29th Energy Technology and innovation Meet

Technical Compendium

Accelerating Energy Innovation:
From Research to Commercialization

27-29 OCTOBER 2026 · URJA BHARAT CONVENTION CENTRE (UBCC), ATI-ONGC, GOA

Organised by Centre for High Technology, Ministry of Petroleum & Natural Gas, Government of India
Co-hosted by Hindustan Petroleum Corporation Limited

पेट्रोलियम एवं प्राकृतिक गैस मंत्रालय
MINISTRY OF PETROLEUM AND NATURAL GAS
सत्यमेव जयते
सीएचटी Centre For High Technology
Ministry of Petroleum & Natural Gas
Government of India
HP
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Contents

What you will find in this compendium

01 Messages

From the Ministry of Petroleum & Natural Gas, HPCL and CHT

- Hon'ble Minister of Petroleum & Natural Gas
- Hon'ble Minister of State, Petroleum & Natural Gas
- Secretary, MoPNG
- Joint Secretary (R&M), MoPNG
- Chairman & Managing Director, HPCL
- Foreword by the Executive Director, CHT

02 Centre for High Technology

- Indian Refining Scenario
- Refinery, Pipeline & Petrochemical Benchmarking
- LPG Supply Management during West Asia Crisis
- GOBARdhan and PM JI-VAN Yojana
- Joint Working Groups constituted by DCPC
- Green Hydrogen in Refineries: SIGHT Mode 2B

03 Technical Abstracts

95 papers from refiners, research institutions, technology licensors and start-ups

24 Refining, Catalysts & Petrochemicals
15 Biofuels, CBG & Waste to Value
9 Carbon Capture & Decarbonisation
22 Digital, AI & Automation
12 Hydrogen & Fuel Cells
13 Energy Efficiency, Power & Reliability

Hardeep S Puri

Hon'ble Minister of Petroleum & Natural Gas

हरदीप एस पुरी
HARDEEP S PURI

सत्यमेव जयते

मंत्री
पेट्रोलियम एवं प्राकृतिक गैस
भारत सरकार
Minister
Petroleum and Natural Gas
Government of India

MESSAGE

India's progress towards energy self-reliance depends on our ability to turn research into technologies that industry can deploy at scale. Under the leadership of Prime Minister Shri Narendra Modi, initiatives such as Samudra Manthan for offshore exploration and GOBARdhan for compressed biogas provide opportunities to apply Indian science and engineering to the country's energy needs. Developing these capabilities will help us secure reliable and affordable energy for a Viksit Bharat.

The theme of the 29th Energy Technology and Innovation Meet, "Accelerating Energy Innovation: From Research to Commercialization", calls for close engagement between those who develop new technologies and those who will use them. Promising technologies need opportunities to prove their reliability under operating conditions and demonstrate their commercial viability. Our energy companies have an important role in this: working with research institutions and start-ups from an early stage, providing facilities for trials and demonstration, and supporting the adoption of successful technologies.

I hope ETM 2026 will strengthen these partnerships, bring more Indian technologies into commercial use, and enhance our ability to compete internationally. I congratulate the Centre for High Technology and its co-host, Hindustan Petroleum Corporation Limited, and extend my best wishes to all participants for fruitful deliberations and a successful meet.

(Hardeep S Puri)

Place : New Delhi
Date : 21 October, 2026

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Suresh Gopi

Hon'ble Minister of State, Petroleum & Natural Gas

It gives me great pleasure that the 29th Energy Technology and innovation Meet is being held in Goa, organised by the Centre for High Technology and co-hosted by Hindustan Petroleum Corporation Limited.

The true measure of our energy sector is what it means for the common citizen. During this year's supply disruption in West Asia, the industry kept cooking gas flowing to over 33 crore families. Through GOBARdhan and PM JI-VAN Yojana, crop residue and waste are becoming clean fuel and a new source of income for our farmers.

I am glad that ETM 2026 has opened its doors to the CBG ecosystem, advanced biofuels, start-ups and academia. This compendium brings together their work alongside that of our oil companies.

I hope it inspires many more to take ideas from research to commercialization. My best wishes to CHT, HPCL and every participant for a fruitful meet.

(Suresh Gopi)

Minister of State for Petroleum & Natural Gas
Government of India

New Delhi, October 2026

Dr. Neeraj Mittal

Secretary, Ministry of Petroleum & Natural Gas

I am pleased that the Centre for High Technology, with Hindustan Petroleum Corporation Limited as co-host, is organising the 29th Energy Technology and innovation Meet. Much larger than the last edition, it runs five parallel technical sessions, integrates the FIPI R&D Conclave and opens ETM to the CBG ecosystem, advanced biofuels, start-ups and academia.

As the Ministry's technical arm, CHT has shown its value this year. Benchmarking has lifted PSU refinery efficiency, and Mission Q1 targets top-quartile performance by 2030. During the West Asia crisis, CHT helped protect household LPG while keeping critical chemical and pharmaceutical supply chains running. Under SIGHT Mode 2B, green hydrogen has been awarded to PSU refineries at prices as low as ₹279 per kg.

The theme, *Accelerating Energy Innovation: From Research to Commercialization*, calls on us to shorten the path from idea to plant. I urge oil companies, research institutions and start-ups to use this meet to build partnerships with measurable outcomes. My congratulations to CHT and HPCL.

[Dr. Neeraj Mittal]

Secretary
Ministry of Petroleum & Natural Gas
Government of India

New Delhi, October 2026

Sujata Sharma

Joint Secretary (Refineries & Marketing), MoPNG

It is a pleasure to present this Technical Compendium for the 29th Energy Technology and innovation Meet, organised by the Centre for High Technology and co-hosted by HPCL. With five parallel technical sessions, this edition is bigger and broader than the last.

Indian refineries processed 272 MMT of crude oil in 2025-26, operating at 105.4% of their installed capacity. Building on this strong performance, Mission Q1 sets an ambitious target: to position India's PSU refineries in the global top quartile for energy efficiency and operational availability by 2030.

This compendium is a resource for that journey. Part 1 covers the refining scenario, benchmarking, how the industry secured LPG supplies during the West Asia crisis, GOBARdhan, PM JI-VAN and green hydrogen. Part 2 carries abstracts of technical papers from oil companies, research centres, academia and start-ups.

I encourage refinery and R&D teams to take the most promising of these ideas from trial to deployment. My compliments to CHT and the authors.

(Sujata Sharma)

Joint Secretary (Refineries & Marketing)
Ministry of Petroleum & Natural Gas
Government of India

New Delhi, October 2026

Vikas Kaushal

Chairman & Managing Director, HPCL

India’s energy future will be shaped by our ability to turn innovation into impact.

Technology must enable us to meet growing demand while strengthening competitiveness and accelerating decarbonisation.

I warmly welcome delegates to the 29th Energy Technology and innovation Meet in Goa, co-hosted by Hindustan Petroleum Corporation Limited.

From advanced process technologies and cleaner fuels to circularity, the opportunity is to create greater value from every unit of input.

Success will depend on how quickly we translate promising ideas into reliable and commercially viable solutions.

Our shared priority must be to shorten the journey from research to deployment. Stronger collaboration among industry, academia, technology providers and start-ups can accelerate adoption and position India as a leader in energy innovation.

This compendium brings together knowledge and experience to support that endeavour. I commend the Centre for High Technology, the authors and all contributors, and wish delegates productive deliberations and enduring partnerships.

May the ideas exchanged here become practical solutions that strengthen India’s energy future.

(Vikas Kaushal)
Chairman & Managing Director
Hindustan Petroleum Corporation Limited

Mumbai, October 2026

Sankar Gunasekaran

Executive Director, Centre for High Technology

Since 1987, the Centre for High Technology has served as the technical arm of the Ministry of Petroleum & Natural Gas, building indigenous capability in the hydrocarbon sector. The Energy Technology and innovation Meet, now in its 29th edition, is our principal forum for sharing this work with industry.

ETM 2026, co-hosted with HPCL at ATI-ONGC, Goa, is our largest edition yet: 2,500+ delegates, 250+ speakers, 44 technical sessions across five parallel tracks and 200+ exhibition stalls. With the FIPI R&D Conclave, MC² and a State-level CBG Conference joining ETM, the meet now spans the energy value chain, from upstream oil and gas and refining to CBG, advanced biofuels, academia and start-ups.

This Compendium brings CHT's sector analysis together with papers from innovators across that value chain. We hope it serves engineers, researchers and decision-makers as a ready reference and a starting point for new partnerships.

In keeping with the theme, *Accelerating Energy Innovation: From Research to Commercialization*, ETM 2026 is built around outcomes, including about ten MoUs with IITs and national institutes for sponsored PhD programmes, and new business partnerships through the exhibition. CHT will follow up on the most promising ideas from this meet and help take them from pilot to plant scale. I thank the Ministry for its guidance, HPCL for co-hosting, ONGC for the venue, and the authors, reviewers and CHT team for their contributions.

