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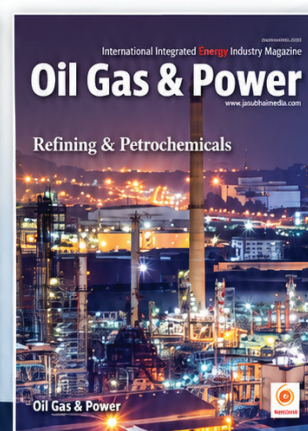
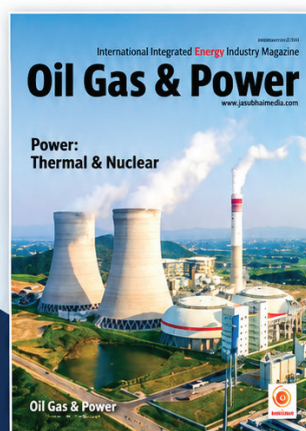
AD INDEX

Aeron Composite Limited	3
Sealmatic India Ltd	2
Suraj Limited	5

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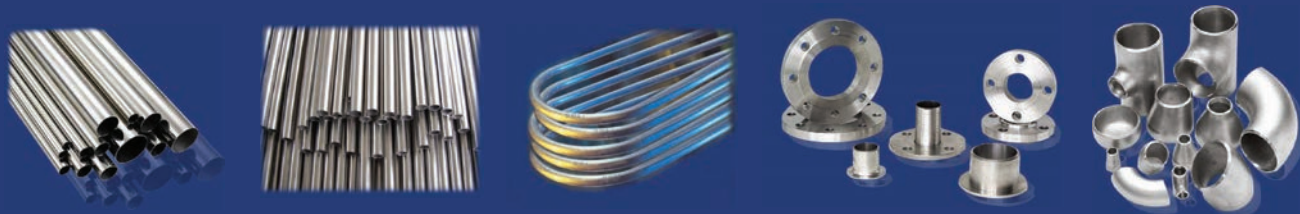
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CONTENTS

GUEST COLUMN

Thorium Is a Chemistry Problem 18



Prabhat Ranjan
CEO and Co-founder
ASPL Fusion

When Pre-treatment Becomes a Performance Advantage - A Prasinos Tech Innovations Perspective 21



Dr. Aditi Mullick
Managing Director
Prasinos Tech Innovations

Powering India's Energy Transition: The Evolving Role of Nuclear and Thermal Energy 24



S Narayana Prasad
Chief Executive Officer
Triveni Turbines

Recent Trends in Steel Pipes Used for Oil & Gas Supply – API Grades 26



Rajiv Thakur
President – Corporate Affairs
Fortran Steel Pvt Ltd

BUSINESS TALK

Kosol Energie Consolidating as a Trusted, Clean Energy Solutions Provider! 31



Kalpesh Kalthia
Chairman and Managing Director
Kosol Energie Pvt. Ltd

NEWS

07

PROJECT UPDATES

11

FEATURE

Accelerated Engineering Project Execution Strategies & Role of Process Engineering 35



Pratik G. Bhagat
Process Engineer



Sukumar Nath Roy
General Manager - Process
NPCC Engineering Pvt. Ltd.

From Port to Plant: Managing Complex Project Cargo for India's Chemical Industry 39



Santosh Chauhan
Head – Project Logistics &
EPC Solutions
Triton Logistics & Maritime

Membrane Dehumidification & Heat Transfer: A Fresh Lens on HVAC Moisture Control 42



Ajay Sekar Chandrasekaran
Thermal Engineer
NVIDIA

NEWS FEATURE

Unusual wave-like heat transport in crystalline solid signals breakthrough converting waste heat in industries 16

IMPACT FEATURE



Suraj Limited: Dedicated towards Technical Excellence & Quality Products 46



48

From Hydrogen to Data Centers: The Evolving Role of Expanded PTFE Sealing Technology

ONGC strikes gas in Mahanadi deepwater under Samudra Manthan



New Delhi: Oil and Natural Gas Corporation Limited (ONGC) has struck gas at deepwater well MN-DW18-1-H-D in the Mahanadi Offshore Basin, off the Odisha coast, under the Samudra Manthan initiative. The well drilled to a target depth (TD) of 1,623 metres recorded the gas strike at 1,441–1,452 metre interval.

The well is located approximately 43 km off Konark and is the first well in the Mahanadi Basin under the campaign. Its relative proximity to the coast offers potential for early monetization, subject to further appraisal, and commercial evaluation.

The well was spudded on 25 July 2026 by Hon'ble Minister of Petroleum & Natural Gas Shri Hardeep Singh Puri. On 27 August 2026, ONGC Chairman & CEO Mr. Arun Kumar Singh; Director (Technology & Field Services) Mr. Vikram Saxena, and Director (Exploration) Mr. O. P. Sinha visited drillship Platinum Explorer and interacted with the team engaged in the drilling campaign.

The well is flowing gas with encouraging flow and reservoir pressure for last three days. The discovery strengthens ONGC's deepwater exploration programme and India's efforts to expand its indigenous hydrocarbon resource base. This find, along with other discoveries in the area, can be a candidate for development through shared facilities enabled by the PNG Rules, 2025, bringing deepwater resources onstream.

Shripad Naik holds bilateral meeting with European Parliament's Committee on ITRE delegation



New Delhi: Mr. Shripad Naik, the Minister of State for Power and New and Renewable Energy, held a bilateral meeting with a delegation of the European Parliament's Committee on Industry, Research and Energy (ITRE), in New Delhi. The meeting was held to review and further strengthen the ongoing cooperation between India and the European Union in the power sector.

The discussions covered a wide range of areas, including energy security, power sector transformation, low-carbon development, nuclear energy, carbon markets and development of new technologies. Both sides exchanged views on ongoing initiatives and explored avenues to deepen collaboration, building on the strong momentum in India-EU relations, including the significant progress achieved in the India-EU Free Trade Agreement.

Mr. Shripad Naik highlighted India's rapidly transforming power sector and the country's efforts to build a resilient, reliable and future-ready energy system. He noted India's progress in expanding non-fossil fuel capacity, including achieving the NDC commitments in this regard much ahead of the target, strengthening transmission and distribution infrastructure, deploying energy storage and smart-grid solutions, and advancing nuclear energy, energy efficiency and green hydrogen.

Both sides discussed opportunities for enhanced cooperation in emerging areas, including long-duration energy storage, digital power-system technologies, green hydrogen, carbon capture, utilization and storage, and nuclear technologies, including Small Modular Reactors. They also exchanged perspectives on carbon markets and the evolving carbon-pricing landscape,

including Carbon Border Adjustment Mechanism (CBAM).

The meeting reaffirmed the importance of energy and power cooperation as a key pillar of the India-EU partnership. Both sides expressed their commitment to continued engagement, exchange of expertise and deeper technological and institutional cooperation to support secure, resilient and sustainable energy systems.

7th high-level meeting of the OPEC-India energy dialogue held in New Delhi

New Delhi: The seventh high-level meeting of the OPEC-India Energy Dialogue was held in New Delhi, India. The meeting was co-chaired by HE Hardeep Singh Puri, India's Minister of Petroleum and Natural Gas, and HE Haitham Al Ghais, OPEC Secretary General.

Discussions focused on oil market stability, energy security and the importance of adequate and timely investment across the oil industry. Both parties reviewed the short-, medium- and long-term outlooks, underscoring India's crucial role in global economic expansion and energy demand growth.

In his remarks, Mr. Hardeep Singh Puri underlined that India and OPEC share a naturally complementary and mutually beneficial relationship and thanked Secretary General for his contribution in strengthening this partnership. He emphasized that India values its longstanding engagement with OPEC and its Member Countries, which has contributed significantly to mutual understanding and cooperation on key energy issues.

He noted that "As one of the world's fastest-growing major economies, India will remain an important driver of global energy demand in the decades ahead. A sustained dialogue between producers and consumers is essential to support investment, strengthen energy resilience and ensure reliable energy supplies for global growth and development."

Appreciating OPEC's efforts towards promoting stability and transparency in global energy markets during a period marked by geopolitical uncertainties and market volatility, he called on OPEC and India to work closely in advancing a balanced, stable and predictable global energy market.

In his remarks, HE Al Ghais stated that "Dialogue with India is a priority for OPEC because we recognize India's importance within the current global energy landscape and the fact that this importance will only increase in the decades ahead". He added that the "OPEC-India Energy Dialogue is eleven years strong, having been launched in New Delhi in 2015".

The Secretary General commended India's balanced, realistic and pragmatic approach to addressing energy challenges, emphasizing that "many of India's energy priorities are OPEC's priorities".

HE Al Ghais also praised the Indian Government's firm commitment to international collaboration and dialogue. He stressed, "What is particularly heartening about our dialogue is the fact that the Indian Government has consistently advocated diplomacy and dialogue as the means of resolving the great challenges of our age".

The meeting commended the progress achieved to date within the framework of the dialogue, including at the technical level. It concluded with both parties underscoring the vital importance of fostering even deeper energy cooperation between OPEC and India.

It was agreed to hold the 8th High-Level Meeting of the OPEC-India Energy Dialogue at a mutually convenient date in Vienna, Austria.

India and France reaffirm commitment to power sector cooperation



New Delhi: Mr. Pankaj Agarwal, Secretary, Ministry of Power, held a meeting in New Delhi with Mr. Bernard Fontana, Chairman and Chief Executive Officer, EDF, France, to review the ongoing engagement between India and EDF on the proposed deployment of EPR reactors in India. The meeting was attended by officials from the Ministry of Power, the Ministry of External Affairs, Central Electricity Authority (CEA), NTPC Limited and NPCIL on the Indian side, and by officials of

EDF and the Embassy of France in India on the French side.

The discussions centred on the deployment of EPR technology, India's regulatory reforms for the nuclear sector, cooperation on pumped hydro storage projects, and the way forward for a robust, mutually beneficial partnership.

EDF apprised the Indian side of its efforts to build an ecosystem and supply chain in India for large-scale localization, and reiterated that a sizeable programme with multiple nuclear reactors would give suppliers confidence and enable economies of scale by leveraging Indian industry's capabilities.

Secretary (Power) briefed the French side on the progress made in finalizing India's regulatory framework for the nuclear power sector, including the Draft SHANTI (Sustainable Harnessing and Advancement of Nuclear Energy for Transforming India) Rules and Regulations, placed by the Department of Atomic Energy in the public domain for stakeholder consultation. The Rules provide for a streamlined, time-bound licensing framework and enable participation of private and foreign partners in India's nuclear power programme.

The two sides also discussed cooperation on pumped hydro storage projects, building on the proposed NTPC-EDF joint venture in this area.

SECI celebrates its 15th Foundation Day with Stakeholders' Meet

New Delhi: "SECI's 15-year journey stands as a reflection of India's growing leadership in the global renewable energy transition," said Mr. Shripad Yesso Naik, Minister of State, Ministry of New & Renewable Energy and Power while addressing the gathering at the celebration of the 15th Foundation Day of Solar Energy Corporation of India Limited (SECI) as the Chief Guest.

Mr. Naik said that SECI has consistently delivered on the nation's clean energy vision and expressed confidence that the corporation will continue to play a central role towards its achievement. The event was also graced by Shri Ghanshyam Prasad, Chairperson, CEA, Shri Mayank Tewari, Additional Secretary, MNRE and Shri Vivek Jain, Chairman, INOXGFL Group along with other senior officials of the Renewable Energy sector.



Speaking at the event, Mr. Akash Tripathi, Managing Director, SECI, said that SECI remains committed to open new opportunities in the renewable energy sector, working closely with all stakeholders and innovating with market's requirements. These 15 years have been a testament to SECI's dedication and the nation's collective will towards sustainable energy. We are thankful to all our stakeholders for putting their faith in us.

The Stakeholders' Meet featured two thematic sessions, "Reimagining Industry through Green Molecules" and "The Changing Energy Landscape: Distributed Renewables and New Energy Markets," bringing together policymakers, industry leaders and financial institutions to deliberate on emerging opportunities and challenges shaping India's energy transition.

The first session, "Reimagining Industry through Green Molecules," explored the role of green hydrogen and its derivatives in decarbonizing hard-to-abate sectors and creating new avenues for industrial growth. The session covered opportunities for domestic production and emerging applications, along with the policy support, infrastructure, technology and financing required to develop green molecule markets on a scale.

The second session, "The Changing Energy Landscape: Distributed Renewables and New Energy Markets," examined the evolving role of distributed RE in India. Key areas of discussion included greater consumer participation, integration of distributed energy resources and emerging market mechanisms, as well as the policy and regulatory frameworks needed to facilitate their effective integration and support the expansion of renewable energy.

Incorporated on September 20, 2011, SECI, a Navratna CPSE under the Ministry of New and Renewable Energy, began as the country's dedicated implementing agency for the National Solar Mission and has since grown into

the foremost CPSE focused exclusively on Renewable Energy, with a mandate spanning the complete renewable energy ecosystem.

Ministry of Steel announces apex body for strengthening safety standards and improve safety culture in steel sector

New Delhi: The Ministry of Steel, Government of India, has decided to set up a Steel Industry Safety Council (SISC) as an apex-level industry safety body under the administrative control of the Ministry of Steel. The initiative is aimed at strengthening safety standards, practices, accident prevention and safety awareness across the steel industry.

The Council will be headed by the Secretary, Ministry of Steel, as Chairman and will include senior officials of the Ministry, Chief Executives of integrated steel producers, and representatives of key technical and statutory organizations including the Directorate General of Mines Safety (DGMS), Petroleum and Explosives Safety Organisation (PESO), National Disaster Management Authority (NDMA) and recognized steel technology institutions.

The SISC will assess the safety situation in the steel industry, facilitate studies and improvements in safety practices, approve industry safety standards and recommended practices, and review serious accidents, accidents and near-miss incidents. It will also provide directions for strengthening safety awareness, training and preventive measures.

To provide technical and professional support to the Council, a Steel Industry Safety Directorate (SISD) will be established. The Directorate will have expertise in areas including process safety, blast furnaces, steel melting, rolling mills, coke ovens, refractory systems, electrical and mechanical safety, occupational health, fire engineering and disaster management.

The SISD will oversee implementation of the Council's decisions, undertake periodic safety audits and reviews, maintain and disseminate accident and near-miss information, conduct investigations into serious safety incidents, review emergency preparedness and safety training programmes, and develop and issue Steel Industry Safety Standards, Recommended Practices and Guidelines suited to Indian conditions.

