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BUREAU OF ENERGY EFFICIENCY
Government of India, Ministry of Power

GOVERNMENT OF INDIA
MINISTRY OF POWER

ASPIRE
Programme

Accelerating Smart Power & Renewable Energy in India

INDUSTRIAL ENERGY EFFICIENCY/ DECARBONISATION OUTLOOK

COMPENDIUM OF GLOBAL INDUSTRIAL ENERGY EFFICIENCY AND DECARBONISATION TECHNOLOGIES

iDeeksha

Industrial Decarbonisation and
Energy Efficiency
Knowledge Sharing Platform

FEBRUARY 2025

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Abbreviations

Abbreviations	Definition
ASPIRE	Accelerating Smart Power and Renewable Energy in India
ADI	Amberpack™ Deionization
AI	Artificial Intelligence
BLG	Black Liquor Gasification
BEE	Bureau of Energy Efficiency
CNT	Carbon Nanotubes
CO_2	Carbon Dioxide
CAE	Computer-Aided Engineering
COP	Conference of Parties
DCs	Designated Consumers
ERP	Enterprise Resource Planning
FCDO	Foreign, Commonwealth and Development Office
GRP	Glass Fibre Reinforced Polyester
GoI	Government of India
HCT	Heat Control Technology
IDEEKSHA Platform	Industrial Decarbonisation and Energy Efficiency Knowledge Sharing Platform
IEED	Industrial Energy Efficiency and Decarbonisation
IoT	Internet of Things
kW	Kilowatt
LRP	Liquid Ring Pump
ML	Machine Learning
MOM	Manufacturing Operations Management
MW	Megawatt
MCPA	Membrane Cell Performance Analyser
MSMEs	Micro, Small and Medium Enterprises
MTOE	Million Tonne of Oil Equivalent
$MTCO_2$	Million Tonne of Carbon di Oxide
MNRE	Ministry of New and Renewable Energy
NDCs	Nationally Determined Contributions
PITA	Paper Industry Technical Association
PFSA	Perfluoro Sulfonic Acid
PAT	Perform Achieve and Trade
PE	Polyethene
PEM	Polymer Electrolyte Membrane
R&D	Research & Development

Abbreviations	Definition
RPB	Rotating Packed Beds
TC	Technology Compendium
TEMS	Thermal Energy Management System
WVTR	Water Vapor Transmission Rate

1 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.

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 is organising workshops and industry study trips for the above 4 new focus sectors to enhance energy efficiency measures and enable decarbonisation in the industrial sectors. In February and March 2024, 3 capacity building workshops and industry study trips focussed on pulp & paper, chlor-alkali and sugar sectors were organised. The platform would also publish newsletters showcasing case studies on leading IEED best practises 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.

Purpose of this compendium

This compendium on global IEED technologies aims to act as a comprehensive resource housing tailored low carbon and energy efficiency technology solutions available globally. It specifically targets hard to abate sectors like **chlor-alkali, pulp and paper, sugar** and **tyre manufacturers**, offering insights into technology maturity anticipated benefits, key technology suppliers/developers, etc.

2 PULP & PAPER SECTOR

2.1 Chlorine Dioxide Solution Heater

- **Category of the technology:** Core process – Pulp Beaching
- **Developer/Supplier:** A.H. Lundberg Systems, Canada
- **Development stage:** Commercialised
- **Website hyperlink for supplier / developer**

  https://www.ahlundberg.com/products/heat-transfer/pulp-paper-heat-exchanger/

- **Description of the technology:**
  - The application of heat exchangers in the bleach plant is designed to improve energy efficiency by utilising hot effluent to heat the chlorine dioxide solution. The chlorine dioxide solution heater enables heat exchange between the chlorine dioxide solution and the filtrates from the extraction stage.
  - This process reduces the need for steam in the bleach plant, which would otherwise be necessary to reheat pulp in the bleaching tower cooled by the cold bleaching solution.
  - By warming the chlorine dioxide solution with the extraction stage filtrate, the temperature of the filtrate directed to the effluent treatment system is reduced. This approach effectively addresses the challenge of excessive temperature loading in the effluent treatment system.
  - To achieve these outcomes, shell and tube units are employed, positioned at a slight incline horizontally to allow for the safe removal of any gases released from the chlorine dioxide solution. This setup ensures optimal operational safety and efficiency.
- **Cost and Energy Efficiency**

  Chlorine dioxide solution heaters improve energy efficiency by optimising the heating process for chlorine dioxide generation, reducing energy consumption by 10-15%.

- **Process Emission Reduction Potential**

  These heaters reduce emissions by minimising energy use and improving the efficiency of chlorine dioxide generation, leading to a 10-20% reduction in greenhouse gas emissions.

- **Major consumers of the technology**

  Companies from the pulp & paper sector, water treatment plants and chemical manufacturers.

- **Relevance to the Indian industrial sectors**
  - **Pulp & Paper Industry –** Enhances whitening efficiency in paper production.
  - **Textile Processing –** Aids bleaching and dyeing operations.
  - **Pharmaceutical & Healthcare –** Used for medical-grade disinfection solutions.
- **Expected benefits of the technology:**


Optimised energy consumption


Reducing high temperature loading and improved treatment efficiency

Significant cost savings

2.2 WideGap Plate Heat Exchanger

- **Category of the technology:** Core process
- **Developer/Supplier:** Alfa Laval, Sweden
- **Development stage:** Commercialised
- **Website hyperlink for supplier / developer**

  https://www.alfalaval.com/products/heat-transfer/plate-heat-exchangers/gasketed-plate-and-frame-heat-exchangers/widegap/

- **Description of the technology**[1]**:**
  - Alfa Laval has developed WideGap plate heat exchangers tailored specifically for the pulp and paper industries, designed to efficiently cool effluent containing fibres and other components. These heat exchangers feature wide gaps between the plates, a specialised plate pattern, and smooth port design, facilitating easy flow of fibres and particles to minimise clogging and maximise uptime.
  - Utilising a counter-current flow, WideGap heat exchangers can efficiently heat the cold stream to a temperature closely matching that of the entering hot stream, thereby maximising energy recovery. This enables the utilisation of previously wasted heat sources, reducing the consumption of live steam, and allowing excess steam to be redirected for electricity production.

- **Cost and Energy Efficiency**
  - The cost ranges from $10,000 to $50,000 depending on size and specifications.
  - These heat exchangers improve thermal efficiency by reducing fouling and enhancing heat transfer, leading to energy savings of 20-30% compared to conventional systems.

- **Major consumers of the technology**

  Companies from the pulp & paper sector, food processing and diary sector, and chemical & petroleum processing.

- **Relevance to the Indian industrial sectors**
  - **Pulp & Paper Industry –** Handles high-viscosity fluids like black liquor.
  - **Sugar Industry –** Optimises heat exchange in molasses processing.
  - **Biogas & Waste Management –** Enhances efficiency in digestate treatment.
  - **Pharmaceutical Industry –** Used in temperature control for high-viscosity syrups.

- **Expected benefits of the technology:**

Minimised clogging and maximised uptime when cooling effluent.

1 WideGap gasketed plate-and-frame heat exchangers | Alfa Laval

Reduced need for additional heat sources and enhanced enenrgy efficiency

Generates additional revenue streams through sale of excess steam for electricicty generation

2.3 Vacuum System Optimisation

- **Category of the t echnology:** Core Process – Pulping Station
- **Developer/Supplier:** Valmet Limited, UK
- **Development stage:** Commercialised
- **Website hyperlink for supplier / developer**

  https://www.valmet.com/board-and-paper/services-for-board-and-paper/process-upgrades/vacuum-systems/

- **Description of the technology:**
  - Optimising the vacuum system offers a systematic approach to identifying and achieving significant energy savings within vacuum systems. The primary cause of efficiency losses in paper machine vacuum systems is the discrepancy between pump capacity and the requirements of the paper machine, particularly in the regulation of vacuum levels.
  - Addressing this misalignment necessitates updating the vacuum control logic to ensure proper synchronization between pump capacity and machine needs. In traditional Liquid Ring Pump (LRP) systems, bleed air controls vacuum, and similar inefficiencies may arise in blower systems with substantial fluctuations in paper machine airflow.
  - The enhancement of the vacuum system typically occurs in two phases:
    - The initial phase involves adjustments to vacuum controls and pump connections.
    - The subsequent phase introduces new variable-speed drives, occurring later to allow assessment of the vacuum system's performance across at least two felt life cycles, thereby identifying additional potential energy savings.
    - Alternatively, the second phase may entail the substitution of blower technology for water ring pumps.
  - Vacuum System Optimisation is applicable to all vacuum systems equipped with LRP pumps and blowers, regardless of the machine supplier.
- **Cost and Energy Efficiency**
  - By optimising these systems, energy savings of 20-50%can be achieved, depending on the existing system's inefficiencies.
  - The cost of implementation typically ranges from $50,000 to $200,000.
- **Process Emission Reduction Potential**

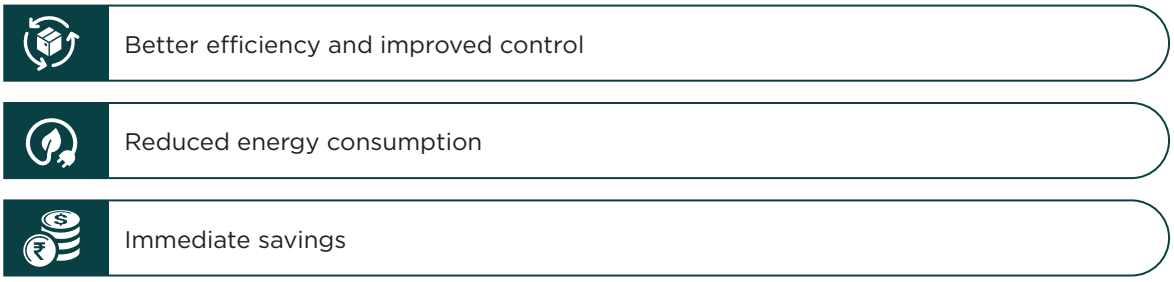
  This technology can reduce emissions by 10-30%, depending on the scale of the operation and the energy mix used.

- **Major consumers of the technology**

  Companies from the pulp & paper manufacturing, chemical & pharmaceutical industry, and food & beverage processing.

- **Relevance to the Indian industrial sectors**
  - **Paper & Packaging Industry –** Enhances vacuum-assisted water removal.
  - **Textile Manufacturing –** Reduces drying time in fiber processing.
  - **Oil Refining & Petrochemicals –** Optimises vacuum distillation units.

- **Expected benefits of the technology:**



2.4 Top Screen™ Barrier Coating Technology for Paper Cup Stocks

- **Category of the technology:** Core process
- **Developer/Supplier:** Solenis, UK and UK Paper Industry Technical Association (PITA)
- **Development stage:** Commercialised
- **Website hyperlink for supplier / developer**

  https://www.solenis.com/en/research-and-development/innovations/topscreen-barrier-coatings-for-cupstock/

- **Description of the technology:**
  - TopScreen™ cup stock coatings offer a versatile solution for manufacturers to produce next-generation cup stock with a superior liquid barrier, eliminating the need for polyethene (PE) film.
  - The technology consists of two layers: a precoating and a topcoat. The precoating enhances coating holdout and improves receptivity for the topcoat on the paper substrate.
  - The topcoat provides the necessary properties for the coated paper, offering a barrier against hot and cold liquids. The coating also features heat-seal properties, allowing the conversion of coated paper using standard cup converting applications such as hot-air and ultrasonic.
  - TopScreen™ cup stock barrier coatings effectively create a water barrier on cup stock paper, making it suitable for a variety of paper cups and food containers. These waterborne dispersions can be applied using conventional coating methods, including metered size presses, film, rod, air knife, and curtain coaters, as well as gravure and flexographic presses.

- These barrier coatings are ideal for applications such as hot and cold drink cups, ice cream containers, and other quick-serve items. Additionally, coated paper cups can be printed with typography, logos, and graphics, offering customisation options for branding and marketing purposes.

- **Cost and Energy Efficiency**
  - This technology reduces energy consumption during production by 10-20% compared to conventional PE coating processes.
  - The cost of implementation depends on the scale of the operation but typically ranges from $100,000 to $500,000.

- **Process Emission Reduction Potential**

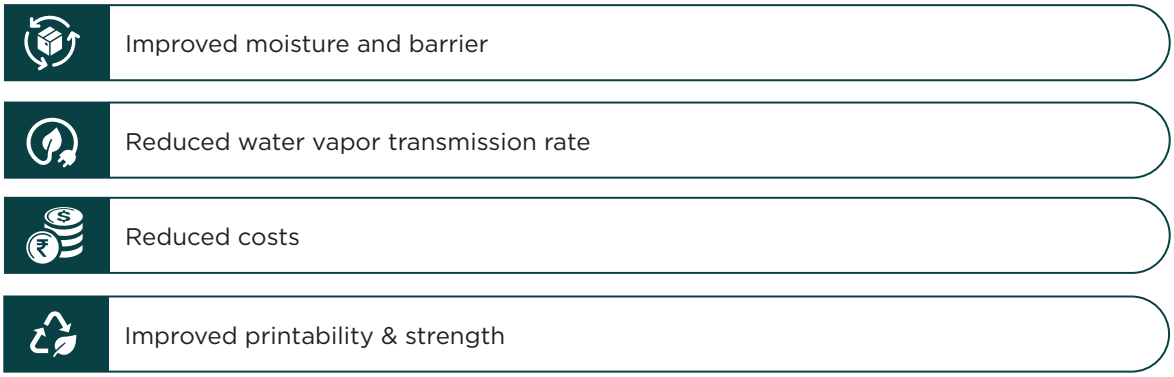
  It can reduce CO_2 emissions by 30-50% per ton of paper cup stock produced.

- **Major consumers of the technology**

  Companies from the paper & packaging industry, food & beverage sector, and printing & specialty paper manufacturing.

- **Relevance to the Indian industrial sectors**
  - **Retail & E-commerce –** Used in sustainable paper-based delivery packaging.
  - **Paper & Packaging -** Supports eco-friendly alternatives to plastic coatings.

- **Expected benefits of the technology:**



2.5 Aspen Plus – a process simulation software

- **Category of the technology:** Software/Digitalisation
- **Developer/Supplier:** AspenTech Limited, UK
- **Development stage:** Commercialised
- **Website hyperlink for supplier / developer**

  https://www.aspentech.com/en/products/engineering/aspen-plus

- **Description of the technology:**
  - Aspen Plus is a process simulation software utilised to model and analyse pulping and papermaking processes. This powerful tool aids in enhancing efficiency, quality, cost-effectiveness, and safety across various industries, including the pulp and paper, chemical, and petroleum sectors.
  - The software enables the study of different process parameters such as temperature, pressure, and chemical composition, offering insights into their effects on operations. Aspen Plus can also assist in designing new processes and optimising existing ones.
  - Additionally, Aspen Plus is employed to:
    - Troubleshoot problems
    - Predict the performance of new or modified processes
    - Estimate capital and operating costs
    - Conduct environmental impact assessments

- **Cost and Energy Efficiency**
  - The software helps identify energy-saving opportunities, leading to 5-15% energy efficiency improvements.
  - The cost of licensing Aspen Plus varies based on the scale of use but typically ranges from $20,000 to $100,000 annually.

- **Process Emission Reduction Potential**

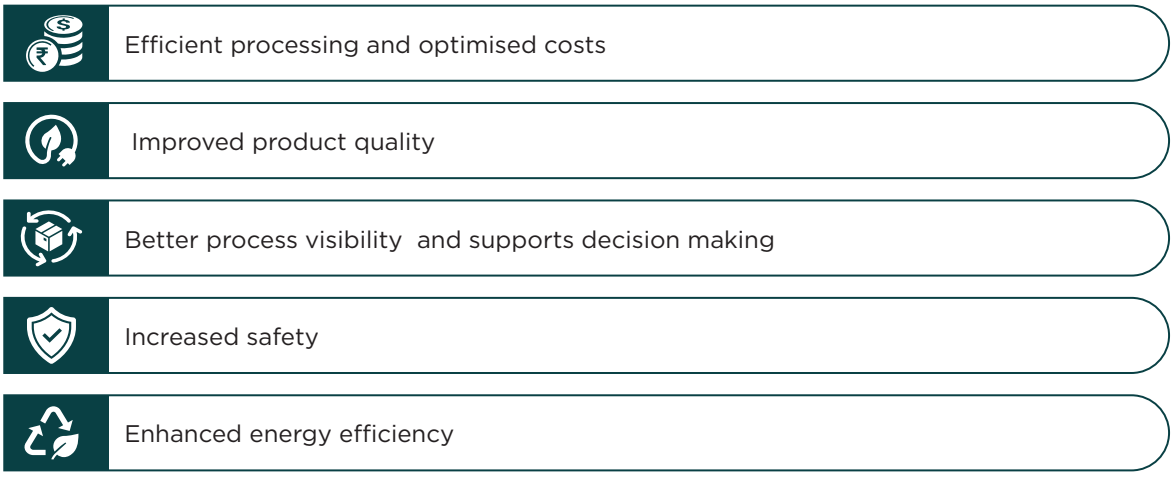
  Aspen Plus can help reduce CO_2 emissions by 10-25% in pulp and paper mills.

- **Major consumers of the technology**

  Companies from the chemical & petrochemical industry, energy & power generation, pharmaceuticals, and large-scale paper mills.