(Sankar Gunasekaran)
Executive Director
Centre for High Technology
Ministry of Petroleum & Natural Gas
Government of India

Noida, October 2026

29TH ETM 2026 · COMPENDIUM

Centre for High Technology

Technical wing of the Ministry of Petroleum & Natural Gas

ORGANISED BY

Centre for High Technology
Ministry of Petroleum & Natural Gas, Government of India

CO-HOSTED BY

Hindustan Petroleum Corporation Limited (HPCL)

ETM 2026 · ORGANISER

CENTRE FOR HIGH TECHNOLOGY (CHT)

Technical Arm of the Ministry of Petroleum & Natural Gas, Government of India

The **Centre for High Technology (CHT)** serves as the technical wing of the Ministry of Petroleum and Natural Gas (MoP&NG), Government of India. Providing scientific, technological, and strategic support to the downstream hydrocarbon sector, CHT has spent nearly four decades modernising India's energy infrastructure. The organization functions as a vital hub for assessing futuristic demands and acquiring new technological capabilities. By driving operational excellence, sustainability, and energy efficiency, CHT continuously enhances the competitiveness of India's petroleum refining, petrochemical, pipeline, and clean energy sectors through meticulous benchmarking and the adoption of global best practices.

CORE AREAS OF WORK

Performance benchmarking

Coordinates refinery, pipeline and petrochemical benchmarking with global agencies to close gaps in energy efficiency, reliability and cost competitiveness.

Energy conservation & sustainability

National facilitator for energy conservation in the downstream sector; drives studies, technical surveys and roadmaps aligned with India’s energy-transition goals.

Clean-energy initiatives

Implementation agency for flagship Government of India programmes: GOBARdhan, advanced biofuels, Green Hydrogen, SAF, Compressed Biogas, Biomass aggregation and related Pipeline infrastructure.

R&D, innovation & indigenous technology

Coordinates R&D on Refining & Petrochemicals, Green Hydrogen, fuel cells, Biofuels, catalysts and import substitution advancing Atmanirbhar Bharat.

Knowledge dissemination

Organizing conferences, Technical Workshops, Activity Committee Meets and Webinars. The annual flagship Energy Technology & innovation Meet (ETM) is a premier forum for industry, researchers, technology providers, academia, start-ups and policymakers.

Advisory & regulatory support

Extending Technical assistance to MoPNG and supporting Govt. Procurement policies promoting Atmanirbhar Bharat.

SECTION 01

Indian Refining Scenario

India in the global refining landscape

With an installed capacity of **267.1 MMTPA**, India is the **fourth-largest refiner in the world**, and the third-largest crude oil importer. Reliance Industries' Jamnagar complex 33.0 MMTPA in the domestic tariff area (DTA) and 35.2 MMTPA in the special economic zone (SEZ) is the world's largest refining site. The Energy Institute's *Statistical Review of World Energy 2025* places India's share of global refining capacity at about 4.9% in 2025, behind China (17.7%), the United States (17.6%) and Russia (6.5%).

267.1
MMTPA Installed refining capacity (2026)

4th
largest refiner in the world

23
operating refineries

105.4%
capacity utilisation, 2025-26

Capacity and ownership

India's refining capacity has risen from 215.1 MMTPA in 2014 to 267.1 MMTPA in 2026, marking a substantial growth of approximately 24%.

Ownership and Structure (2026)

The country operates 23 active refineries:

Public Sector (PSUs)
19 refineries
commanding 62.7% of the nation's total capacity.

Private Sector
3 refineries.

Joint Venture
1 refinery.

The 23rd refinery, HPCL Rajasthan Refinery Ltd (HRRL), located at Pachpadra, Barmer, was officially dedicated to the nation by the Hon'ble Prime Minister on 4 July 2026. This integrated facility pairs a 9 MMTPA refinery with an advanced petrochemical complex.

Capacity Utilisation Excellence

Indian refineries consistently run above nameplate capacity due to robust domestic demand, operational efficiency, and aggressive debottlenecking:

Crude Processed (2025-26)
272 MMT

Design Capacity (2025-26)
258.1 MMTPA

Utilisation Rate
105.4%

Growth Projections (2029-30)

Driven by public sector expansions, India's refining infrastructure is poised for major growth over the next few years:

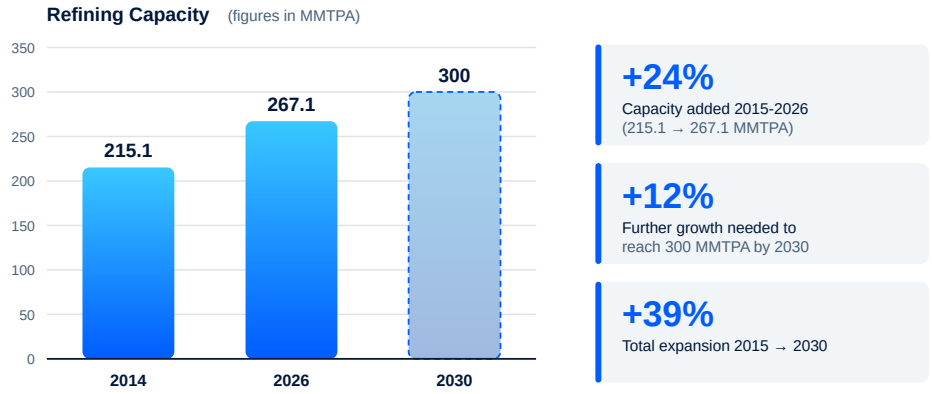


Figure 1. Growth of India's refining capacity, 2014-2030.

Refineries at a Glance:

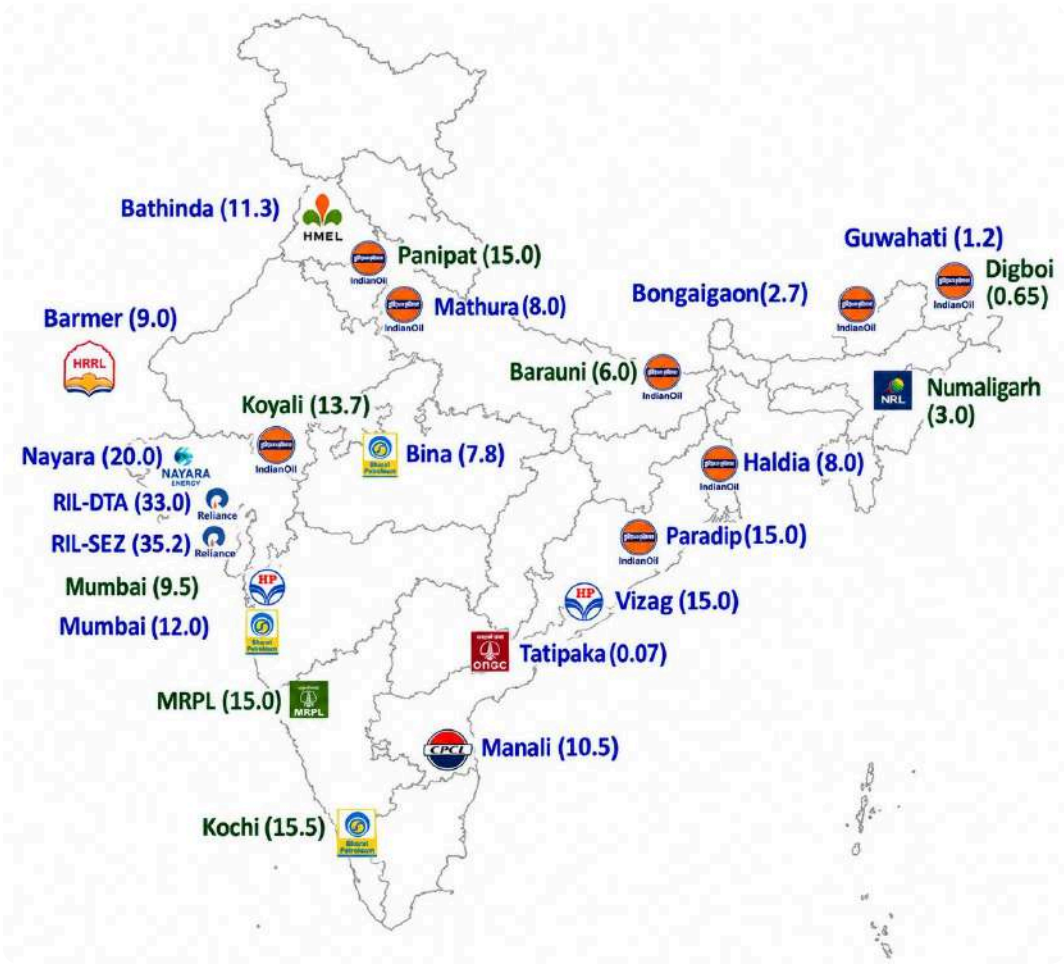


Figure 2. Refineries at a glance: location, operator and capacity (MMTPA).

