings help to reduce operational cost and 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. These coatings are supported by warranties, ensuring reliability and performance.

Anode and Cathode Coatings:[4]

- **Cathode Coatings**: These coatings resist impurity poisoning, reverse currents during shutdown, and come with up to 16-year warranties. They promote hydrogen evolution at low voltage and contain precious metals for durability. Trials have shown superior performance over time. Cathode coatings remain unaffected by reverse current, preserving their catalyst and enhancing their resilience during shut down situations, unlike alternative coatings.
- **Anode Coatings**: Anode coatings deliver up to 20mV energy savings, have low chlorate levels, and exhibit high alkali wear resistance. They promote chlorine evolution at low voltage and have lower over-potential compared to alternative coatings. Demonstrations have shown that the alkali wear performance is better than alternative coatings. These coatings come with up to 12-year warranties.

Methodology

CHLORCOAT™ can be applied to any titanium or nickel electrode used in the chlor-alkali manufacturing plants. The process involves depositing a thin layer of a specially formulated coating onto the surface of the electrode in the following manner:

- o **Step 1 Cleaning**: The electrodes are cleaned to remove any dirt or impurities that could interfere with the coating process. This is typically done using a solvent or an alkaline solution.
- o **Step 2 Preheating:** The electrodes are preheated to a specific temperature. This helps to ensure that the coating will adhere properly to the surface of the electrode.
- o **Step 3 Applying the coating**: The coating solution is applied to the electrodes using a variety of methods, including spraying, dipping, or brushing.
- o **Step 4 Curing**: The electrodes are cured at a specific temperature. This helps to set the coating and make it more durable.

2 INEOS_Tech_BICHLOR.pdf (chemwinfo.com)
3 en---ineos---chlorcoat---mar-2024.pdf
4 en---ineos---chlorcoat---dec-2023.pdf

- **Step 5 Inspection**: The electrodes are inspected to ensure that the coating is applied correctly. This is typically done using a visual inspection or an electrical test.

Opportunity for Indian industrial sectors

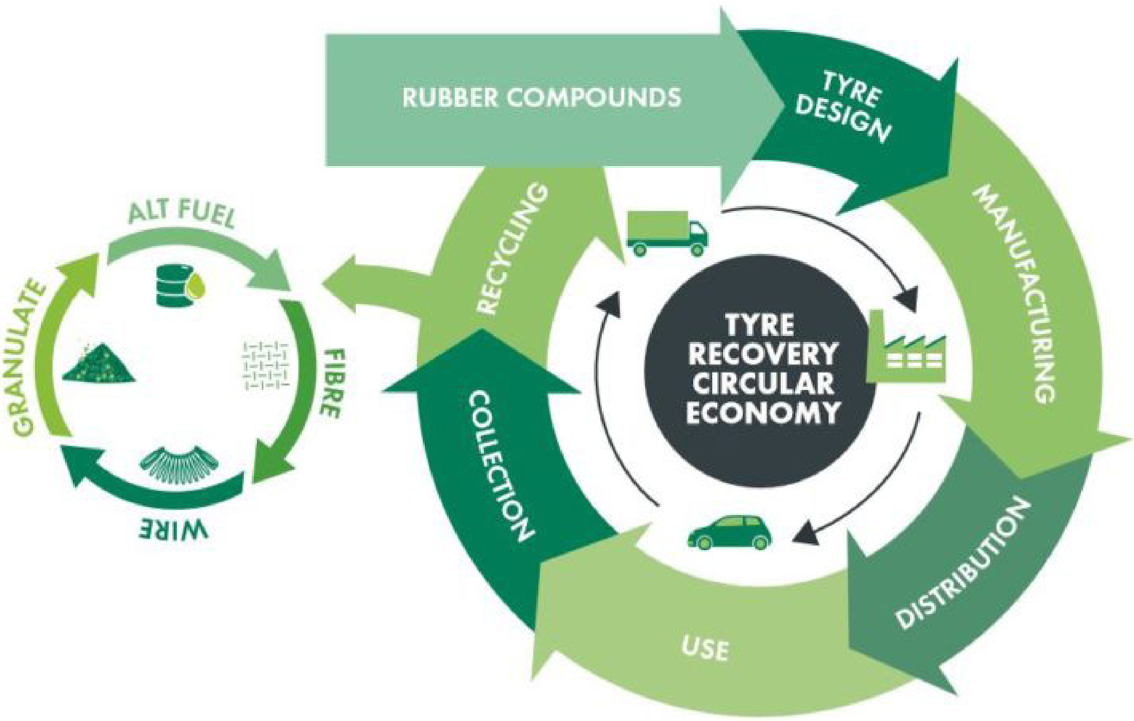
INEOS' CHLORCOAT™ electrode coatings offer Indian chlor-alkali manufacturers an opportunity to enhance performance, reliability, and cost-efficiency in electrolysis processes which is at heart of caustic soda production process. Chlor–alkali manufacturers can benefit from INEOS's modular coating and refurbishment services. They refurbish all types of membrane electrolyser electrode including repair and coating of electrodes, flanges, coated mesh and feed tubes. With increasing pressure to optimise production processes and reduce operational costs, the adoption of advanced electrode coatings presents a transformative opportunity for the chlor-alkali sector in India. INEOS also offers a range of CHLORCOAT coatings for non-chlor-alkali applications (such as sodium chlorate production) and extensive refurbishment facilities to re-life and repair many brands of used titanium, nickel and stainless-steel electrodes, for the highest operating efficiency and production peace of mind.[5]

5 Markets | INEOS Electrochemical Solutions

1.3 Circular Economy in Tyre Recovery

Introduction

The world faces a massive issue with tyre waste, discarding over 1.5 billion tyres per annum. This challenge poses serious environmental threats, including the spread of disease, fires, and soil contamination from toxic pollutants. Pyrolysis, a process that thermally decomposes tyres in the absence of oxygen at high temperatures, offers a promising solution for reclaiming valuable materials from end-of-life tyres. By breaking down rubber and other tyre components, pyrolysis yields valuable byproducts such as tyre pyrolysis oil (TPO), recovered carbon black, syngas, and steel.