- **Relevance to the Indian industrial sectors**
  - **Oil & Gas Refining –** Enhances process control in crude distillation units.
  - **Steel & Cement Manufacturing –** Models carbon capture and waste heat recovery.
  - **Renewable Energy Sector –** Simulates hydrogen production and energy storage

- **Expected benefits of the technology:**



2.6 GUPEX® HDS paper machine steam extraction hood

- **Category of the technology:** Others
- **Developer/Supplier:** GUPEX, UK
- **Development stage:** Commercialised
- **Website hyperlink for supplier / developer**

  https://www.gupex.co.uk/main/products.php?content=pulp_paper

- **Description of the technology[2]:**
  - The GUPEX® HDS paper machine steam extraction hood is an advanced system engineered for the extraction of steam and hot moist air from paper production machines. The removal of moist, humid air is essential to prevent condensation, which can lead to corrosion and damage of concrete structures, steel reinforcements, and machinery surfaces within paper and pulp facilities.
  - Utilising ventilation fans alone may be insufficient, as some vapor can still accumulate on machines, resulting in gradual corrosion. The GUPEX® HDS hood system presents a proven and effective method to enhance the quality and efficiency of paper production while optimising environmental performance and reducing operating costs for paper mills worldwide.
  - Constructed from glass fibre reinforced polyester (GRP), the system is inherently resistant to corrosion. Its non-condensing surface prevents the dripping of condensed water, ensuring a clean and efficient production environment. The GUPEX® HDS hood system can be supplied as an integrated unit for optimal air extraction and is available in various sizes to suit different paper production machines.
  - Additionally, the system recovers heat energy from the extracted air, which can be utilised to preheat incoming air. This process effectively reduces the energy required to heat the paper machine, contributing to energy efficiency and cost savings.
- **Cost and Energy Efficiency**
  - By optimising steam extraction, it reduces energy consumption by 10-20% compared to conventional systems.
  - The cost of implementing this technology ranges from $200,000 to $500,000.
- **Process Emission Reduction Potential**

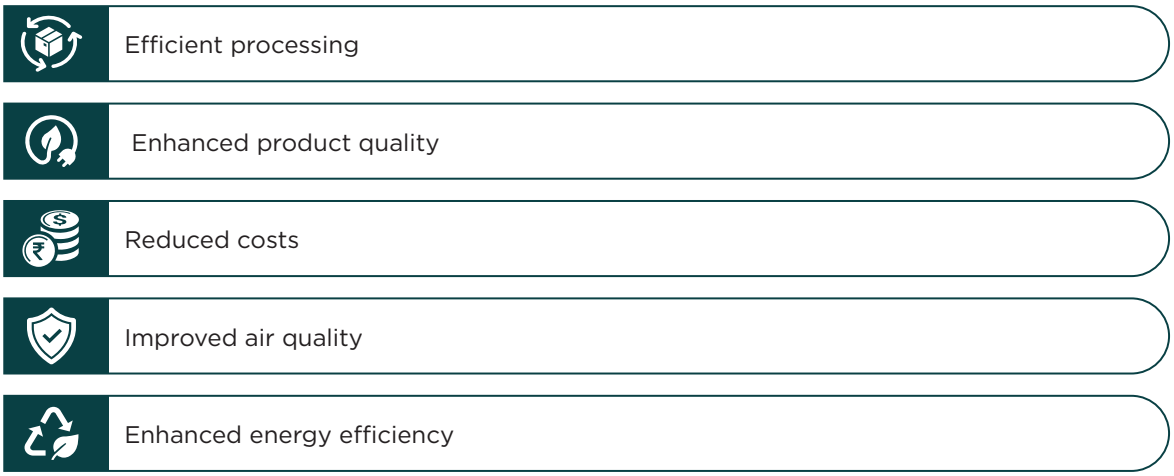
  It can reduce emissions by 15-30% in the drying section, depending on the energy source (e.g., coal, natural gas, or biomass).

- **Major consumers of the technology**

  Companies from the pulp & paper manufacturing sector, textile & nonwoven fabric production, and printing & coating industries.

2 Paper machine ventilation of moist, humid air and heat energy recovery (gupex.co.uk)

- **Relevance to the Indian industrial sectors**
  - **Paper and Packaging -** Reduces energy costs in drying.
  - **Tissue & Hygiene Product Manufacturing –** Improves softness and texture control.
  - **Specialty Paper Industry –** Enhances quality in fine-grade papers.
- **Expected benefits of the technology:**



2.7 Nyex™ - advanced waste-water treatment process

- **Category of the technology:** Others – Industrial waste-water treatment
- **Developer/ Supplier:** Arvia Technology, UK
- **Development stage:** Commercialised
- **Website hyperlink for supplier / developer**

  https://arviatechnology.com/arvia-technology-products/nyex-a
- **Description of the technology:**
  - The Nyex™ technology provides targeted removal of organic pollutants across a range from milligrams per litre to parts per billion, utilising a combination of adsorption and oxidation. The treatment process merges adsorption with electrochemical oxidation within a single, scalable unit.
  - As water enters the reactor tank, contaminants are concentrated onto the surface of proprietary Nyex™ adsorbent media, which is characterised by its non-porous nature and high electrical conductivity. Simultaneously, a low-electrical current passes through the media bed, fully mineralising the adsorbed contaminants into water, hydrogen, and carbon dioxide.
  - Unlike activated carbon, Nyex™ media is effectively regenerated in situ, enabling continuous operation without the need for interruption or incineration to renew the media. The treated water exits the reactor tank, ready for in-process use, reuse, or safe discharge.

- The use of conductive adsorbent significantly reduces electricity consumption, and concentrating contaminants prior to oxidation ensures high removal rates and efficiency.

- **Cost and Energy Efficiency**
  - It is highly energy-efficient, consuming 30-50% less energy when compared to conventional treatment methods like activated carbon or ozonation.
  - The cost of implementation depends on the scale but typically ranges from $100,000 to $500,000.

- **Process Emission Reduction Potential**

  It can reduce CO_2 emissions by 20-40% compared to traditional methods, as it avoids the use of energy-intensive processes like incineration or chemical oxidation.

- **Major consumers of the technology**

  Companies from pharmaceutical & chemical processing, textile & dyeing industry, and food & beverage industry.

- **Relevance to the Indian industrial sectors**
  - **Industrial Wastewater Management –** Helps achieve stringent discharge limits.
  - **Leather & Tanning Industry –** Removes heavy metals and organic pollutants.
  - **Municipal Water Treatment –** Supports advanced oxidation processes.

- **Expected benefits of the technology:**

2.8 Black Liquor Gasification

- **Category of the technology:** Others – Cogeneration Unit
- **Developer/Supplier:** Cranfield University, UK
- **Development stage:** Research & Development (R&D)
- **Website hyperlink for supplier / developer**

  https://dspace.lib.cranfield.ac.uk/bitstream/1826/17140/1/Black_liquor_gasification-2021.pdf

- **Description of the technology:**
  - Black Liquor Gasification (BLG) is a process that converts black liquor, a byproduct of the kraft pulping process, into syngas—a mixture of carbon monoxide and hydrogen.
  - Black liquor, known for its dark and viscous nature, comprises dissolved organics from wood and spent pulping chemicals. Prior to gasification, it is typically concentrated to approximately 65-80% solids.
  - The gasification process takes place in a reactor at elevated temperatures (700-900°C) and pressures (10-30 bar). During this process, black liquor is heated in the presence of a gasifying agent such as steam or oxygen, causing the organics to break down. This results in the production of syngas, along with some tar and ash.
  - The syngas produced through this process has a wide range of applications, including electricity and steam generation, fuel production, and the synthesis of chemicals such as methanol and di-methyl ether.
- **Cost and Energy Efficiency**
  - This technology improves energy efficiency by 10-20% compared to traditional recovery boilers.
  - The capital cost required for BLG systems ranges from $200 million to $500 million.
- **Process Emission Reduction Potential**
  - It can lower CO_2 emissions by 30-50% in kraft pulp mills. Additionally, it reduces
  - sulfur emissions and improves the overall sustainability of the pulping process
- **Major consumers of the technology**

  Companies from the pulp & paper industry, biorefinery & bioenergy production, and chemical & petrochemical sectors.
- **Relevance to the Indian industrial sectors**
  - **Paper & Pulp Mills –** Reduces dependency on fossil fuels for power generation.
  - **Renewable Energy Industry –** Supports bioenergy transition from waste materials.
  - **Carbon-Neutral Chemical Manufacturing –** Enhances waste valorisation.
- **Expected benefits of the technology:**

Black liquor, a high-energy fuel, can decrease dependence on fossil fuels and optimise energy costs

Help mitigate the environmental impact by reducing GHG emissions and other pollutants

Generate additional revenue streams by sale of syngas

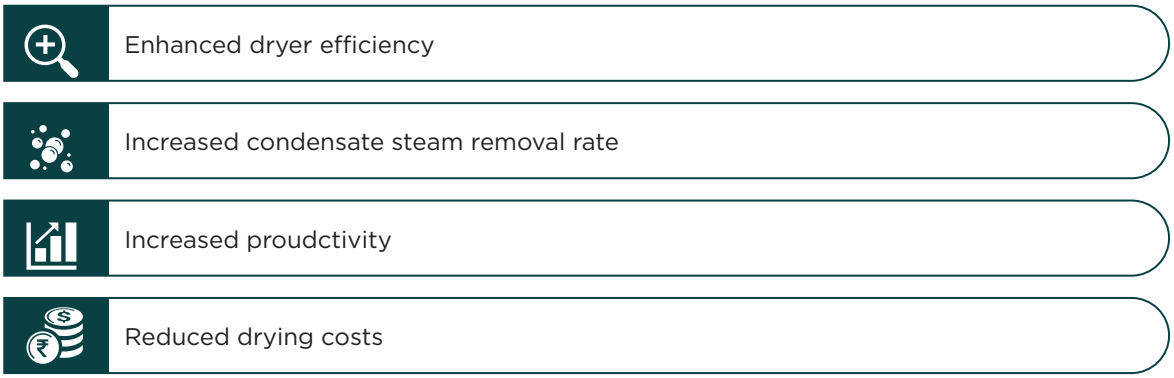
2.9 Syphon Systems in Paper Drying

- **Category of the technology:** Others – Paper Drying
- **Developer/Supplier:** Deublin, UK; Kadant Inc., USA; Forbes Marshall, UK
- **Development stage:** Commercialised
- **Website hyperlink for supplier / developer**

  https://www.deublin.eu/siphon-systems-for-the-paper-industry

- **Description of the technology:**
  - Paper manufacturers primarily focus on optimising the operational efficiency of paper machines, particularly in response to rising energy costs. The dryer section, which accounts for up to 55% of total energy expenses, presents a significant opportunity for improvement. Enhancing the steam and condensate system is essential for increasing manufacturing capacity and minimising drying costs.
  - Efforts to optimise dryer sections centre around advancements in steam systems and condensate drainage technologies, including stationary and rotating syphons. Syphons enable fluid flow from within the cylinder to stationary piping outside. Fluid flow is driven by differential pressure, which is affected by factors such as centrifugal force, fluid viscosity, and syphon configuration.
  - Two main types of syphons are commonly used in the industry: rotary and stationary. Rotary syphons require high differential steam pressures, while stationary syphons maintain low pressure requirements regardless of machine speed. This approach reduces blow-through steam and improves dryer efficiency.
- **Cost and Energy Efficiency**
  - This technology has the potential to improve the energy efficiency by 5-15%.
  - The cost of upgrading syphon systems ranges from $50,000 to $200,000.
- **Process Emission Reduction Potential**
  - By reducing steam consumption, syphon systems can lower CO_2 emissions by 10-20% in the drying section of paper machines.
- **Major consumers of the technology**
  - Companies from the pulp & paper manufacturing sector, textile processing, and printing & coating applications.
- **Relevance to the Indian industrial sectors**
  - **Paper & Packaging Industry –** Reduces steam consumption and operational costs.
  - **Board & Corrugated Paper Manufacturing –** Improves drying speed and uniformity.
  - **Industrial Textile Production –** Enhances energy efficiency in heat-intensive processes.

- **Expected benefits of the technology:**



For enquiries regarding potential collaboration opportunities with the mentioned technology providers please contact:

Bureau of Energy Efficiency

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

ASPIRE Programme Team

In-fmaspire@kpmg.com

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

Vikas Gaba
Partner and National Lead Power & Utilities
KPMG India
vikasgaba@kpmg.com

3 CHLOR-ALKALI SECTOR

3.1 BICHLOR™ Bipolar Membrane Electrolyser

- **Category of the technology:** Core Process
- **Developer/Supplier:** Ineos Group, UK
- **Development stage:** Commercialised
- **Website hyperlink for supplier / developer**

  https://www.ineos.com/businesses/ineos-electrochemical-solutions/products/bichlor-electrolyser/

- **Description of the technology:**
  - BICHLOR™ Electrolyser is a modular, bipolar electrolyser that delivers superior efficiency and safety for chlor-alkali production process. The membrane technology delivers significant energy savings and long-lasting performance over a lifetime of chlor alkali production and is installed in over 35 countries around the world. Its operation is like traditional electrodes, so it can be easily adopted and scaled in new factories.
  - The BICHLOR™ Electrolyser features several innovative features that contribute to its efficiency and performance including:
    - A bipolar design allows for the use of a thicker membrane, which reduces the energy required for the electrolysis process.
    - A proprietary CHLORCOAT™ coating on the electrodes reduces corrosion and increases lifespan.
    - A modular design that allows for optimised operation and reduced maintenance, further contributing to energy savings
- **Cost and Energy Efficiency**

  This technology operates at a cell voltage of 2.8-3.2 V, significantly lower than traditional electrolysers, resulting in energy savings of 15-20%.

- **Process Emission Reduction Potential**

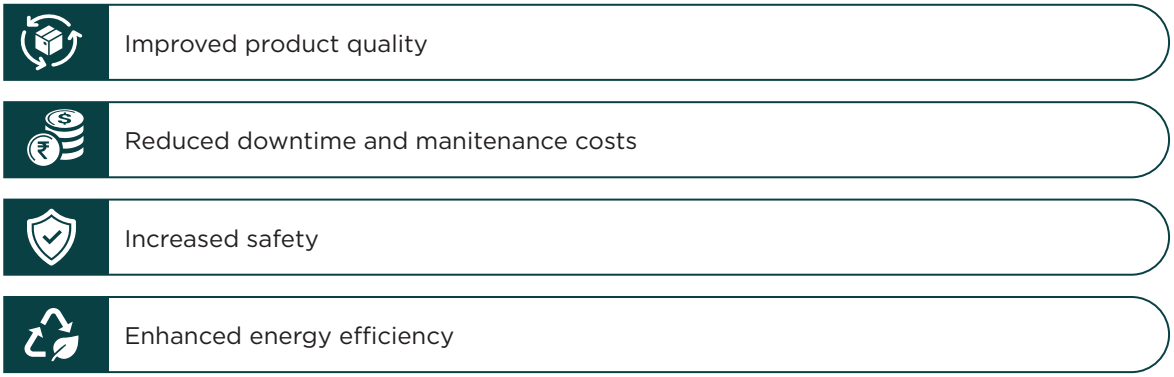
  The BICHLOR™ electrolyser reduces emissions by producing high-purity chlorine and caustic soda with minimal byproducts. It eliminates the need for mercury or asbestos-based technologies, reducing hazardous waste and greenhouse gas emissions by 30-40%.

- **Major consumers of the technology**

  Companies in the chlor-alkali production sector, water treatment, and chemical processing.

- **Relevance to the Indian industrial sectors**
  - **Chemical & Petrochemical Industry –** Used in large-scale chlor-alkali plants.
  - **Pharmaceutical Manufacturing –** Produces sodium hydroxide for drug synthesis.
  - **Textile Processing –** Used for bleaching and fiber treatment.

- **Expected benefits of the technology:**



3.2 CHLORCOAT™- advanced electrode coating

- **Category of the technology:** Core Process
- **Developer/Supplier:** Ineos Group, UK
- **Development stage:** Commercialised
- **Website hyperlink for supplier / developer**

  https://www.ineos.com/businesses/ineos-electrochemical-solutions/products/electrode-coatings--refurbishment/electrode-coatings/

- **Description of the technology:**
  - CHLORCOAT™ technology is a proprietary process developed by INEOS Electrochemical Solutions for coating titanium and nickel electrodes used in the chlor-alkali industry to reduce corrosion during the production process.
  - The process involves depositing a thin layer of a specially formulated coating onto the surface of the electrode in the following manner:
    - **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.
    - **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.
    - **Step 3 Applying the coating**: The coating solution is applied to the electrodes using a variety of methods, including spraying, dipping, or brushing.
    - **Step 4 Curing**: The electrodes are cured at a specific temperature. This helps to set the coating and make it more durable.
    - **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.

- **Cost and Energy Efficiency**

  CHLORCOAT™ electrode coatings are designed to enhance energy efficiency and reduce operational costs in the chlor-alkali process. The anode coatings deliver energy savings of up to 20mV, which translates to approximately 14 kWh/ton of NaOH produced.

- **Process Emission Reduction Potential**

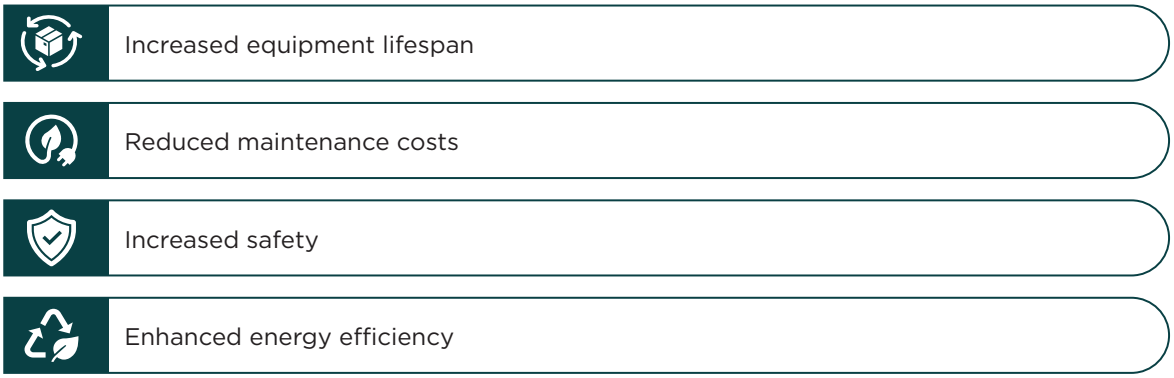
  CHLORCOAT™ coatings significantly reduce emissions by lowering chlorate formation in the brine solution.