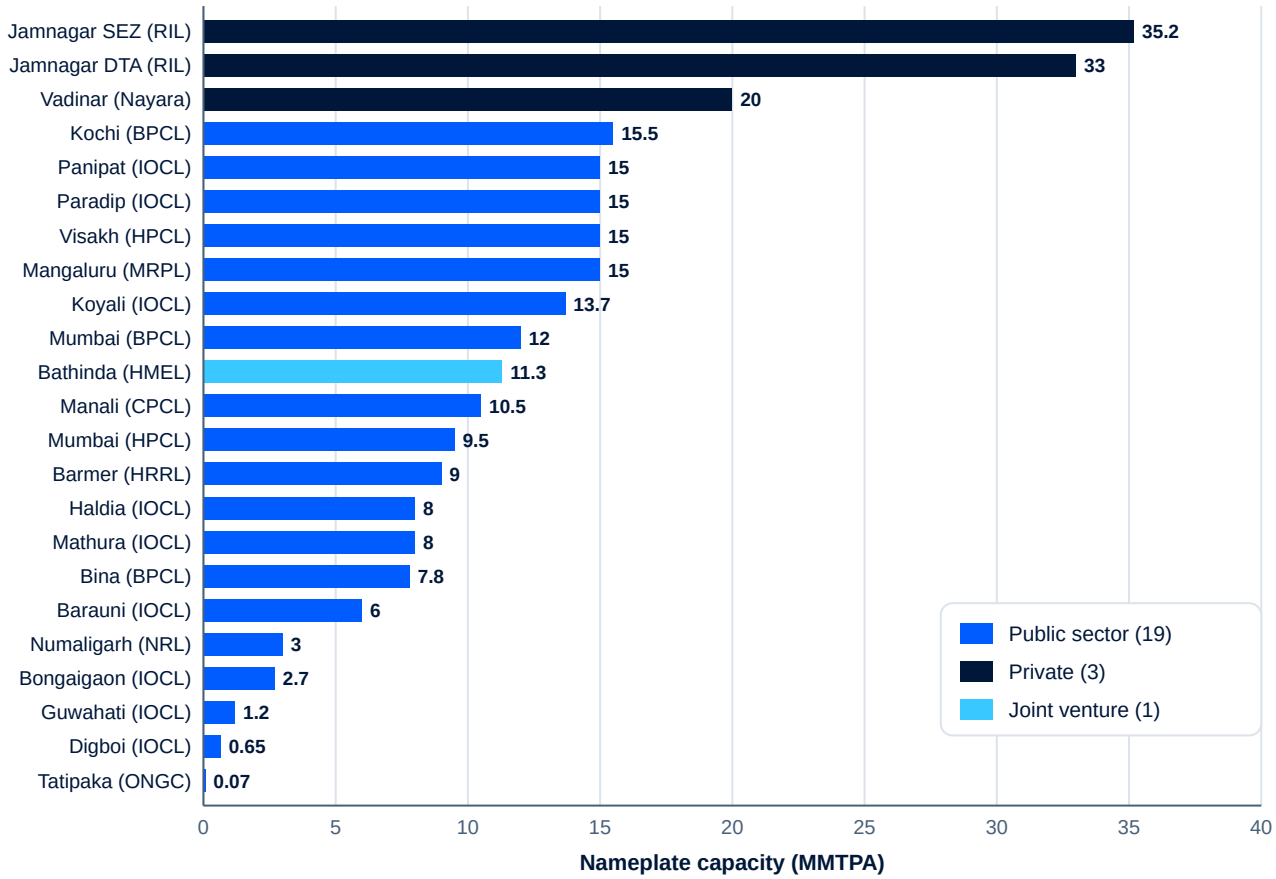


Figure 3. Refinery-wise nameplate capacity, grouped by ownership.

SECTION 02

PSU Refinery Benchmarking

The Centre for High Technology (CHT) facilitates a major performance benchmarking initiative for Indian public sector undertaking (PSU) refineries in collaboration with a global consultant.

This framework acts as a critical mechanism to evaluate Indian refineries against global peers, allowing operators to spot operational gaps, establish measurable performance milestones, and track long-term progress over successive study cycles (Figure 4)

Seventeen PSU refineries have been benchmarked every two years (biennially) since 2010. Regular participation in the global benchmarking study cycles directly drives strategic and structural improvements. The exercise has produced tangible benefits across core areas: it has helped refineries in reducing operating costs, improve reliability and availability, optimise utility consumption and set realistic performance targets.

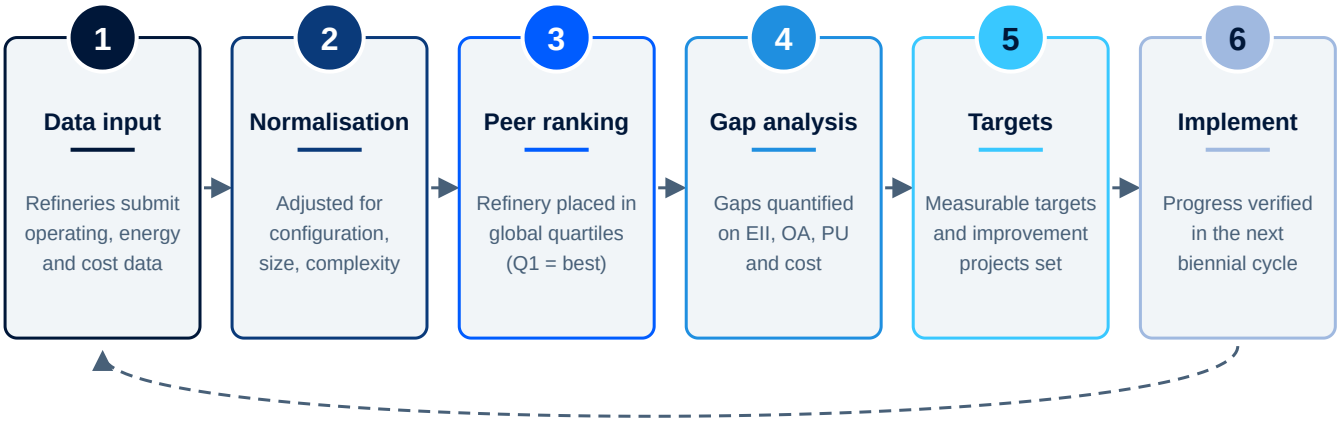


Figure 4. The biennial benchmarking cycle used for Indian PSU refineries.

The study uses three principal parameters, summarised in Table 1.

Table 1. Principal benchmarking parameters.

Parameter	What it measures
Energy Intensity Index (EII)	Actual energy consumption relative to a standard energy requirement for a refinery of the same configuration and throughput (global benchmarking methodology)
Operational Availability (OA)	Share of time that process units are available for operation after allowing for turnarounds and unplanned downtime
Process Utilisation (PU)	Degree to which installed process-unit capacity is actually utilised

Note: the descriptions above are indicative; formal definitions follow the global consultant's proprietary methodology.

Performance Milestone Shifts (2010 vs. 2024)

Refinery performance is grouped globally into quartiles, where Quartile 1 (Q1) represents top-tier efficiency and Quartile 4 (Q4) represents the bottom tier (Figure 5). Recent study cycles show a major upward shift across three critical operational pillars:

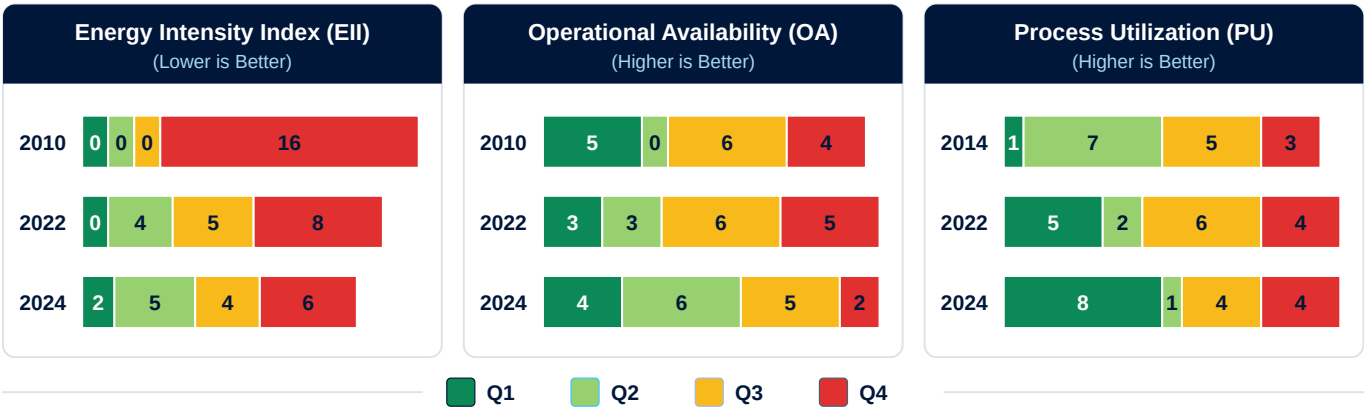
> **Energy Efficiency Indicator (EII)**: Bottom-Quartile (Q4) refineries Slashed from 16 in 2010 down to just 6 refineries in 2024. 2 refineries achieved Q1 status for the first time in 2024.

> **Operational Availability:** Bottom-Quartile (Q4) refineries dropped from 4 to 2 refineries and Mid-Tier (Q2) Scaled up from 0 refineries to 6, signaling a massive shift toward reliable operations.

> **Process Utilisation:** Top-Quartile (Q1) refineries Surged from 1 in 2014 to 8 refineries in 2024, demonstrating superior asset utilization.

Indian PSU Refineries: Benchmarking Improvement (2010-2024)

Quartile distribution across Energy Intensity Index (EII), Operational Availability (OA) and Process Utilization (PU)



EII:
- Q4 refineries reduced from 16 to 6; Q1 increased from 0 to 2.

OA:
- Q4 reduced from 4 to 2; Q2 increased from 0 to 6.

PU:
- Q1 increased from 1 to 8.

Quartile counts from CHT refinery benchmarking snapshot; EII years 2010/2022/2024, OA years 2010/2022/2024, PU years 2014/2022/2024.

Figure 5**.** Quartile distribution of Indian PSU refineries on EII, OA and PU across benchmarking cycles.

Value created

VALUE CREATED BY BENCHMARKING

≈ ₹4,500 crore per year, value created since 2010 by the top five PSU refineries.

≈ US$94.5 million (₹850 crore) per year, savings identified in the 2024 study from energy-efficiency initiatives taken by all PSU refineries since 2022.