Source: https://tyrerecovery.org.uk/know-tyre-waste/circular-economy/

About ELT Recovery Ltd.

ELT Recovery (ETLR) Ltd. leads in sustainable innovation, transforming the way end-of-life tyres are managed. The company emphasises environmental stewardship and renewable product creation through state-of-the-art pyrolysis processes. Their pyrolysis equipment facility in the UK contributes significantly to sustainability resulting in a reduction of **60,000 tonnes** of CO_2 per annum.

Process description

Step 1: Front end: ETLR sources end-of-life tyres from various channels, including used automobile tyres, industrial scrap, and discarded rubber products. Prior to the core process, steel and textile (fabric) are extracted from the tyres.

Step 2: Core process: The collected tyres are subjected to high temperatures in the absence of oxygen, within a reactor. This prevents combustion and allows the tyres to break down through thermal decomposition. As the temperature increases, complex compounds in the tyres turn into simpler molecules like gases, liquids, and solid char. The vaporous components then move to the next chamber. There, these vapours undergo further changes, resulting in the separation of the material into two valuable products: recovered Carbon Black (rCB) and TPO fuel.

Step 3: Back end: The rCB undergoes milling and processing into pellet form, ready for shipment to customers.

Application of the byproducts

- **Steel:** Recovered steel can be repurposed for use in tyre manufacturing and other applications.
- **Textile:** Extracted fabric within tyres can employed in the aggregate industry.
- **TPO:** TPO can be used as fuel or refined into higher-value goods, acting as an eco-friendly alternative to fossil fuels.
- **rCB:** It is generally used to provide physical and mechanical characteristics in rubber products, usually tyres, but can also act as a pigment, UV stabiliser, and conductive or insulating agent in a variety of rubber, plastic, ink, and coating applications.
- **Syngas:** A mixture of carbon monoxide and hydrogen produced during pyrolysis, syngas can be harnessed for energy or as a chemical resource.

Opportunity for Indian industries

India is the third-largest automobile market globally, the largest manufacturer of three-wheelers, passenger vehicles, and tractors, and the second-largest manufacturer of two-wheelers (as of May 2024)[6]. As the vehicle market expands, the Indian tyre market experiences similar growth. Tyre production in India increased by **21%** in 2022 and an additional **6%** in 2023, reaching a total production of **217.4** million units annually. Annually, India produces approximately **2.5** million metric tonnes (MT) of tyres.

However, this growth presents challenges. After accounting for tyre wear and tear (about 20%), around 2 million MT of tyres are discarded as scrap each year. Additionally, India imports approximately 0.8 million MT of scrap tyres annually from countries such as Australia, UAE, etc. where recycling of tyres is not allowed. This brings India's total tyre waste to **2.8** million MT annually.

In 2022, India's Ministry of Environment, Forests and Climate Change (MoEFCC) introduced **Extended Producers' Responsibility (EPR)** for waste tyres. EPR holds producers or importers accountable for the safe disposal of end-of-life tyres. They can purchase EPR certificates from recyclers, who then convert waste tyres into environmentally safe products. This initiative paves the way for tyre recycling in India, enabling recyclers to invest in eco-friendly technologies such as pyrolysis that promote resource recovery and reduce the carbon footprint associated with tyre disposal.

6 India's Automobile Industry: Growth & Trends | IBEF

Section 2

Case Studies on National IEED Technologies

2.1 Vapor Absorption vs. Vapor Compression Machine: Streamlining the Chilled Water Generation Cost

Mr. Mayank Shukla
Deputy General Manager, Grasim Industries – Aditya Birla Chemicals

Background

In the chlor-alkali sector, refrigeration systems play a critical role in maintaining optimal operating conditions and ensuring efficient chemical processes. These systems provide chilled water, which is essential for temperature control in various stages of the production cycle, including electrolysis, brine preparation, and chlorine liquefaction.

Vapor compression refrigeration (VCM) and vapor absorption refrigeration (VAM) are the two primary types of systems commonly used in the industry. Both systems utilise refrigerants to manage heat exchange, however they differ in their energy sources and methods of operation. VCM uses mechanical energy as the driving force for refrigeration, while VAM uses thermal energy as a driving force. VCM and VAM both accomplish the removal of heat through the evaporation of refrigerant at low pressure and rejection of the heat through the condensation of refrigerant at high pressure. The method of creating the pressure difference and circulating the refrigerant is the primary difference between the two cycles.

In recent years, there has been growing interest in optimising refrigeration systems to achieve cost savings and enhance sustainability. The choice between VCM and VAM can have significant implications for operational efficiency, environmental footprint, and overall production costs.

This case study, based on actual data, will explore the performance, advantages, and disadvantages of VCM and VAM systems in the chlor-alkali sector, aiming to identify the most suitable refrigeration solution based on specific operational requirements and constraints. The performance of the systems is assessed by comparing a double-stage vapor absorption machine to a single-stage vapor compression cycle under the same heat load conditions.