- **Major consumers of the technology**

  Companies in the chlor-alkali production sector, hydrogen generation, and electrochemical processing.

- **Relevance to the Indian industrial sectors**
  - **Chemical & Basic Material Industry –** Enhances chlorine and caustic production.
  - **Energy Sector –** Supports efficient hydrogen production.
  - **Metal Refining –** Improves electrochemical processes in metal extraction.

- **Expected benefits of the technology:**



3.3 6th Generation (Zero gap type) Cell

- **Category of the technology:** Core Process
- **Developer/Supplier:** Royal Society of Chemistry, UK
- **Development stage:** Research & Development (R&D)
- **Website hyperlink for supplier / developer**

  https://pubs.rsc.org/en/content/articlehtml/2016/ra/c6ra22242k

- **Description of the technology:**
  - The 6th generation (zero gap type) cell is an advanced membrane cell utilised in the chlor-

alkali industry. Characterised by a minimal space between the anode and cathode, it greatly reduces the crossover of ions between the two compartments, enhancing efficiency. This design maximises the production of chlorine and sodium hydroxide while lowering energy consumption for cell operation.

- The cell consists of a series of parallel plates, with anodes and cathodes positioned on opposite sides. It achieves up to a 95% yield of chlorine and sodium hydroxide, a significant improvement over earlier cell generations. This high efficiency makes the 6th generation cell a more cost-effective option for chlor-alkali production.

- **Cost and Energy Efficiency**

  This design achieves energy savings of up to 20 mV, translating to approximately 14 kWh/ton of NaOH produced.

- **Process Emission Reduction Potential**

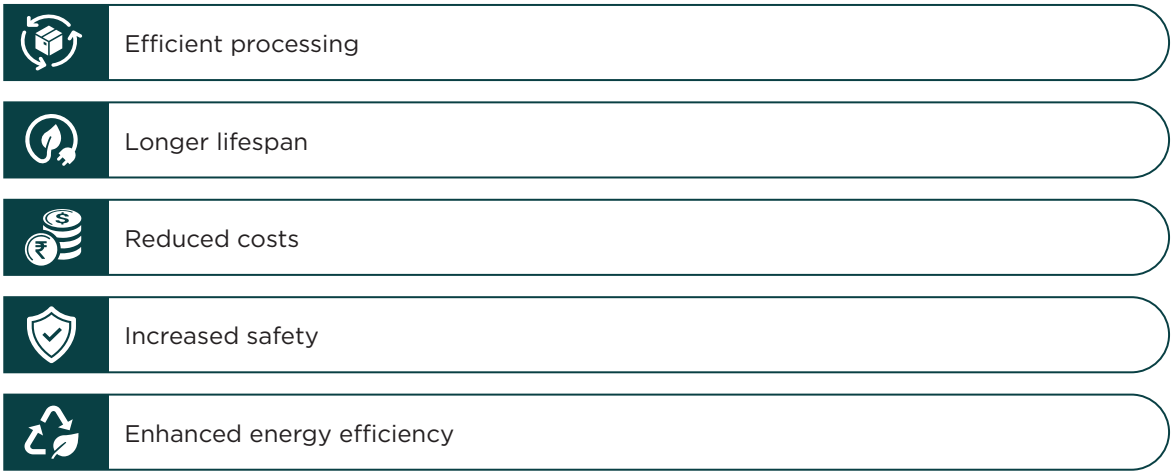
  The zero-gap design, which incorporates oxygen-depolarised cathodes, has demonstrated the potential to reduce energy consumption by up to 28% compared to conventional membrane cells.

- **Major consumers of the technology**

  Companies from the chlor-alkali industry, hydrogen fuel production, and electrochemical manufacturing.

- **Relevance to the Indian industrial sectors**
  - **Chemical Industry –** Reduces operational costs in large-scale chlor-alkali plants.
  - **Renewable Energy –** Helps in hydrogen production for fuel cells.
  - **Metal & Mining –** Used in electro-winning and metal recovery.

- **Expected benefits of the technology:**



3.4 Polymer Electrolyte Membrane (PEM) Fuel Cell Technology

- **Category of the technology:** Core Process
- **Developer/Supplier:** DEMCOPEM-2MW, Netherlands
- **Development stage:** Research & Development (R&D)
- **Website hyperlink for supplier / developer**

  https://www.clean-hydrogen.europa.eu/projects-dashboard/projects-repository/demcopem-2mw_en

- **Description of the technology:**
  - The chlor-alkali process produces hydrogen as a by-product, which can be utilized to fuel a Polymer Electrolyte Membrane (PEM) fuel cell for generating electricity and heat.
  - The electricity produced can power the chlor-alkali plant or be supplied to the grid. The heat from the fuel cell can be harnessed to warm the brine solution, thereby enhancing the efficiency of the chlor-alkali process.

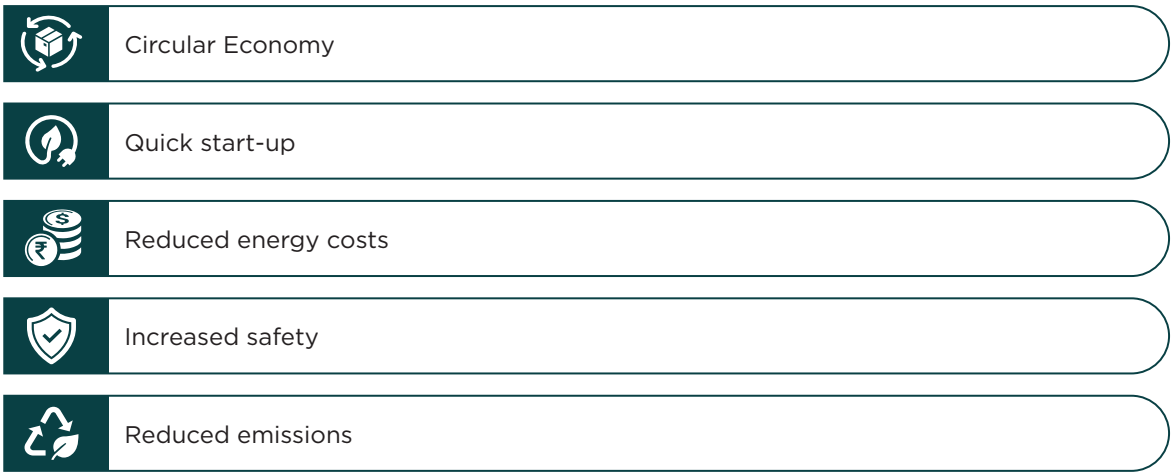
    The PEM fuel cell consists of a thin, solid film separating the hydrogen and oxygen electrodes, enabling proton transport while blocking electron flow. This design allows the fuel cell to operate at relatively low temperatures and pressures, offering a more efficient and eco-friendlier alternative compared to other fuel cell types.

    The electricity generated by the fuel cell can be used to run the chlor-alkali plant, while the heat can be applied for various other purposes. This technology has the potential to enhance the efficiency and sustainability of chlor-alkali production while reducing the industry's environmental impact.
- **Cost and Energy Efficiency**
  - PEM fuel cells can achieve 40-60% electrical efficiency, significantly reducing energy consumption compared to traditional methods.
  - The initial capital cost of PEM fuel cells ranges from $50 to $100 per kW.
- **Process Emission Reduction Potential**

  When integrated into chlor-alkali processes, they can reduce greenhouse gas emissions by up to 30-50% compared to conventional energy sources.
- **Major consumers of the technology**

  Used in grid energy storage, hydrogen fuel cells, and backup power systems.
- **Relevance to the Indian industrial sectors**
  - **Transportation & Mobility –** Enables hydrogen-powered buses and logistics vehicles.
  - **Energy Sector –** Integrates hydrogen storage for clean power grids.
  - **Industrial Manufacturing –** Provides clean energy backup for critical operations.

- **Expected benefits of the technology:**



3.5 FORBLUE FLEMION Membranes

- **Category of the Technology:** Core Process
- **Developer/Supplier:** AGC Chemicals, UK; Pure Aqua, USA; Hyflux, Amsterdam
- **Development stage:** Commercial
- **Website hyperlink for supplier / developer**

  https://www.agc-chemicals.com/jp/en/fluorine/products/detail/index.html?pCode=JP-EN-F020

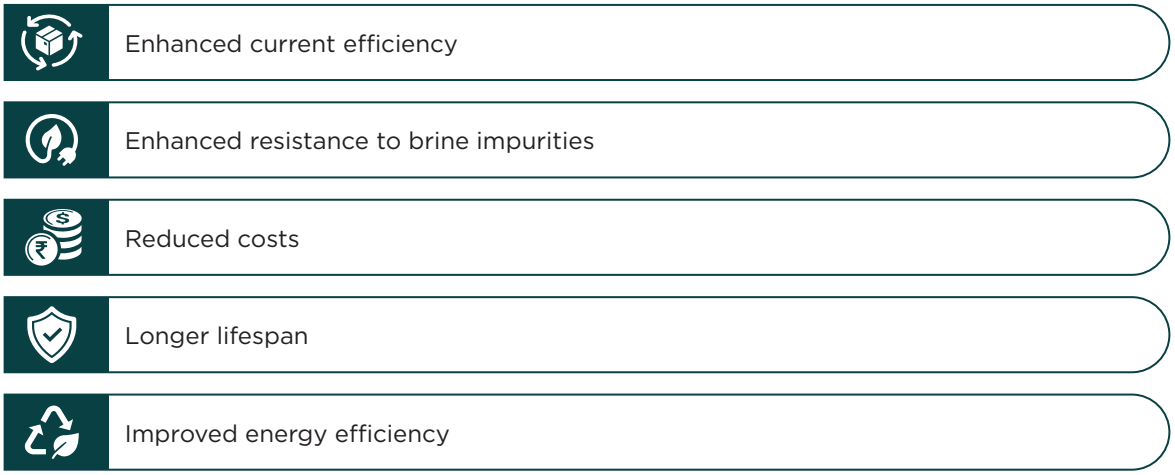
- **Description of the technology:**
  - FLEMION™ is a fluorinated ion exchange membrane designed for the production of caustic soda and caustic potash while achieving significant energy savings.
  - This membrane is known for its ease of handling, as it is both flexible and soft yet durable. Its thin homogeneous structure provides low electrical resistance and exceptional efficiency in concentrating the target material.
  - Manufactured with advanced grafted polymerisation technology, FLEMION™ does not require reinforcing fabric and offers superior strength. It maintains high electrical current efficiency and exhibits stable performance due to its high resistance to impurities.
- **Cost and Energy Efficiency**

  They offer low electrical resistance and high current efficiency, reducing energy consumption by up to 10-15% compared to traditional membranes.

- **Major consumers of the technology**

  Companies from the chlor-alkali industry, hydrogen production, and chemical processing.

- **Relevance to the Indian industrial sectors**
  - **Chlor-Alkali Industry:** Used in modern membrane-based electrolysis at caustic soda plants, replacing older mercury and diaphragm cell technologies for higher efficiency and lower environmental impact.
  - **Petrochemical Sector:** Supports chlorine production for PVC manufacturing, pharmaceuticals, and chemical intermediates.
  - **Renewable Hydrogen Production:** A key component in electrolysers for India's National Green Hydrogen Mission, promoting clean hydrogen production.
- **Expected benefits of the technology:**



3.6 FORBLUE™ S Series

- **Category of the Technology:** Core Process
- **Developer/Supplier:** AGC Chemicals, UK
- **Development stage:** Commercial
- **Website hyperlink for supplier / developer**

  https://www.agc-chemicals.com/file.jsp?id=jp/en/products/pdf/Sx-2301_EN.pdf
- **Description of the technology:**
  - FORBLUE™ S Series is a fluorinated sulfonic acid ion exchange membrane designed for use in electrolysis and electrodialysis processes. Despite being an ion exchange membrane, it exhibits low corrosion when exposed to chemicals and acids, providing flexibility and exceptional strength.
  - The membrane offers enhanced resistance to super-strong acids and facilitates high dissociation of ions. Membranes with a much higher ion exchange functional group (depending on the grade up to 37% more than conventional membranes) are also available in the market.

- FORBLUE™ S Series achieves high mechanical strength and ease of handling through the incorporation of special polytetrafluoroethylene (PTFE) fibre reinforcement into the sulfonic acid polymer film. It maintains high cation permeability and features excellent chemical resistance due to its fluorinated base polymer. This versatile membrane is suitable for use in various demanding conditions.

- **Cost and Energy Efficiency**

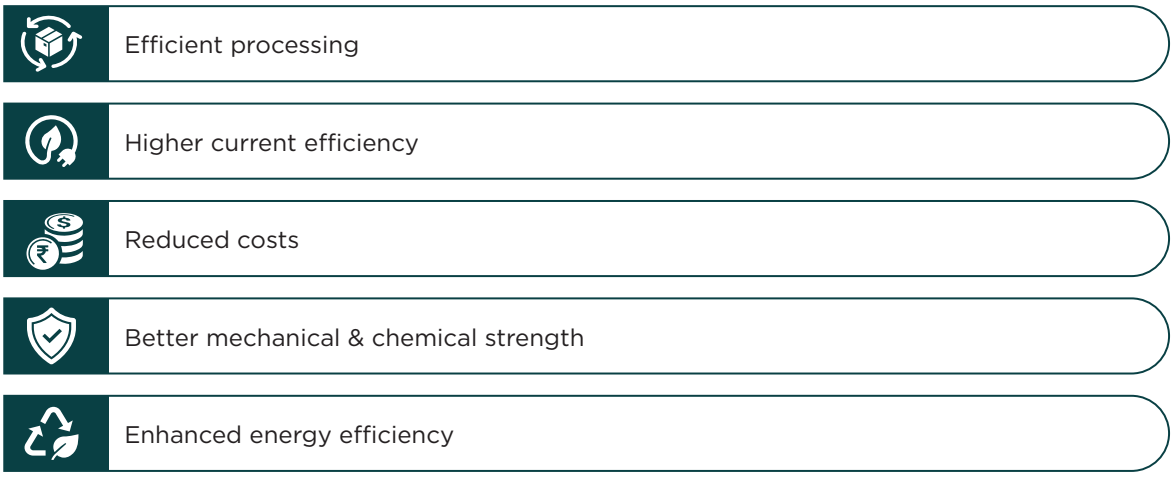
  They reduce operational costs by 10-20% through improved current efficiency and reduced maintenance

- **Major consumers of the technology**

  Companies from the chlor-alkali industry, battery & energy storage, and water treatment.

- **Relevance to the Indian industrial sectors**
  - **Chemical Industry:** Used in next-generation chlor-alkali plants for higher efficiency and lower emissions.
  - **Renewable Energy Sector:** Supports hydrogen fuel cells and advanced battery storage, vital for clean energy transition.
  - **Water Purification:** Integrated into pharmaceutical and semiconductor industries requiring ultra-pure water.

- **Expected benefits of the technology:**



3.7 FORBLUE™ Selemion

- **Category of the Technology:** Core Process
- **Developer/Supplier:** AGC Chemicals, UK
- **Development stage:** Commercialised

- **Website hyperlink for supplier / developer**

  https://www.agcchem.com/products/forblue-membranes-polymers/forblue-selemion/

- **Description of the technology:**
  - FORBLUE™ Selemion is a hydrocarbon-based cation and anion exchange membrane designed for use in concentration, desalination, and acid recovery processes. Unlike conventional ion exchange resins that use ionic particles bound together by resins, Selemion utilises a highly efficient amorphous phase in film-like membranes to concentrate target materials.
  - FORBLUE™ Selemion is known for its ease of handling, flexibility, softness, and durability. Its thin, homogeneous membrane provides low electrical resistance, enhancing overall performance.
  - The technology has a range of applications, including electrodialysis, diffusion dialysis, and electrolysis. It is used for concentration processes such as producing table salt from seawater and extracting salt from foodstuffs. Additionally, it aids in the purification of food and beverages, desalination of wastewater and various types of water, and recovery of valuable ions from industrial solutions. It is also useful for acid recovery operations.

- **Cost and Energy Efficiency**

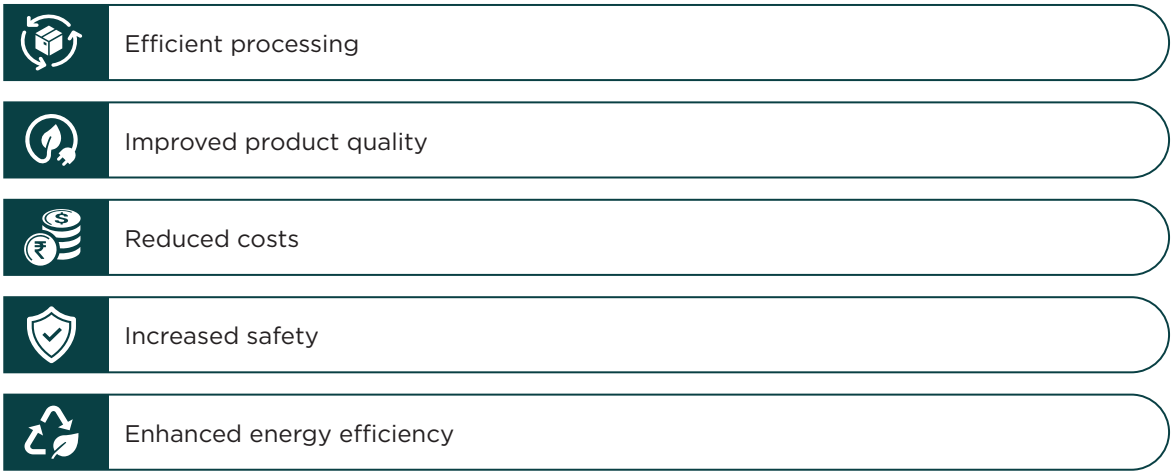
  It is highly energy-efficient, consuming 30-50% less energy compared to conventional treatment methods like activated carbon or ozonation.