Mission Q1: top quartile (Q1) by 2030

Mission Q1 is a high-impact strategic initiative led by the CHT under the guidance of the MoPNG. The program challenges Indian public sector refineries to achieve top-quartile (Q1) global benchmarks in energy efficiency and reliability, using the global benchmarking study metrics.

The initiative primarily targets PSU refineries with a capacity above 3 MMTPA, aiming to elevate them to Reach Q1 status in both the Energy Intensity Index (EII) and Operational Availability by 2030, and bring them on par with the world's most reliable and energy-efficient plants.

For energy efficiency, the program outlines an aggressive upward shift for the 17 benchmarked PSU refineries from their 2024 baselines - from just two Q1 refineries in the 2024 cycle to fourteen by 2030, with the remaining three in Q2 and none in the lower half (Figure 6).

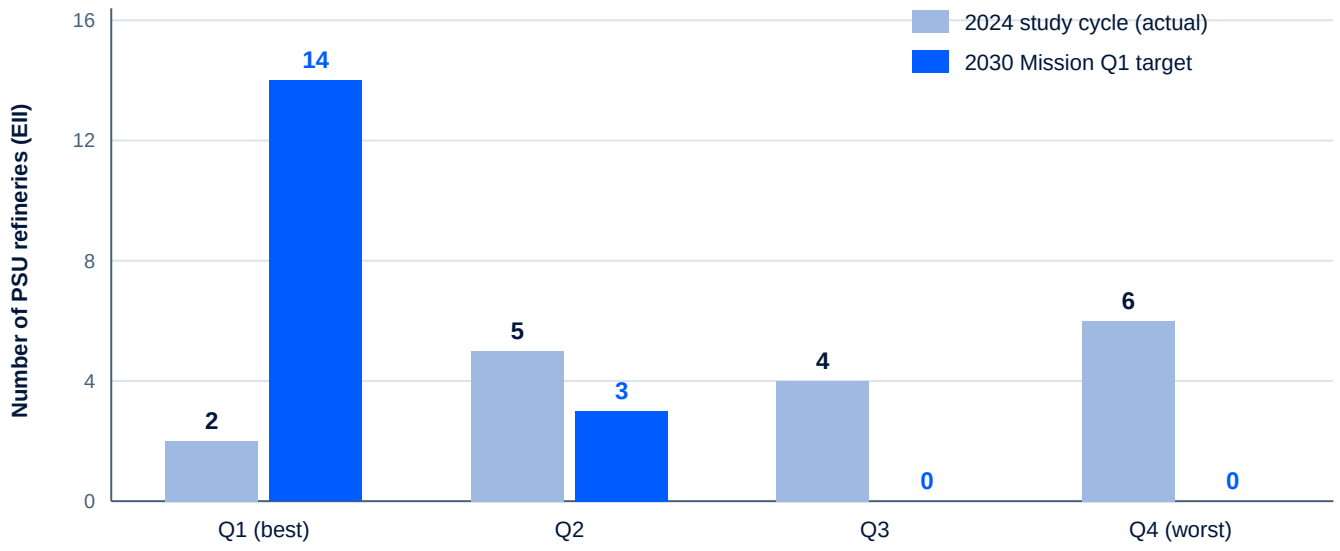


Figure 6**.** Mission Q1, EII quartile distribution of 17 PSU refineries: 2024 study cycle versus the 2030 target.

Extending benchmarking beyond refineries

Building on the success of refinery benchmarking programme, CHT has started pipeline and petrochemical benchmarking with global agencies. Applying the same quartile-based, data-driven approach to cross-country pipelines and petrochemical complexes is intended to bring the discipline of measurable targets and peer comparison to the whole downstream value chain.

SECTION 03

Pipeline Benchmarking

CHT has completed three cycles (2018, 2020 and 2022) of benchmarking of Oil & Gas Pipeline assets of PSUs in collaboration with a global consultant, covering crude oil, multi-product, LPG and natural gas pipelines and also single-point mooring systems (SPMs). Assets are ranked in quartiles against global peers from North America, Latin America, Europe and Asia (Q1 = top 25%), on KPIs including utilisation, Energy Intensity Index (EII), measurement accuracy, spills and leaks, unplanned shutdowns, and maintenance, operating-expense and personnel-cost indices. Table 2 lists the participating assets, and Figure 7 shows their quartile positions.

41
pipelines (35 liquid, 6 gas)

5
single-point moorings

5
participating PSUs

3
study cycles: 2018, 2020, 2022

Table 2. Participating pipeline assets and liquid-pipeline KPIs by company (2022 cycle).

Company	Liquid pipelines	Gas pipelines	SPMs
BPCL	6	-	2
GAIL	2 (LPG)	6	-
HPCL	8	-	1
IOCL	17	-	2
OIL	2	-	-
Total	**35**	**6**	**5**

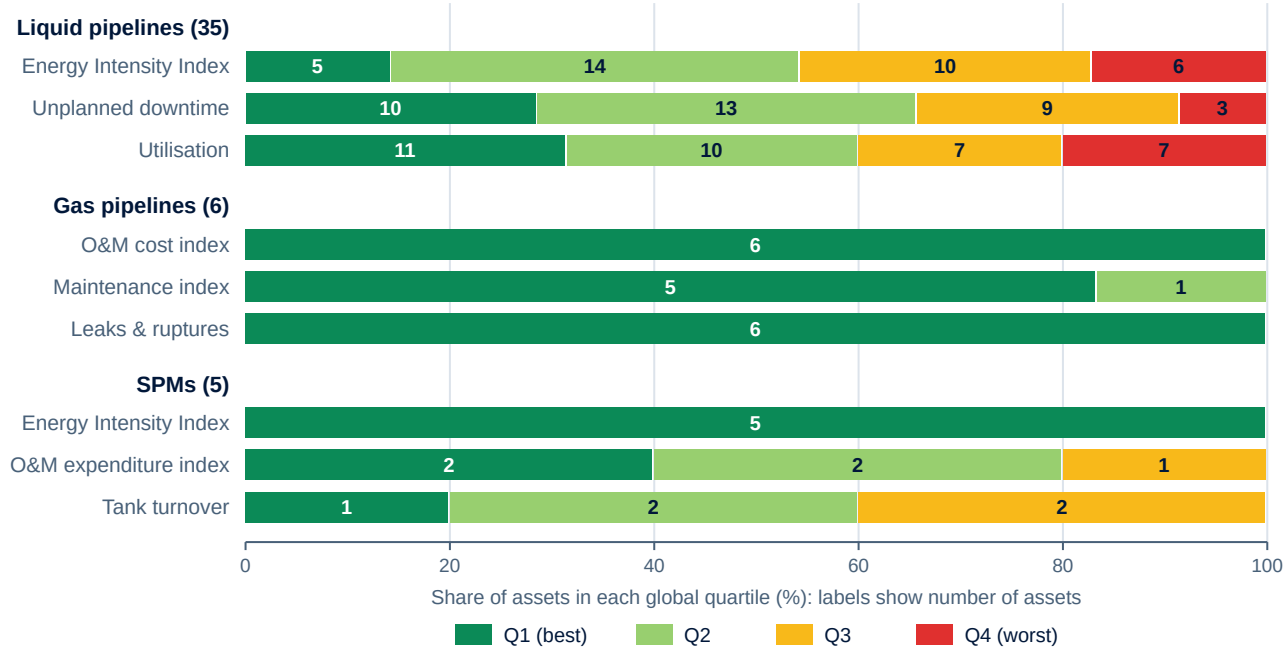


Figure 7. Quartile position of Indian PSU pipeline assets in the latest global benchmarking study cycle.

> **Latest benchmarking results**:

The latest cycle highlights significant efficiency gains.

> **Energy Efficiency & Monitoring:** High electricity costs in India make continuous energy monitoring essential. 19 out of 35 liquid pipelines now rank in Top-Tier Standings (Q1 or Q2) globally. Every participating company successfully improved its Energy Intensity Index (EII) from 2020 to 2022.

> **Asset Utilisation & Reliability:** While asset utilization remains strong, mechanical reliability presents clear areas for operational tightening

- **Utilisation**: Positioned in the overall second quartile (Q2), sitting just below the elite Q1 threshold.
- **Reliability**: Currently ranked in the third quartile (Q3) for unplanned downtime. The metric has shown only marginal improvement since 2018.

> **Measurement Accuracy:** Overall accuracy improved from Q4 to Q3. To bridge the remaining gap, the global consultant recommends the immediate deployment of highly calibrated meters and the standardisation of temperature-compensated quantities.

World-Class Assets (Gas Pipelines & SPMs)

India's gas networks and marine terminals are leading the peer groups with world-class, top-quartile (Q1) performance. All 6 Gas pipelines rank in Q1 for Operations & Maintenance (O&M) cost, as well as leaks and ruptures and 5 out of 6 achieve Q1 specifically for maintenance efficiency.

All 5 Point Mooring Systems (SPMs) gets Q1 status for their EII scores, setting a global benchmark for marine energy efficiency.

SECTION 04

Petrochemical Benchmarking

Steam cracking ranks among the most energy-intensive processes in the petrochemical industry. The operational performance of these crackers and their downstream polymer units directly impacts the cost competitiveness of integrated refinery-petrochemical complexes. To systematically optimize these high-value assets, the Centre for High Technology (CHT) is executing its petrochemical benchmarking initiative across two distinct tracks:

Track 1

Global Cracker Benchmarking in collaboration with a global consultant.