Evaluation criteria

The following criteria are considered to compare VAM against VCM:

First Cost	Operating expenses	Economic Factors	Maintenance Requirements	Advantages and Disadvantages

First cost

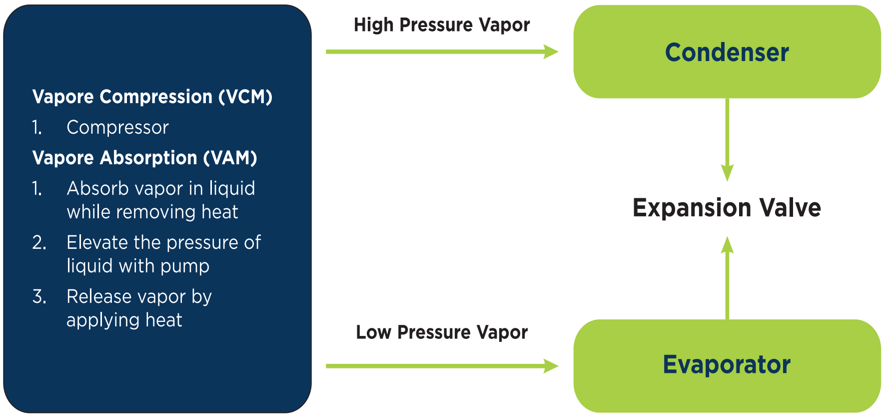
Capacity (Ton of refrigeration)	VAM (Typical Cost)	VCM (Typical Cost)
300	INR 60,00,000 (GBP ~57,200)	INR 90,00,000 (GBP ~85,800)

Table 1: First cost data for VAM & VCM

The first cost analysis considers a chilled water temperature requirement of **7°C**. The cost of a flooded screw chiller for refrigeration is approximately **1.3** times higher than that of a VAM. Table 1 provides the first cost data for both types of equipment. The capital cost of VAM system is over 30% lower than that of VCM system and the overall cost of VCM system is higher than VAM system due to the need for significant electric infrastructure such as transformers, switchgear, cabling, and space.

During the study, it was observed that, both VAM & VCM systems are cost-effective in terms of their respective energy sources and overall costs when evaluated on the basis of energy efficiency, operational and maintenance cost and payback period. Figure 2 illustrates the basic difference between the working of these two technologies.

Figure 2 Basic differences between VAM and VCM



Economic factors

The choice of refrigeration equipment to achieve a specific cooling duty depends on several key variables:

- Refrigeration load
- Temperature levels
- Energy source for driving the equipment
- Quantity & temperature of available condensing media
- Space availability

The actual operating cost includes maintenance expenses and is compared for the different systems. For Net Present Value (NPV) calculations, a five-year timeframe is considered.

Table 2 presents the critical parameters for the refrigeration systems. The cost of the machine per ton of refrigeration (TR) is based on actual data. The chilled water temperature is set to 7°C and 12°C. VAM tends to be less efficient than vapor compression refrigeration VCM, making it a more suitable option when there is access to waste heat, process hot water, or low-cost fuels such as hydrogen in the chlor-alkali industry.

Parameters	UOM	VAM	VCM
Machine capacity	Ton of Refrigeration (TR)	300	300
Cost of machine	Rs/TR	20,000	25,000
Installation cost	Rs Lacs	60	75
Chilled water flow rate	m^3/hr	185	185
Inlet/ outlet temperature	°C	7/12	7/12
Actual coefficient of performance (COP)	-	1.4	5.7
Energy input	kW	-	188.3
Steam input	Kg/ hr	1566	-
Steam price	Rs/ton	1150	1150
Electricity tariff	Rs/unit	6	6
Water tariff	Rs/m^3	30	30
Annual operating hours	Hrs	8400	8400
Pumping power	kW/hr	23	25
Water consumption	Kg/hr	1750	2012

Table 2: Critical parameters under consideration

In practical operating conditions, VAM systems have been observed to consume more energy than their rated values, resulting in an estimated **7%** increase in steam consumption for these operations. The actual cost of operation is detailed in Table 3.

Parameters	UOM	VAM	VCM
Annual energy cost	Rs. Lacs	134.9	99.9
Annual water cost	Rs. Lacs	4.4	5.1
Annual pumping cost	Rs. Lacs	12	13
Annual operating cost	Rs. Lacs	154.9	120.1
Annual maintenance cost	Rs. Lacs	4	2.5
Maintenance	%	3	2
Discount factor (for NPV)	%	12	12
NPV for operating cost over 5 years	Rs. Lacs	474	393
Difference in NPV cost over 5 years	**%**		**21**

Table 3: NPV of VAM & VCM over 5 years period

Operating Expenses

As per the tables 2&3, it can be inferred that there is a significant annual operating cost difference of **INR 35,00,000** (~GBP 33,400) between VCM and VAM at the given energy prices. VAM consumes more energy in all aspects, making it less efficient than VCM. The comparison uses a steam cost of **INR 850** (~GBP 8) per ton and an electricity cost of **INR 8** (~GBP 0.08) per unit. Annual maintenance costs for VAM system is also higher, with maintenance charges nearly **1.3** times to that of flooded chillers due to the system's complexity.

The NPV of operating cost over a 5 year period for a VAM system is about 21% higher than that of a VCM system (see table 3). Further, VAM systems tend to have a shorter lifespan than VCM systems, with VCM systems lasting around 20-25 years as compared to 15-20 years for VAM systems.

During actual operation, common issues with VAM include failures in the low temperature heat exchanger (LTHE), high temperature heat exchanger (HTHE), and pumps within a 5 to 8-year timeframe. VAM systems use lithium bromide (LiBr) solution, which is corrosive and requires inhibitors to protect against metal corrosion. Additionally, LiBr is highly viscous and prone to crystallisation. If there is an issue in the cycle, the salt and water can separate permanently, causing the LiBr to crystallise on the absorber walls. Once solidified, the chiller may cease to function. Crystallisation can be triggered by low cooling water temperatures; for instance, a 65% LiBr solution crystallises at 42°C, while a 60% solution crystallises at 17°C, and a 55% solution crystallises below 15°C.