The establishment of SISC and SISD represents an important institutional step towards promoting a stronger safety culture, improving prevention of industrial accidents and advancing consistent safety practices across India's steel industry.

Ministry of New & Renewable Energy gears up for special campaign 6

New Delhi: The preparatory phase of Special Campaign 6 is underway in the Ministry of New & Renewable Energy (MNRE). Launched by the Department of Administrative Reforms & Public Grievances (DARPG), the campaign aims to institutionalize Swachhata and minimizing pendency in Government offices. It is being implemented in the ministry along with its two CPSUs and three autonomous institutes.

The CPSUs include Indian Renewable Energy Development Agency Ltd. (IREDA) and Solar Energy Corporation of India Ltd. (SECI), and Autonomous Institutes include National Institute of Solar Energy (NISE), National Institute of Wind Energy (NIWE) and Sardar Swarn Singh National Institute of Bio Energy (SSS-NIBE).

The Implementation Phase of Special Campaign 6 will commence from 2nd October, 2026, during which concerted efforts will be made to achieve the targets identified during the Preparatory Phase and further institutionalize Swachhata, efficient record management and timely disposal of pendency across the Ministry and its PSUs/Institutions.

During the preparatory phase of Special Campaign 6, the following activities are being undertaken by the Ministry and its PSUs/Institutions: Identification and disposal of pendency under various parameters; Review, categorization and weeding out of physical records as per extant guidelines; Conduct of cleanliness campaigns for maintaining cleanliness in the Ministry and its PSUs and Autonomous Institutes and Identification and segregation of e-waste as per MoEFCC guidelines for target setting during the Implementation Phase. ■

Cochin Shipyard Ltd and Drydocks World form joint venture to strengthen India's ship repair industry



New Delhi: Drydocks World, a DP World company, and Cochin Shipyard Limited (CSL) have announced the signing of a joint venture agreement to operate and expand the International Ship Repair Facility (ISRF) Cochin.

The agreement was signed by Captain Rado Antolovic, PhD, CEO, Drydocks World, and Mr. Jose V J, Chairman & Managing Director of Cochin Shipyard Ltd., in the presence of Sarbananda Sonowal, Union Minister of Ports, Shipping and Waterways (MoPSW), and H.E. Omran Sharaf Alhashimi, UAE Assistant Foreign Minister for Advanced Science and Technology.

The agreement builds on the Memorandum of Understanding (MoU) signed by Drydocks World (DDW) and CSL during India Maritime Week 2025, under which the two organizations agreed to explore opportunities for collaboration in ship repair and allied maritime services. The companies have now formalised this collaboration through a 50:50 joint venture, marking the establishment of a first-of-its-kind public-private partnership in India's ship repair sector.

Under the arrangement, the joint venture will operate, consolidate and expand the International Ship Repair Facility (ISRF) in Cochin, creating additional capacity to service a wider range of vessels and meet the growing requirements of Indian, regional and international customers.

The partnership is expected to strengthen Cochin's position as a maritime services hub, while creating opportunities across ship repair, engineering, fabrication and associated maritime services in Kerala.

Sarbananda Sonowal, Union Minister of Ports, Shipping and Waterways, said: "The partnership between Cochin Shipyard and Drydocks World marks an important milestone in strengthening India's ship repair ecosystem and reflects the enduring maritime relationship between India and the UAE, which has flourished through centuries of trade, commerce and people-to-people ties. The shared vision and resolve of Prime Minister Narendra Modi and His Highness Sheikh Mohamed bin Zayed Al Nahyan are giving a new momentum to this relationship across strategic and economic sectors. By combining India's growing shipbuilding and ship repair capabilities with the UAE's global maritime expertise, this joint venture will create new capacity, skills and economic opportunities, while strengthening Cochin as a maritime services hub."

His Excellency Omran Sharaf Alhashimi, Assistant Foreign Minister for Advanced Science and Technology, UAE, said, "The UAE and India share a longstanding relationship rooted in mutual trust, economic cooperation and a common ambition to create new pathways for growth. The joint venture between Drydocks World and Cochin Shipyard is a strong example of how this partnership can translate into tangible industrial outcomes, bringing together complementary expertise to strengthen India's maritime capabilities. By combining India's growing maritime potential with the UAE's global experience, collaborations such as this can support more efficient ship repair services, strengthen maritime connectivity and contribute to the continued growth of trade and commerce between our two countries."

Vijay Kumar, Secretary, Ministry of Ports, Shipping & Waterways said, "This Joint Venture shall not be limited to Kochi. It is a replicable model that can be extended across India's extensive coastline, creating hubs of excellence in ship repair and conversion. By leveraging India's strategic location and proximity to global trade routes, the JV will attract foreign investments, generate foreign exchange, and create thousands of skilled jobs. It will also align with the Maritime Amrit Kaal Vision 2047, positioning India as a global powerhouse in ship building and ship repair. The signing of this Joint Venture Agreement is more than a business agreement, it is a statement of intent. It signals India's readiness to compete globally, deliver world-class maritime services, and forge partnerships that strengthen our economy and strategic capabilities."

PROJECT UPDATES

Captain Rado Antolovic, PhD, CEO, Drydocks World, said: "This partnership with Cochin Shipyard is an important milestone for India's ship repair industry and builds on the strong foundation of our MoU last year. By combining Cochin Shipyard's local expertise and skilled workforce with Drydocks World's global capabilities and technology, we are creating a world-class ship repair offering. Our ambition goes beyond one facility - we see opportunities to expand ship repair and fabrication capabilities across India."

Jose V J, Chairman and Managing Director, Cochin Shipyard Ltd., said: "This joint venture with Drydocks World Dubai marks a defining moment in India's journey to become a global ship repair hub. By combining CSL's deep domestic experience with DDW's world-class expertise, we are not just scaling up business - we are onboarding global best practices, accelerating turnaround times, and setting new benchmarks for quality and safety. Anchored at the International Ship Repair Facility in Kochi, this partnership will catalyse a thriving repair cluster, attract international fleets, generate high-skilled employment, and advance the vision of Maritime India 2030 and Amrit Kaal 2047."

The partnership combines CSL's established shipbuilding and repair capabilities, engineering expertise and skilled workforce with Drydocks World's global experience in high-end vessel repair and maintenance, major conversions, and offshore engineering, procurement and construction (EPC). Strategically located along major international shipping routes, the facility features a state-of-the-art ship lift system and modern docking facilities capable of servicing a wide range of vessels.

Drydocks World and Cochin Shipyard Ltd. will each hold a 50 per cent stake, with initial capital funded through equity contributions from both parties.

Indian Army and City Gas Distribution industry join hands to accelerate PNG transition

New Delhi: In a significant step towards strengthening energy resilience and accelerating the adoption of cleaner and reliable energy solutions across Army establishments, the Indian Army PNG Transition Webinar 2026 was organized at Manekshaw Centre, New Delhi, under the theme "Sena Sampark - Nirantar Urja, Nirantar Suraksha."



The programme was organized by Bharat Petroleum Corporation Limited (BPCL) in association with the Indian Army and the Petroleum and Natural Gas Regulatory Board (PNGRB), on behalf of the City Gas Distribution (CGD) industry, bringing together key stakeholders to establish a coordinated roadmap for accelerating PNG adoption across Army establishments.

As part of the first phase, 41 Army establishments have been identified for PNG conversion. A key outcome of the initiative was the signing of Letters of Understanding (LoUs) between 8 Army Stations and 6 CGD entities, covering more than 20,000 households. The participating CGD entities include Bharat Petroleum Corporation Ltd. (BPCL), Indraprastha Gas Limited (IGL), Think Gas, Torrent Gas, Hindustan Petroleum Corporation Limited (HPCL) and Central U.P. Gas Limited (CUGL), with the CGD industry coming together to support the Army's PNG transition.

Speaking on the occasion, Mr. Rahul Tandon, Business Head - Gas, BPCL, said, "The transition of Army establishments to PNG is an important step towards building a reliable, continuous and future-ready energy ecosystem for critical establishments. 'Sena Sampark - Nirantar Urja, Nirantar Suraksha' brings together the Army, regulator and CGD industry towards a common objective of enabling a structured transition to PNG. BPCL is committed to facilitating this collective effort and supporting the Army through the transition journey"

The initiative will focus on streamlining the transition through coordinated planning across network readiness, statutory permissions, regulatory requirements, infrastructure development, retrofitting and customer service. A PNG Handbook was also released during the programme as a ready reference for Army establishments undertaking the transition.

The Indian Army has committed to taking the initiative forward in a structured and time-bound manner. Twelve establishments are already actively participating,

while another 29 are being taken up, covering all 41 establishments identified under the first phase. The Army and participating CGD entities have committed to completing the PNG infrastructure and connections for these establishments by the end of FY 2026-27.

NMDC commissions ₹5,427 crore iron ore processing plant, slurry pipeline and pellet plant in Chhattisgarh



New Delhi: NMDC Ltd has commissioned its 2 million tonne per annum (MTPA) pellet plant at Nagarnar in Chhattisgarh, as part of a ₹5,427-crore integrated project of iron ore processing, pipeline and pellet making connecting its iron ore operations at Bacheli with the company's steel plant at Nagarnar.

The project includes a new iron ore processing plant at Bacheli, a 15 MTPA slurry pipeline and the 2 MTPA pellet plant at Nagarnar. The 135 km slurry pipeline carries processed iron ore concentrate from Bacheli to Nagarnar, providing an alternative to transporting the material by road.

The maiden production from the pellet plant was monitored live from NMDC's headquarters by Chairman and Managing Director Amitava Mukherjee and the company's senior leadership, as adverse weather conditions prevented them from travelling to the project site.

The facilities will enable NMDC to process iron ore fines and slimes from its Bailadila mines into concentrate and subsequently convert the concentrate into pellets. The pellet plant uses Straight Grate Induration technology to produce pellets for use in steelmaking.

"Today is a day of immense pride for everyone at NMDC. This has not been an easy project to execute. It involved the processing facilities, the actual slurry pipeline and the pellet plant. But today is a red-letter

day—a day we have been waiting for a long time. This is the day when our collective dream is coming true," said Amitava Mukherjee, Chairman and Managing Director, NMDC Ltd.

The project is part of NMDC's broader expansion and diversification strategy as the company works towards increasing its iron ore production capacity to 100 million tonnes in the long term.

The slurry pipeline passes through 61 villages in Bastar and Dantewada districts and is designed to reduce the movement of processed ore by road, provide alternate mode of evacuation and lower dependency on Railways and ensures a dedicated link between NMDC's Bacheli operations and Nagarnar.

India's first port-based e-Methanol production facility to produce and supply green fuel to ships



Gujarat: India took a major step toward becoming a green energy exporter as Gujarat Chief Minister Bhupendra Patel, Union Minister of Ports, Shipping and Waterways (MoPSW), Sarbananda Sonowal and Assam's Chief Minister Dr Himanta Biswa Sarma laid the foundation stone for the country's first port-based e-methanol plant at Deendayal Port Authority (DPA) in Kandla, Gandhidham, Gujarat.

The 150-tonne-per-day plant will use renewable power, water and biogenic CO₂ to produce e-methanol, a green fuel that will enable cleaner shipping, and supply it to vessels plying on the Asia-Europe International Trade Corridor, one of the world's busiest trade routes. The project positions India as an exporter of green fuel to global shipping. The plant will position India as a global leader in the production and supply of green

PROJECT UPDATES

fuel, and will produce green methanol at a much more competitive rate compared to other global producers, just US\$750 per tonne, against a global rate of US\$1,300 per tonne.

The ₹2,300 crore plant is a joint initiative of Deendayal Port Authority (DPA) and Namrup-based Assam Petro-Chemicals Ltd. (APCL), and will be installed in phases, as scalable modules. Phase I of the project will add 50 tonnes per day of capacity at an investment of ₹1,200 crore, targeted for completion by January 2027, followed by Phase II, which will add a further 100 tonnes per day at an investment of ₹1,100 crore, targeted for March 2027, taking the total investment to ₹2,300 crore. The capital contribution between the two partners stands at a ratio of 76:24 between DPA and APCL. DPA's contribution to the project includes equity capital of ₹567.32 crore, 75 acres of land, desalinated water, and renewable energy in the form of green hydrogen. It shall be amongst the largest e-methanol production facilities in India and shall create more than 3,500 direct and indirect jobs. It shall stimulate the complete green energy value chain in and around Kandla, including transportation, storage, supply and other associated ancillaries involved in production of green molecules.

The government plans to add 100 new ships to the country's merchant fleet over the next five years and aims to make India one of the world's top five ship-owning nations by 2047. Global shipping major Maersk has also begun ordering containers manufactured in India. As part of Deendayal Port Authority's wider mega port push, the DPA-Cochin Shipyard Limited (CSL) shipbuilding project at Vadinar, worth ₹1,520 crore, is also underway, alongside a proposed greenfield shipbuilding and repair cluster at Kuchhadi, Porbandar, which has received in-principle approval.

TrueRE Oriana Power wins bid to set up 900 MW/1800 MWh Battery Energy Storage Systems in Maharashtra

New Delhi: TrueRE Oriana Power Limited has secured two Letters of Award (LOAs) from Maharashtra State Electricity Distribution Company Limited (MSEDCL) for setting up an aggregate 900 MW / 1,800 MWh Battery Energy Storage System (BESS) capacity across Maharashtra. The two awards carry an aggregate consideration of approximately ₹3,870 crore over a 15-year term, excluding GST.

The project has been split into two components. The first is a standalone BESS project of 500 MW / 1,000 MWh at MSETCL substations, at a tariff of ₹2,38,000/MW/month. The second is a 400 MW / 800 MWh BESS at MSEDCL substations, at a tariff of ₹2,40,000/MW/month, awarded under the Mukhyamantri Saur Krushi Vahini Yojana 2.0 (MSKVY 2.0), which is Maharashtra's flagship scheme for decentralized solarisation of agricultural feeders.