- **Major consumers of the technology**

  Companies from the water treatment industry, and chemical & specialty chemical production.

- **Relevance to the Indian industrial sectors**
  - **Municipal and Industrial Water Treatment:** Used for brine recovery, desalination, and water purification.
  - **Chemical Processing Industry:** Enhances fine chemical and specialty chemical production with improved ion exchange capabilities.
  - **Sustainable Industrial Operations:** Helps industries minimise wastewater discharge and improve process efficiency.

- **Expected benefits of the technology:**



3.8 Nafion™ Membranes

- **Category of the technology:** Core Process
- **Developer/Supplier:** Chemours, USA
- **Development stage:** Commercialised
- **Website hyperlink for supplier / developer**

  https://www.nafion.com/en/applications/fuel-cells

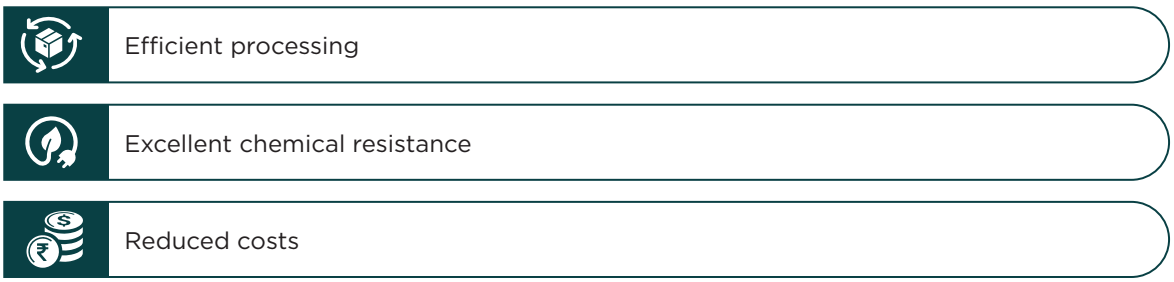
- **Description of the technology:**
  - Nafion™ membranes are ionomers, which are polymers with both ionic and covalent bonds—that enable efficient ion conduction while resisting chemical degradation. These membranes have a wide range of applications across sectors, including in the chlor-alkali industry.
  - In chlor-alkali production, Nafion™ membranes are used to separate the chlorine and sodium hydroxide generated during the electrolysis of brine. Constructed from perfluorosulfonic acid (PFSA) polymer, a highly ion-selective material, the membranes permit only cations (positively charged ions) to pass through while blocking anions (negatively charged ions).
  - This ion selectivity allows for the production of high yields of chlorine and sodium hydroxide with minimal energy consumption. Nafion™ membranes are also exceptionally durable and can withstand the harsh conditions of the chlor-alkali process.
- **Cost and Energy Efficiency**

  The use of this technology has the potential to reduce energy consumption by 10-20%

- **Major consumers of the technology**

  Companies from the fuel cell industry, hydrogen production, chlor-alkali industry, and chemical processing.

- **Relevance to the Indian industrial sectors**
  - **Hydrogen Production:** Used in PEM electrolysers for green hydrogen generation.
  - **Fuel Cell Industry:** Key component in hydrogen fuel cells for power generation and mobility.
  - **Chlor-Alkali Industry:** Used in membrane cell electrolysis for caustic soda and chlorine production.
  - **Chemical Processing:** Applied in ion-exchange processes for specialty chemical manufacturing.
- **Expected benefits of the technology:**




High conductivity


Enhanced energy efficiency

3.9 Advanced Amberpack™ Deionization (ADI) technology

- **Category of the technology:** Core Process
- **Developer/Supplier:** SAMCO Technologies/ Latern Technologies/ pure water group, USA
- **Development stage:** Commercialised
- **Website hyperlink for supplier / developer**

  https://samcotech.com/technologies-innovations/resin/amberpack-adi/

- **Description of the technology:**
  - Advanced Amberpack™ ADI technology is a high-yield ion exchange system utilising proprietary resin to remove ions from water, thereby optimising production efficiency in chlor-alkali plants.
  - The resin consists of small beads coated with charged groups. As water flows through the resin, the ions in the water are attracted to the charged groups on the resin, allowing for an exchange with the ions already on the resin. This process results in purified water that is free of ions.

    ADI technology is employed to produce high-purity water essential for the production of chlorine and caustic soda. It offers a reliable and efficient method of water purification, making it an ideal choice for use in the chlor-alkali industry and other sectors where high-purity water is required.

- **Cost and Energy Efficiency**

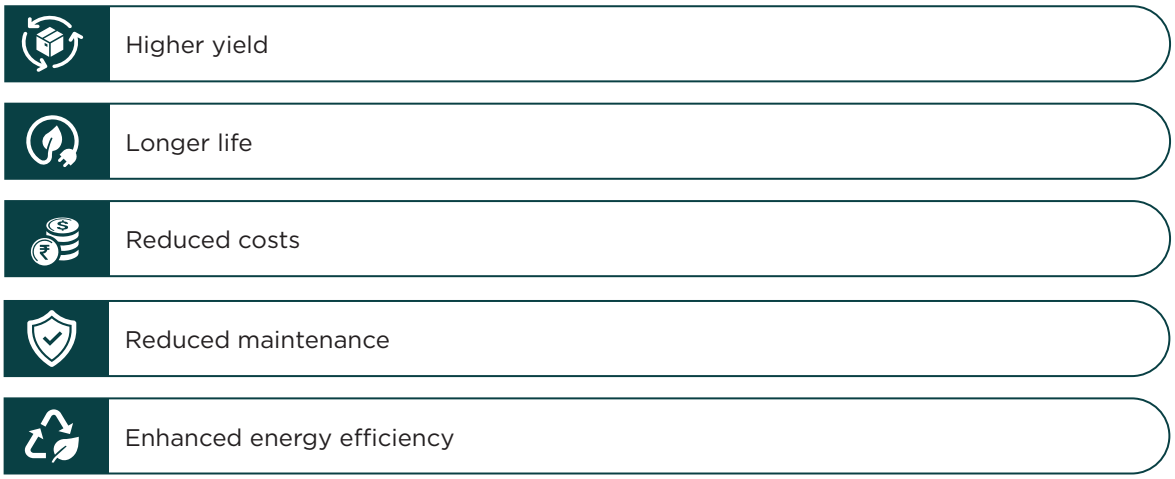
  ADI technology reduces energy consumption by 20-30% compared to traditional deionisation methods.

- **Major consumers of the technology**

  Companies from the chlor-alkali industry, power generation, pharmaceuticals, and semiconductor manufacturing.

- **Relevance to the Indian industrial sectors**
  - **Thermal Power Plants:** Used for high-purity boiler feedwater, improving turbine efficiency and lifespan.
  - **Pharmaceutical Industry:** Ensures ultrapure water quality for API manufacturing.
  - **Chlor-Alkali Industry:** Enhances brine treatment, reducing impurities and improving membrane life in electrolysis processes.
  - **Electronics & Semiconductor Industry:** Essential for high-purity water needs in Bharat Electronics Ltd. and semiconductor fabs

- **Expected benefits of the technology:**



3.10 EMOS® Cell Performance Analyser (Membrane)

- **Category of the Technology:** Software/Digitalisation
- **Developer/Supplier:** R_2 Chlor Alkali, Canada; Durham Instruments, Canada; Innovative Membrane Technologies, Netherlands
- **Development stage:** Commercial
- **Website hyperlink for supplier / developer**

  https://r2.ca/products/predictive-maintenance/emos-cell-performance-analyzer-service/

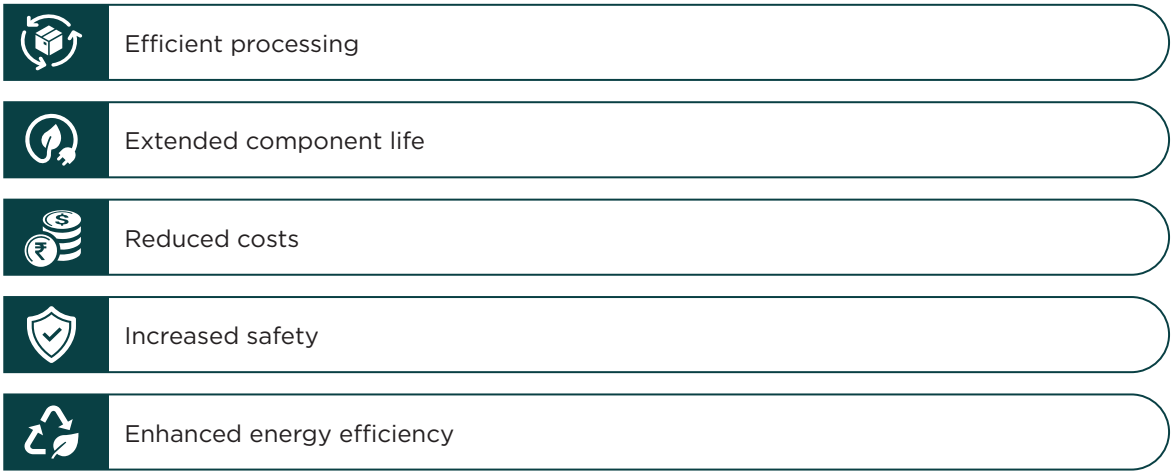
- **Description of the technology:**
  - EMOS® Cell Performance Analyser (membrane cell performance analyser) is a software tool designed to assess the performance of membrane cells. It provides measurement, analysis, and diagnostic capabilities for a range of membrane cell types, including bipolar, monopolar, and diaphragm cells.
  - The software utilises various sensors to collect data on cell performance, such as current, voltage, temperature, conductivity, and flow rate. It offers tools for identifying and troubleshooting issues with the cells, including performance trend analysis and fault detection and isolation.
  - By facilitating the analysis of membrane cell performance, it supports efficient cell operation and helps recommend corrective actions when necessary.
- **Cost and Energy Efficiency**

  This technology has the potential to reduce energy consumption by 5-10%

- **Major consumers of the technology**

  Companies from the chlor-alkali industry, chemical processing, and digitalised manufacturing.

- **Relevance to the Indian industrial sectors**
  - **Chlor-Alkali Plants:** Used for real-time membrane health monitoring, optimising energy consumption and production efficiency.
  - **Digitalisation of Chemical Manufacturing:** Supports smart monitoring systems in refineries and chemical plants.
  - **Sustainability & Energy Efficiency:** Helps industries reduce downtime, energy losses, and maintenance costs.
- **Expected benefits of the technology:**



3.11 Brine management systems

- **Category of the Technology:** Software/Digitisation
- **Developer/Supplier:** Evoqua Water Technologies, UK
- **Development stage:** Research & Development (R&D)
- **Website hyperlink for supplier / developer**

  https://www.xylem.com/en-us/brand/evoqua/
- **Description of the technology:**
  - Brine management systems in the chlor-alkali industry play a crucial role in ensuring the quality and purity of brine, which serves as the feedstock for producing chlorine, caustic soda, and other chemicals.
  - These systems are designed to eliminate impurities such as calcium, magnesium, and sulphate from the brine, as these contaminants can damage membranes and decrease plant efficiency.
  - Key components of brine management systems include the following:
    - A brine well or tank for brine storage.
    - A brine purification system to remove impurities.
    - A brine pump for circulating brine through chlor-alkali cells.

- A brine recovery system to reclaim unused brine from chlor-alkali cells.

➢ There are two main types of brine management systems:

- Thermal-based: These use heat to evaporate the water from the brine, leaving behind a concentrated salt residue.
- Membrane-based systems: These use membranes to filter out the water from the brine, resulting in a solid salt cake with a lower salt concentration.

- **Cost and Energy Efficiency**

  Brine management systems reduce energy consumption by 10-15% through efficient brine recycling and purification.

- **Major consumers of the technology**

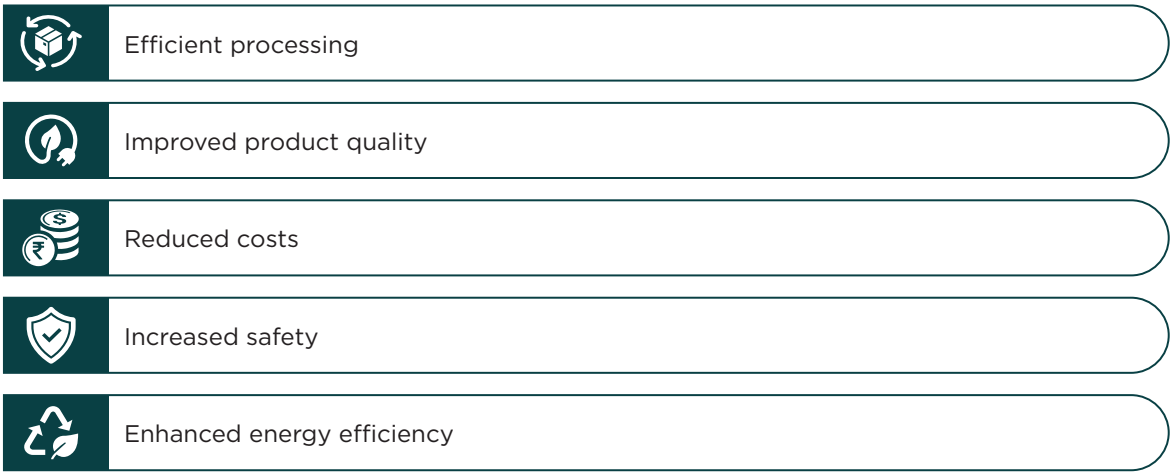
  Companies from the chlor-alkali industry, chemical manufacturers, and water treatment plants.

- **Relevance to the Indian industrial sectors**

  ➢ **Chlor-Alkali Industry:** Used to optimise brine quality in energy-efficient membrane electrolysis systems.

  ➢ **Water Desalination & Recycling:** Applied in municipal water treatment and industrial effluent treatment plants to reduce salt waste.

- **Expected benefits of the technology:**



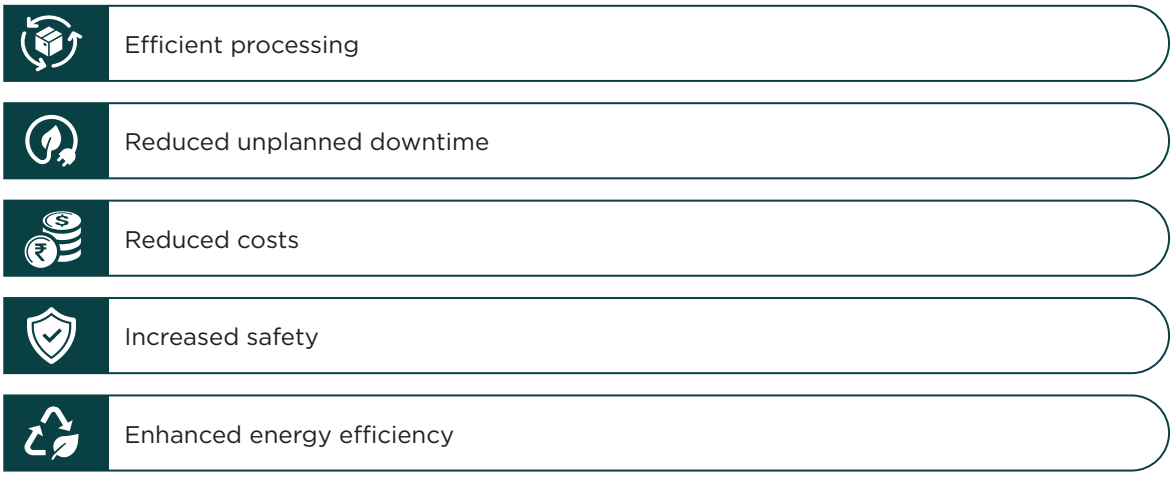
3.12 EMOS® Predictive Maintenance Package

- **Category of the technology:** Software / Digitalisation
- **Developer/Supplier:** R_2 Chlor Alkali, Canada
- **Development stage:** Commercialised
- **Website hyperlink for supplier / developer**

  https://r2.ca/products/predictive-maintenance/emos-cell-performance-analyzer-service/

- **Description of the technology:**
  - EMOS® Predictive Maintenance Package is a software solution designed for the chlor-alkali industry that leverages advanced analytics to forecast equipment failures.
  - The software can monitor a broad range of equipment, such as cells, pumps, compressors, and heat exchangers. By utilising historical and sensor data, EMOS® can identify patterns signaling an impending failure.
  - The software employs advanced analytics techniques, including machine learning and statistical analysis, to detect patterns in historical and real-time sensor data. Once potential issues are identified, EMOS® generates alerts to allow for proactive maintenance before equipment failure occurs.
- **Major consumers of the technology**