VAM		VCM	
Advantages	**Disadvantages**	**Advantages**	**Disadvantages**
No moving parts	Risk of potential refrigerant leaks	Capable of large operating refrigeration at lower initial	Parts may wear out
No vibration / noise in small systems	Poor efficiency	Highly Efficient	Relatively Noisy
Small systems can operate without electricity using only heat	Bulky and difficult to service and repair	Compact system for small to large heat loads	Risk of potential refrigerant leaks
Can make use of waste heat	Stalls in hot ambient conditions	Cycle can be reversed for heat pump operation	Operates in limited orientation

Table 4: Advantages and disadvantages of VAM & VCM

The advantages and disadvantages of VAM and VCM systems are outlined in Tables 4. Utility consumption is a key factor to consider during procurement, as each site may have varying requirements. Utility consumption data for a 300 TR machine is detailed in Table 5.

Figure 3: Maintenance Cost of VAM versus VCM

Parameters	UOM	VAM	VCM	VCM (subcooling)
Heat duty	one million kilo calories	0.921		
Cost of machine	TR	305		
Chilled water flow rate	m³/hr	185	185	185
Inlet/outlet temperature	°C	7/12	7/12	7/12
Refrigerant	-	13746	19188	13413.3
Cooling water flow	m³/hr (33°C/40°C)		152	152
Power	kW		195	195
Hot water	m³/hr (91°C/85°C)	202		

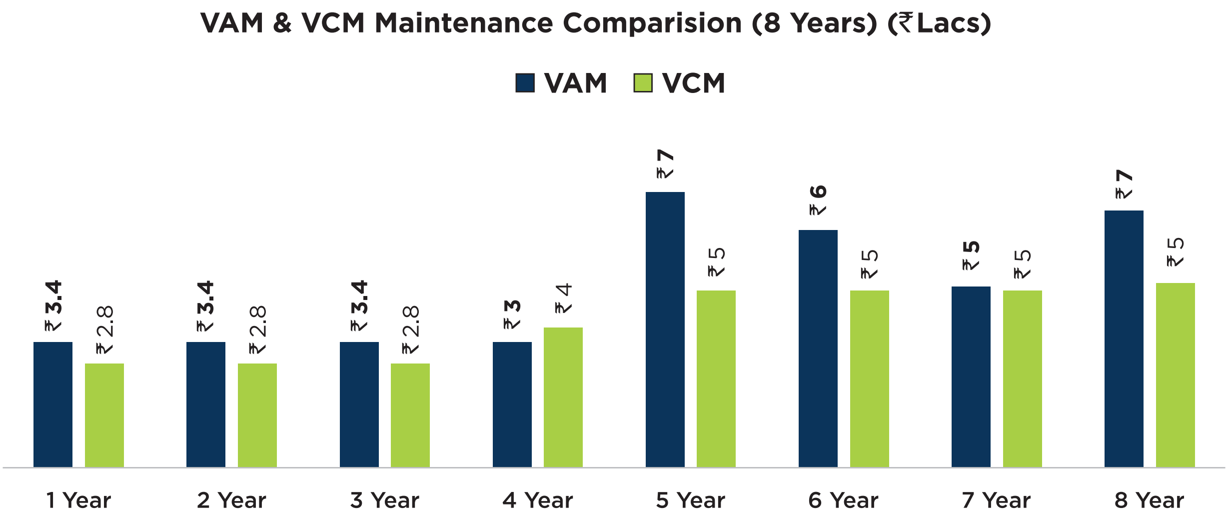


Table 5: Utility consumption for VAM & VCM

Maintenance Requirements

Maintenance is a critical factor for any site when considering refrigeration systems. VAM systems are complex and challenging to maintain. They consist of upper and lower shells, and typically, site maintenance teams do not handle the opening and closing of these parts, which requires a skilled VAM inspection mechanic.

Original equipment manufacturers (OEMs) provide annual maintenance contracts for VAM systems at nearly 1.4 times higher price than that of VCM systems. Major VAM maintenance occurs every 3-4 years and frequently involves failures in the purge pump, HTHE and LTHE. Maintaining the appropriate concentration of LiBr is crucial, as crystallisation can lead to significant maintenance challenges.

In VCM systems, primary expenses are towards compressor maintenance and refrigerant leaks. Whereas, in VAM systems, major maintenance of compressors is relatively uncommon. However, the overall cost of maintenance in VAM systems is about 1.6 times higher as compared to that of VCM systems. The recurring maintenance costs over a period of eight years for both the system is depicted in Figure 3. Significant differences in the cost of the two systems during the 5th, 6th, and 8th years can be observed due to issues such as failure of purge pump, LTHE, and HTHE in VAM systems. In VCM systems, costs in the 6th and 7th years are higher due to refrigerant leaks. Further, it may be observed that the cost of maintenance for VCM systems increases 5th year onwards, primarily due to the need to maintain and overhaul the compressor annually to sustain performance.

Results

Overall, VCM and VAM systems have their respective advantages and disadvantages. While VCM systems have a longer payback period, but they are ~**21%** more cost-effective than VAM systems. On the other hand, VAM systems operate with lower noise levels as compared to VCM systems.

Absorption machines, such as VAM, may be a preferable choice in certain circumstances, such as:

- When there is an abundance of excess heat sources, such as excess steam from a boiler.
- When low-pressure steam is available for a dump condenser, which can be used to operate the VAM.
- When heat is being inefficiently released into the atmosphere, such as exhaust from diesel generators, steam from turbine outlets, flue gas emissions, or water evaporation units.
- When operational expenditure is significantly lower than that of VCM, such as when the industry faces challenges with power supply from the grid.
- When the production cost of steam is minimal, such as using hydrogen to generate steam in the chlor-alkali industry.

A summary of the key differences between VAM and VCM systems has been provided in table 6.

Parameters	VAM	VCM
Initial cost	low	high
Maintenance	complex	easy
Maintenance cost	high	medium
Volume needed	1.3 m^3	0.79 m^3
Components	complex	simple
Availability	less	more
Weight	more	less
Vibration and noise	Quiet and vibration free	Noisy
Emergency button	required	Not required
Losses	High	Low
Kind of energy required	Thermal	Electrical
Refrigerant	LiBR	R134a
Life	15-20 years	20-25 years

Table 6: Summary table

Conclusion

The results from the technical evaluation conclude that both VCM and VAM systems can be cost-effective when evaluating their life cycle costs, which is essential for any purchase or replacement decision.