Track 2

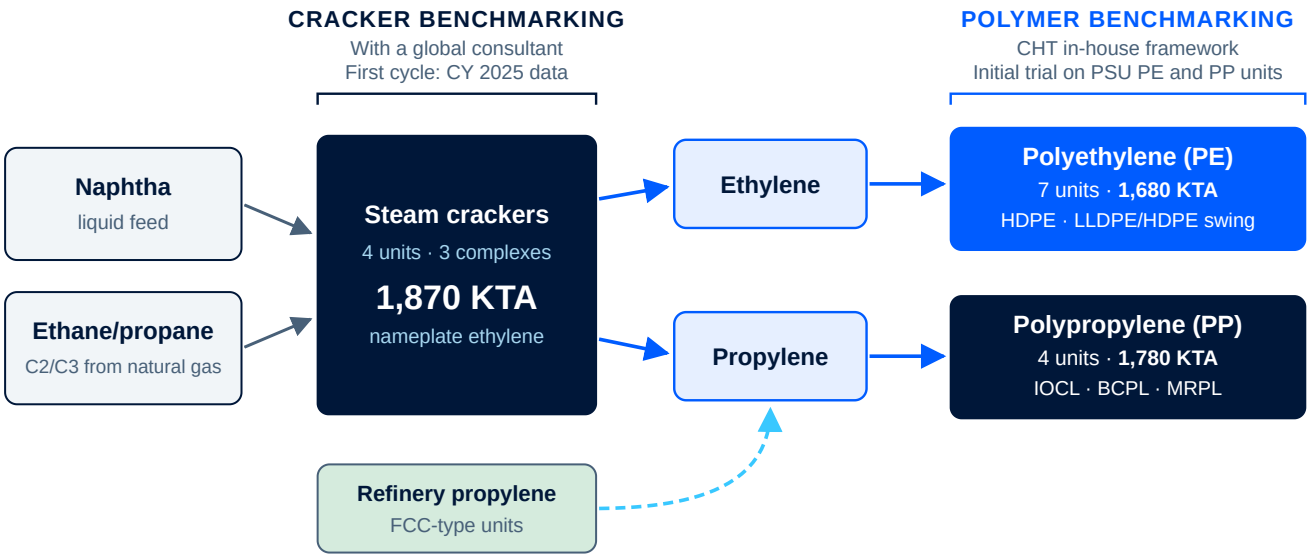
Domestic Polymer Benchmarking through an in-house framework developed internally by CHT, tailored specifically for PSU's Polyethylene (PE) and Polypropylene (PP) plants (Figure 8).

4
cracker units in the first study cycle

1,870
KTA nameplate ethylene capacity covered

11
PE and PP units in the initial polymer trial

3,460
KTA nameplate polymer capacity covered



Scope of the first exercise: 4 cracker units (1,870 KTA ethylene) and 11 polymer units (3,460 KTA)

Figure 8. Scope of petrochemical benchmarking along the olefins-polyolefins value chain.

Cracker benchmarking

The first centralised benchmarking study of PSU cracker units will cover four cracker units across three complexes: IOCL Panipat, BCPL Lepetkata, and GAIL Pata. These units have a combined nameplate ethylene production capacity of 1,870 thousand tonnes per annum (KTA), as detailed in Table 3.

The participating units comprise both naphtha-based and gas-based crackers. As the specific energy consumption and product yields of a steam cracker depend strongly on feedstock slate, cracking severity and plant configuration, comparison with global peers will be undertaken on a normalised basis, consistent with the approach followed for refineries. The **first study cycle** will be based on operating data for **calendar year (CY) 2025**.

Table 3. Cracker units participating in the first cycle of the cracker benchmarking study.

Plant	Unit	Licensor	Nameplate ethylene capacity (KTA)
IOCL, Panipat	Naphtha cracker unit	Lummus Technology, USA	800
BCPL, Lepetkata	Ethylene cracker unit	Lummus Technology, USA	220
GAIL, Pata	Gas cracker unit-1	Technip, USA	400
	Gas cracker unit-2	Technip, USA	450
Total (4 cracker units)			**1,870**

Note: KTA, thousand tonnes per annum; capacities are annual nameplate ethylene production capacities.

Polymer benchmarking

Using an in-house developed polymer benchmarking framework, being developed by CHT for PE and PP, initially seven PE units with a combined nameplate capacity of 1,680 KTA and four PP units with 1,780 KTA, together 3,460 KTA across five complexes, shall be benchmarked (Table 4).

Table 4. Polyethylene and polypropylene units considered for the initial trial of the polymer benchmarking framework.

Plant	Unit	Licensor	Nameplate capacity (KTA)
Polyethylene (PE) units			
IOCL, Panipat	HDPE	LyondellBasell, Germany	300
	Swing unit (LLDPE/HDPE)	NOVA Chemicals, Canada	350
BCPL, Lepetkata	Swing unit (LLDPE/HDPE)	INEOS Technologies	220
GAIL, Pata	HDPE-1	Mitsui, Japan	100
	HDPE-2	Mitsui, Japan	100
	Swing unit-1 (LLDPE/HDPE)	NOVA Chemicals, Canada	210
	Swing unit-2 (LLDPE/HDPE)	Univation Technologies LLC, USA	400
Sub-total, PE (7 units)			**1,680**
Polypropylene (PP) units			
IOCL, Panipat	Polypropylene unit	LyondellBasell, Italy	600
IOCL, Paradip	Polypropylene unit	LyondellBasell, Italy	680
BCPL, Lepetkata	Polypropylene plant	Lummus Novolen Technology GmbH	60
MRPL, Mangaluru	Polypropylene plant	Novolen	440

Plant	Unit	Licensor	Nameplate capacity (KTA)
Sub-total, PP (4 units)			**1,780**
Total (11 polymer units)			**3,460**

Note: HDPE, high-density polyethylene; LLDPE, linear low-density polyethylene; swing units produce LLDPE or HDPE grades in campaign mode.

The trial set spans the principal commercial process routes for PE, slurry, solution and gas-phase, as well as two families of PP process technology, licensed from six technology licensors in all, and includes swing units that alternate between LLDPE and HDPE grades. Meaningful comparison across such diverse units requires normalisation for process technology, product slate and grade mix, and unit capacity, which is a key consideration in the design of the framework.

SECTION 05

LPG Supply Management during West Asia Crisis

The disruption of shipping through the Strait of Hormuz from 28 February 2026, which the International Energy Agency (IEA) described as “the largest supply disruption in the history of the global oil market” was the most severe test of India’s energy-security architecture in recent years. India imports close to 90% of its crude oil requirement, nearly half of which normally transits the Strait, and around 60% of its LPG requirement. To put the scale in perspective, the IEA estimated that flows through the Strait had fallen by more than 90% from about 20 million barrels per day, and that the conflict would cut global supply by about 8 million barrels per day in March 2026. India consumed about 31.3 million tonnes of LPG in 2024-25, making it one of the world’s largest LPG importers. Figure 9 summarises the sequence of events and policy actions.

Figure 9. Timeline of the 2026 LPG supply crisis and India’s policy response.

Supply-side and demand-side response

Before the crisis, domestic refineries and gas-processing plants met about 40% of LPG demand (roughly 34-36 TMT per day), while imports from Qatar, Saudi Arabia, the UAE and other Middle Eastern countries met the remaining 60% (about 54-56 TMT per day). To resolve the shortage, strategic interventions targeted both the production and demand sides (Table 5). Domestic production averaged about 48 TMT per day in May-June 2026 and peaked at 53-54 TMT per day, more than 50% above the pre-crisis level of about 35 TMT per day. At the same time, demand management brought daily consumption down from about 90 TMT to 70 TMT (Figure 10), and no distributor dry-outs were reported.

Table 5. Key measures in India's LPG crisis response.

Lever	Measure	Detail
Production	**LPG Control Order (9 March 2026)**	Issued under the Essential Commodities Act, 1955 and the Petroleum Products (Maintenance of Production, Storage and Supply) Order, 1999. All refineries, including petrochemical complexes, directed to route their entire C3 and C4 streams to LPG
Production	**Coordinated operations**	Process optimisation, higher LPG recovery from refinery and gas-processing streams, deferral of non-essential maintenance and higher unit utilisation by oil and gas companies.
Production	**Sourcing diversification**	Residual imports diversified towards the United States and Australia.
Demand	**Prioritisation**	Domestic cooking use given priority; commercial LPG held at about 70% of pre-crisis requirement.
Demand	**Booking discipline**	Refill booking intervals extended to 25 days (urban) and 45 days (rural); online booking promoted; delivery made contingent on a Delivery Authentication Code (DAC).