  Companies from the chlor-alkali sector, digitalised manufacturing, industrial IoT & automation, and chemical manufacturers.
- **Relevance to the Indian industrial sectors**
  - **Chlor-Alkali Plants:** Used for AI-driven equipment monitoring, reducing unexpected failures and maintenance costs.
  - **Manufacturing Industry:** Integrated into digital transformation strategies in chemical and petrochemical plants.
- **Expected benefits of the technology:**



For enquiries regarding potential collaboration opportunities with the mentioned technology providers please contact:

Bureau of Energy Efficiency

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

ASPIRE Programme Team

In-fmaspire@kpmg.com

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

Vikas Gaba
Partner and National Lead Power & Utilities
KPMG India
vikasgaba@kpmg.com

4 SUGAR SECTOR

4.1 Sugar Centrifuges

- **Category of the technology:** Core Process
- **Developer/Supplier:** Thomas Broadbent & Sons Ltd, UK
- **Development stage:** Commercialised
- **Website hyperlink for supplier / developer**

  https://broadbent.co.uk/sugar/sugar-centrifuge-applications/sugar-centrifuges/

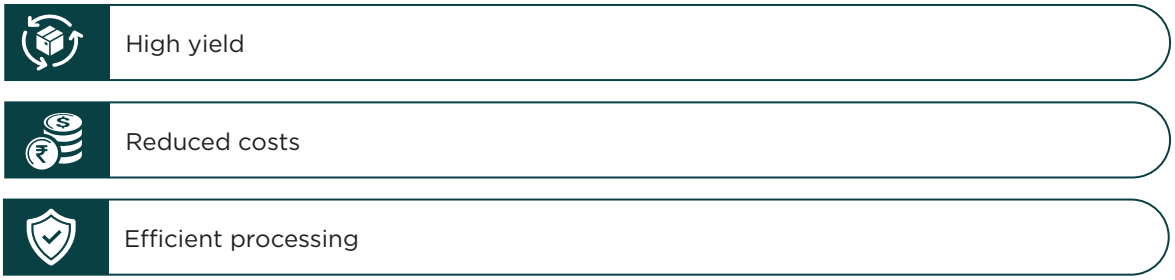
- **Description of the technology:**
  - Sugar centrifuges, also known as centrifugal machines, play a pivotal role in the sugar production process by separating sugar crystals from molasses. These machines consist of a rotating cylindrical basket designed to efficiently extract sugar crystals from the massecuite, which is a mixture of sugar crystals and molasses.
  - The centrifuge operates by spinning the massecuite in a perforated basket at speeds of up to 1,200 revolutions per minute (rpm). This high-speed rotation creates centrifugal force, which separates the sugar crystals from the molasses.
  - As the massecuite is spun in the perforated basket, the molasses is forced outward through the perforations and collects on the outside of the centrifuge. From there, it is drawn out of the centrifuge and sent to storage tanks for further processing or reuse.
  - The sugar crystals, being denser than the molasses, remain inside the lined centrifuge basket. This retention allows for the collection and transfer of the sugar crystals for further processing or packaging.
- **Cost and Energy Efficiency**

  Sugar Centrigues technology can reduce the energy consumption by 10-15%.

- **Major consumers of the technology**

  Companies from sugar processing industry, ethanol production industry, and byproduct recovery industry.

- **Relevance to the Indian industrial sectors**
  - **Sugar Mills & Refineries –** Used for efficient separation of sugar crystals from molasses, improving purity and processing efficiency.
  - **Bioethanol Production Plants –** Optimises molasses extraction, a key raw material in ethanol blending programs under India's biofuel initiatives.
- **Expected benefits of the technology:**




Enhanced energy efficiency

4.2 Ultrafiltration

- **Category of the technology:** Core Process
- **Developer/Supplier:** Membranes International Ltd., USA
- **Development stage:** Commercialised
- **Description of the technology:**
  - Ultrafiltration is a membrane separation process that plays a crucial role in the sugar industry by effectively separating larger molecules such as proteins and polysaccharides from smaller molecules such as sucrose. The technology utilises membranes with pore sizes ranging from 0.001 to 0.01 micro-meters to achieve this selective separation.
  - The process is commonly employed to purify sugar syrups by removing impurities such as proteins and colorants. This process enhances the quality of the sugar, ensuring a cleaner, more consistent product. Additionally, the removal of impurities contributes to an extended shelf life for sugar products.
  - The process can also be used to concentrate sugar solutions, which involves reducing the water content in the solution. By concentrating sugar solutions before further processing, manufacturers can reduce the energy required for heating, leading to cost savings and environmental benefits.
- **Cost and Energy Efficiency**

  Ultrafiltration systems reduce energy consumption by 15-20% by efficiently clarifying juice and reducing the need for chemical additives.
- **Major consumers of the technology**

  Companies from the sugar processing industry, water treatment industry, and ethanol & distillery industry.
- **Relevance to the Indian industrial sectors**
  - Sugar Mills & Refineries – Ensures high-efficiency juice purification, improving sugar quality and reducing impurities.
  - Effluent Treatment & Zero Liquid Discharge (ZLD) Systems – Used in wastewater treatment and reuse, minimising environmental impact.
  - Bioethanol Production – Enhances pre-treatment of molasses for fermentation, optimising ethanol conversion.
- **Expected benefits of the technology:**


Reduced Energy Consumption


Enhanced product quality


Increased Shelf Life

4.3 Ion Exchange

- **Category of the technology:** Core Process
- **Developer/Supplier:** Danaher Corporation, USA; Innovative Water Technologies, USA; Pure Water Solutions, USA
- **Development stage:** Commercialised
- **Website hyperlink for supplier / developer**

  https://ionexchangeglobal.com/

- **Description of the technology:**
  - Ion exchange is a highly effective technology used in the sugar industry for the purification of sugar solutions. Specifically, it is employed to remove colour from solutions caused by impurities or reactions during manufacturing, thereby enhancing the quality and appearance of sugar products.
  - The ion exchange process involves passing sugar solutions through a bed of ion-exchange resin. As the solution flows through the resin, impurities and colour-causing compounds are trapped and replaced with hydrogen or hydroxyl ions, resulting in the removal of up to 95% of colour without generating by-products.
  - Over time, the ion-exchange resin becomes saturated with trapped impurities and colour. However, the resin can be regenerated through immersion in an acid or base, allowing it to be reused multiple times. This regeneration process extends the resin's lifespan and ensures ongoing efficiency.
  - Ion exchange is employed in the sugar industry to remove colour from solutions, caused by impurities or reactions during manufacturing.
- **Cost and Energy Efficiency**

  Ion exchange systems reduce energy consumption by 10-15% by efficiently removing impurities from sugar juice.

- **Major consumers of the technology**

  Companies from the sugar refining industry, boiler feed water treatment industry, process water softening industry.

- **Relevance to the Indian industrial sectors**
  - **Refined Sugar Processing –** Ensures high-purity sugar production by removing colorants and mineral contaminants.
  - **Power & Steam Generation in Sugar Mills –** Plays a crucial role in boiler water treatment, extending equipment life.

- **Expected benefits of the technology:**

Improved ptoduct quality

Reduced costs


Efficient processing

4.4 TEMA type NEN heat exchangers

- **Category of the technology:** Process efficiency
- **Developer/Supplier:** Heat Exchange Group, UK
- **Development stage:** Commercialised
- **Website hyperlink for supplier / developer**

  https://heatexchangegroup.co.uk/news/british-sugar-sweet-partnership-with-heat-exchange-group/

- **Description of the technology:**
  - TEMA type NEN heat exchangers are a specific type of shell and tube heat exchanger designed in accordance with the standards set by the Tubular Exchanger Manufacturers Association (TEMA). The type designation "NEN" refers to a particular configuration of the heat exchanger, characterized by the design of its components and their arrangement within the exchanger.
  - In a TEMA type NEN heat exchanger, the tubes are arranged in a fixed tube sheet, and the shell houses a single pass with baffles to direct the fluid flow. The fixed end design of both the front and rear of the heat exchanger makes it relatively straightforward and cost-effective to manufacture.
  - These heat exchangers are suitable for a variety of applications, particularly in situations where the fluids being exchanged are clean and the pressures are moderate. They are commonly used in industries such as chemical processing, petrochemicals, and oil and gas.
  - It recovers heat from furnaces, incinerators, static diesel or gas engines, gas turbines and other sources of waste heat generated by systems' exhaust gases.
- **Cost and Energy Efficiency**

  TEMA NEN heat exchangers reduce energy consumption by 10-20% through efficient heat transfer in evaporation and crystallisation processes.

- **Major consumers of the technology**

  Companies from the Sugar Evaporation & Crystallisation sector.

- **Relevance to the Indian industrial sectors**
  - **Sugar Mills & Refineries –** Used in multi-effect evaporators for efficient juice concentration, reducing energy consumption.
  - **Co-generation Plants –** Enhances waste heat recovery from steam processes, improving power generation efficiency.
- **Expected benefits of the technology:**


Compact and efficienct


Robust and durable design


Versatile applications across industries


Compliance with industry Standards


Ease of Installation due to fixed design

4.5 Multiple-Effect Evaporator

- **Category of the technology:** Process Efficiency
- **Developer/Supplier:** Kapwell, UK
- **Development stage:** Pre-commercial
- **Website hyperlink for supplier / developer**

  https://kapwell.co.uk/wp-content/uploads/2023/08/Kapwell-Product-Catalogue.pdf

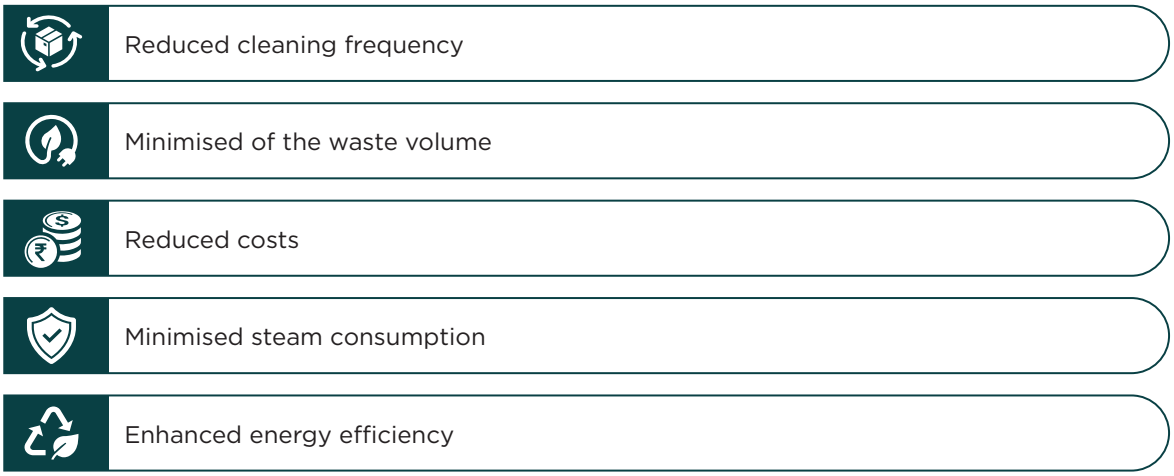
- **Description of the technology:**
  - A multi-effect evaporator is an advanced system designed to evaporate water or other liquids from a solution efficiently and cost-effectively. It utilizes multiple stages, known as effects, where each stage operates at a lower pressure than the one before it. This creates a cascading process that maximises the use of energy and minimises waste.
  - The system begins with the solution being heated in the first effect, where it undergoes evaporation. The vapor generated in this stage is then used as the heat source for the next effect. This process continues through subsequent stages, with each effect operating at a progressively lower pressure.
  - By recycling the vapor as a heat source for the subsequent stages, the system significantly reduces the overall energy required for evaporation. This energy-efficient design leads to cost savings and lesser environmental footprint.
  - Multi-effect evaporators are widely used in the sugar industry for the concentration and evaporation of sugar beet or sugar cane juice. The technology is instrumental in producing high-quality sugar syrups or molasses with precise sugar concentrations.
  - The concentrated syrups and molasses produced by multi-effect evaporators serve as the raw materials for further processing into refined sugar or other sugar-based products. This technology plays a critical role in ensuring the quality and consistency of sugar products.
- **Cost and Energy Efficiency**

  This technology reduces energy consumption by 20-30% by reusing steam in successive stages.

- **Major consumers of the technology**

  Companies from the sugar processing industry, energy recovery industry, and ethanol production industry.

- **Relevance to the Indian industrial sectors**
  - **Sugar Mills & Refineries –** Reduces energy consumption in juice concentration, improving process efficiency.
  - **Ethanol Plants –** Enhances molasses pre-treatment, making fermentation more effective.
  - **Waste Heat Recovery Systems –** Contributes to energy savings and sustainability, lowering production costs.
- **Expected benefits of the technology:**



4.6 ACUMEN AI System

- **Category of the technology:** Software / Digitalisation - Artificial Intelligence (AI) powered solution
- **Developer/Supplier:** ASH, UK
- **Development stage:** Commercialised
- **Website hyperlink for supplier / developer**

  https://www.ashvision.com/acumen-ai/
- **Description of the technology:**
  - The ACUMEN AI system is an advanced AI - powered solution specifically designed for accurately and efficiently counting yeast cells. Developed in collaboration with British Sugar, the system aims to enhance the efficiency and precision of the cell counting process, a critical aspect of yeast production.
  - The ACUMEN AI system employs a custom-built microscope and camera setup to capture high-resolution images of yeast cells. These images are then processed by an AI algorithm that analyses and identifies the cells. The system can accurately count both live and dead yeast cells, as well as differentiate between various yeast cell types.

- Since its adoption by British Sugar in 2020, the ACUMEN AI system has significantly improved the quality and consistency of the company's yeast products. The system's precision ensures that yeast cultures maintain their desired characteristics and performance levels.
- By automating the cell counting process, the ACUMEN AI system reduces the time and cost associated with manual counting methods. The efficiency of the system allows British Sugar to streamline its production processes and allocate resources more effectively.
- The system's AI algorithm can be tailored to specific applications, enabling it to adapt to different yeast strains and production requirements. This flexibility makes the ACUMEN AI system a valuable tool for various industries that rely on yeast for their operations.

- **Cost and Energy Efficiency**

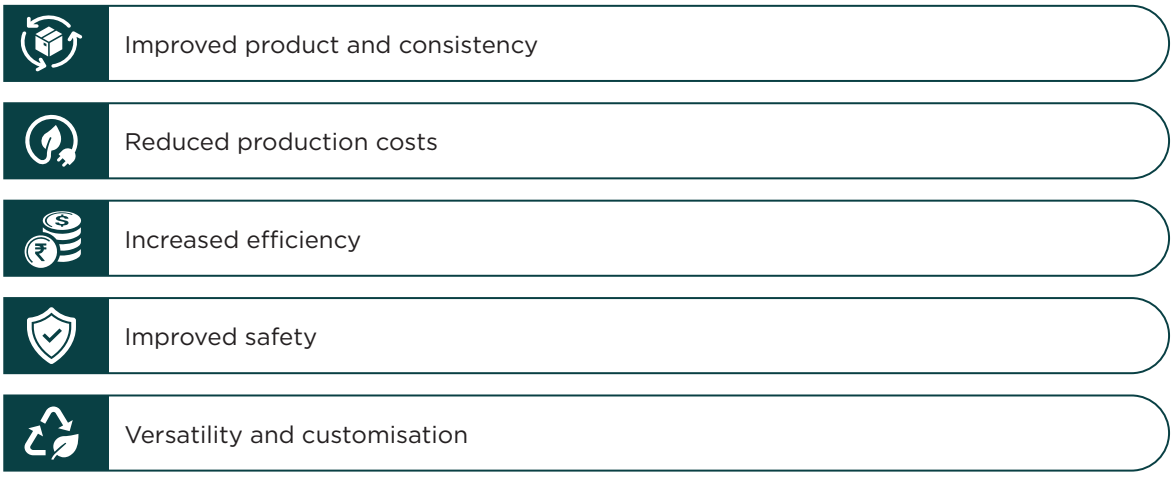
  ACUMEN AI optimises the sugar production processes by reducing energy consumption by 5-10% and improving operational efficiency.

- **Major consumers of the technology**

  Companies from the smart manufacturing industry, predictive maintenance industry, and sugar manufacturing industry (to improve sugar recovery rates).

- **Relevance to the Indian industrial sectors**
  - **Automated Sugar Mills –** Enables real-time process control, increasing production efficiency.
  - **Manufacturing Industry -** Helps in optimising energy use and reducing raw material wastage, improving profitability.

- **Expected benefits of the technology:**



4.7 ABB Ability Manufacturing Operations Management (MOM) Software

- **Category of the technology:** Software/Digitalisation
- **Developer/Supplier:** ABB, UK
- **Development stage:** Commercialised

- **Website hyperlink for supplier / developer**

  https://new.abb.com/industrial-software/operational-excellence/manufacturing-operations-management-mom

- **Description of the technology**:
  - ABB Ability Manufacturing Operations Management (MOM) software is a comprehensive data management and analysis solution designed to enhance operational efficiency and informed decision-making in manufacturing plants. The software provides manufacturers with the tools they need to streamline processes and improve performance across various aspects of production.
  - ABB Ability MOM software collects data from a wide range of sources, including control systems, Enterprise Resource Planning (ERP) systems, and sensors placed throughout the plant. This data encompasses various aspects of the manufacturing process, providing a holistic view of plant operations.
  - The software stores the collected data in a central repository, ensuring that information is easily accessible and securely maintained. This centralised storage facilitates data sharing and collaboration among different departments and teams within the organisation.
  - Advanced data analysis capabilities allow the software to identify trends, patterns, and anomalies within the collected data. This insight can reveal opportunities for process improvements, quality enhancements, and cost reductions.
  - The software generates detailed reports based on the analysed data, offering actionable insights for decision-makers. These reports can be customized to focus on specific metrics, enabling users to track performance against key performance indicators (KPIs) and identify areas for improvement.
  - By leveraging the insights gained from data analysis, ABB Ability MOM software helps manufacturers optimise production processes, resulting in increased efficiency, reduced downtime, and improved product quality.