However, after analysing all the relevant parameters, one may prefer VCM due to its lower long-term operating costs, smaller size, wider availability in the market, simplicity, and lower maintenance requirements. VCM systems are also suitable for a broad range of applications in industrial and commercial settings. VAM systems may be a better choice in situations where cheap energy sources and waste heat recovery options are available, or when the facility requires hot water integration.

Ultimately, the final decision should be based on a comprehensive evaluation of all critical factors, including capital, operating, and maintenance costs, along with other site-specific considerations

2.2 Leading Practices in Energy Efficiency and Decarbonisation adopted by Orient Paper Mills in their Cogeneration and Precipitated Calcium Carbonate Complex

Dr. T.G. Sundara Raman, Consultant- Energy & DC
Dr. C.S. Kashikar, COO & A K Srivastava, GM-PP
Orient Paper & Industries Ltd., Amlai
Grasim Industries – Aditya Birla Chemicals

Introduction

The need to rapidly adopt energy efficiency measures in the pulp and paper industry is crucial for meeting decarbonisation targets established by the Bureau of Energy Efficiency under the Perform, Achieve, and Trade (PAT) Scheme. Orient Paper Mills (OPM) in Amlai, Madhya Pradesh, has embarked on an energy transition journey that encompasses its entire cogeneration complex and mill operations. This approach aims to surpass the specific energy consumption (SEC) and specific greenhouse gas emission reduction (SGR) targets specified under the PAT Scheme.

Two case studies from the OPM plant demonstrate how the facility is implementing energy efficiency and decarbonisation strategies. The cogeneration power plant complex includes:

- A **150** tons per hour (TPH) atmospheric fluidised bed combustion (AFBC) coal-fired boiler, which is connected to a **30** MW multistage extraction condensing steam turbine generator.
- Two **90** TPH stoker-fired boilers and one **90** TPH chemical recovery high pressure (HP) green boiler (operating at **64** kilogram per square centimetre (ksc)/450°C), which are connected to a **25** MW multistage extraction condensing steam turbine generator.

Both turbine generators are supported by water-cooled condensers, which use a common spray pond to manage the return cooling water. The chemical recovery HP boiler is integrated with a seven-effect evaporator that concentrates weak black liquor (WBL) into black liquor solids (BLS) with a concentration of **70%**, providing an additional source of green fuel for the facility.

Orient Paper Mill - Amlai - ENERGY TRANSITION - Available Options - Implementation Mill - wide - March towards Net Zero Emission

The AFBC boiler in operation has a high steam flow rate of **150** TPH, with main steam pressure set at **88** ksc, and a temperature of 510°C. This boiler uses an atmospheric bubbling bed design and burns locally sourced high-ash, low-gross calorific value (GCV) coal. Boiler feed water is initially preheated through a low pressure (LP) heater before moving to the atmospheric deaerator. Thereafter, the hot water exits the deaerator and is further heated via an HP heater, reaching a temperature of 190°C. The heated water is then fed into the boiler's economiser, contributing to a reduced gross heat rate and improved steam economy of ~5.

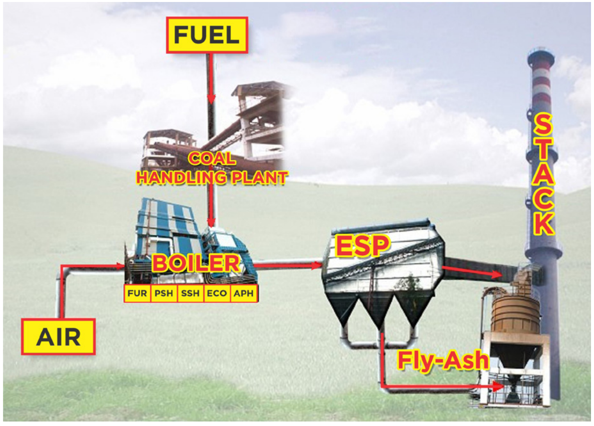


Figure 5 AFBC Boiler - Flow Chart Illustration

To achieve a low flue gas temperature of 140°C, a large economiser heating surface is used in conjunction with a flue gas air preheater, maintaining low excess air at 4% and achieving high thermal efficiency (~80%) due to minimised stack heat loss. Plans are in place to decrease coal consumption by increasing the use of biowaste fuel. A generously sized, high-efficiency electrostatic precipitator (ESP) at the back end ensures minimal suspended particulate matter (SPM) in the flue gas emissions.

Maintaining low excess air for coal combustion not only enhances boiler thermal efficiency but also allows for efficient utilisation of the high CO_2 concentration (12% to 13%) in the boiler's flue gas for the production of precipitated calcium carbonate (PCC). This process will be covered in detail in the subsequent case study.

Case Study 1 - Decarbonisation in Precipitated Calcium Carbonate Plant

Eco-innovating a carbon capture usage (CCU) and storage solution

To diversify and enhance productivity with a value-added filler, OPM in Amlai invested in a 8,000 MT per annum capacity precipitated calcium carbonate (PCC) plant (Fig. 6). The plant captures CO_2 from the flue gas of the AFBC boiler stack and converts it into PCC, a cost-effective mineral used to produce high-quality paper and paperboard. This mineral serves as a substitute for traditional materials like wood pulp, additives, and other minerals.

Introduction of PCC in slurry form into the production process significantly improves quality of the product while simultaneously increasing paper production. The key advantage is the ability to reduce the consumption of fibers and pulp by incorporating 12% more filler.