Commenting on the win, Rupal Gupta, Founder, MD & CEO, TrueRE Oriana Power, said, "As India's power system integrates increasing volumes of renewable energy, storage will play a critical role in improving flexibility, reliability and the ability to match generation with demand. The award of 900 MW / 1,800 MWh of BESS capacity by MSEDCL marks an important milestone in TrueRE Oriana Power's journey. This new win reflects our capabilities in the renewable energy and energy storage value chain and will further strengthen our presence in the utility-scale BESS segment. We have a disciplined project selection approach that supports sustainable growth, healthy operational profitability, and a strong portfolio of projects on the ground that boost our long-term growth trajectory."

The awards were secured through a tariff-based global competitive bidding process and reverse auction, with Viability Gap Funding (VGF) support under the Power System Development Fund (PSDF) scheme. The company expects VGF of approximately ₹324 crore, based on the current estimated project cost.

The projects will operate under Battery Energy Storage Purchase Agreements (BESPA) for 15 years from their respective Commercial Operation Dates. The scheduled commissioning dates will be determined in accordance with the respective BESPA, which are yet to be executed.

Yokogawa wins orders from Kawasaki Heavy Industries to supply integrated automation systems for world's largest liquefied hydrogen carrier and for hydrogen-fueled vessels



Artist's impression of the 40,000 m³ liquefied hydrogen carrier
(Courtesy of Kawasaki Heavy Industries, Ltd.)

Japan: Yokogawa Electric Corporation has received orders from Kawasaki Heavy Industries, Ltd. to supply integrated automation systems for a 40,000 m³ liquefied hydrogen carrier that will be the world's largest vessel of its type, and for two hydrogen-fueled vessels. The company will contribute to the realization of a sustainable society by supporting the promotion of new energy utilization through the provision of monitoring and control solutions for the hydrogen supply chain, including storage and transportation.

As the adoption of hydrogen accelerates, establishing a supply chain capable of safely transporting and storing large volumes of hydrogen is increasingly important. Liquefied hydrogen is expected to play a key role in such a supply chain, while efforts to use hydrogen as a maritime fuel are also progressing. In Japan, demonstration projects covering the entire hydrogen supply chain are underway for the commercialization of liquefied hydrogen.

The system that Yokogawa will supply for the liquefied hydrogen carrier provides integrated monitoring and control of onboard equipment and incorporates emergency shutdown functions. It supports the safe and efficient handling of liquefied hydrogen that is transported at extremely low temperatures, helping to ensure safe and reliable vessel operations. In addition, its advanced integrated control capabilities will help

to improve equipment performance and reduce crew workload throughout the vessel's lifecycle.

Yokogawa has also received an order to supply integrated automation systems for marine hydrogen fuel systems (MHFS) that are to be installed on hydrogen-fueled vessels. An MHFS consists of liquefied hydrogen tanks and fuel supply equipment, and is a key technology for advancing maritime decarbonization.

These vessels are being built as part of a Green Innovation Fund project led by Japan's New Energy and Industrial Technology Development Organization (NEDO) and will support safe, large-scale maritime transportation, contributing to the development of the liquefied hydrogen supply chain and the transition to a sustainable society.

Koji Nakaoka, a Yokogawa Electric executive vice president & executive officer and head of the company's Energy & Sustainability Business Headquarters, commented, "Yokogawa has extensive experience with liquefied natural gas carriers, and our technology is also being applied to liquefied hydrogen carriers. Leveraging the technologies and expertise we have developed in the field of control and safety instrumentation, we will continue to provide solutions that support safe and reliable operations for our customers in the energy sector, including hydrogen." ■

Unusual wave-like heat transport in crystalline solid signals breakthrough converting waste heat in industries

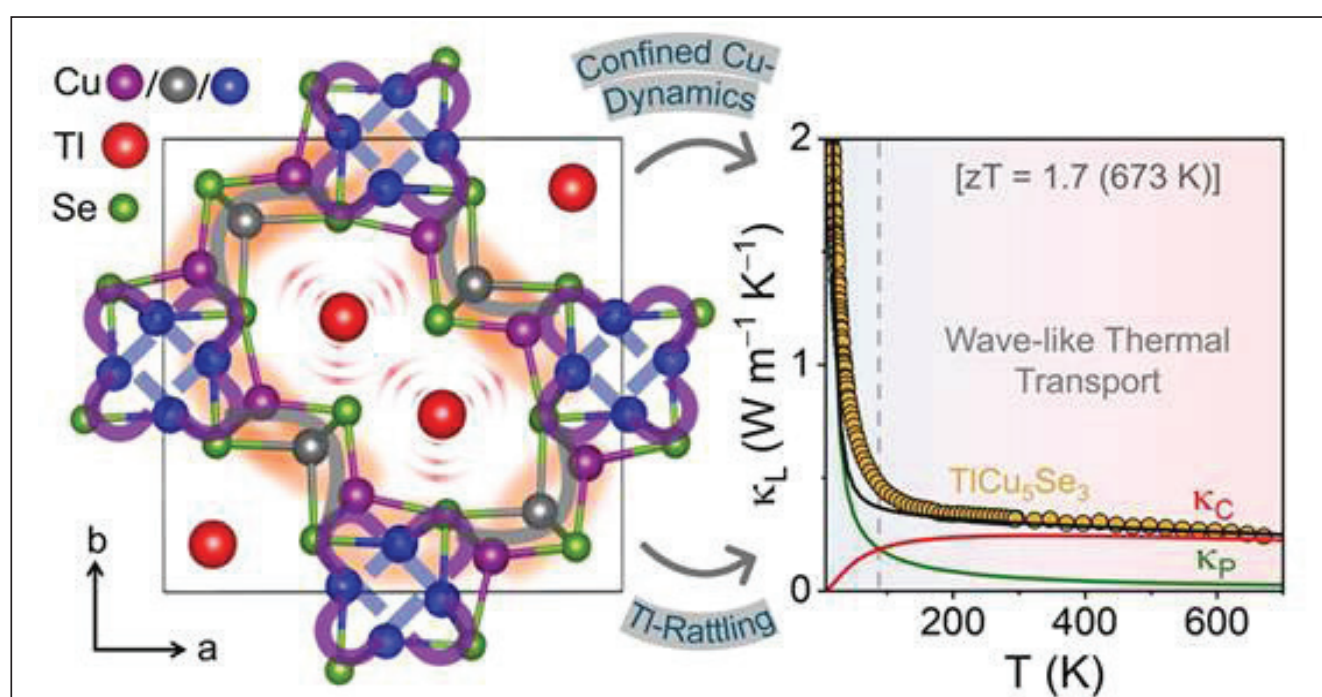
An unusual heat transport regime detected in a newly studied copper chalcogenide material called thallium copper selenide (TlCu₅Se₃) could pave way for efficient conversion of waste heat to electricity via thermoelectric energy conversion in power plants, cement industries, steel plants, automobiles, data centers and battery heat management systems.

An unusual heat transport regime detected in a newly studied copper chalcogenide material called thallium copper selenide (TlCu₅Se₃) could pave way for efficient conversion of waste heat to electricity via thermoelectric energy conversion in power plants, cement industries, steel plants, automobiles, data centers and battery heat management systems.

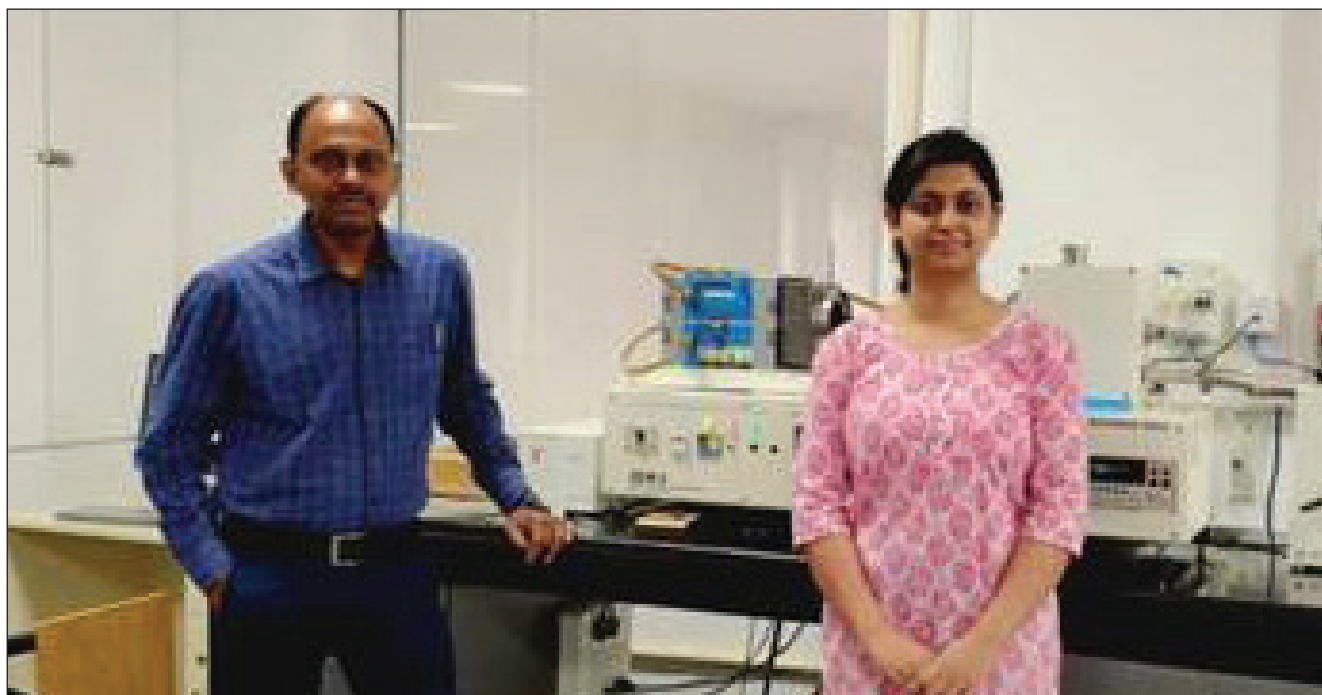
Conventional superionic materials can achieve low lattice thermal conductivity via highly mobile ions. But excessive ion migration may cause structural instability and compromise its thermoelectric performance. Confined ion diffusion, where ionic motion remains restricted within a complex crystalline

framework, offers a way to suppress heat transport while preserving structural stability and promoting unconventional heat-transport mechanisms.

In crystalline materials, heat is conventionally understood to be transported by particle-like phonons, with phonon mean free path (MFP) typically much larger than the interatomic distance. In contrast, strong disorder and anharmonicity (phenomenon in which atomic vibrations become asymmetric and deviate significantly from normal parabolic behaviour, disrupting propagation of heat) in glasses reduce the MFP to nearly the interatomic length scale, suppressing conventional phonon propagation.



A schematic illustrating the complex knot-like structural framework that leads to a confined Cu dynamic, resulting in unusual heat transport and ultrahigh thermoelectric performance in TlCu₅Se₃.



Prof. Kanishka Biswas (L) and Sayantoni Choudhury (R), Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore.

This conventional picture, however, becomes increasingly inadequate when strong anharmonicity and structural disorder can retain long-range crystallographic order while exhibiting highly localized, closely spaced vibrational modes that interact strongly with one another.

In this intermediate regime, thermal energy can be transported not only through particle-like phonon propagation but also through wave-like coherence between different vibrational modes, enabling ultralow lattice thermal conductivity. Such ultralow thermal conducting materials have immense importance in thermal barrier coatings, thermoelectric energy conversion, thermal decoherence free quantum technology.

Researchers at Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR), Bengaluru (an autonomous institution under the Department of Science & Technology, Govt. of India) and other research team members have found an unusual wave-like thermal transport regime in a newly studied copper chalcogenide material, TiCu_5Se_3 that can lead to high-performance thermoelectric conversion.

The complex crystal framework of TiCu_5Se_3 was expected to restrict the motion of Cu atoms rather than

allowing long-range migration providing opportunity to investigate whether this confined dynamic behaviour could generate strong anharmonicity and suppress heat transport without causing structural instability.

In this work, led by Prof. Kanishka Biswas and his Ph.D. students, Ms. Sayantoni Choudhury and Dr. Animesh Bhui from the New Chemistry Unit (NCU) at JNCASR, published in the prestigious journal, *Science Advances*, investigated the structural and thermoelectric properties through experiments and conducted advanced theoretical calculations to understand the origin of the unusual heat transport.

They showed that the complex crystal structure and intrinsically confined dynamic disorder of the Cu sublattice generate exceptionally strong anharmonicity, leading to predominantly wave-like phonon transport and an intrinsically ultralow lattice thermal conductivity. ■

Thorium Is a Chemistry Problem



Prabhat Ranjan
CEO and Co-founder
ASPL Fusion

*India has the world's largest thorium reserves and almost no thorium electricity. The obstacles lie less in reactor physics than in separations, dissolution and materials — which is to say, in this readership's territory, opines **Prabhat Ranjan, CEO and Co-founder, ASPL Fusion.***

On 6 April 2026 the Prototype Fast Breeder Reactor at Kalpakkam attained first criticality, 22 years after construction began. India has formally entered the second stage of the three-stage programme Homi Bhabha sketched in 1954. The third stage is thorium.

The popular account treats thorium as a reactor problem. Mostly it is not. Reactor concepts have existed for decades and several are well understood. What stands between India and thorium electricity is a chain of chemical engineering problems: ore cracking, solvent extraction, dissolution chemistry, molten-salt corrosion, and fabrication under a hard gamma field.

Why Thorium is a Chemistry Problem

Natural thorium is essentially all Th-232, which is fertile, not fissile. It must absorb a neutron to become Th-233, which beta-decays with a 22-minute half-life to protactinium-233, which in turn decays over 27 days to uranium-233. Only then is there fuel.

That 27-day step is a process problem before it is a physics one. Protactinium sitting in a neutron flux absorbs neutrons that would otherwise breed U-233, so any design seeking a good breeding ratio wants protactinium out of the flux and held while it decays. In solid-fuel systems that means irradiate, cool, reprocess. In liquid-fuel systems it means continuous extraction from a hot, intensely radioactive salt — the most demanding separation in the concept.

The product carries its own burden. Bred U-233 always arrives contaminated with U-232, whose decay chain yields a 2.6 MeV gamma from thallium-208. U-232 is formed largely by (n,2n) threshold reactions on Th-232, Pa-233 and U-233, so the harder the neutron spectrum, the more of it accumulates.