- **Cost and Energy Efficiency**

  ABB Ability MOM reduces energy consumption by 10-15% by optimising production processes and improving resource utilisation.

- **Major consumers of the technology**

  Companies from the sugar process control industry, and supply chain & logistics industry.

- **Relevance to the Indian industrial sectors**
  - **Large-Scale Sugar Factories –** Ensures end-to-end process visibility, reducing operational inefficiencies.
  - **Automated Sugar Refineries –** Supports digitalisation of operations, minimising waste and maximising output.

- **Expected benefits of the technology:**

Optimise the sugar processing and product quality

Reduced downtime

4.8 Drones

- **Category of the technology:** Other
- **Developer/Supplier:** British Sugar, UK; Cargill, USA; Louis Dreyfus Company, Netherlands; Raizen, Brazil
- **Development stage:** Commercialised
- **Website hyperlink for supplier / developer**

  https://www.cargill.com/products

  https://www.britishsugar.co.uk/media/news/2022-01-25-british-sugar-and-virgin-media-o2-business-launch-first-multi-site-private-mobile-network

- **Description of the technology:**
  - Drones have become valuable tools in the sugar industry, providing innovative solutions for various aspects of sugar production and crop management.
  - They offer a range of applications that enhance efficiency, productivity, and sustainability in the industry including the following:
    - **Crop Health Monitoring:** Drones equipped with advanced imaging technology can capture high-resolution images of sugar fields. These images allow for early detection of pests and diseases, enabling timely intervention and targeted treatment to protect crops and minimise losses.
    - **Field Mapping:** Drones facilitate efficient field mapping by providing detailed aerial surveys of sugarcane fields. This data can be used to optimise irrigation and harvesting plans, ensuring efficient use of resources and maximising crop yield.
    - **Precision Agriculture:** Drones enable precise application of fertilisers, pesticides, and herbicides, targeting specific areas that require treatment. This precision minimises waste and reduces environmental impact while enhancing crop yield.
    - **Accurate Sowing and Planting:** Advanced drones can be programmed to sow seeds and plant sugarcane with high accuracy and efficiency. This capability ensures uniform crop distribution and optimised use of available land.
    - **Yield Estimation and Planning:** Drones can provide valuable data on crop growth and maturity, supporting accurate yield estimation and planning for harvest. This information aids in supply chain management and production scheduling.
    - **Surveillance and Security:** Drones can be used for security purposes, such as monitoring large sugarcane fields for unauthorised activity or theft.

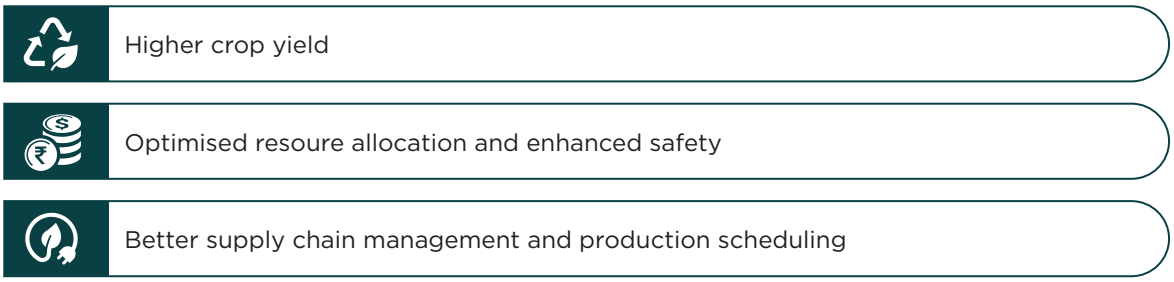
- **Research and Development:** In research settings, drones can be used to study crop genetics, growth patterns, and the effects of different agricultural practices. This data can inform breeding programs and lead to improved sugarcane varieties.

- **Major consumers of the technology**

  Companies from the sugarcane farming & plantation industry, aerial survey & mapping, and logistics & surveillance industry.

- **Relevance to the Indian industrial sectors**
  - **Precision Agriculture in Sugarcane Farming –** Helps in remote field monitoring, reducing manual labor.
  - **Sugar Mill Supply Chain Management –** Enhances tracking of sugarcane deliveries and inventory management.

- **Expected benefits of the technology:**



For enquiries regarding potential collaboration opportunities with the mentioned technology providers please contact:

Bureau of Energy Efficiency

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

ASPIRE Programme Team

In-fmaspire@kpmg.com

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

Vikas Gaba
Partner and National Lead Power & Utilities
KPMG India
vikasgaba@kpmg.com

5 TYRE MANUFACTURERS SECTOR

5.1 Soya bean-based tyre oil

- **Category of the technology: Core Process**
- **Developer/Supplier:** British Tyre Manufacturer's Association
- **Development stage:** Commercialised
- **Website hyperlink for supplier / developer**

  https://btmauk.com/

- **Description of the Technology:**
  - Soybean-based oil is an eco-friendly alternative to petroleum oil in tyre manufacturing. It offers several benefits, including:
    - **Enhanced Flexibility**: Soybean oil improves tyre flexibility at low temperatures, keeping the rubber pliable in cold weather and enhancing traction during rain and snow.
    - **Improved Compatibility**: Soybean oil blends seamlessly with rubber compounds, reducing energy consumption during manufacturing and increasing production efficiency.
    - **Enhanced Performance**: The use of soybean oil contributes to better tyre performance, including durability and responsiveness on various road conditions.
- **Process Emission Reduction Potential**

  This technology reduces carbon emissions by 15-20% compared to petroleum-based oils, as soybean cultivation absorbs CO_2 during growth.

- **Major consumers of the technology**

  Companies from the rubber compounding industry, tyre manufacturing industry, and biodegradable material development.

- **Relevance to the Indian industrial sectors**
  - **Green Tyre Manufacturing –** Reduces reliance on petroleum-derived oils, making tyres more sustainable.
  - **Performance Tyre Production –** Enhances traction and durability, particularly for high-performance and all-weather tyres.
  - **Bio-Based Lubricants & Additives –** Used in greener industrial formulations, reducing emissions.
- **Expected benefits of the technology:**

5.2 Algae Based Tyre Oil

- **Category of the technology:** Core Process
- **Developer/Supplier:** Hankook Tyre, Korea
- **Development stage:** Commercialised
- **Description of the Technology:**

  Algae tyre oil, derived from algae-based biofuels, offers a sustainable alternative to traditional petroleum-based oils in tyre manufacturing. By combining algae oil with bio-polyurethane and silica sourced from agricultural waste, this innovative blend can be mixed with rubber compounds to produce vehicle tyres.

- **Process Emission Reduction Potential**

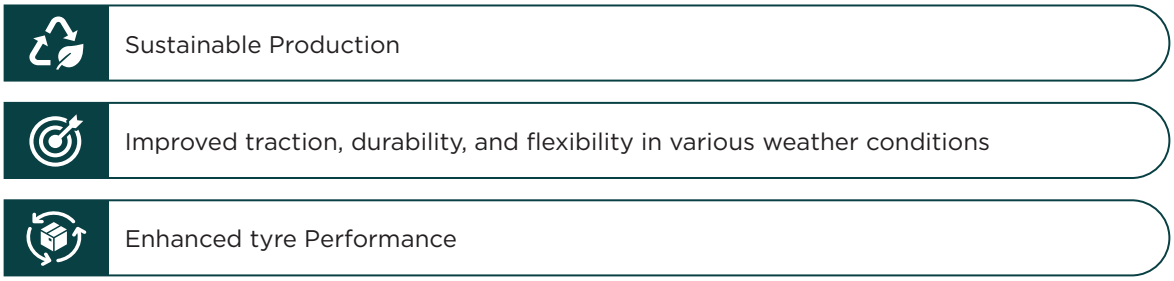
  This technology reduces lifecycle emissions by 30-40% by utilising CO_2-absorbing algae during production.

- **Major consumers of the technology**

  Companies from the rubber processing industry, biofuel & lubricants industry, and polymers & coatings manufacturing.

- **Relevance to the Indian industrial sectors**
  - **Sustainable Rubber Manufacturing –** Reduces dependence on crude oil-based additives in tyre production.
  - **Mobility Sector –** Supports low-carbon tyre production, in line with India's electric vehicle (EV) expansion.
  - **Paint & Coatings Industry –** Helps develop durable, biodegradable coatings for multiple sectors.

- **Expected benefits of the technology:**



5.3 Sustainable Tyres

- **Category of the technology:** Core Process
- **Developer/Supplier:** Hankook Tyre, Korea
- **Development stage:** Research and Development

- **Description of the Technology:**
  - Sustainable tyres are produced using renewable, recycled, or bio-based materials, such as recyclable synthetic rubber, recycled polyethylene terephthalate (PET) cord, and bio-based oils and resins.
  - These tyres often feature improved rolling resistance, resulting in better fuel efficiency and lower vehicle emissions. Designed for durability and performance, sustainable tyres tend to have a longer lifespan and may be easier to recycle at the end of their life.
  - Many sustainable tyres adhere to specific industry standards and certifications, such as the International Sustainability and Carbon Certification (ISCC), ensuring compliance with sustainable sourcing and production practices.
  - Hankook Tyres has made significant investments in the research and development of tyres made from 100% sustainable materials. They have successfully developed tyres using 55% sustainable raw materials, including ISCC PLUS-certified synthetic rubber, recycled PET cord, recycled carbon black, bio-based silica, oil, and resin.
  - Compared to conventional tyres (based on 1,000 units), Hankook's sustainable tyres reduce carbon dioxide emissions by approximately 7,000 kg CO_2eq, equivalent to the annual absorption of about 1,400 trees.

- **Process Emission Reduction Potential**

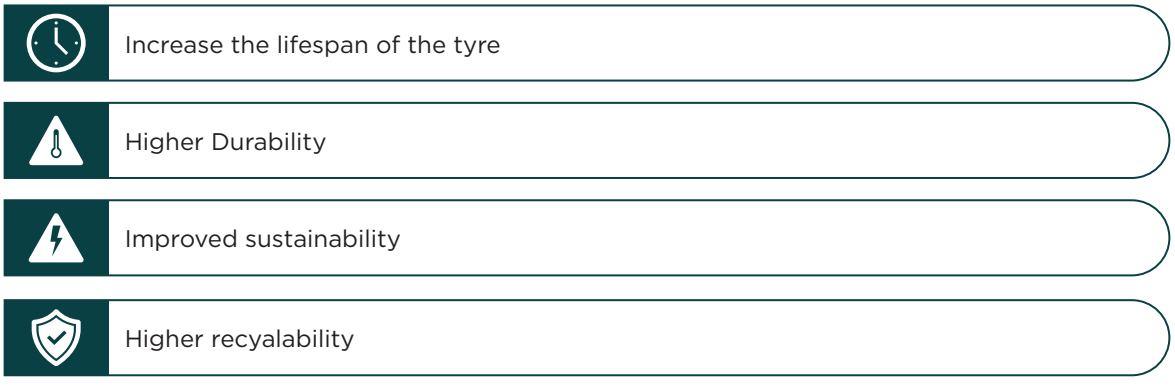
  The usage of Sustainable Tyres cuts emissions by 25-35% through reduced material extraction and waste generation.

- **Major consumers of the technology**

  Companies from the tyre manufacturing industry, and electric vehicle (EV) & fuel-efficient tyre production.

- **Relevance to the Indian industrial sectors**
  - **EV & Hybrid Vehicle Market –** Supports energy-efficient tyres, extending battery range.
  - **Fleet & Logistics Industry –** Reduces carbon footprint in commercial transport, aligning with emission norms.

- **Expected benefits of the technology:**



Enhanced energy efficiency and reduced carbon emissions

5.4 Graphene Reinforced Rubber Tyres

- **Category of the technology:** Core Process
- **Developer/Supplier:** University of Manchester, UK
- **Development stage:** Research and Development
- **Website hyperlink for supplier / developer**

  https://www.manchester.ac.uk/about/news/spacemat-graphenes-answer-to-recycling-tyre-rubber-launches-to-market/

- **Description of the Technology:**

  Graphene-reinforced rubber integrates graphene, a one-atom-thick carbon lattice known for its extraordinary physical and chemical properties, to enhance the overall performance of rubber. By incorporating graphene into the rubber compound, manufacturers can achieve a significant improvement in key properties, such as:

  - **Increased Strength and Stiffness**: Graphene reinforces the rubber, boosting its tensile strength and stiffness. This allows the rubber to better withstand stress and pressure during use, contributing to longer-lasting, more resilient tyres.
  - **Improved Electrical and Thermal Conductivity**: Graphene's exceptional electrical and thermal conductivity can be transferred to the rubber, allowing for better heat dissipation and potentially enabling new applications in tyre technology.
  - **Enhanced Wear Resistance**: The inclusion of graphene in the rubber formula increases its resistance to wear and tear, extending the lifespan of the tyres and improving overall durability.
  - **Superior Gas Barrier Resistance**: Graphene's dense carbon structure provides a formidable barrier against the permeation of gases. This property can help maintain optimal tyre pressure over longer periods and improve tyre safety and performance.

- **Cost and Energy Efficiency**

  Graphene additives improve tyre durability, reducing replacement frequency and energy consumption in manufacturing by 5-10%.

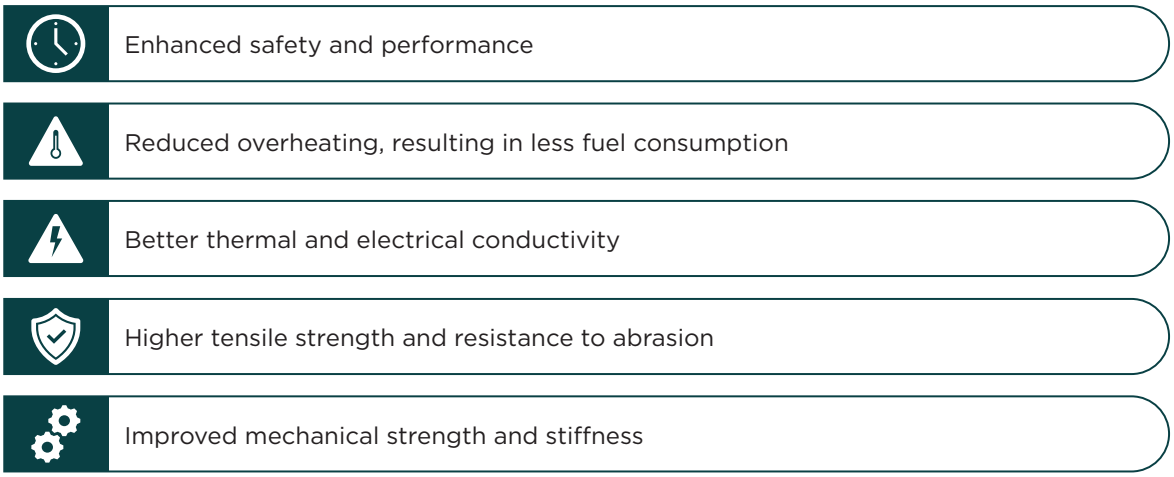
- **Process Emission Reduction Potential**

  They reduce the rolling resistance, lowering vehicle fuel consumption and CO_2 emissions by 10-15%.

- **Major consumers of the technology**

  Companies from the tyre manufacturing industry, performance & motorsport tyre industry, and aerospace & defence.

- **Relevance to the Indian industrial sectors**
  - **Automobile Industry –** Increases tyre lifespan, reducing replacement frequency.
  - **Tyre Manufacturing –** Reduces rolling resistance, leading to lower fuel consumption.
  - **Aerospace & High - Performance Applications –** Strengthens critical components for extreme conditions.
- **Expected benefits of the technology:**



5.5 Compression Moulding

- **Category of the technology:** Core Process
- **Developer/Supplier:** Harboro Rubber Ltd., UK
- **Development stage:** Commercialised
- **Website hyperlink for supplier / developer**

  https://www.harboro.co.uk/
- **Description of the Technology:**
  - Compression moulding is a rubber manufacturing process that involves placing a specified amount of raw rubber material into a heated mould cavity. This method offers several distinct advantages and is well-suited for producing rubber parts in low to medium quantities.
  - Implementation Process is as follows:
    - The process begins with placing the raw rubber material into the mould cavity, which is then closed under controlled heat and pressure. The application of heat causes the rubber to soften and take the shape of the mould.
    - The mould cavity is opened and closed multiple times during the process to expel trapped air. This is important to ensure the final product is free of defects such as air bubbles or voids. Over time, the rubber heats up by conduction, initiating the curing process that transforms the material into a stable, durable form.

- Once the rubber has fully cured, the mould cavity is opened, and the finished part is removed. This part may undergo further processing or quality checks depending on the specific application.
- Compression moulding is relatively more cost-effective than other moulding methods such as injection moulding, making it a preferred choice for small to medium production runs. The process's simplicity and efficiency can lead to reduced setup and operational costs.
- The mould cavity is opened and closed multiple times to remove air from it, and over time, the rubber gains heat by conduction and cures.
- Eventually, the mould cavity is opened, and the part is taken out.
- This process is suitable for manufacturing rubber parts in low to medium quantities and is relatively cheaper than other types of moulding.

- **Cost and Energy Efficiency**

  This technology reduces energy use by 10-15% compared to injection moulding, with lower machinery costs.

- **Process Emission Reduction Potential**

  They help minimise material waste and energy consumption, cutting emissions by 10-20%.

- **Major consumers of the technology**

  Companies from the tyre manufacturing industry, rubber component production, and medical device industry.