Additionally, the process results in substantial emissions reduction through carbon capture from the AFBC boiler, which is utilised in the PCC plant. This integration supports the company's sustainability goals while enhancing overall productivity and product quality.

Figure 6 OPM – Onsite PCC Plant

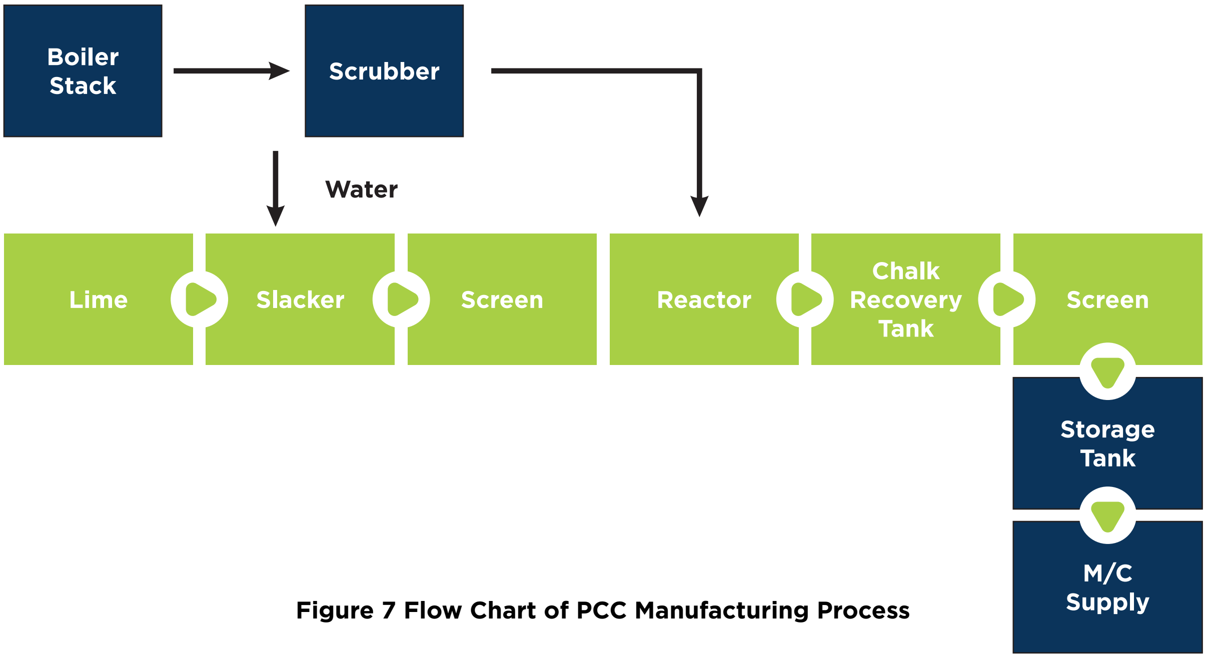


Figure 7 Flow Chart of PCC Manufacturing Process

Precipitated calcium carbonate (PCC) plant

The PCC plant uses locally sourced, high-purity lime. In the slaker unit, luke-warm water (~50°C) is added for slaking the lime, producing hydrated lime that is then filtered through a screen to remove unwanted silt and dirt. The process requires a high concentration of CO_2 (~12%) from the flue gas of the coal-fired 150 TPH AFBC boiler. This CO_2 is sourced from the dedusted flue gas exiting the electrostatic precipitator (ESP) of the AFBC boiler, which is scrubbed for wet cleaning to remove fine particulates and unwanted gaseous pollutants. The cleaned flue gas, rich in CO_2 and O_2, is then directed to the calcination reactor. Reagent lime is added for the calcination reaction, which benefits from the high CO_2 concentration by reducing the batch process time and increasing the calcination efficiency.

The resulting cleaned, high-purity $CaCO_3$ (calcium carbonate) is screened and stored in a tank before being used as a filler in the paper-making process. This $CaCO_3$ serves as an effective substitute for pulp (Refer Fig. 7).**Design operating data – PCC**

The design input data relating to $CaCO_3$ product output is provided in Table 7.

Product output: 22 tons per day (TPD)

Table 7: Input parameters

	CaO	CO_2	Water	Steam	Power
Units	Kg/t	t/t	M^3	Kg/t	kW/t
Value	700	0.44	10	22	220
Daily	15.4t	9.68t	-	0.484t	4840 units

The worksheet relating to decarbonisation by way of CCU is elicited in Table 8.

Table 8: Decarbonisation by way of carbon capture usage (CCU)

Parameter	Value
PCC Production Capacity	8000 MTA
PCC Production	7000 MTA
Pulp Substituted	3600 MTA
CO_2 trapped from Boiler	300 MTA
Carbon Capture Utilisation (CCU)	3300 tCO_2/ year

Decarbonisation analysis

To provide a better understanding of the decarbonisation process, the journey from input to product (Scope 1 and Scope 3 emissions, from cradle to gate) has been illustrated in the form of a flow chart in Figure 8.

Coal is the primary energy source for the plant and is sourced from the nearby South Eastern Coalfields Limited. Proximity to the source of coal reduces carbon emissions significantly, as opposed to the higher emissions that would result from importing coal via marine vessels and transporting it by road from distant ports, requiring significant diesel usage. The plant uses 150 TPA of LP steam, which requires power consumption of 1,500 million units. These operational practices result in a carbon footprint of only ~1,800 tCO_2e per annum, highlighting the plant's efforts to minimise its impact on the environment.