Accelerator-driven and fusion-driven systems therefore pay a heavier remote-handling penalty than thermal routes do, and those of us working on them should say so. Fabrication cannot be a glovebox operation; it needs shielded cells and remote handling, which drives

Six roads, one bottleneck

Every thorium pathway is, in the end, an answer to the same question: how do we get more U-233, sooner?

RELIES ON THE FUEL'S OWN NEUTRON ECONOMY

1 • Fast breeder blankets

PFBR · FBTR · KAMINI — operating today

2 • Heavy water reactors

AHWR · thoria bundles in PHWRs · PRTRF

3 • Light water reactors

Th-Pu MOX pellets — utilisation, not closure

4 • Molten salt

IMSBF — online Pa-233 removal

DRIVEN BY AN EXTERNAL NEUTRON SOURCE

5 • Accelerator-driven

Spallation neutrons · sub-critical assembly

6 • Fusion-driven hybrid

14.1 MeV neutrons · k-eff 0.90–0.95

U-233 fissile inventory

The seed every route
needs — and competes for

Stage 3 thorium fleet

DAE projects extensive use
beyond 2070 on current routes

Why the external routes matter

In a critical reactor every neutron is committed to sustaining the chain reaction, so breeding runs on a thin margin. A sub-critical assembly is not required to sustain itself — so its surplus neutrons can be spent on breeding instead.

Roads 1, 2 and 4 are Department of Atomic Energy programmes. Road 6 is ASPL Fusion's PRABHA-Hybrid, a design study. Figure: P. Ranjan.

A schematic showing the six routes converging on a single U-233 node.

plant layout and capital cost. That same gamma is also what makes the material unattractive to divert: the inconvenience and the safeguard are one physical fact.

It Begins with Monazite

India's thorium sits in monazite, a rare-earth phosphate carrying some 8 to 10 per cent thoria — and 55 to 60 per cent rare-earth oxides — concentrated in the beach placers of Kerala, Tamil Nadu, Odisha and Andhra Pradesh. Government figures put in-situ monazite at about 11.93 million tonnes, containing on the order of a million tonnes of thorium — though a parliamentary answer in 2012 put the exploitable fraction nearer 4 million tonnes, or some 225,000 tonnes of recoverable metal. 'Largest reserves' and 'largest economically extractable reserves' are different statements.

Cracking monazite is a caustic operation: digestion in hot concentrated sodium hydroxide, yielding trisodium phosphate as a saleable by-product and a mixed hydroxide cake from which selective dissolution separates thorium from the rare earths. India has run this chemistry at IREL for decades.

Which raises a point this industry should press harder. Those proportions tell the story: monazite is not a

thorium mineral with rare earths in it, it is a rare-earth mineral with thorium in it. We have spent decades treating the thorium as the prize and the rare earths as somebody else's business — at a moment when rare-earth supply security has become a defining industrial question. The separation trains, the effluent handling and the radiological controls are shared; the business case should be too. A serious public assessment of the coastal placers as a joint resource would improve decisions in both sectors, and would very likely change the economics of thorium extraction.

The Dissolution Problem

Recovering U-233 from irradiated thoria means THOREX — solvent extraction with tributyl phosphate, conceptually a cousin of PUREX and harder in practice. Thoria is refractory. Unlike urania it does not dissolve readily in nitric acid, and needs fluoride ion catalysis, with aluminium nitrate added to complex free fluoride and protect stainless steel from attack. Each of those steps is a corrosion, materials-selection and waste-stream decision. Anyone who has specified nitric service will recognise the shape of the problem.

Six Routes, and What Each Asks

Fast breeder blankets. The sanctioned route, and now operating. Thoria blanket assemblies irradiated in the Fast Breeder Test Reactor have been reprocessed at IGCAR, and KAMINI at Kalpakkam remains the only reactor anywhere fuelled by U-233. The ask is THOREX at scale and remote fabrication.

Heavy water reactors. BARC's Advanced Heavy Water Reactor is a 300 MWe design intended to draw most of its power from thorium. Design is complete, AERB has accorded pre-licensing approval and there is in-principle site approval at Tarapur, but no unit has begun construction. Thoria bundles have separately been irradiated in operating PHWRs, with a dedicated facility built to reprocess them. The ask is high-density thoria pellet fabrication, remotely.

Light water reactors. Thorium-plutonium MOX dropping into existing hardware has obvious commercial logic, and several ventures internationally pursue it. Two cautions: it consumes U-233 as fast as it breeds it, so it is thorium utilization rather than cycle closure; and our fleet is PHWR-dominated. A BARC team concluded in Current Science in March that a proposed HALEU-thorium blend could not be dropped into our 220 MWe PHWRs without significant design change.

Molten salt. The Indian Molten Salt Breeder Reactor programme targets liquid fluoride fuel and coolant near 650 degrees Celsius, coupled to a supercritical carbon dioxide cycle. Chemically it is the most elegant answer, because protactinium and fission products can be removed continuously. It is also by far the hardest plant: lithium-7 enrichment, redox control of the salt to hold corrosion in check, nickel-molybdenum-chromium alloys, and materials qualification under simultaneous corrosion and irradiation. China has operated a small liquid-fuelled thorium MSR and reported converting thorium into usable fuel.

Accelerator-driven systems. Spallation neutrons from a high-power proton accelerator drive a sub-critical assembly, decoupling neutron supply from the criticality of the fuel. The ask is a high-availability accelerator and a spallation target with a punishing thermal and corrosion duty.

Fusion-driven sub-critical hybrids. The same logic with a different source: a deuterium-tritium reaction yields

a 14.1 MeV neutron, far more energetic than anything fission produces.

Why External Sources Change the Arithmetic

In a critical reactor every neutron is committed to sustaining the chain reaction, so only the thin margin left over is available for breeding: you breed roughly what you burn. An external source changes that budget. Run deliberately sub-critical, the assembly need not sustain itself, and what remains is genuine surplus — available for breeding U-233 and transmuting long-lived actinides. There is no prompt-critical pathway either: switch off the source and fission power falls away.

The Pacing Item

These six routes have uncorrelated failure modes — salt corrosion, accelerator availability and fusion driver risk are independent of one another — which argues for funding a portfolio rather than picking a winner.

But note what the routes have in common. Every one of them needs monazite cracked, thoria dissolved, protactinium managed, U-233 separated and fuel fabricated behind shielding. The reactor differs; the chemistry does not. The Department of Atomic Energy projects extensive thorium deployment beyond 2070, and that projection is governed less by reactor availability than by the throughput of the fuel cycle that feeds it.

Which is to say the pacing item for India's third stage is a process industry problem, and it belongs to this readership as much as to the reactor physicists. ■

ABOUT THE AUTHOR

Prabhat Ranjan is Co-founder and Chief Executive Officer of ASPL Fusion. He was formerly Project Leader of the ADITYA tokamak and of the SST-1 Operation and Control Group at the Institute for Plasma Research, and Executive Director of TIFAC.

Declaration of interest. ASPL Fusion is developing a fusion-driven sub-critical system — the sixth of the six routes described here. The author has no financial interest in the other five.

When Pre-treatment Becomes a Performance Advantage — A Prasinos Tech Innovations Perspective



Dr. Aditi Mullick
Managing Director
Prasinos Tech Innovations

*Oil and gas operations generate complex wastewater streams, particularly oily wastewater and produced water, containing dispersed oil, grease and suspended solids that require effective separation before downstream treatment or reuse. As treatment systems face increasing demands for efficiency, compactness and operational reliability, advanced pre-treatment is becoming an important part of the treatment strategy. It is in this space that **Prasinos Tech Innovations** brings its expertise in cavitation technologies to industrial water treatment. Its **Cavitation Air Flotation (CAF)** technology applies hydrodynamic cavitation and air flotation to enhance the separation of oil, grease and suspended contaminants, offering a potential solution for demanding industrial wastewater applications. **Dr. Aditi Mullick, Managing Director, Prasinos Tech Innovations,** explains the technology in detail.*

Industrial wastewater treatment is often judged by what happens at the end of the treatment train: whether the final effluent meets the required standard. But in complex industrial operations, the real difference may be determined much earlier — at the point where wastewater first enters the treatment system.

For oil and gas, petrochemical and power facilities, wastewater is rarely a simple stream. It can carry oil and grease, suspended solids, organic matter and other contaminants, often with considerable variation in concentration and flow. In oil and gas operations, produced water alone represents a particularly complex

treatment challenge, requiring multiple separation and polishing steps depending on its characteristics and the intended end use. Flotation is already an established part of many such treatment trains because of its ability to separate dispersed oil and suspended matter.

The challenge, therefore, is not simply to add another treatment step. It is to make the first separation step work harder and smarter. As industries seek greater resource efficiency, smaller treatment footprints and more reliable operation, pre-treatment is beginning to take on a larger role in overall treatment performance. An effective front-end separation process can reduce the contaminant

burden reaching downstream units and help create more favourable conditions for subsequent treatment. Recent reviews of produced-water treatment similarly highlight pre-treatment requirements, energy demand and operational reliability as important considerations in designing effective treatment systems.

This is creating renewed interest in flotation technologies that can generate fine bubbles without relying on the conventional configuration of pressurisation, saturation and external air compression. Research into hydrodynamic-cavitation-based flotation has demonstrated the feasibility of using cavitation to generate bubbles for the separation of oil and suspended solids, opening an alternative pathway for industrial wastewater treatment.

It is within this evolving landscape that Prasinos Tech Innovations is exploring a different approach to industrial pre-treatment: combining hydrodynamic cavitation with air flotation to intensify contaminant separation in a compact treatment configuration.

The premise is simple, but significant: when the first step of treatment is engineered for better separation, pre-treatment can become more than a compliance requirement—it can become a performance advantage.

A Different Way to Approach Pre-treatment

The opportunity is not simply to remove contaminants — it is to **make the separation stage work more effectively with a simpler process configuration.**

Prasinos Tech Innovations' Cavitation Air Flotation approach brings together hydrodynamic cavitation and air flotation to create the conditions needed for rapid separation of oil, grease and suspended matter. The process uses a high-speed submerged impeller to generate cavitation and naturally entrain atmospheric air, producing the fine bubbles that drive flotation.

What follows is a **compact, continuous separation process** in which the contaminants are concentrated at the surface and continuously skimmed away. The system is designed without an external air compressor, and also consumes low energy, reduced chemical requirements and low maintenance as key features. For large industrial facilities, these characteristics can matter

as much as removal efficiency. **A treatment technology that occupies less space, requires fewer supporting systems and can operate continuously has the potential to change how pre-treatment is designed—not just how wastewater is treated.**

And that is where the conversation moves from **removal efficiency to overall treatment performance.**

Where the Impact is Felt

The real value of any pre-treatment technology is ultimately measured downstream. Removing a significant portion of oil, grease and suspended solids at the front end can reduce the burden placed on subsequent treatment stages and help maintain more consistent operating conditions. This becomes particularly relevant in industrial facilities where wastewater characteristics can vary with production schedules, process conditions and operating cycles. A robust separation step can provide a degree of buffering, allowing downstream systems to receive a more manageable wastewater stream.

The CAF system is designed with this objective in mind. It can achieve **nearly 95 per cent reduction in TSS and up to 99 per cent removal of oil and grease**, along with significant BOD and COD reduction. The figure (CAF system) demonstrates the potential of the technology, although actual performance will depend on wastewater characteristics and operating conditions.

For oil and gas and power-sector applications, the larger proposition is therefore not simply how much can be removed. It is **how effectively the first separation stage can prepare wastewater for everything that follows.** That is where a well-designed pre-treatment system can translate into better overall treatment performance.

Building on Expertise in Cavitation Technology

The development of CAF is part of a broader technology focus at **Prasinos Tech Innovations**, where expertise in **cavitation technology** forms the foundation for developing advanced water and wastewater treatment solutions and established multiple water management and wastewater treatment technologies including advanced nanobubble technology, green technologies like ozone, ultrasonic algae control system, membrane systems.



Where Innovation Takes Treatment Next

As industrial sectors move towards greater resource efficiency and tighter environmental performance, wastewater treatment will increasingly be evaluated not only by compliance, but by **how intelligently the treatment process uses energy, space and infrastructure.**

This makes pre-treatment an important opportunity for innovation. When oil, grease

and suspended matter can be separated efficiently at the front end, the entire treatment train stands to benefit. The focus therefore shifts from simply adding treatment capacity to **improving the performance of each stage.**

For Prasinos Tech Innovations, this is where the potential of cavitation and nanobubble technologies becomes particularly relevant. CAF demonstrates how a deeper understanding of bubble behaviour and fluid dynamics can be translated into a practical industrial treatment solution.

CAF represents one such application. Here, the organisation's understanding of cavitation is applied to flotation — using hydrodynamic effects to facilitate air entrainment and bubble generation within the treatment process.

The broader opportunity is to develop treatment systems that are **simpler, more compact, resource-conscious and capable of delivering consistent performance** in demanding industrial environments.

The broader technology portfolio also extends into **nanobubble-based solutions**, reflecting a common underlying objective: **using advanced bubble and cavitation technologies to improve the way water and wastewater processes perform.**

Ultimately, the future of industrial wastewater treatment may not lie in doing more. It may lie in **doing the first things better**—and turning pre-treatment from a preliminary requirement into a genuine performance advantage. ■

This technology-led approach is particularly relevant to sectors such as **oil and gas and power**, where treatment systems must balance performance with footprint, energy use, operational simplicity and reliability.

For more details, please contact:

For Prasinos Tech Innovations, therefore, CAF is not the destination, it is **one expression of a deeper technology platform built around cavitation, bubbles and process intensification.**

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Powering India's Energy Transition: The Evolving Role of Nuclear and Thermal Energy



S Narayana Prasad
Chief Executive Officer
Triveni Turbines

*India's energy transition depends on strengthening existing thermal and nuclear assets as much as it depends on building new renewable capacity, and on managing the grid stability challenge that a growing share of variable solar and wind power brings with it, emphasizes **S. Narayana Prasad, Chief Executive Officer, Triveni Turbines.***

India's power sector is adding renewable capacity at a record pace. Non-fossil sources now make up more than half of the country's installed generation base, according to Ministry of Power data¹. Even so, thermal power still supplies close to seventy percent of the electricity generated across the grid, and the government's Nuclear Energy Mission has set a target of raising nuclear capacity from under nine gigawatts today to 100 gigawatts by 2047², in line with India's broader net-zero-by-2070 commitment.