- **Relevance to the Indian industrial sectors**
  - **Tyre Manufacturing –** Used in manufacturing consistent, high-quality tyres at scale.
  - **Automotive OEM Tyre Suppliers –** Ensures precise tread patterns for optimised performance.
  - **Healthcare & Biomedicine –** Helps manufacture precision-moulded medical components.

- **Expected benefits of the technology:**

Less capital intensive as special equipments are not required

Ideal for producing rubber tyres in low to medium quantities

5.6 Heat Control Technology (HCT)

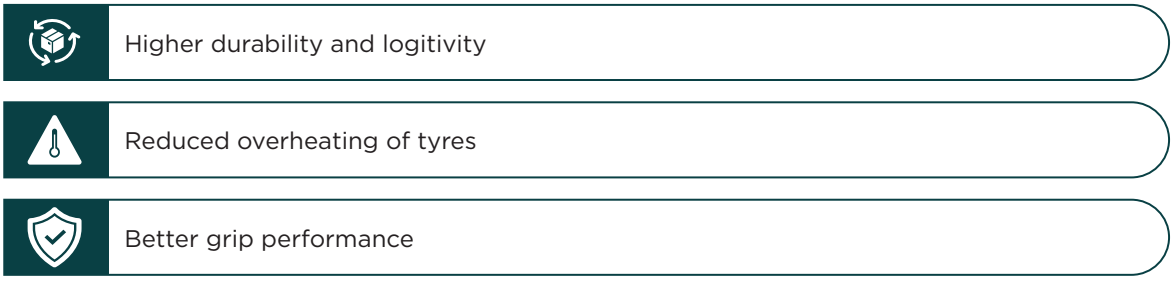
- **Category of the technology:** Core Process
- **Developer/Supplier:** Dunlop, UK
- **Development stage:** Commercialised
- **Website hyperlink for supplier / developer**

  https://www.dunlop.eu/en_gb/motorcycle/safety-and-technology/technology-and-innovation.html

- **Description of the technology:**
  - Heat Control Technology is an advanced tyre engineering approach designed to regulate heat build-up, optimising tyre performance for a variety of driving conditions. The technology comprises two distinct rubber compounds: a cap (outer) compound and a base (lower) compound, working together to create a thermal gradient within the tyre's construction.
  - **Cap Compound**: The outer cap compound is engineered to heat up quickly and efficiently during tyre operation. It then transfers the generated heat to the base compound, preventing excessive heat build-up in the outer layer. This process helps maintain optimal tyre temperatures, which is crucial for providing excellent grip and traction on different road surfaces.
  - **Base Compound**: The lower base compound contains carbon black, which aids in warming the compound efficiently. This layer acts as a heat sink, absorbing and dissipating heat transferred from the cap compound. The base layer not only helps regulate the tyre's internal temperature but also contributes to the tyre's overall durability and longevity.
  - The outer cap compound is designed to resist wear and tear, ensuring the tyre retains its performance characteristics over time. This resistance to abrasion extends the tyre's lifespan and maintains its ability to grip various surfaces.
- **Process Emission Reduction Potential**

  The use of this technology lowers energy-related emissions by 15-20% in tyre curing.
- **Major consumers of the technology**

  Companies from the tyre manufacturing industry, automobile industry, and aerospace & defence.
- **Relevance to the Indian industrial sectors**
  - **Tyre Manufacturing Industry –** Ensures cooler tyres for heavy-duty trucking applications.
  - **Automobile Insdustry–** Lowers heat-induced energy loss, reducing fuel consumption.
  - **Heavy Machinery & Industrial Equipment –** Enhances thermal performance in rotating equipment.
- **Expected benefits of the technology:**



5.7 Moldflow® Simulation Software

- **Category of the technology:** Software/ Digitalisation
- **Developer/Supplier:** Autodesk, UK
- **Development stage:** Commercialised

- **Website hyperlink for supplier / developer**

  https://www.autodesk.com/uk/products/moldflow/overview?term=1-YEAR&tab=subscription

- **Description of the Technology:**

  - Moldflow® simulation software is a Computer-Aided Engineering (CAE) tool that models the injection moulding process of rubber materials. It provides insights into the flow of molten material into moulds, the cooling process of moulded parts, and the curing of thermoset materials. This information supports the optimisation of mould and part designs and helps address any issues encountered during the moulding process.
  - Utilisation of Moldflow® Simulation Software in the Rubber Industry:
    - **Define Mould and Part Geometry**: Create a 3D CAD model of the mould and part, ensuring compatibility with Moldflow® simulation software.
    - **Select Material Properties**: Choose the properties of the rubber material, such as viscosity, thermal conductivity, and curing kinetics, for the moulded part.
    - **Set Process Parameters**: Specify essential process parameters, including injection pressure, injection speed, cooling time, and curing time.
    - **Run the Simulation**: Once the mould, part, material properties, and process parameters have been established, execute the simulation to calculate the flow of molten rubber into the mould, the cooling of the moulded part, and the curing of the thermoset material.
    - **Analyse the Results**: Examine the simulation results to improve mould and part designs and troubleshoot any moulding issues. For example, the simulation can predict areas of high stress and identify potential part warping.

- **Process Emission Reduction Potential**

  This technology minimises material waste and energy use, cutting emissions by 10-15%.

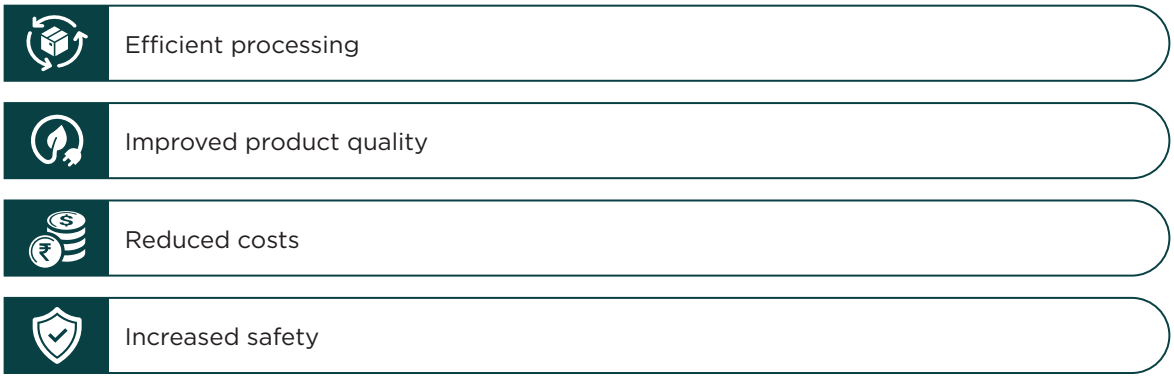
- **Major consumers of the technology**

  Companies from the tyre manufacturers industry, and plastics & injection molding industry.

- **Relevance to the Indian industrial sectors**

  - **Automotive & Aerospace Manufacturing –** Reduces defects and optimises moulding for lightweight parts.
  - **Medical Device Manufacturing –** Supports high-precision plastic and rubber components.

- **Expected benefits of the technology:w**



5.8 Thermal Energy Management System (TEMS) technology

- **Category of the technology:** Others
- **Developer/Supplier:** Dellner Polymer Solutions, UK
- **Development stage:** Commercialised
- **Website hyperlink for supplier / developer**

  https://www.dellnerpolymer.com/technologies/thermal-energy-management-systems/

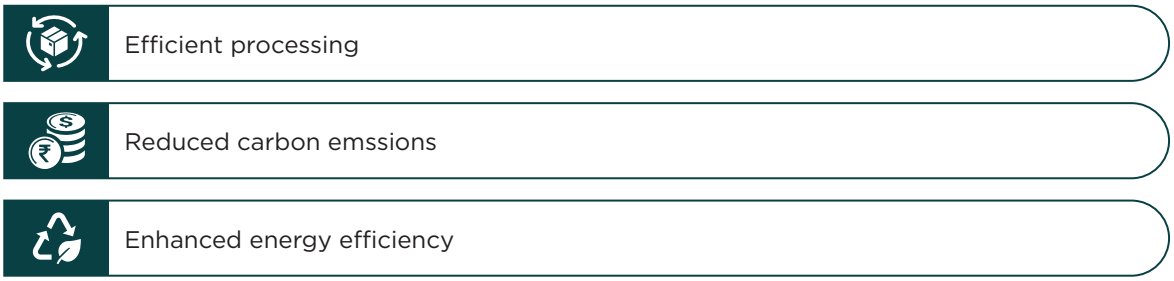
- **Description of the technology:**
  - Thermal Energy Management System (TEMS) is an advanced technology that optimises energy efficiency in industrial processes by leveraging heat recovery and exchange.
  - In the rubber industry, TEMS enables the recovery of heat from the vulcanisation process, redirecting it to other parts of the production line such as mixers and extruders. This results in substantial energy savings and a reduction in emissions.
  - The process includes the following steps:
    - Heat from the vulcanisation process is captured using a heat exchanger.
    - The heat exchanger transfers the captured heat to a heat recovery unit.
    - The heat recovery unit stores the heat in a thermal energy storage system.
    - The thermal energy storage system releases the stored heat as needed to other parts of the production line.
- **Process Emission Reduction Potential**

  The use of this technology has the potential to cut CO_2 emissions by 20-25% through energy recycling.

- **Major consumers of the technology**

  Companies from the tyre manufacturing industry, and renewable energy & battery storage industry.

- **Relevance to the Indian industrial sectors**
  - **Manufacturing & Process Optimisation –** Reduces heat loss and energy waste in industrial production.
  - **Power & Energy Efficiency Initiatives –** Supports sustainable power management strategies.
- **Expected benefits of the technology:**



5.9 Carbon nanotubes

- **Category of the technology:** Others
- **Developer/Supplier:** Thomas Swan & Co. Ltd, UK; Molecular Rebar Design, USA
- **Development stage:** Research & Development (R&D)
- **Website hyperlink for supplier / developer**

  https://thomas-swan.co.uk/swan-chemical-inc-announced-as-north-american-distribution-partner-for-molecular-rebar-in-oil-mro-products-reinforcing-carbon-nanotube-additives-for-rubber/

- **Description of the Technology:**
  - Carbon nanotubes (CNTs) are a type of nanomaterial that enhances the performance and longevity of tyres by improving their tensile strength, tear resistance, and durability. By incorporating CNTs, tyres benefit from the following improvements:
    - **Rolling Resistance**: CNTs reduce rolling resistance, leading to improved fuel efficiency and reduced emissions.
    - **Wet Grip**: CNTs enhance wet grip, minimising the risk of hydroplaning and increasing safety on wet surfaces.
    - **Abrasion Resistance**: CNTs improve abrasion resistance, extending the tyre's lifespan and reducing wear.
    - **Heat Dissipation**: CNTs facilitate heat dissipation, maintaining optimal tyre performance even under high stress conditions.
  - Implementation Process is as follows:
    - **Selection:** The manufacturer selects a specific type of CNT tailored to the desired application and performance requirements.
    - **Incorporation:** The CNTs are blended with a rubber compound and integrated into the tyre's structure during the moulding process.
    - **Curing and Testing:** The tyre undergoes a curing process and rigorous testing to ensure it meets industry performance standards and safety regulations.
- **Cost and Energy Efficiency**
  - This technology enhances tyre strength and reduces rolling resistance, improving fuel efficiency by 5-10%.
  - The Initial cost for this technology is high but it can be offset by its longevity.
- **Process Emission Reduction Potential**

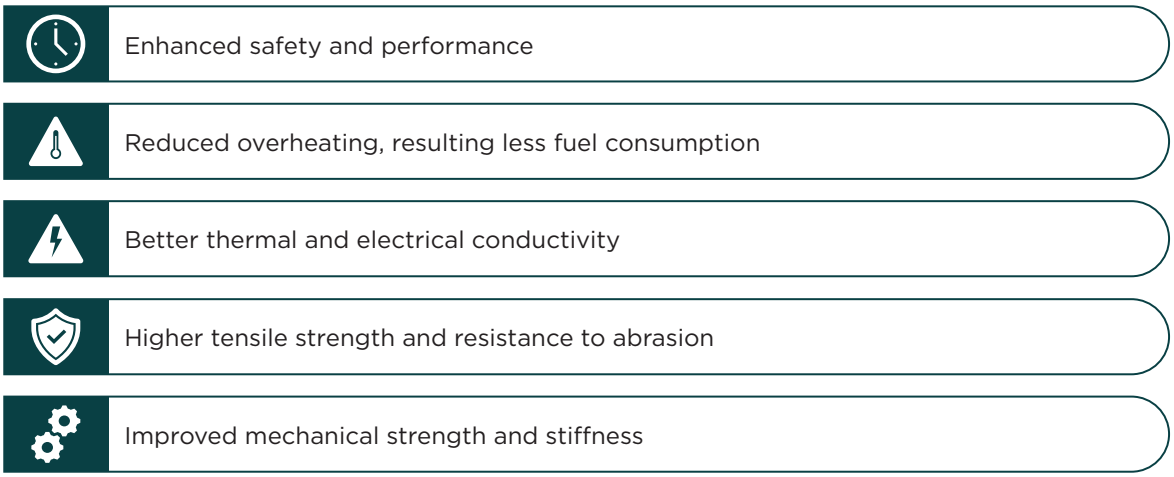
  The use of this technology reduces vehicular emissions by 10-15% due to lower rolling resistance.

- **Major consumers of the technology**

  Companies from the tyre & rubber industry, electronics & conductive coatings, and biomedical & nanotechnology applications.

- **Relevance to the Indian industrial sectors**
  - **Automotive & EV Market –** Improves wear resistance and efficiency in vehicle tyres.
  - **Healthcare & Biotechnology –** Supports nanomedicine and advanced biomaterials.

- **Expected benefits of the technology:**



For enquiries regarding potential collaboration opportunities with the mentioned technology providers please contact:

Bureau of Energy Efficiency

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

ASPIRE Programme Team

In-fmaspire@kpmg.com

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

Vikas Gaba
Partner and National Lead Power & Utilities
KPMG India
vikasgaba@kpmg.com

6 CROSS SECTORAL

6.1 Air-to-Water Heat Pump

- **Category of the technology:** Core Process
- **Developer/Supplier:** Bosch Thermotechnology Ltd, UK
- **Development stage:** Commercialised
- **Website hyperlink for supplier / developer**

  https://www.bosch-industrial.com/gb/en/ocs/commercial-industrial/air-to-water-heat-pumps-18789719-c/

- **Description of the technology:**
  - The Air-to-Water Heat Pump is an efficient heating solution designed for commercial and industrial applications.
  - Unlike traditional heating systems, it uses electricity to transfer heat from the surrounding atmosphere to water, achieving a Seasonal Coefficient of Performance (SCOP) of up to 4.7.
  - The pump employs environmentally friendly R290 refrigerant and features an inverter-driven compressor, integrated heat recovery systems, and advanced thermally insulating materials to enhance energy efficiency.
- **Cost and Energy Efficiency**

  Air-to-water heat pumps reduce energy consumption by 30-50% compared to traditional heating systems

- **Process Emission Reduction Potential**

  They have the potential to reduce CO_2 emissions by 40-60% by utilising ambient air for heating instead of fossil fuels.

- **Major consumers of the technology**

  Companies from the food & beverage processing sector, industrial heating & cooling, and chemical processing.

- **Relevance to the Indian industrial sectors**
  - **Textile & Leather Processing –** Reduces energy consumption in dyeing and drying processes.
  - **Hospitality & Commercial Buildings –** Supports sustainable heating solutions for hotels and offices.
  - **Pharmaceutical & Biotech Industries –** Helps maintain process temperatures in drug manufacturing.
- **Expected Benefits of Technology:**


More energy efficient compared to electric heaters


Environment friendly


Remote control capabilities for convinient monitoring and operations

Reduced operational costs

6.2 Steam Boiler

- **Category of the technology:** Core Process
- **Developer/Supplier:** CFB Boilers Ltd, UK
- **Development stage:** Commercialised
- **Website hyperlink for supplier / developer**

  https://steamboilers.co.uk/steam-boilers/

- **Description of the technology:**
  - The 4VT steam boiler, developed by CFB Boilers Ltd, is a highly efficient and versatile steam generation system designed for various industrial applications.
  - The boiler is known for its precise and controlled temperature delivery, making it ideal for a wide range of steam applications.
  - It utilises an innovative four-pass heat exchange system, which enhances energy transfer efficiency. This design allows for more complete combustion, resulting in reduced fuel consumption and lower operational costs.
  - The boiler has a 30% larger steam chamber which provides a stable steam supply, accommodating fluctuating demands and ensuring consistent performance.
  - It operates at an efficiency of 92-94%, significantly higher than many traditional boilers.
  - The boiler features built-in heat recovery systems that capture and reuse waste heat from the exhaust gases.
  - The 4VT steam boiler uses high-quality insulating materials that minimises heat loss during operation, further enhancing the boiler's energy efficiency.
- **Cost and Energy Efficiency**

  Modern steam boilers achieve 85-90% thermal efficiency, reducing fuel costs by 10-20% compared to older models.
- **Process Emission Reduction Potential**

  Advanced boilers reduce emissions by 20-30% through improved combustion efficiency and reduced fuel consumption
- **Major consumers of the technology**

  Companies from the food processing & beverages industry, power generation, and chemical & petrochemical processing.
- **Relevance to the Indian industrial sectors**
  - **Sugar & Ethanol Production –** Essential for juice extraction and evaporation.
  - **Pulp & Paper Industry –** Supplies steam for drying and bleaching.
  - **Oil Refineries & Petrochemicals –** Used in hydrocracking and distillation processes.