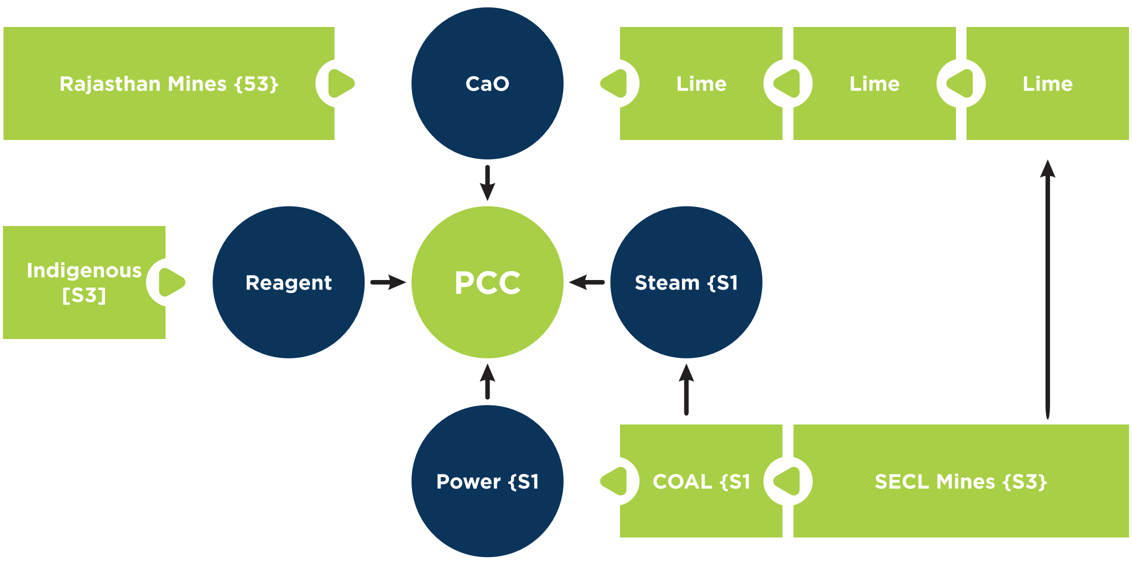


Figure 8 Input to Product

Carbon Emission Reduction (CER) Credit

Utilisation of **7,000** TPA of PCC filler in the production of **43,800** TPA of paper (~16%), the need for equivalent pulping is eliminated, thereby minimising Scope 1 and Scope 3 emissions associated with paper production.

Scope 3 emission reduction

With indidenous procuremnet of Calcium oxide (CaO), which is the main raw material, emission from logistics (lowered transportation and diesel usage for hauling the trucks carrying CaO) is minimal.

Carbon capture and utilisation

CO_2 in the flue gases drawn from the AFBC Boiler exit is being captured and used for calcination in PCC manufacture, resulting in emission reduction of over **3300** tCO_2e per annum in the cogeneration plant. This is equivalent to SGR of ~**0.04** tCO_2e per ton of paper produced.

Energy Conservation Schemes

Planned energy conservation measures (such as steam avoidance for hot water generation and the use of energy-efficient motors, IE3/IE4) will lead to decline in fossil fuel consumption in the PCC production unit. This, in turn, will lower carbon emissions (Scope 1) and improve the SGR figure.

Case Study 2: Low-grade waste heat recovery in chemical recovery- multi-effect evaporator (MME) station

Prelude

The MEE in the HP chemical recovery boiler has seven effects and is designed to concentrate weak black liquor (renewable fuel) from 14% solid concentration to 70% solid concentration using LP steam. Exhaust steam vapor is condensed under a vacuum (0.1 kilogram-force per centimetre square or ksca) using cooling water in a closed circulation system with an integrated cooling tower. About 1,500 m^3/h of water is heated to 42°C (from 34°C) as per design. The lukewarm water from the condenser discharge is cooled to 4°C above ambient temperature in the cooling tower before returning to the condenser, maintaining a continuous cycle.

Innovative scheme implemented

A portion of the lukewarm water is diverted from the cooling water return pipe to a plate heat exchanger (PHE), where it heats demineralised (DM) water, recovering what would otherwise be wasted heat. The warm DM water is then directed to the deaerator of the chemical recovery boiler (refer Fig. 9). Implementation of this innovative energy conservation scheme, the temperature of the DM water increases by over 10°C, resulting in a reduction in LP steam consumption in the deaerator by over 1 TPH. This allows for increased green energy availability from the chemical recovery cogeneration plant, offsetting the need for fossil fuel firing in the coal-fired boilers.

Seasonal impact

The implementation of this energy-saving scheme revealed an interesting seasonal impact. The make-up DM water temperature can vary from as low as 18°C to 20°C during peak winter season to 28°C to 30°C during summer season. This variation leads to higher steam consumption in the deaerator during winter compared to summer. However, with consistent return of condenser cooling water at over 40°C, the DM water temperature can be maintained at 38°C to 40°C consistently by adjusting the flow of cooling water from the cooling water pipe connecting the condenser and cooling tower.

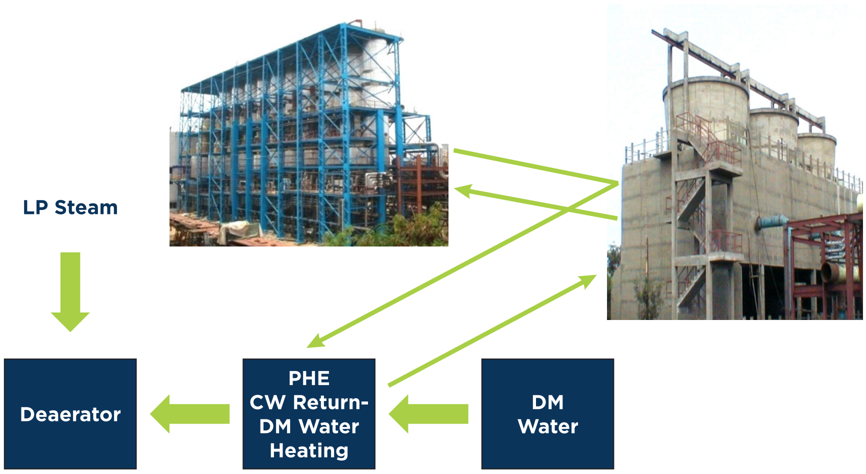


Figure 9 MEE Condenser Cooling Water Return Preheating DM Water

Spin-off energy gains

Parameters	Units	Value
Luke-warm cooling water flow	m3/h	50 [Summer] to 100 [Winter]
DM water flow	m3/h	45 to 50
DM water temp. in – PHE	℃	18 to 30
DM water temp. out – PHE	℃	38 to 40
DM water temp. rise	℃	10 to 20
LP steam reduction - Winter	TPH	1.6 to 1.8
LP steam reduction – Summer	TPH	0.8 to 0.9
Carbon Credits	tCO^2e/yr	~3600