Extending the Life of Critical Energy Assets

Triveni Turbine's installed base includes more than 6,000 steam turbines, representing over 16 gigawatts of capacity and more than one billion cumulative operating hours. This base is evidence of a pattern the company has observed across the sector. Extending the life and improving the efficiency of an existing plant frequently

delivers more value, at a lower capital cost, than building a new one. That principle applies as much to nuclear and thermal assets as it does to any other class of energy infrastructure.

Supporting the Modernisation of India's Nuclear Infrastructure

India's nuclear expansion plans rely on lifecycle extension of operating plants, not new construction alone. Triveni Turbine has worked on modernization and retrofit projects tied to some of the oldest Atomic Power Station, India's first commercial nuclear facility, which has gone through multiple refurbishment and life-extension programmes over the years.

This work is a reminder that reliability enhancement and precision engineering carry the same weight as new-build capacity in a roadmap that calls for more than a tenfold increase in nuclear scale by mid-century. These

projects show how engineering expertise can help utilities raise asset utilisation without compromising on safety or reliability. Achieving the 2047 target will need this kind of asset-level work at scale, alongside new reactors and small modular reactor programmes now under development.

Enhancing Industrial Reliability through Retrofit Solutions in South Africa

Triveni Turbine's refurbishment and lifecycle-services business extends this approach beyond India. Its South African operations provide repair, refurbishment, modernisation, reverse engineering and efficiency upgrades for steam turbines and other rotating equipment used across the power, sugar, petrochemical and manufacturing sectors in the Southern African Development Community (SADC) region.

These services help customers cut downtime, extend asset life and improve operating efficiency without committing to major capital expenditure. This is a working example of a broader principle. Modernizing existing assets can add as much reliability to a system as new capacity does, whether the system in question is in India or elsewhere.

The Reinvention of Thermal Power

Thermal power's role is shifting from steady baseload generation to a far more demanding operating profile. Coal and gas plants are now called on for rapid ramping, better part-load efficiency and flexible output, largely to offset the variability of solar and wind generation. Efficiency gains in these plants are turning into a source of competitive advantage in their own right.

Across industries such as steel, cement, fertilisers, petrochemicals, sugar, paper and captive power generation, Triveni Turbine's customers want more output from the same steam-cycle assets. They want it delivered with less fuel and fewer emissions per unit of power. This is where the fastest decarbonisation gains sit. Upgrading a plant that already exists tends to cost less and move faster than commissioning a new one, at a time when the sector needs both speed and scale.

Building India's Energy Security on Existing Foundations

Triveni Turbine's reading of the sector places thermal and nuclear power alongside renewables as parts of the same transition, not as competing tracks. For India, keeping the installed thermal fleet efficient and extending the operating life of nuclear plants can support grid stability during the renewable build-out. It can cut fuel consumption and reduce emissions intensity, even as new capacity continues to come online.

Triveni Turbine's project history spans more than one billion turbine-operating hours across sectors and geographies, offered as one indicator of what a combined approach, resting on new capacity and modernised existing assets alike, can look like in practice. In a power system moving toward a lower-carbon mix, the company maintains that the assets already on the ground remain as central to that outcome as the ones yet to be built. ■

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Recent Trends in Steel Pipes Used for Oil & Gas Supply – API Grades



Rajiv Thakur
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*The oil and gas pipeline sector is moving from a simple “strength-based grade selection” toward a combination of high strength, weldability, fracture toughness, sour-service resistance, hydrogen compatibility, lower carbon footprint and life-cycle economics, emphasizes **Rajiv Thakur, President – Corporate Affairs, Fortran Steel Pvt Ltd.***

1. Shift toward higher-strength API 5L grades

The principal line-pipe grades remain API 5L X52, X60, X65, X70 and X80, with X70 increasingly representing an important high-strength grade for major transmission projects. X70 has a minimum yield strength of about 483 MPa, while X80 is about 552 MPa.

Key trend: X70 offers a good balance between strength, weldability, availability and cost. X80 becomes attractive where the reduction in wall thickness and steel tonnage can justify its higher qualification and fabrication requirements.



2. X70 is becoming the “sweet spot”

For long-distance transmission pipelines, increasing grade from X60/X65 to X70 can permit lower wall thickness for a given design pressure.

The benefits are:

- Lower steel consumption per length of pipe
- Lower pipeline weight
- Potentially lower transportation and handling costs



- Higher operating pressure capability
- Better economics for large-diameter pipelines
- Improved material efficiency

However, in actuality the industry is not simply moving toward the highest possible grade because of certain inherent weaknesses like Weldability, Fracture control & Toughness which leads to criticality in the field construction.



3. X80 adoption is increasing selectively

API 5L X80 is attractive for very high-pressure and large-diameter transmission systems because its higher yield strength can permit thinner pipe walls.

But X80 has challenges:

- More demanding steelmaking and TMCP control
- Greater sensitivity to welding parameters
- More stringent fracture-control requirements
- More specialised welding procedure qualification

- Fewer qualified manufacturing sources
- Higher concern regarding hydrogen-assisted cracking

Therefore, **X80 is generally a project-specific economic decision rather than an automatic replacement for X70**

4. PSL 2 is increasingly important

There is a clear movement toward **API 5L PSL 2** rather than PSL 1 for demanding oil & gas applications.

PSL 2 provides tighter control over:

- Chemical composition
- Yield and tensile strength
- Impact toughness
- Ductility
- Carbon equivalent
- Weldability



- Non-destructive testing
- Fracture resistance

For modern high-strength line pipe, **low carbon equivalent + high toughness + controlled microstructure** is becoming more important than simply achieving high tensile strength.

5. Sour-service pipe is a major specialised segment

Oil & gas production increasingly involves **H₂S-containing "sour" environments**. This creates serious concerns about:

- Hydrogen-induced cracking (HIC)
- Sulphide stress cracking (SSC)
- Stress-oriented hydrogen-induced cracking (SOHIC)

Consequently, pipe for sour service requires extremely clean steel, controlled inclusion morphology, low S/P, controlled segregation and appropriate HIC/SSC testing.

Interestingly, **higher strength does not automatically mean better pipe** for sour service. Some operators have historically restricted wet-sour applications to lower grades because increasing strength can increase susceptibility to hydrogen-related damage.

SI No	API 5L Grade	Min. Yield Strength	Typical application/ trend
1	X42	~290 MPa	Lower-pressure/ gathering lines
2	X52	~360 MPa	Gas, oil and general transmission
3	X60	~415 MPa	Higher-pressure transmission
4	X65	~450 MPa	High-pressure, sour/offshore applications
5	X70	~485 MPa	Major gas/oil transmission; high-pressure lines
6	X80	~555 MPa	Large-diameter, high-pressure transmission
7	X90–X120	Higher strength	Development/ limited specialised applications

Trend: Development is therefore moving toward **high-strength + sour-resistant grades**, rather than simply increasing yield strength.

6. Hydrogen is changing future API line-pipe requirements

One of the most important emerging trends is the potential use of existing and new pipelines for:

- Natural gas + hydrogen blends
- Pure hydrogen
- Hydrogen-rich gases
- Hydrogen transmission networks

Hydrogen can cause hydrogen embrittlement and **hydrogen-induced cracking**, making grade selection and microstructure particularly important.

Current research focuses heavily on X52, X65, X70 and X80 because these grades could potentially play roles in future hydrogen infrastructure. However, higher-strength grades can have greater hydrogen-related susceptibility, so X80/X100 cannot simply be assumed to be suitable for pure-H₂ service.

7. CO₂ pipelines and Carbon Capture & Storage (CCS)

The energy-transition economy is creating another important line-pipe market: CO₂ transportation pipelines for Carbon Capture, Utilisation and Storage.

These pipelines have different material challenges because CO₂ can cause severe corrosion and fracture-propagation concerns, particularly when water and impurities are present.

Consequently, pipeline steels are increasingly being developed and qualified not only for conventional oil and natural gas but also for CO₂ transportation.

8. TMCP and micro alloyed steels are becoming standard technology

Modern API 5L high-strength line pipes increasingly depend on thermo-mechanical controlled processing (TMCP) rather than simply adding more alloying elements.

Typical micro alloying involves controlled additions of:

- Nb

- V
- Ti

The objective is to obtain:

Fine-grained microstructure → high strength → high toughness → low carbon equivalent → good weldability

This is particularly important for X65/X70/X80 grades.

9. LSAW/HSAW and large-diameter pipe demand

For major transmission pipelines, there is continuing demand for **large-diameter welded line pipe**, particularly:

- LSAW/JCOE
- UOE
- HSAW/spiral welded pipe

Large-diameter pipes are particularly attractive for gas transmission because increasing diameter can significantly increase transportation capacity. For



offshore applications, however, grade selection is more complicated because **collapse resistance, wall thickness, bending and installation loads** can become more important than simply maximising yield strength.

10. Toughness and fracture control are becoming as important as strength

Modern pipeline design is increasingly concerned with preventing **running fractures**.

Therefore, buyers increasingly specify:

- Charpy impact toughness
- DWTT — Drop Weight Tear Test
- CTOD/fracture toughness where required
- Controlled Y/T ratio
- Full-body ultrasonic inspection
- Weld inspection
- Dimensional control
- Toughness at low operating temperatures

This represents an important change in philosophy:

The objective is no longer maximum strength; it is the optimum combination of strength, toughness, weldability and fracture resistance.

11. Sustainability is entering API line-pipe procurement

Large oil & gas companies are increasingly looking beyond the conventional purchase price.

Future procurement criteria can include:

Steel grade → manufacturing route → recycled content → energy consumption → CO₂ intensity → transport → coating → service life → recyclability

This creates opportunities for **low-carbon line-pipe steel**, including steel produced with greater scrap utilisation, renewable electricity and eventually hydrogen-based ironmaking.

Overall trend

The evolution can be represented as:

X52 → X60 → X65 → X70 → selective X80

but simultaneously:

Conventional line pipe → PSL 2 → sour-service resistant → hydrogen-compatible → CO₂/CCS-compatible → lower-carbon steel.

What this means for Indian steel & pipe manufacturers



For an Indian manufacturer looking at the API oil & gas market, the strongest opportunities are likely to be in:

1. **API 5L X65/X70 PSL 2**
2. Sour-service X65/X70 with HIC/SSC resistance
3. Large-diameter line pipe
4. High-toughness TMCP steels
5. X80 for selected high-pressure projects
6. Hydrogen-blend-compatible pipeline steels
7. CO₂/CCS pipeline grades
8. Low-carbon/API-certified line pipe
9. Higher-value customised grades rather than commodity API pipe

Summary

Strategically, X70 PSL 2 appears to be one of the most attractive grades to focus on because it sits at the intersection of high strength, material efficiency, weldability and established market acceptance. X80 and beyond are more specialised opportunities where project economics and qualification justify the additional complexity. ■

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(This is the second article of a 3-series on steel pipes used for transportation of oil and gas)

The part one of the series can be accessed here:



Kosol Energie Consolidating as a Trusted, Clean Energy Solutions Provider!



Kalpesh Kalthia
Chairman and Managing Director,
Kosol Energie Pvt. Ltd

*Gujarat-based Kosol Energie has embarked on a mission to drive the green energy revolution by developing products that free us from fossil fuel dependency. The company has termed this vision as – Empowering Solar Living – a step towards a sustainable, energy-independent future. In an exclusive interview with **Oil Gas & Power**, **Kalpesh Kalthia, Chairman and Managing Director, Kosol Energie Pvt. Ltd.**, reflects on the company's global footprint and its trajectory shaped by strategic expansion, a diverse product portfolio, and the pressing challenges confronting the renewable energy sector.*

Kosol Energie is one of India's leading brand in the solar industry, pioneering innovative solar solutions. Recalling the company's inception and the industry landscape at the time, Kalpesh Kalthia, Chairman and Managing Director, Kosol Energie Pvt. Ltd, explains, "We entered the photovoltaic (PV) module manufacturing space in 2012 with a firm commitment to uncompromising quality. At a time when automated solutions from China were virtually unavailable, we established a fully automated production environment by importing state-of-the-art equipment from Europe. Today, Kosol Energie's growth represents a strategic synthesis of rigorous engineering and innovative business models.

Our advanced setup incorporated electric laminators and premium raw materials, including high-grade EVA from Korea and DuPont's Tedlar-based backsheets."

Mr. Kalthia further noted, "Operating in a highly cost competitive market with a premium tier offering demanded rapid adaptation. While competitors leaned on standardized 25-year warranties, we distinguished ourselves by pioneering an 'Energy Guarantee' business model. By shifting the value proposition from mere equipment assurance to a guarantee of tangible financial returns for project owners, we effectively de-risked their investments and secured our position in the industry."



Product Diversification

Reflecting on product diversification, he said, “As we achieved economies of scale, our cost structure matured, enabling us to align premium quality standards with aggressive competitiveness in utility scale and commercial markets. This foundation allowed us to expand into targeted ecosystems; Sunray, our dedicated B2C brand, simplifies solar technology for residential consumers, while Koraam, our B2F (Business to Farmer) division, delivers decentralized infrastructure such as solar dryers and solar cold storage — empowering the agricultural sector.”

Looking ahead to the next frontier of grid integration and power continuity, Kosol Energie is embarking on a major expansion into Battery Energy Storage Systems (BESS) with a 6 GWh automated manufacturing facility. Speaking about this initiative, Mr. Kalthia remarked, “It is anchored in our commitment to technological sovereignty, featuring proprietary, indigenously developed Battery Management Systems (BMS) and Energy Management Systems (EMS) designed in house to optimize efficiency, safety, and performance across utility, industrial, and residential applications. Scaling these ventures requires navigating a complex macro environment defined by global supply chain volatility, fluctuating raw material costs, and evolving regulatory mandates. Ultimately, Kosol Energie continues to prove that long-term success in the renewable sector is achieved not merely through superior hardware, but by pairing technological rigor with the agility to meet the distinct needs of diverse market segments.”

Highlighting what sets Kosol's solar modules apart from other Indian and global manufacturers, Mr. Kalthia explained, “Kosol Energie's competitive edge lies in our identity as energy engineers who prioritize customer benefit above all else, ensuring every module delivers the lowest Levelized Cost of Energy

(LCOE) and maximum long-term value. Unlike standard manufacturers focused purely on volume, we differentiate ourselves through an uncompromising premium Bill of Materials (BOM) policy — employing POE-POE encapsulation, high transparency anti-reflective glass, and optimized ribbon sizes. These choices minimize cell to module losses, enhance low light performance, and ensure superior durability in harsh environments.”