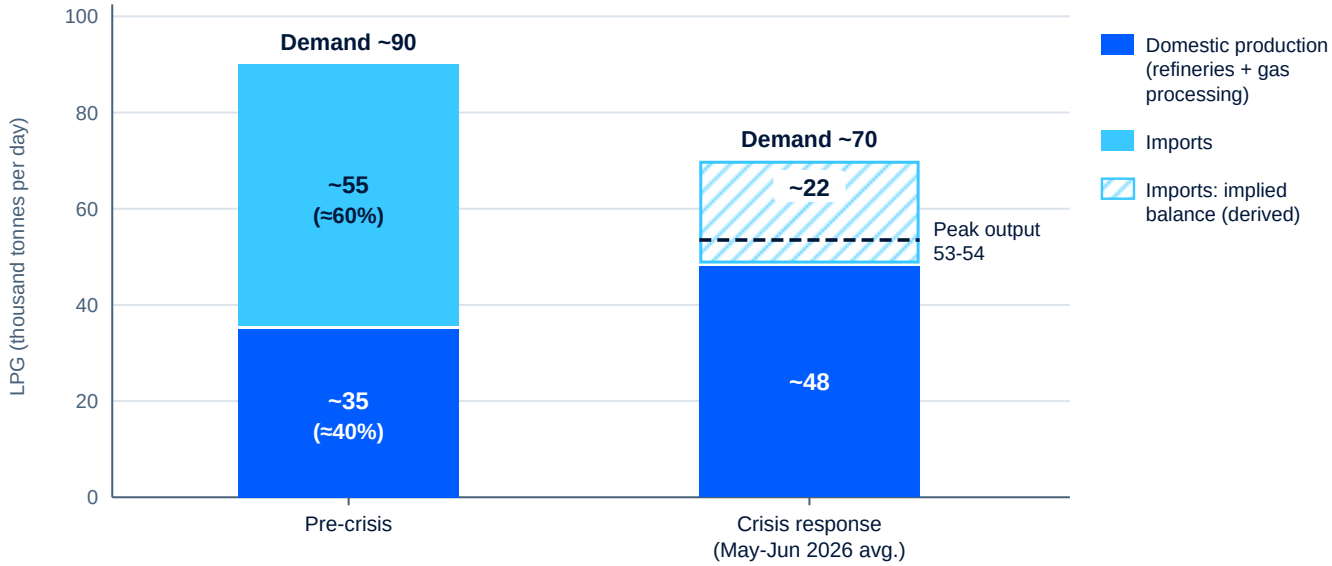


Figure 10. Daily LPG supply-demand balance before and during the crisis (TMT per day).

Protecting critical downstream industries

The Control Order's blanket priority for cooking gas threatened the pharmaceutical, chemical, and paint industries, which require a continuous supply of propylene and butylene. To protect these sectors, CHT helped design a calibrated carve-out rather than a total restriction (Figure 11):

- CHT defined critical sectors and supported the inter-ministerial Joint Working Group (JWG) to set up to secure domestic availability of petrochemical feedstock.
- Under the **directive of 1 April 2026**, refineries, including integrated petrochemical complexes, released minimum quantities of C3 and C4 streams to these sectors even as the Control Order continued to prioritise cooking gas.
- A dedicated provision of **1,120 MT per day from the LPG pool** ensured that these industries were not cut off during peak household-priority operations.
- To bridge the immediate LPG gap, petrochemical operations were temporarily moderated at the Paradip, Panipat and Gujarat refineries, and were progressively restored as supply improved.

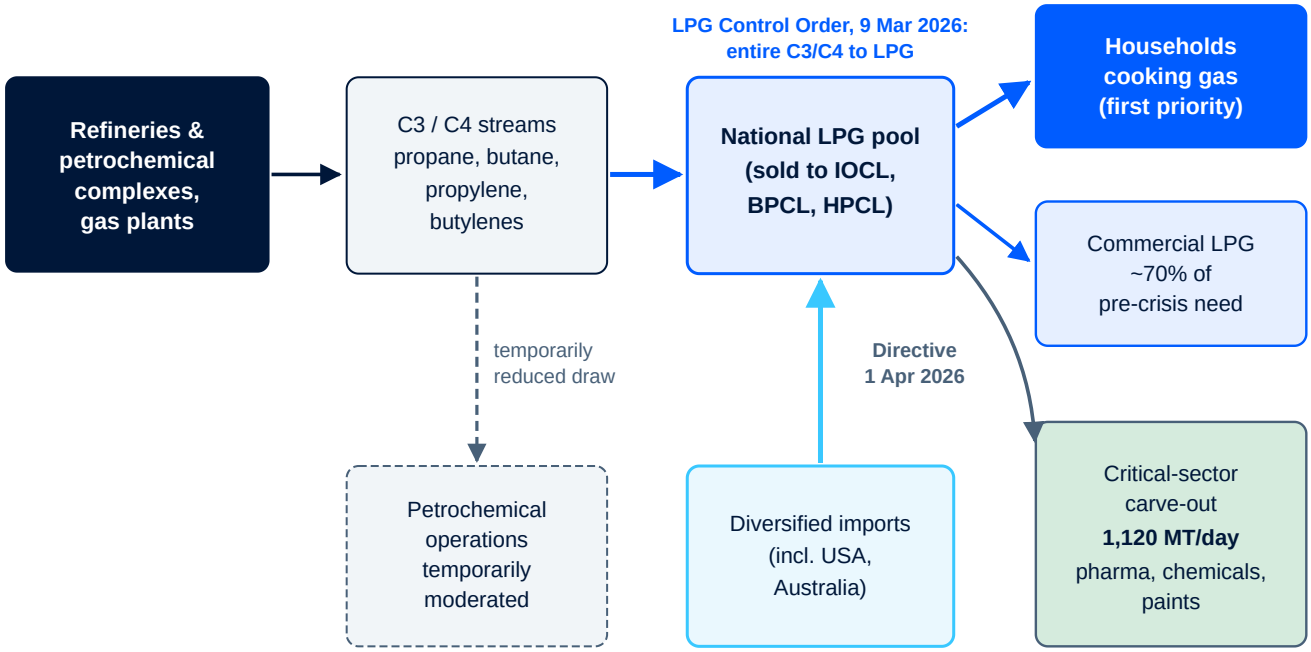


Figure 11. Allocation of refinery C3/C4 streams under the LPG Control Order and the critical-sector carve-out.

Refinery 's ability to redirect C3/C4 streams lifted domestic LPG output by more than half within weeks. **Demand management viz.,** Booking intervals, authentication codes and commercial allocation reduced demand by about 20 TMT per day without distributor dry-outs.

SECTION 06

06

GOBARdhan (Galvanizing Organic Bio-Agro Resources Dhan)

The National Unified Scheme for Compressed Biogas approved by the Union Cabinet on **6 August 2026**, GOBARdhan brings all central support for Compressed Biogas (CBG) under one framework to raise domestic CBG production about **ten-fold**. It converts cattle dung, crop residue and biodegradable waste into clean fuel and organic manure, and subsumes SATAT, MDA, Biomass Aggregation Machinery (BAM), Development of Pipeline Infrastructure (DPI) and CFA under the National Bioenergy Programme.

₹23,731 cr
Total outlay

10 years
FY 2026-27 to FY 2035-36

₹2,110
per MMBTU administered CBG price (≈ ₹105/kg)

5%
CBG blending in CNG & PNG from FY 2028-29

Scheme components

The scheme rests on six mutually reinforcing components (Table 4) that address the main barriers to CBG investment: uncertain offtake, volatile prices, capital intensity, connectivity, access to credit and feedstock logistics. Figure 12 maps these components onto the CBG value chain.

Table 4. The six components of GOBARdhan.

1 Assured offtake

City gas distribution (CGD) entities blend CBG in CNG (transport) and PNG (domestic): 3% in FY 2026-27, 4% in FY 2027-28 and 5% from FY 2028-29.

2 Stable pricing

Administered price of ₹2,110 per MMBTU, assured for at least 10 years, giving producers revenue visibility.

3 Capital assistance

Up to ₹2 crore per TPD of installed capacity for greenfield plants; brownfield expansions, aggregation and manure assets also eligible.

4 Pipeline infrastructure

Support for cluster-based and standalone pipelines linking CBG plants to trunk lines and CGD networks.

5 Credit guarantee

Cover of up to 85% of eligible loans for MSME-based CBG projects, easing collateral requirements.

6 Ecosystem Challenge Fund

District-level feedstock mapping, aggregation, technology adoption, manure value addition and capacity building.

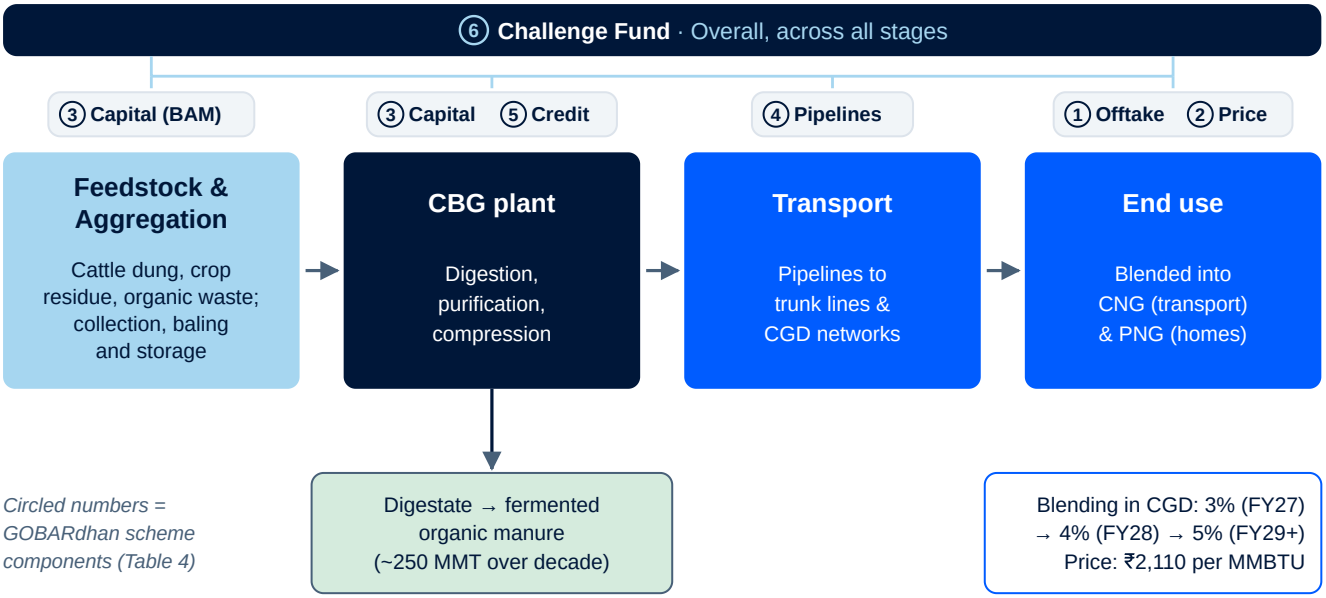


Figure 12 The CBG value chain and the GOBARdhan components that support each stage.