Table 9: MEE Condenser Cooling Water Return Diverted from Cooling Tower for DM Water Heating. Non – Impact of Seasonal Temperature Variation on Energy Consumption

The implementation of this scheme took place during winter season, resulting in energy steam gains two times higher than expectation. Since water temperatures ranged from 18°C to 20°C, the temperature increase was also twice as significant compared to summer days (refer to Table 9). The flexibility to divert more lukewarm water contributed to these increased energy gains.

Power saving with reset of DM water pump

OPEM realised a consistent reduction of ~500 units per day in auxiliary power consumption by adjusting the pressure parameters of the DM feed water pump used for transferring boiler feed water to the deaerator of the chemical recovery boiler resetting it with a VFD to 5 ksc instead of the design value of 10 ksc.

Summary

In summary, the low waste heat recovery scheme leads to a reduction of about **0.9 to 1.8** TPH in LP steam consumption in the deaerator, depending on the season and time of day of operation. This, in turn, offsets the equivalent amount of coal used in the coal-fired HP boiler. The accrued carbon emission reduction from the offsetting of indigenous coal is estimated at around **4,000** tCO_2e per annum. This achievement exemplifies cross-sector knowledge exchange, offering potential benefits to a wide range of industries in other sectors.

Section 3

From the Archives

3.1 From the Archives: Timeless Gems to Revive Your Reading List

A sectoral workshop on 'Best Practices in Energy Efficiency in Sugar Sector: A Path for Decarbonisation' was organised by the ASPIRE programme in collaboration with Bureau of Energy Efficiency (BEE) on 21st March 2024 in Lucknow, Uttar Pradesh. The workshop witnessed participation from **60+** stakeholders including senior officials from the BEE, Uttar Pradesh State Designated Agency (UPSDA), National Sugar Institute (NSI), Indian Sugar Mills Association (ISMA), leading sugar manufacturers such as Balrampur Chinni Mills Limited, Avadh Sugar & Energy Ltd, DCM Shriram Ltd., Sugar & Distillery Unit, Bajaj Hindusthan Sugar Ltd, Works 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 include advanced energy analytics using wireless sensors, CCUS, leveraging AI & automation, advanced evaporator technology, 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.

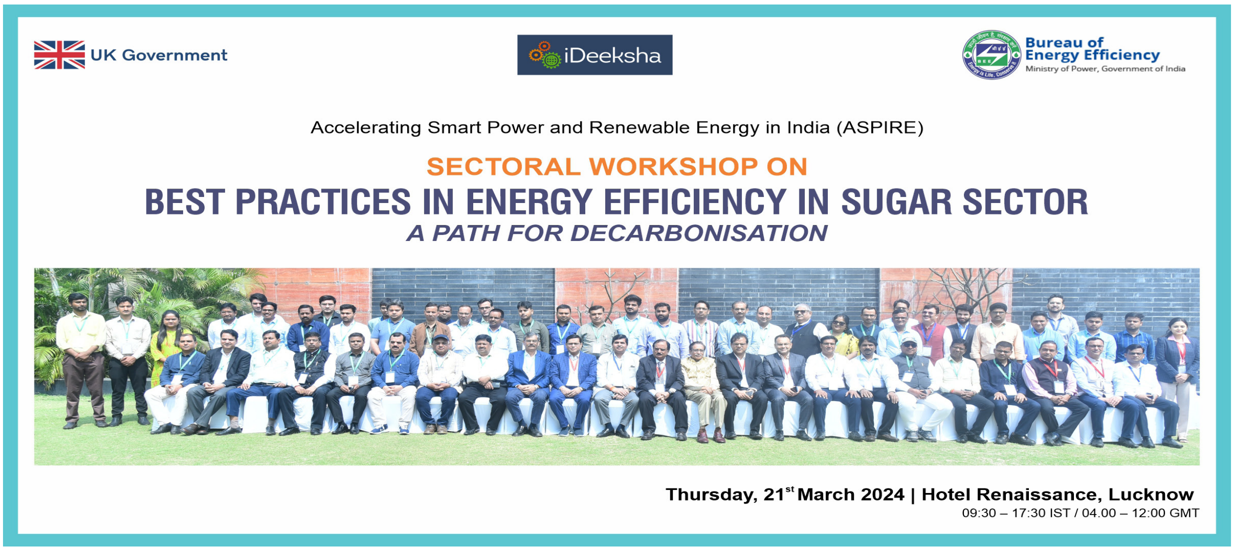


Figure 9: IDEEKSHA sectoral workshop on 'Best Practices in Energy Efficiency in Sugar Sector: A Path for Decarbonisation' held in Lucknow on 21st March 2024

The workshop was followed by a study trip to Balrampur Chini Mills Limited (BCML), Haidergarh on 22nd March 2024. During the study trip, **30+** stakeholders (including **11%** women participants) got an opportunity to develop deeper understanding of the sugar refining process, understand new and innovative IEED technologies implemented by BCML, foster an ambitious, mutually beneficial, and outcome-focused relationship with other industry stakeholders.

Figure 10: IDEEKSHA sectoral study trip to Balrampur Chini Mills Limited, Haidergarh on 22nd March 2024

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