- **Expected benefits of the technology:**

Enhanced boiler efficiency

Reduced fuel consumption and lower operational costs

Suitable for a variety of industrial applications

6.3 Carbon sequestration

- **Category of the technology:** Low Carbon Technology
- **Developer/Supplier:** CO_2CO Ltd, UK
- **Development stage:** Pre-Commercial
- **Website hyperlink for supplier / developer**

  https://co$_2$gas.co.uk/

- **Description of the technology:**

  CO_2CO is an early-stage startup focused on addressing climate change by using a technology-enabled, nature-based solution. They remove atmospheric carbon dioxide using microalgae, convert the biomass into biochar, and sequester this carbon in the biosphere for long-term storage. This biochar is used in agriculture to enhance soil quality, reducing the need for artificial fertilisers, pesticides, and irrigation.

- **Cost and Energy Efficiency**

  Carbon sequestration costs range from $50 to $100 per ton of CO_2

- **Process Emission Reduction Potential**

  This technology captures 90-95% of CO_2 emissions from industrial processes, significantly reducing carbon footprints.

- **Major consumers of the technology**

  Companies from the cement & concrete manufacturing sector, forestry & land management, and agricultural sector.

- **Relevance to the Indian industrial sectors**
  - **Steel & Cement Industries –** Reduces carbon emissions through CO_2 mineralisation.
  - **Agriculture & Land Restoration –** Improves soil carbon retention for climate resilience.
  - **Carbon Credit & Trading Markets –** Enables carbon offset programs for industries.

- **Expected Benefits of Technology:**

Reduced carbon footprint

6.4 Carbon Capture

- **Category of the technology:** Low Carbon Technology
- **Developer/Supplier:** Carbon Clean, UK
- **Development stage:** Commercialised
- **Website hyperlink for supplier / developer**

  https://www.carbonclean.com/technology

- **Description of the technology:**

  Carbon Clean offers modular and semi-modular carbon capture technology. Modular solutions enable industrial facilities of all sizes to decarbonise easily and affordably. Carbon Clean's modular systems are prefabricated off-site, containerised, and delivered to the site ready to install.

  The CycloneCC unit is Carbon Clean's combination of two proven technologies: advanced, proprietary amine-promoted buffer salt solvent (APBS-CDRMax®) and a process technology – rotating packed beds (RPBs). When utilised together they ensure CycloneCC is far more efficient than conventional carbon capture methods, reducing costs while matching performance.

- **Cost and Energy Efficiency**

  Carbon capture systems reduce energy efficiency by 10-15%.

- **Process Emission Reduction Potential**

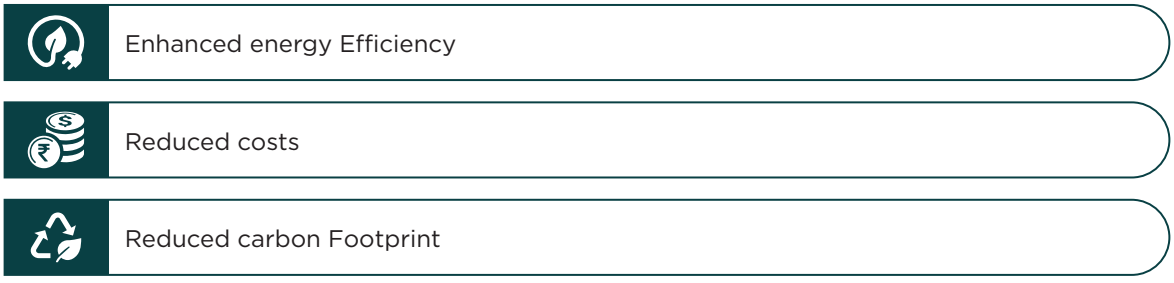
  They capture 85-90% of CO_2 emissions, reducing overall plant emissions by 30-50%.

- **Major consumers of the technology**

  Companies from the petrochemical & fertiliser industry, thermal power plants, and industrial waste management.

- **Relevance to the Indian industrial sectors**
  - **Coal-Based Power Generation –** Helps meet emission reduction targets.
  - **Cement & Steel Manufacturing –** Captures process emissions for reuse.
  - **Green Hydrogen Production –** Supports low-carbon hydrogen initiatives.

- **Expected Benefits of Technology:**



6.5 4IR IoT

- **Category of the technology:** Digitalisation
- **Developer/Supplier:** Ascalia, Croatia
- **Development stage:** Commercialised
- **Website hyperlink for supplier / developer**

  https://ascalia.io/

- **Description of the technology:**

  Ascalia have developed an AI-powered quality assurance platform that utilises tailored AI algorithms to detect defects and issues early in the production process, reducing scrap and downtime. The software monitors production in real-time and produces live alerts and optimisation tips.

- **Process Emission Reduction Potential**

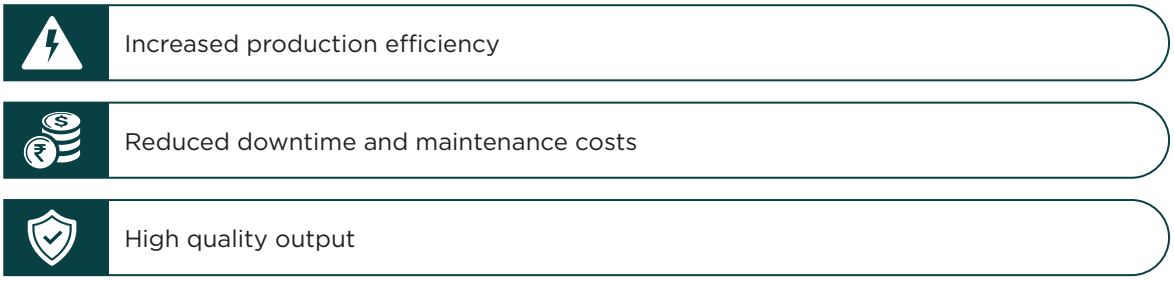
  This technology optimises energy use, reducing emissions by 15-20% in industrial processes.

- **Major consumers of the technology**

  Companies from manufacturing, logistics, and energy sectors.

- **Relevance to the Indian industrial sectors**
  - **Automotive & Heavy Machinery –** Optimises production efficiency in smart factories.
  - **Power & Renewable Energy –** Enables smart grid and real-time energy monitoring.
  - **FMCG & Consumer Goods –** Enhances supply chain visibility and operational efficiency.

- **Expected Benefits of Technology:**



6.6 AI Based Industrial Intelligence Platform

- **Category of the technology:** Digitalisation
- **Developer/Supplier:** Smartia, UK
- **Development stage:** Commercialised

- **Website hyperlink for supplier / developer**

  https://www.smartia.tech/

- **Description of the technology:**

  Smartia's industrial intelligence platform - MAIO, combines edge computing, big data technology and AI-driven applications to provide a comprehensive digital solution for improving energy efficiency in manufacturing and engineering industries. Their devices and software provide a plug-and-play approach to digitising assets and supports industrial protocols. The interface provides data visualisation, allowing users to contextualise data across multiple sources. MAIO comes with an integrated Machine Learning (ML) infrastructure that makes it easy to deploy and operationalise AI algorithms.

- **Process Emission Reduction Potential**

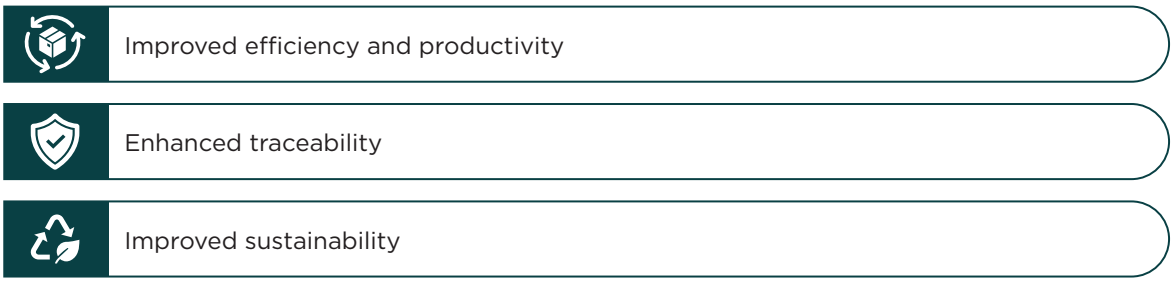
  This technology reduces emissions by 20-25% through improved efficiency and waste reduction.

- **Major consumers of the technology**

  Companies from manufacturing, energy, and logistics sectors.

- **Relevance to the Indian industrial sectors**
  - **Textile & Apparel Industry –** Reduces wastage and improves production efficiency.
  - **Steel & Heavy Engineering –** Detects equipment failure in advance.
  - **Smart Grid & Energy Management –** Helps balance demand and supply in power distribution.

- **Expected Benefits of Technology:**



6.7 IOT based Energy Management Solution

- **Category of the technology:** Digitalisation
- **Developer/Supplier:** Centrica PLC, UK
- **Development stage:** Commercialised
- **Website hyperlink for supplier / developer**

  https://go.centricabusinesssolutions.com/l/343211/2024-02-09/8h7kbc?download=brochure

- **Description of the technology:**

  Centrica provides end-to-end energy management solution. PowerRadar is a powerfully simple energy management platform that gives organisations the flexibility to control and manage

all their energy data using a single, holistic view of their energy footprint. It provides detailed and up-to-date visibility of energy performance – helping clients to use precise and reliable data to confidently turn energy into a competitive asset. It also provides real-time device-level monitoring of energy data.

- **Process Emission Reduction Potential**

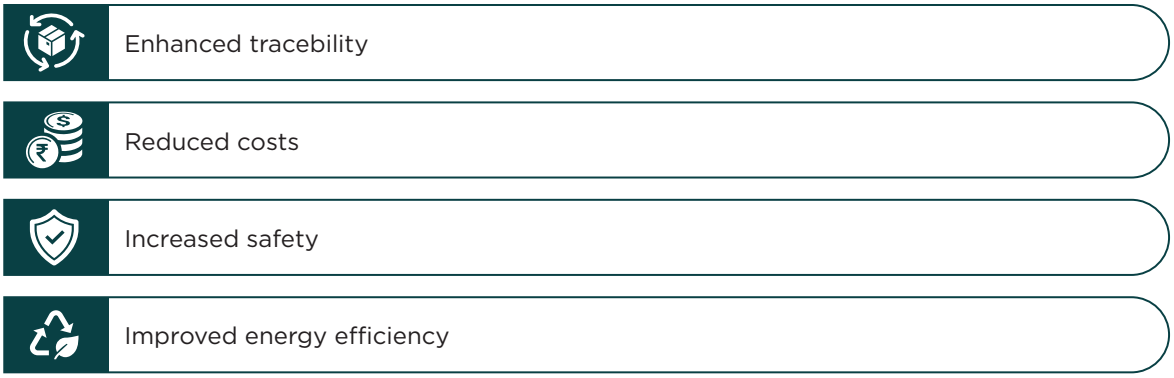
  This technology lowers emissions by 20-30% through efficient energy use and reduced waste.

- **Major consumers of the technology**

  Companies from the manufacturing & process industries, industrial energy monitoring, and commercial buildings & data centers.

- **Relevance to the Indian industrial sectors**
  - **Textile & Paper Mills –** Lowers energy use in steam and drying processes.
  - **Food Processing Plants –** Optimises refrigeration and heating operations.
  - **Chemical & Pharma Industry –** Ensures efficient energy consumption in batch processes.

- **Expected Benefits of Technology:**



6.8 Centrifugal and Axial Flow Fans

- **Category of the technology:** Others
- **Developer/Supplier:** Flakt Group, UK
- **Development stage:** Commercialised
- **Website hyperlink for supplier / developer**
  - https://www.flaktgroup.com/in/products/air-movement/ventilation-fans/axial-fans/?&scmd=1
- **Description of the Technology:**
  - The technology involves the use of fans with both centrifugal and axial flow designs, which can extract up to twice the pressure compared to conventional fans. This advanced system utilises contra-rotating impellers, where two fans rotate in opposite directions within the same housing.

- The contra-rotating impellers significantly enhance the fan's ability to generate pressure. This dual fan setup can produce 2.7 times more pressure compared to a single fan, resulting in improved performance and efficiency.
- By utilising two fans that rotate in opposite directions, the technology optimises airflow and reduces energy consumption. This leads to higher overall efficiency, making the system more effective in a variety of applications.
- The increased pressure and efficiency provided by the technology make it suitable for a range of uses, such as ventilation systems, industrial processes, and HVAC (heating, ventilation, and air conditioning) applications.

- **Cost and Energy Efficiency**

  High-efficiency fans reduce energy consumption by 10-15% compared to conventional models.

- **Process Emission Reduction Potential**

  They reduces emissions by 10-20% through optimised airflow and energy use.

- **Major consumers of the technology**

  Used in HVAC systems, power plants, and industrial ventilation.

- **Relevance to the Indian industrial sectors**
  - **Cement & Steel Industry –** Enhances furnace air supply and cooling efficiency.
  - **Thermal & Renewable Energy –** Used in boiler operations and wind tunnel testing.
  - **Chemical & Petrochemical Plants –** Provides ventilation for hazardous environments.

- **Benefits of the Technology:**

6.9 Resistant Coatings for Centrifugal Pumps

- **Category of the technology:** Others
- **Developer/Supplier:** Apex Pumps, UK
- **Development stage:** Commercialised
- **Website hyperlink for supplier / developer**

  https://www.apexpumps.com/pumps/coating-pumps/

- **Description of the technology:**
  - Apex pump coatings provide a protective layer to the castings of pumps, safeguarding them from erosion and corrosion.

- These coatings offer a range of benefits that extend the lifespan and enhance the performance of pumps in various applications.
- Apex pump coatings form a barrier against corrosive substances such as acids, alkalis, and other chemicals that may be present in the pumped fluids or in the environment. This protection prevents the degradation of pump materials, particularly in harsh or aggressive conditions.
- The coatings also shield pump castings from erosion caused by abrasive particles in the fluid being pumped. This erosion resistance helps maintain the structural integrity and efficiency of the pump.
- By preventing erosion and corrosion, Apex pump coatings increase the overall durability and longevity of pumps. This reduces the need for frequent maintenance and replacement, resulting in cost savings for operators.
- The coatings ensure that pumps operate smoothly and efficiently by minimising wear and tear on internal components. This enhances the overall performance and reliability of the pump.

- **Cost and Energy Efficiency**

  This technology improves energy efficiency by 5-10%.

- **Process Emission Reduction Potential**

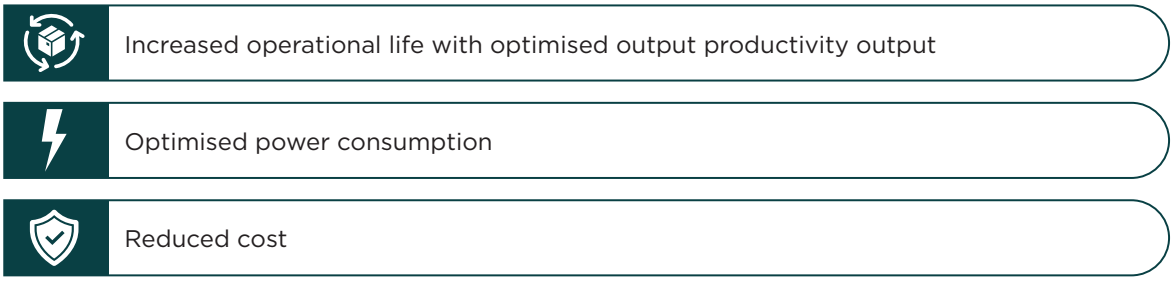
  They reduce emissions by 10-15% through improved pump efficiency and reduced downtime.

- **Major consumers of the technology**

  Companies from the water treatment, chemical, and oil & gas industries.

- **Relevance to the Indian industrial sectors**
  - **Oil & Gas Pipelines –** Extends lifespan of pumping stations.
  - **Power Generation & Cooling Systems –** Reduces maintenance in cooling water pumps.
  - **Agriculture & Irrigation** – Improves pump reliability in harsh water conditions.

- **Benefits of the Technology:**



6.10 Modular Drying technology

- **Category of the technology:** Others
- **Developer/Supplier:** Coomtech Clean Technologies, UK
- **Development stage:** Commercialised
- **Website hyperlink for supplier / developer**

  https://coomtech.com/

- **Description of the technology:**
  - Coomtech has developed an innovative modular drying technology known as the 'Kinetic Drying System'.
  - This system uses high-velocity, low-pressure air to remove moisture from bulk raw materials without relying on high temperatures, which are typical in traditional thermal drying processes.
  - By leveraging aerodynamic turbulence, the technology efficiently shears moisture from the surface of particles, significantly reducing energy consumption and CO_2 emissions significantly compared to conventional methods.
- **Cost and Energy Efficiency**

  Modular dryers reduce energy consumption by 20-30% through precise control and scalability.

- **Process Emission Reduction Potential**

  This technology lowers emissions by 15-20% through optimised energy use and reduced waste.

- **Major consumers of the technology**

  Companies from the food processing & agro-industries, pharmaceutical industry, and paper & textile manufacturing.

- **Relevance to the Indian industrial sectors**
  - **Biomass & Renewable Energy –** Improves efficiency in biofuel pellet production.
  - **Leather & Textile Finishing –** Enhances moisture control in production lines.
- **Expected Benefits of Technology:**

Increased pressure generation

Enhanced energy efficiency

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Bureau of Energy Efficiency

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

ASPIRE Programme Team

In-fmaspire@kpmg.com

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

Vikas Gaba
Partner and National Lead Power & Utilities
KPMG India
vikasgaba@kpmg.com

For more information please contact:

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

ASPIRE Programme Team
In-fmaspire@kpmg.com