CHT is the **Programme Management Agency** for GOBARdhan and operates through a dedicated **CBG Coordination Cell**. Its responsibilities and the scheme's expected benefits are summarised in Table 6.

Table 6. Expected benefits of GOBARdhan and the role of CHT as implementing agency.

EXPECTED BENEFITS

- **Energy security:** displaces ~10 MMT of fossil fuel; foreign-exchange savings of over ₹40,000 crore.
- **Climate action:** cuts over 40 MT of CO_2 emissions by diverting waste from burning and landfills.
- **Growth and jobs:** adds over ₹75,000 crore to GDP and 1.5 lakh+ jobs across the value chain.
- **Farmers and soil health:** income from feedstock sales; ~250 MMT of fermented organic manure.
- **Investment:** long-term price and offtake certainty makes CBG projects bankable.
- **Swachhta:** cleaner villages and cities through scientific management of organic waste.

ROLE OF CHT

- **Policy and technical support** to MoPNG across all six components.
- **Appraisal** of applications for capital, pipeline and other assistance for the approval committees.
- **Verification** of plants, machinery and milestones before release of funds.
- **Portal and MIS** coordination on the Unified Registration Portal, including merged BAM and DPI.
- **Stakeholder coordination** with developers, oil and gas PSUs, CGD entities, banks and States.
- **Capacity building** and outreach for developers and districts.
- **Monitoring and reporting** of physical and financial progress to the Ministry.

Benefit estimates are over the scheme period, as stated in the Cabinet approval [5].

WAY FORWARD

Closing the gap between registered and commissioned plants, through reliable feedstock aggregation, faster pipeline connectivity and easier finance, will make CBG a mainstream part of India's gas mix and a pillar of the energy transition.

SECTION 07

PM JI-VAN Yojana: From crop residue to clean fuel

The *Pradhan Mantri Jaiv Indhan, Vatavaran Anukool Fasal Awashesh Nivaran Yojana* (PM JI-VAN Yojana) was notified in 2019 to provide financial assistance for second-generation (2G) ethanol projects. In August 2024 the Union Cabinet extended the scheme to 2028-29 and widened its scope to advanced biofuels from lignocellulosic feedstocks, industrial waste, synthesis gas and algae. CHT issues the Requests for Selection (RFS) and supports appraisal of projects.

₹1,950 cr
total outlay

~12 + 10
commercial + demonstration plants envisaged

₹150 / ₹15 cr
maximum assistance per commercial / demo plant

14
Approvals

Objectives, funding rules and benefits

Role & Objectives

- **Set up plants:** commercial and demonstration-scale advanced biofuel (2G ethanol, SAF) plants.
- **Policy:** implement the National Policy on Biofuels and boost the Ethanol Blended Petrol programme.
- **R&D:** promote and commercialise indigenous advanced biofuel technologies.
- **Viability gap funding:** commercial, lowest of 20% of cost, ₹5 Cr per 10 lakh L/yr, or ₹150 Cr; demo, 50% of capex up to ₹15 Cr.
- **Approval:** RFS by CHT → Expert Committee → SAC → Steering Committee chaired by Secretary, MoPNG.

Key Benefits

- **Cleaner air:** rice straw, bagasse and bamboo become fuel instead of being burnt.
- **Farmer income:** a paid market for crop residue.
- **Energy security:** lower crude imports; higher ethanol blending and SAF uptake.
- **Lower emissions:** reduced greenhouse gases from transport and aviation.
- **Jobs:** rural and industrial employment along the biomass supply chain.
- **Cheaper fuel:** FA lowers product price, e.g. 2G ethanol from ₹145/L to ₹124/L (Spray Engg.).

Technology pathways

The current project portfolio spans three conversion routes (Figure 13): biochemical conversion of lignocellulosic residues to 2G ethanol; hydroprocessing of used cooking oil to SAF via the HEFA (hydroprocessed esters and fatty acids) route; and alcohol-to-jet conversion of ethanol or sugar-derived intermediates to SAF.

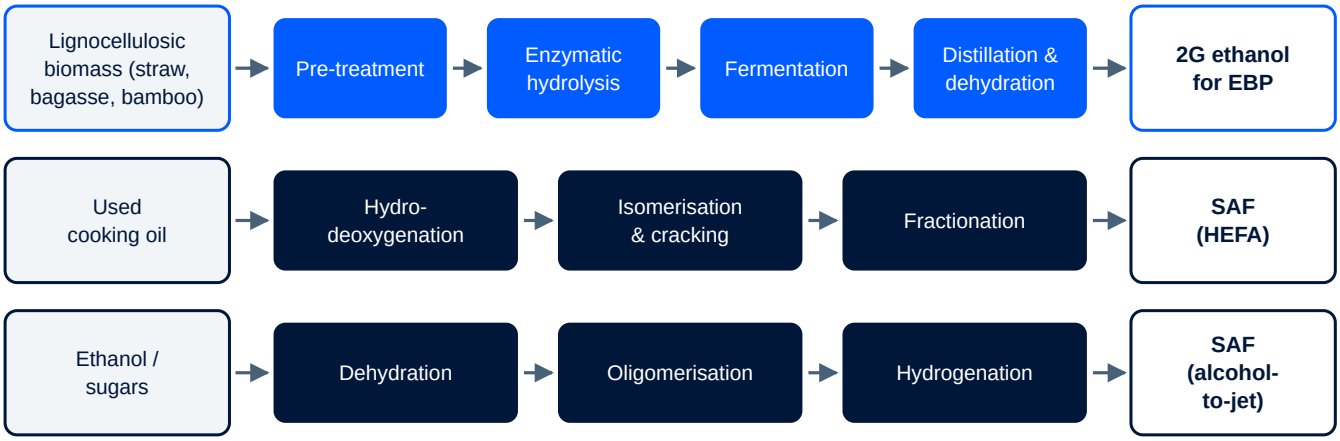


Figure 13. Generic conversion pathways for the advanced biofuels supported under PM JI-VAN.

Project portfolio and fund position

Table 6 lists the 14 projects in the portfolio, nine 2G ethanol and five SAF projects, of which nine are commercial-scale and five are demonstration plants. Financial assistance totals **₹1,329.25 crore**, leaving a balance of **₹620.75 crore** of the ₹1,950-crore outlay (Figure 12).

Table 7. PM JI-VAN Yojana project portfolio (sanctioned and RFS-V projects).

Developer	Fuel	Scale	Location	KLPD	Feedstock	FA (₹ cr)
IOCL	2G ethanol	Commercial	Panipat, Haryana	100	Rice straw	150
ABRPL	2G ethanol	Commercial	Numaligarh, Assam	185	Bamboo	150
BPCL	2G ethanol	Commercial	Bargarh, Odisha	100	Rice straw	150
HPCL	2G ethanol	Commercial	Bathinda, Punjab	100	Rice straw	150
IOCL R&D	2G ethanol	Demo	Panipat, Haryana	2.5	Rice straw	15
Lignopura Agrotech	2G ethanol	Demo	Sangli, Maharashtra	1.27	Bagasse	13.25
M11 Energy	SAF	Commercial	Udupi, Karnataka	422	Used cooking oil	150
TruAlt Bioenergy	SAF	Commercial	Bagalkot, Karnataka	300	Ethanol	150
Triveni Engg. & Industries	2G ethanol	Commercial	Muzaffarnagar, UP	100	Bagasse	150
Spray Engg. Devices	2G ethanol	Commercial	Amroha, UP	91	Bagasse	150
MRPL	SAF	Commercial	Mangaluru, Karnataka	33.7	Used cooking oil	56
HPCL	SAF	Demo	Visakhapatnam, AP	18.4	Used cooking oil	15
DCM Shriram	2G ethanol	Demo	Surendranagar, Gujarat	3	Agri-residue	15
Syn-Bio	SAF	Demo	Narwar, MP	1.4	Sugar	15
Total						**1,329.25**

Fund Position (of ₹1,950 Cr outlay)

Sanctioned ₹1329.25 Cr **Balance ₹620.75 Cr**

SECTION 08

Joint Working Groups constituted by DCPC

The Department of Chemicals and Petrochemicals (DCPC), under the Ministry of Chemicals and Fertilizers, has established specialized Joint Working Groups. As an active member of Joint Working Group-3 on Petrochemicals (JWG-PC) and the Joint Working Group-4 on Recycling & Circular Economy (JWG-RC), CHT provides critical technical expertise to drive national policy leveraging its deep institutional knowledge in Performance benchmarking, Technology assessment and assisting in R&D coordination tailored for the downstream hydrocarbon sector.

The recommendations of the sub-groups are to be specific and actionable, categorised into short-, medium- and long-term measures.