Mr. Kalthia further emphasized, “Our operational agility distinguishes us both domestically and globally. With a multi-line manufacturing setup, we can simultaneously produce diverse high efficiency formats — from 500 Wp, 570 Wp, and 610 Wp TOPCon modules to specialized BIPV variants and rectangular G12R platforms — providing developers with tailored solutions that reduce balance of system costs. By combining this technology agnostic, LCOE-first design philosophy with resilient supply chains, strategic domestic cell partnerships, and expansion into integrated Battery Energy Storage Systems (BESS), Kosol Energie delivers an unmatched blend of cutting-edge efficiency, long-term reliability, and bankable project economics.”

Looking ahead, Kosol is preparing for emerging technologies such as green hydrogen and AI driven energy management. The company has taken bold steps in both domains. For AI enabled energy solutions, Kosol has partnered with Gridscape, a Silicon Valley pioneer in advanced microgrids and distributed energy systems since 2015. Speaking about this collaboration, Mr. Kalthia explained, “Through this strategic partnership, we are bringing Gridscape's proven, software driven microgrid technologies to India — integrating smart, AI powered controls and energy storage to enhance power reliability and grid resilience. On green hydrogen, Kosol Energie has already formulated a comprehensive internal strategy to enter and support this space, and we look forward to unveiling our strategic roadmap in the near future.”

Mr. Kalthia remarked, “Our operational agility sets us apart both globally and domestically. With a multi-line manufacturing setup, we can simultaneously produce diverse high efficiency formats — ranging from 500 Wp, 570 Wp, and 610 Wp TOPCon modules to specialized BIPV variants and rectangular G12R platforms — offering developers tailored solutions that reduce

balance of system costs. By combining this technology agnostic, LCOE-first design philosophy with resilient supply chains, strategic domestic cell partnerships, and expansion into integrated Battery Energy Storage Systems (BESS), Kosol Energie delivers an unmatched blend of cutting edge efficiency, long term reliability, and bankable project economics."

To reinforce its international presence, Kosol Energie is actively strengthening its reach across global markets, with exports to the USA, Mexico, Africa, and the Middle East. Mr. Kalthia explained, "Kosol Energie has built a strong physical footprint in North America, anchored by two corporate offices in California — San Jose and San Diego — supported by a strategically located network of regional warehouses across the United States. This direct local presence, combined with dedicated inventory hubs in key markets, enables us to deliver prompt customer support, streamlined logistics, and reliable lead times for our American partners."

He further added, "At the same time, we are expanding across the Middle East and Africa by preparing to enter full scale EPC services, leveraging our engineering expertise to deliver turnkey solar projects in these fast growing regions. By combining robust US infrastructure with EPC expansion in emerging markets, seamless international certifications, and advanced module platforms such as TOPCon and G12R, Kosol Energie is rapidly consolidating its position as a trusted, bankable global energy solutions provider."

Dedicated Brand Verticals

While, the residential, industrial, and agricultural sectors are driving the strongest growth, each demands distinct engineering focus, product innovation, and market attention to fully unlock its potential. Mr. Kalthia explained, "Recognizing these differences, Kosol Energie established two dedicated

brand verticals — Koraam for the agricultural sector and Sunray for individual and residential consumers —each supported by specialized operational teams. By giving these domains tailored focus rather than applying a one-size-fits-all approach, both Sunray and Koraam have expanded more than 2.5 times. Koraam continues to deliver deep rural impact through solar water pumping, dryers, cold storage, and bulk milk chilling solutions, while Sunray extends clean energy access directly to households with customized rooftop and solar living applications. Together, these verticals enable Kosol Energie to scale rapidly across multiple high growth fronts."

Elaborating on the unique features of these verticals, Mr. Kalthia added, "Koraam is our specialized brand dedicated to empowering the agricultural sector, driving rural prosperity and enhancing farmer income through innovations such as solar thermal dryers, cold storages, bulk milk chillers, and advanced pumping infrastructure. Sunray, on the other hand, is our customer centric brand designed to make clean energy accessible, seamlessly delivering solar living solutions to households, commercial users, and decentralized applications through offerings like solar water heaters, rooftop systems, and localized power packs. The core Kosol parent brand continues to power our large scale utility, C&I engineering, and high efficiency module manufacturing ecosystem, enabling us to serve every level of the market—from individual consumers and farmers to multi megawatt projects—with purpose built technology."

Kosol Energie's VFD-based solar pumping technology delivers a dual impact —empowering Indian farmers while simultaneously easing structural pressures on the national grid to support large-scale solar farms. Offering insight into the innovation, Mr. Kalthia explained, "Through our specialized Koraam vertical, we integrate Variable Frequency Drives (VFD) into agricultural pumps, enabling real-time optimization of motor speeds based on available solar irradiance. This maximizes water output for farmers — the true backbone of India — without dependence on erratic grid supply or costly diesel."

He further added, "From a macro-energy perspective, standalone solar pumps eliminate the need for expensive, long-distance agricultural grid extensions to remote rural areas, effectively decentralizing rural energy demand. By





removing heavy agricultural loads from the central grid during peak daytime hours, this technology alleviates transmission congestion and reduces feeder strain. In turn, India's grid infrastructure operates more efficiently, seamlessly absorbing power from large-scale utility solar farms and grid-connected projects."

As India's rapid growth drives rising electricity demand across rural and semi urban regions, grid infrastructure faces mounting strain — manifesting in frequent outages, severe voltage fluctuations, and erratic power quality that disrupts daily life and commercial operations. Mr. Kalthia explained, "Kosol's hybrid and off grid solar power packs directly address these critical challenges by serving as dependable, decentralized energy sources that deliver firm, uninterrupted power independent of grid instability. Designed to bridge the gap for diverse end users — from rural households and agricultural setups to village dairies, small processing units, and commercial factories — our power packs integrate high efficiency solar modules with intelligent power conditioning units and advanced energy storage. This ensures stable voltage, seamless backup, and protection against harmful voltage spikes, safeguarding sensitive equipment while enabling rural economies to scale sustainably without being constrained by grid limitations."

Kosol Energie's 3.3 GW annual production capacity aligns seamlessly with the vision of 'Make in India' and Atmanirbhar Bharat, reducing reliance on high volume solar imports by delivering world class, indigenously manufactured energy technology. Mr. Kalthia elaborated, "By establishing a fully operational 3.3 GW manufacturing footprint in India across four advanced, automated lines, we provide local developers and government utilities with the scale required to meet strict Domestic Content Requirement mandates — without depending on volatile foreign supply chains."

Mr. Kalpesh Kalthia highlighted, "Our state-of-the-art facilities actively advance India's manufacturing ecosystem by producing next generation technologies such as 610 Wp TOPCon, rectangular G12R formats, and specialized BIPV modules right here at home. This demonstrates that Indian made solar products can not only match but exceed global efficiency benchmarks, while simultaneously creating high tech employment opportunities and retaining economic value within the nation." Sharing his vision for Kosol's role in India's renewable energy journey,

he added, "Kosol Energie views its contribution to India's 2030 renewable energy targets as a complete, end-to-end commitment — grounded in delivering sustainable, reliable, and world class products, turnkey projects, and localized energy solutions. We are walking the talk toward net zero by transitioning our operational footprint so that our entire corporate and manufacturing campus is powered overwhelmingly by renewable energy."

He concluded, "Through our specialized brand verticals, Koraam and Sunray, we directly support farmers and individual consumers with targeted clean energy solutions, while our core Kosol platform powers industrial facilities, commercial enterprises, and large scale government PSUs with on time, bankable project execution. By scaling advanced domestic manufacturing to deliver high efficiency TOPCon and G12R modules, alongside BESS and microgrid integrations, Kosol Energie ensures that every sector of the Indian economy receives dependable, top tier technology — accelerating the nation's clean energy independence well before 2030." ■

Accelerated Engineering Project Execution Strategies & Role of Process Engineering

Oil and gas EPC projects face a significant challenge to deliver faster and within budget due to market volatility and geopolitical risks. As a result, accelerated engineering schedules are becoming common to improve efficiency and enable early monetization. While acceleration can bring benefits such as faster completion and better stakeholder satisfaction, it can also increase risk and create quality challenges. This article summarizes practical strategies for effective acceleration and explains how process engineering supported by digital tools and automation can help deliver key process inputs earlier for downstream disciplines.

Oil and gas EPC projects face numerous interconnected challenges. The key challenges include:

- Safety & regulatory requirements
- Scope management & design changes
- Cost & quality controls
- Procurement delays (long-lead items)
- Market volatility
- Social expectations
- Geopolitical risks etc.

In many EPC projects, engineering execution schedules are accelerated and timelines are compressed. Project delivery in a shorter span increases complexity in the project environment. It can also challenge the timely conduction of project milestone review meetings and the timely incorporation of their recommendations into engineering design deliverables. As a result, an 'Accelerated Project Schedule' is becoming a routine challenge for the project execution.

Accelerated Project Execution

Acceleration refers to speed up the work completion ahead of originally estimated time to provide flexibility to absorb changes (if any).

- Directed acceleration – typically driven by the client
- Unilateral or Voluntary acceleration – typically driven by the contractor.

Accelerated project execution offers numerous benefits:

Early Monetization: Meet critical start-of-production dates and enhance profit by ensuring early production.

Faster Project Completion: Reduce overall project timelines and help clients recover from unforeseen delays across multiple projects.

Cost Savings: Minimize costs through efficient resource utilization.

Progress Incentive: Contractor can enhance profit margins by getting incentives from client.

Stakeholder Satisfaction: Enhance confidence and satisfaction among stakeholders.

Competitive Advantage: Stay ahead of competitors by delivering projects faster.

Enhanced Flexibility: Early availability of machinery and manpower.

Better Resource Management: Optimize the use of available resources.

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Strategies for Effective Acceleration

Following strategies can effectively accelerate the project execution:

Optimized Design & Planning

This is a systematic, data-driven engineering approach that identifies the best possible solution among many alternatives. The following project management and engineering techniques can help achieve milestones when implemented effectively.

Early engagement of EPC Contractor (empanelment) during FEED:

- A strategic approach used to shorten the project schedules, minimize risks, and optimize costs, particularly in fast-track projects.
- Enables early procurement of long-lead items.

Competitive FEED:

- A strategy where multiple contractors are commissioned simultaneously to develop, optimize, and bid on the same project scope.
- By fostering competition during the design phase, owners can achieve better value engineering, lower costs, and reduced risk before finalizing the EPC contract.

Standardization/Modularization in design:

- Reduces complexity, cost, and development time while enabling high level of customization.



Strategies for effective acceleration.

- Standardization uses common components and processes, while modularization breaks systems into smaller, interchangeable units using standardized interfaces.
- Induces the 'Plug & Play' concept and reduces construction time at site.
- Integrated Project Delivery (IPD):
- A collaborative delivery method, which invites key subcontractors to be part of the design process.
- All parties provide constructability feedback in real time during the planning phase when its impact is most beneficial.
- If well executed, all parties share the financial incentives of a project being completed ahead of schedule and below budget.

Efficient Resource Management

There are ways to allocate resources efficiently to

Fast Tracking	Crashing
▪ Parallel processing (concurrent) rather than sequential. ▪ Overlapping activities on critical path. ▪ Repeat Vendors for Standard Materials. ▪ Pre-award tie-up for Long Lead items.	▪ Resources and Machineries are added to the critical path to speed up the schedule. ▪ Works well when the cost associated with finishing is high and when fast tracking doesn't accelerate the project fast enough. ▪ Crashing is chosen when there is financial penalty or milestone bonus.
Lean Engineering	
▪ This methodology applies lean principles to engineering processes, aiming to minimize waste and maximize customer value. ▪ It includes optimizing workflows, increasing productivity, reducing development time, and enhancing quality in design. ▪ Just-In-Time (JIT) is a lean production philosophy designed to increase efficiency and reduce waste by receiving goods only as needed in the process. ▪ This approach requires a high level of accuracy and quality of engineering.	



Efficient Resource Management

achieve acceleration such as Fast Tracking and Crashing.

Risk Management

It is a systematic approach of identifying, assessing, and mitigating threats or uncertainties that could negatively impact the project cost and schedule. Key Risk Management Techniques include:

Pre-emptive Risk Management:

- Identify potential risks early in the project lifecycle and develop mitigation strategies.

Risk mitigation: Develop and monitor risk mitigation plan and assign cost and schedule impact for identified risks.

Contingency Planning: Prepare an alternative strategy and allocate resources to manage potential disruptions, resource strain, plant and machinery availability.

Constructability Reviews: Operability and constructability review integrates safety concepts at early stage of project to enhance operational excellence. Encourage multidisciplinary participation.

Implementation of Lesson Learnt (LL) from past projects

- Organize interdisciplinary review of LLs at the beginning of the project to create awareness of all past lessons learned.
- Adopt Engineering Best Practices (EBPs).

Role of Process Engineering

Process engineering in oil and gas EPC projects is crucial for the successful execution of complex engineering projects. In accelerated project execution, the process discipline faces significant pressure to deliver key process deliverables ahead of schedule to provide timely data for downstream engineering disciplines.

Advance Techniques in Process Design

Advance techniques such as digital tools and automation plays a vital role in process design. The use of simulation software, digital twins, and intelligent P&IDs enhances planning and execution by visualizing processes and predicting outcomes.

The use automation to link deliverables from source data enhances accuracy and efficiency in process design by reducing manual intervention. These advance techniques have a potential to accelerate process engineering workflows.

These AI-enabled techniques are currently under development and experimentation. Adoption should include validation checks and QA/QC review to confirm accuracy before use in engineering deliverables.

Benefits of Techniques (Potential)

Increased Efficiency

- Automation and AI can significantly speed up repetitive and time-consuming tasks allowing engineers to focus on more complex and creative aspects of their work.

Cost Reduction

- Automating routine tasks can reduce manual effort and minimize errors that lead rework.

Improved Accuracy

- AI algorithms can analyse data with a high degree of precision, reducing the likelihood of human error.

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Some examples are described below:

PDF P&IDs -> LINE LIST AND MTO

- P&IDs are drafted through any drawing software and converted into PDF versions.
- PDF P&IDs are input to Artificial Intelligence (AI) driven Digital Tools.
- Tool identifies tags, lines, and symbols within PDF P&IDs.
- Automates Material Take-off (MTO) and line list generation from PDF P&IDs.
- Produces a comprehensive Bill of Material (BOM) and line list.
- This approach can reduce time and manual effort for data extraction.

PDF P&IDs → INTELLIGENT P&IDs

- Mark-up drawings containing schematics, comments, and handwritten text are input to AI-enabled digital tools.
- Tools recognize and process instructional text and schematics.
- Converts comments into actionable items and digitizes handwritten notes.
- Reduces manual editing time and effort.

CONVERT MARKUPS TO DRAWINGS

- Mark-up drawings containing schematics, comments and handwritten texts are input to AI driven Digital Tool.
- Tool recognizes and processes instructional text and schematics.
- Automatically converts comments into actionable items.
- Accurately identifies and digitizes handwritten notes.
- Reduces manual editing time and effort.

- This is beneficial for tasks such as predictive maintenance, where accurate data analysis can prevent equipment failures and extend the lifespan of machinery.

Takeaway

Accelerated project execution demands early planning, strong interface management, and disciplined design reviews. By leveraging acceleration strategies and incorporating process engineering advanced

techniques, oil and gas EPC projects can achieve shorter schedules with improved efficiency, cost performance, and stakeholder confidence.

The insights in this article can help industry professionals navigate accelerated schedules, understand the benefits and challenges of schedule compression, and recognize the role of process engineering in enabling faster and more reliable execution. ■

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From Port to Plant: Managing Complex Project Cargo for India's Chemical Industry

*For India's chemical industry, where plant development and expansion can involve increasingly complex equipment movements, project logistics needs to be integrated much earlier into the execution process. The objective is no longer simply to move a shipment from port to plant. It is to design a safe, feasible and well-planned journey from the first mile to the last, emphasizes **Santosh Chauhan, Head - Project Logistics & EPC Solutions, Triton Logistics & Maritime.***

India's chemical and petrochemical industry is closely linked to large-scale engineering and project development. Setting up or expanding a chemical plant can involve the movement of heavy engineering equipment, vessels, skids, compressors, machinery and other specialized components, many of which cannot be transported through conventional logistics networks.

For such projects, getting the cargo to an Indian port is only one part of the journey. The more complex challenge often begins after the vessel arrives. Moving oversized or heavy equipment from the port to the project site requires detailed planning across port infrastructure, road conditions, regulatory permissions, specialized transportation and last-mile access.

This is where project logistics differs significantly from conventional freight forwarding. It is not simply about moving cargo from one point to another. It is about engineering the movement before execution begins.

Planning before Movement

One of the most important lessons in project logistics is that poor planning can have consequences far beyond transportation costs. EPC projects operate against defined construction and commissioning schedules.

A delay in the movement of critical equipment can consequently affect activities further down the project timeline.

Logistics planning therefore needs to begin much before the cargo arrives at the port. The dimensions and weight of the equipment, discharge port, inland route, road infrastructure, permits, specialized equipment requirements and final delivery location all need to be studied beforehand.

Customers executing large EPC projects increasingly require logistics partners to look beyond port-to-port transportation. A shipment may move successfully across the ocean and still encounter difficulties during the final leg of its journey. For chemical projects, the real measure of successful execution is whether critical equipment reaches the project site safely and according to the required schedule. This has increased the importance of integrated first-mile and last-mile solutions.

This becomes particularly important for Over-Dimensional Cargo (ODC). Unlike standard containerized shipments, ODC movement may

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encounter restrictions that cannot be addressed after the cargo has already reached its destination port.

Choosing a Port is a Logistics Decision

Not every Indian port can accommodate every type of project cargo. Ports can have limitations related to draft, berth infrastructure, handling capability and even exit-gate dimensions. For example, if a piece of

Not every Indian port can accommodate every type of project cargo. Ports can have limitations related to draft, berth infrastructure, handling capability and even exit-gate dimensions. For example, if a piece of equipment is approximately seven metres wide but the selected port has an exit gate of only around five metres, the cargo cannot simply be moved out through the normal route.

equipment is approximately seven metres wide but the selected port has an exit gate of only around five metres, the cargo cannot simply be moved out through the normal route.

The logistics team then needs to examine whether modifications are feasible or whether another port offers a more practical solution. This illustrates why port selection for complex chemical project cargo should not be based only on proximity to the plant. A port that appears geographically closer may ultimately create greater complexity if the equipment cannot be discharged, handled or moved inland efficiently. The assessment therefore has to look at the complete journey from vessel discharge to the plant site.

Route Surveys can Determine Project Feasibility

Once the port is selected, inland movement requires an equally detailed study. For heavy and oversized cargo, route mapping needs to account for road restrictions, bridges, overhead electrical lines, turns, clearances and other physical obstacles. Certain movements may also require prior permissions from relevant authorities.

A conventional route used by trucks every day may not necessarily accommodate an ODC consignment. This makes a physical route survey an essential part of project planning. The objective is not simply to determine how many kilometres the cargo must travel, but whether it can physically complete that journey safely.

The route also needs to be considered in conjunction with the equipment that will transport the cargo. Heavy engineering equipment may require specialized trailers, lifting systems and handling arrangements. The availability of the right equipment and skilled manpower therefore becomes part of the planning process.

Moving beyond Port-to-Port Logistics

Customers executing large EPC projects increasingly require logistics partners to look beyond port-to-port transportation. A shipment may move successfully across the ocean and still encounter difficulties during the final leg of its journey. For chemical projects, the real measure of successful execution is whether critical equipment reaches the project site safely and according to the required schedule. This has increased the importance of integrated first-mile and last-mile solutions.

The logistics plan needs to connect ocean freight, port handling, customs and documentation, inland transportation and final site delivery rather than treating each as an independent movement. Multimodal planning can become particularly important when the size of the cargo, available infrastructure or project location makes a straightforward road movement difficult.

Documentation and Permissions cannot be an Afterthought

Project cargo can also be delayed by issues that have little to do with the physical movement itself. Heavy and over-dimensional cargo may require multiple permissions before it can travel on particular roads or through certain jurisdictions. Documentation at the destination also needs to be ready before the vessel and cargo arrive.

This is especially important for breakbulk and project vessels, where delays can create significant idle time and associated costs. A vessel waiting because the cargo cannot be cleared or moved inland affects not only that particular shipment but potentially the wider project schedule. The documentation, permits and physical logistics plan therefore have to progress together.

Geopolitics is adding Another Layer of Complexity

The current environment has made project logistics even more challenging. Geopolitical disruptions have affected shipping routes, vessel availability and cargo movement across several trade lanes. For project cargo, the challenge can be greater because specialized vessel capacity is not as easily substituted as standard freight capacity. Equipment shortages and manpower constraints can further complicate execution.

Chemical and petrochemical EPC companies therefore need contingency planning around routing, vessel availability and project schedules. Logistics plans developed months earlier may need to be reassessed as operating conditions change.



The current environment has made project logistics even more challenging. Geopolitical disruptions have affected shipping routes, vessel availability and cargo movement across several trade lanes. For project cargo, the challenge can be greater because specialized vessel capacity is not as easily substituted as standard freight capacity. Equipment shortages and manpower constraints can further complicate execution.



This reinforces the need for project logistics to function as a continuous planning exercise rather than a one-time freight booking.

Engineering the journey from Port to Plant

Ultimately, successful chemical project logistics depends on connecting engineering considerations

with transportation realities. Before equipment begins its journey, logistics teams need to ask some fundamental questions: Can the selected port handle the cargo? Can it pass through the port gate? Which inland route can accommodate its dimensions and weight? What permissions will be required? Is specialized transportation equipment available? How will it reach the plant site? And what alternatives exist if the original plan becomes unviable? These questions may appear operational, but their impact can extend to the overall cost and timeline of an EPC project.

For India's chemical industry, where plant development and expansion can involve increasingly complex equipment movements, project logistics needs to be integrated much earlier into the execution process. The objective is no longer simply to move a shipment from port to plant. It is to design a safe, feasible and well-planned journey from the first mile to the last.

For India's chemical industry, the future of project logistics will increasingly depend on one principle: the earlier logistics is engineered into the project, the greater the ability to control cost, schedule, and execution risk. ■

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Membrane Dehumidification & Heat Transfer: A Fresh Lens on HVAC Moisture Control

*As energy codes tighten and outdoor-air ventilation rates rise, engineers are increasingly looking outside conventional refrigeration for ways to decouple latent and sensible conditioning. Membrane-based dehumidification, a technology with roots in gas separation and chemical process engineering, offers exactly that decoupling. For readers who work daily with permeation, selectivity, and driving-force gradients in other separation duties, the underlying physics will feel familiar even though the application, conditioning building and process air, is comparatively new. This article examines the heat and mass transfer mechanisms that make membrane dehumidification work, how it is being integrated into HVAC architectures, and where the technology still needs to mature, explains **Ajay Sekar Chandrasekaran, Thermal Engineer, NVIDIA.***

Humidity control quietly consumes a disproportionate share of the energy budget in modern Heating, Ventilation and Air Conditioning (HVAC) systems. In most vapor-compression plants, moisture is removed by cooling air well below its dew point on a refrigerant coil, condensing the excess water, and then reheating the air back to the desired supply temperature. This “overcool-and-reheat” cycle is thermodynamically wasteful: it forces the compressor to handle a latent load that has nothing to do with the sensible cooling the space actually needs, and it throws away cooling capacity that must be replaced by heat.

As energy codes tighten and outdoor-air ventilation rates rise, engineers are increasingly looking outside conventional refrigeration for ways to decouple latent and sensible conditioning. Membrane-based dehumidification, a technology with roots in gas separation and chemical process engineering, offers exactly that decoupling. For readers who work daily with permeation, selectivity, and driving-force

gradients in other separation duties, the underlying physics will feel familiar even though the application, conditioning building and process air, is comparatively new.

Mass and Heat Transfer Fundamentals

A dehumidification membrane is a thin, selectively permeable barrier, typically a dense hydrophilic polymer layer supported on a porous substrate that allows water vapor to pass through far more readily than nitrogen or oxygen. The driving force is not a pressure difference in the mechanical sense but a difference in water vapor partial pressure (or, equivalently, vapor activity) between the two faces of the membrane.

Moist process air on one side presents a high vapor partial pressure; a drier sweep stream, a vacuum, or a regenerable liquid on the permeate side maintains a low partial pressure. Water molecules dissolve into the polymer at the feed face, diffuse across the membrane

thickness, and desorb into the permeate stream, a solution-diffusion mechanism familiar to anyone who has worked with reverse-osmosis or gas-separation membranes.

Because the water is transported as vapor rather than condensed as liquid, the latent heat of vaporization is not rejected inside the membrane module the way it would be on a chilled coil. That heat effectively travels with the vapor into the permeate stream. This is the central thermodynamic advantage: dehumidification and cooling become two separable unit operations rather than one forced compromise. At the same time, sensible heat transfer does not disappear. In most practical modules the feed and permeate (or exhaust) streams also exchange temperature across the same membrane or an adjacent plate, so the device behaves as a combined total-enthalpy exchanger, moving both moisture and sensible heat simultaneously. Describing performance therefore requires two coupled transport equations, one for water vapor flux driven by the partial-pressure gradient and permeance of the membrane, and one for sensible heat flux driven by the temperature gradient and the effective heat transfer coefficient of the flow channels.

The two are not independent: condensation-free vapor transport changes the local temperature profile, which in turn shifts the vapor pressure gradient along the length of the module. Good module design keeps the two streams in a counter-current arrangement precisely to sustain both gradients as far as possible along the flow path. Practitioners familiar with simultaneous heat and mass transfer in absorption or drying operations will recognise the analogy: the Lewis-number-like coupling between temperature and vapor concentration fields means a module cannot be optimised for moisture removal alone without also accounting for how the accompanying sensible exchange reshapes the driving force it depends on.

In illustrative operation, a membrane module handling outdoor air at 32 degrees Celsius and a humidity ratio near 21 grams of water per kilogram of dry air can typically deliver an exiting stream in the range of 10 to 14 grams per kilogram, a reduction achieved without the process air ever being cooled below its own dew point. The corresponding permeate or exhaust stream picks up that moisture and a share of the sensible heat, so the net effect downstream is a smaller enthalpy difference for the cooling coil to close, rather than a bypassed dehumidification step.

Membrane Materials and Module Configuration

Most commercial dehumidification membranes use hydrophilic, non-porous selective layers, sulfonated fluoropolymers, cellulose derivatives, and polyimide or polyamide composites are common choices, cast onto a mechanically robust microporous support that provides strength without adding significant vapor resistance. Modules are built as hollow-fibre bundles, spiral-wound sheets, or flat-plate cross-flow stacks, largely mirroring geometries already familiar from membrane gas separation and energy-recovery ventilator design. Flat-plate cross-flow or counter-flow stacks dominate HVAC applications because they can simultaneously carry a secondary air path for sensible heat exchange, whereas hollow-fibre modules are more common where only vapor separation, without heat recovery, is required. Permeate-side vacuum, a dry purge air stream, or a hygroscopic liquid desiccant sweep are all used to keep the permeate-side vapor pressure low; the choice affects parasitic energy use as much as the membrane itself does.

Integrating Membranes into HVAC Architecture

The clearest entry point for membrane dehumidification in building systems is the Dedicated Outdoor Air System (DOAS). Ventilation air, which carries a disproportionate share of a building's latent load, especially in humid climates, is passed through a membrane module before it ever reaches the cooling coil.

The coil is then left to handle sensible cooling almost exclusively, which allows it to run at a higher, more efficient evaporating temperature since it no longer needs to be driven below the dew point purely to wring out moisture.

A second, closely related configuration is the membrane Energy-Recovery Ventilator (ERV), where the exhaust air stream leaving a conditioned space is routed as the counter-current permeate path. The dry, cool exhaust air both absorbs moisture from and exchanges sensible heat with the incoming outdoor air, preconditioning it before it reaches the coil at essentially no compressor energy cost.

In new commercial buildings and data-centre support spaces, this combination, membrane preconditioning ahead of a right-sized coil, is being evaluated as a way to trim both installed refrigeration tonnage and annual energy use simultaneously.

FEATURES

Parameter	Membrane Dehumidification	Cooling-Coil Condensation	Solid Desiccant Wheel
Separation principle	Vapour-pressure-driven permeation through a hydrophilic membrane	Condensation on a surface held below the air dew point	Sorption onto a rotating desiccant matrix
Latent heat handling	Carried out with the permeate vapour; not rejected as a sensible refrigeration load	Rejected via the refrigerant at the evaporator	Released as sensible heat during regeneration
Typical reheat requirement	Minimal to none	High, to offset overcooling	Moderate; post-wheel air is already warm
Auxiliary energy driver	Sweep air, vacuum pump, or purge fan	Compressor work	Regeneration heat source
Maintenance profile	Sealed, no moving parts; periodic filtration upkeep	Coil cleaning and refrigerant servicing	Wheel motor, seals, and periodic desiccant renewal
Best-fit duty	Latent-load pre-treatment ahead of a coil in DOAS/ERV systems	Combined sensible and latent cooling, general duty	High-latent, low-dew-point industrial drying

Table 1. Comparative overview of HVAC dehumidification approaches.

Table 1 summarises how membrane dehumidification compares with the two dominant conventional approaches on the metrics that matter most to a plant engineer specifying a system.

The pattern in Table 1 is consistent with the physics described above: membranes trade higher capital cost and larger footprint per unit of moisture removed for a meaningful reduction in reheat energy and compressor cycling, an attractive trade in climates or process spaces where latent load dominates.

Figure 1 illustrates schematically how a membrane module sits within a DOAS-plus-coil arrangement, showing the counter-current process and exhaust streams and the point at which sensible heat and water vapour are exchanged before the conditioned coil.

Applications Relevant to the Process Industry

For chemical engineers, the appeal of membrane dehumidification extends beyond comfort cooling. Pharmaceutical packaging lines, powder-handling and battery-material dry rooms, and food-processing areas

all require tight humidity control without introducing refrigerant piping risk or airborne desiccant particulate near sensitive product. Membrane modules, being fully sealed, solid-state contactors, avoid both concerns. Coastal and monsoon-climate facilities across India face particularly high latent loads for much of the year; a membrane-assisted DOAS can substantially cut the sensible-cooling capacity that would otherwise sit idle simply to satisfy dehumidification, freeing chiller capacity for genuine process cooling duty elsewhere in the plant.

Challenges and Outlook

Membrane dehumidification is not a drop-in replacement for the cooling coil. Vapor flux per unit membrane area remains modest compared with the moisture-removal rate of a condensing coil, so large air volumes require correspondingly large membrane area, and therefore larger, more expensive modules. Long-term fouling from particulates and, in some formulations, gradual loss of hydrophilic selectivity under continuous cycling remain active areas of membrane materials research.

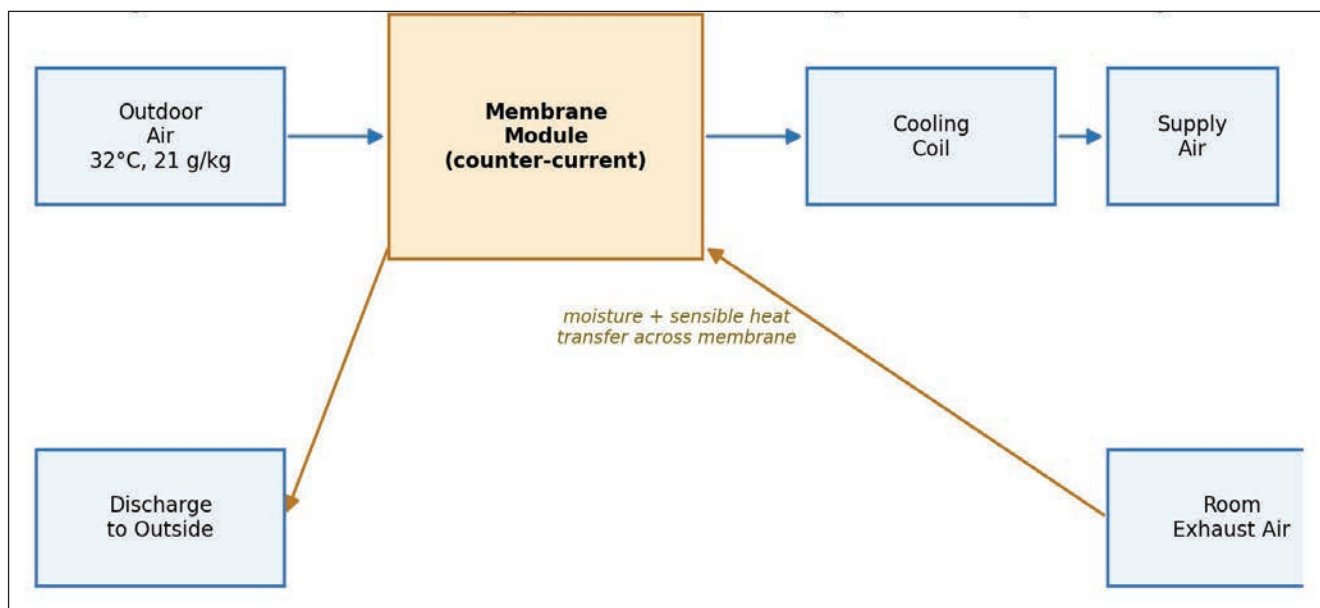


Figure 1: Membrane module integrated ahead of the cooling coil in a DOAS/ERV arrangement.

Maintaining a strong permeate-side vapor pressure gradient also consumes auxiliary energy, whether through a vacuum pump, purge fan, or desiccant regeneration loop, and this parasitic load must be counted honestly against the reheat energy it displaces. The most promising near-term direction is hybridization: pairing a membrane pre-conditioner with a right-sized vapor-compression coil, or coupling membrane vapor separation with waste heat already available on site for permeate-side regeneration, rather than expecting membranes to shoulder the entire latent and sensible load alone.

Conclusion

Membrane dehumidification reframes humidity control as a mass transfer problem rather than a refrigeration problem, which is precisely the vantage point chemical engineers are trained to occupy. By separating water vapor transport from sensible cooling, it removes the energy penalty built into the conventional overcool-and-reheat cycle and opens a genuinely interdisciplinary design space between membrane science and HVAC engineering. The technology is not yet ready to displace the cooling coil outright, but as a targeted latent-load pre-treatment within DOAS and energy-recovery systems, it already offers a credible, physically grounded route to lower-energy humidity control in the buildings and process spaces where it matters most. ■

ABOUT THE AUTHOR

Ajay Sekar Chandrasekaran is thermal engineer at NVIDIA. He has a Masters degree in Mechanical Engineering from Purdue University, USA and a Bachelor's degree in Mechanical Engineering from PSG College of Engineering, India. During his tenure as graduate student at Purdue, Ajay's thesis work was centered around design, operation and validation of membrane based dehumidification systems.



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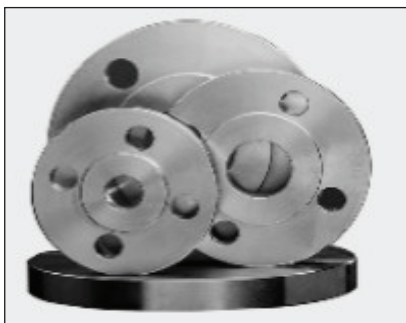
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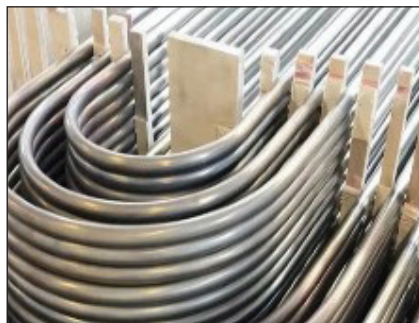
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From Hydrogen to Data Centers: The Evolving Role of Expanded PTFE Sealing Technology



Author

Giovanni Pasqua

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*Industrial transformation is creating a new generation of sealing challenges. Hydrogen infrastructure, carbon capture, utilization and storage (CCUS), high-performance data centers and other emerging technologies are placing increasingly demanding requirements on fluid-handling systems. Although these applications are very different, they share a common requirement: the integrity of every connection is critical. A relatively small sealing component can influence system efficiency, emissions, equipment reliability and process safety, emphasizes **Giovanni Pasqua, International Business Development Manager, KWO Dichtungstechnik GmbH.***

Expanded polytetrafluoroethylene (ePTFE) is already well established in chemical processing and other industries handling aggressive media. Today, however, its combination of broad chemical resistance, high conformability and adaptable mechanical characteristics is creating opportunities in applications that were hardly considered when the technology was originally developed.

The challenge is no longer simply to identify a material that is chemically compatible with the process fluid. Modern sealing engineering must determine whether the gasket can establish and maintain the required tightness throughout the operating life of the connection.

Why Expanded PTFE?

PTFE is known for its exceptional chemical resistance, broad temperature capability and resistance to ageing. Through a controlled expansion process, PTFE develops a characteristic microscopic structure consisting of nodes interconnected by fibrils.

This expanded structure gives the material a high degree of conformability, allowing it to compensate for surface irregularities and establish a seal at comparatively low gasket stresses. This can be particularly valuable on large flanges, irregular sealing surfaces and equipment where excessive bolt loading must be avoided.

These characteristics are increasingly relevant as sealing technology moves into new applications.

Hydrogen: Tightness Becomes Increasingly Important

Hydrogen is expected to play a role in the decarbonization of sectors where direct electrification can be difficult, including parts of heavy industry, chemical production and long-duration energy storage.

From a sealing perspective, hydrogen presents particular challenges. Its small molecular size places strong demands on the tightness of connections. Systems may also operate under significant pressure and experience pressure and temperature cycles. This means that selecting a gasket based only on the chemical compatibility of PTFE with hydrogen would be insufficient.

The ability of the gasket to conform to flange surfaces, achieve the required tightness and maintain sufficient gasket stress during operation becomes equally important. Bolt load, flange stiffness, surface finish, temperature and pressure therefore need to be evaluated together.

Expanded PTFE can be considered for various hydrogen-related sealing duties where its chemical resistance and conformability are advantageous. However, there is no universal “hydrogen gasket.” Suitability must be established for the actual operating conditions and connection design.

This illustrates a broader development in sealing engineering: as allowable emissions and leakage expectations become more demanding, material compatibility must increasingly be combined with quantified tightness performance.

CCUS: More Than Simply Sealing CO₂

Carbon capture, utilization and storage (CCUS) is another rapidly developing field where sealing technology will play an important supporting role. A CCUS chain can include CO₂ capture, treatment, compression, transportation, injection and storage. The conditions encountered at different stages can vary considerably.

Furthermore, captured CO₂ streams are not necessarily pure. Depending on the source and process, they can contain moisture and various impurities. Pressure, temperature and physical state may also change throughout the system.

For gasket selection, the question therefore cannot simply be whether a material is “compatible with CO₂.”

The actual process composition and operating conditions must be considered, together with the mechanical characteristics of the connection.

Here, the broad chemical resistance of PTFE provides an interesting foundation. Expanded PTFE adds the ability to adapt to flange surfaces and can offer advantages where chemical resistance and reliable sealing need to be combined.

At the same time, CCUS demonstrates why application-specific engineering is essential. A gasket used in a capture plant, for example, may experience conditions very different from one installed in a CO₂ transport or compression system. The entire sealing system must therefore be evaluated rather than treating CCUS as a single operating condition.

Data Center Cooling: A Very Different Sealing Challenge

Perhaps one of the less obvious emerging applications for advanced sealing materials can be found in data centers.

The rapid growth of artificial intelligence and high-performance computing is dramatically increasing computing density and associated heat generation. As thermal loads rise, liquid-based cooling architectures are becoming increasingly important alongside traditional air cooling.

This creates a new fluid-handling environment involving cooling distribution units, pumps, piping, manifolds, heat exchangers and other equipment.

The process conditions may appear less severe than those encountered in a chemical plant, but the consequences of leakage can be significant. Cooling systems operate in close proximity to extremely valuable electronic equipment, making long-term connection reliability particularly important.

Different cooling architectures may also use different fluid chemistries, and systems can experience temperature changes and repeated operating cycles.

For sealing engineers, the application therefore requires a different balance of properties: chemical compatibility with the coolant, high conformability, reliable sealing at the available bolt load and stability over repeated thermal cycles.

Expanded PTFE sealing solutions can potentially address a range of these requirements, particularly in auxiliary piping, cooling distribution equipment and heat exchangers. As always, the specific material and gasket design must be selected according to the actual system.

Beyond Today's Traditional Applications

Hydrogen, CCUS and data-center cooling are only three examples of how the environment for industrial sealing is changing.

Battery production, semiconductor manufacturing, electrolyzers, fuel cells, alternative fuels and high-purity processing are creating additional applications where chemical resistance, cleanliness, tightness and controlled mechanical behaviour can be important.

These industries also demonstrate an interesting evolution in gasket requirements. Historically, gasket selection was often strongly associated with pressure, temperature and chemical compatibility. Those parameters remain fundamental, but new applications increasingly add requirements related to emissions, purity, reliability, energy efficiency and lifecycle performance.

The result is a move from simple material selection toward engineered sealing solutions.

From Material Compatibility to Sealing Engineering

Modern gasket characterization reflects this development. Test methodologies such as EN 13555 allow important gasket properties, including minimum seating stress, tightness behaviour, maximum allowable gasket stress and creep/relaxation, to be quantified. Such data can then support calculations

of the complete bolted connection, for example according to EN 1591-1.

Sealing the Technologies of the Future

Expanded PTFE has evolved from a material primarily associated with chemically aggressive industrial applications into a versatile sealing technology capable of addressing a much broader range of engineering challenges.

Its future role will not depend simply on the inherent properties of PTFE. It will depend on how material structure, gasket design, testing and bolted-joint engineering are combined to meet the requirements of each application.

Hydrogen requires increasingly controlled leakage performance. CCUS combines complex process streams with demanding operating conditions. Data-center liquid cooling places exceptional value on reliability and leak prevention. Other emerging industries will introduce their own challenges.

What connects them is the need to look beyond basic material compatibility.

As industrial technology evolves, the question for sealing engineers is therefore changing from "Can this material resist the medium?" to **"Can this sealing system maintain the required performance throughout the complete operating cycle?"**

That shift from material selection to sealing engineering is likely to define the next generation of expanded PTFE applications. ■

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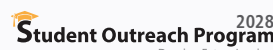


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