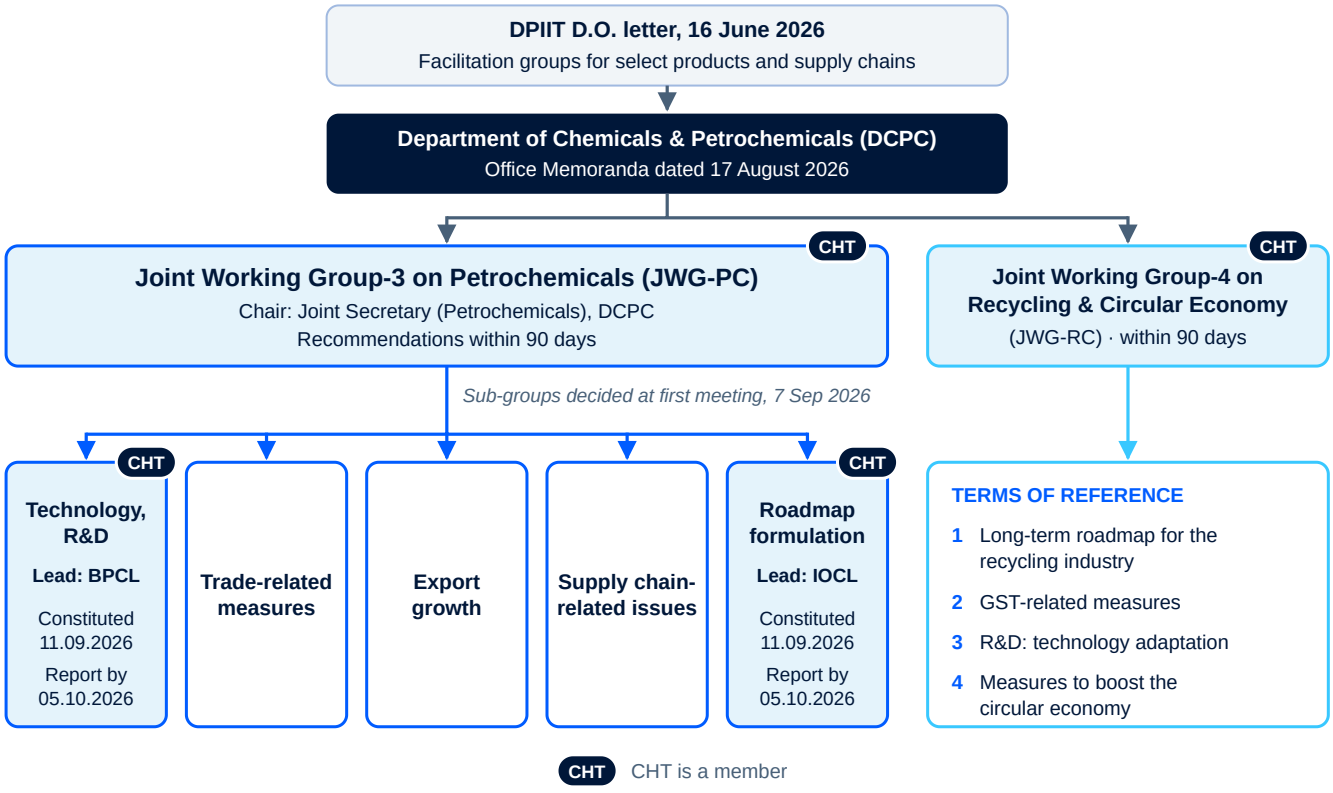


Figure 14. Joint Working Groups constituted by DCPC and CHT membership.

09

SECTION 09

Green Hydrogen in Refineries: SIGHT Mode 2B

STATUS AT A GLANCE

To date, **30 KTPA of green hydrogen supply** has been awarded to four PSU refineries under SIGHT Mode 2B, against the Tranche-I quantum of 2,00,000 MTPA, at discovered prices of **₹279-336 per kg** (pre-tax).

Under Component II of the National Green Hydrogen Mission's Strategic Interventions for Green Hydrogen Transition (SIGHT) programme, Mode 2B is a green hydrogen production-incentive pathway, which allocates ₹17,490 crore of the Mission's total ₹19,744 crore budget through FY 2029-30, including ₹13,050 crore specifically for production incentives. Notified by the MNRE on 16 January 2024 (Table 8), Mode 2B aggregates the green hydrogen demand of multiple refineries to invite supply bids at the lowest price with a fixed incentive, contrasting with Mode 1 where bidders compete on the lowest incentive demanded. Ultimately, this mechanism aims to scale up domestic production, make green hydrogen cost-competitive with fossil-based alternatives, and accelerate its large-scale commercial adoption.

2,00,000
MTPA Tranche-I quantum

30 KTPA
awarded (15% of Tranche I)

₹279-336
per kg discovered prices

₹50 → ₹30
per kg incentive, Years 1-3

Table 8. Salient provisions of SIGHT Mode 2B.

Parameter	Provision
Implementing agencies	Oil and gas companies (demand aggregation, bidding, appraisal) and the Centre for High Technology (CHT), nominated by MoPNG
Tranche-I quantum	2,00,000 MTPA; unallocated capacity carries over to the next tranche
Incentive	₹50/kg (Year 1), ₹40/kg (Year 2), ₹30/kg (Year 3), paid on the lower of allocated capacity or actual supply
Bid parameter	Annual capacity (thousand MT) and a single price in ₹/kg over the Hydrogen Purchase Agreement (HPA) period; L1 allocation, ties to higher capacity
Eligibility	Net worth of at least ₹15 crore per thousand MTPA quoted
Delivery terms	At refinery battery limit; storage and transport by supplier; no trading, arbitrage or double incentive across SIGHT modes
Product standard	Green Hydrogen Standard for India: well-to-gate emissions not above 2 kg CO_2e per kg H_2
Oversight	Scheme Monitoring Committee co-chaired by the Secretaries of MoPNG and MNRE

Tender and award status

During the first round of bidding, PSU refiners tendered 42 KTPA, ultimately awarding 30 KTPA on a build-own-operate (BOO) basis (Table 9). Notably, the Numaligarh award discovered India's lowest green hydrogen price to date at just ₹279/kg.

Table 9. Refinery-wise awards under SIGHT Mode 2B.

Refinery (company)	Capacity (KTPA)	Developer	Price (₹/kg, excl. GST)	Status
Panipat (IOCL)	10	L&T Energy GreenTech	336	Awarded June 2025; completion targeted December 2027
Visakh (HPCL)	5	Ocior Energy	328	Awarded October 2025; 25-year BOO
Numaligarh (NRL)	10	NeuEN Green Energy (BPCL-Sembcorp JV)	279	Awarded March 2026; COD expected September 2028
Bina (BPCL)	5	Ocior Energy	328	Awarded October 2025; 15-year BOO
Total	**30**			

Effect of the green hydrogen subsidy on prices

Under the Mode 2B incentive is fixed and bidders compete on price, the discovered prices are what the refineries pay, and the incentive is paid to the producer. The subsidy therefore shows up as a lower bid price. In Year 1, the ₹50/kg incentive is equivalent to **15-18% of the discovered price**, about ₹329-386/kg of revenue to the producer for every kilogram delivered. As the incentive tapers to ₹30/kg in Year 3 and ends thereafter, its share falls to 9-11%, and the producer depends entirely on the contracted price for the rest of the agreement. On the 30 KTPA awarded, the indicative incentive outgo is ₹150 crore, ₹120 crore and ₹90 crore in Years 1-3, **₹360 crore in all** (Figure 15).

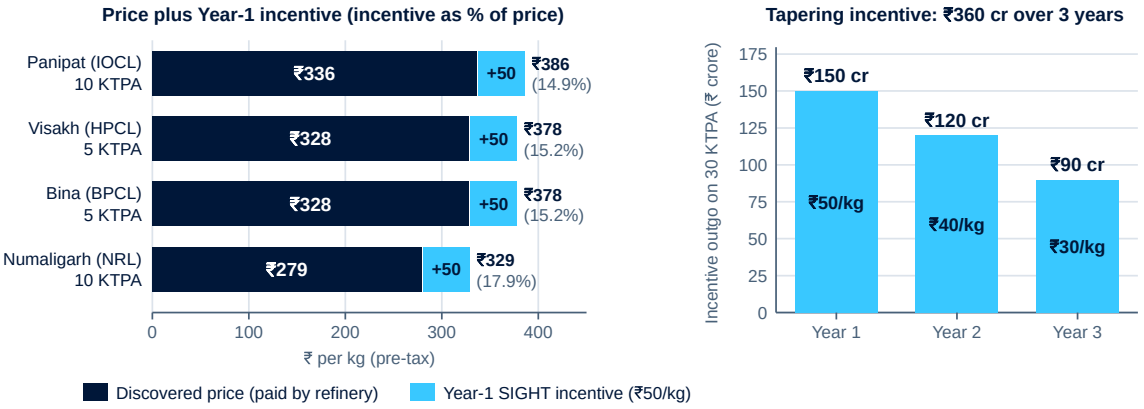


Figure 15. Green hydrogen subsidy under SIGHT Mode 2B: discovered price plus Year-1 incentive by award, and the tapering incentive outgo on 30 KTPA.

Table 10. Incentive as a share of the discovered price, by year.

Discovered price (₹/kg)	Award(s)	Year 1 (₹50/kg)	Year 2 (₹40/kg)	Year 3 (₹30/kg)
279	Numaligarh (NRL)	17.9%	14.3%	10.8%
328	Visakh (HPCL), Bina (BPCL)	15.2%	12.2%	9.1%
336	Panipat (IOCL)	14.9%	11.9%	8.9%

29th ENERGY TECHNOLOGY & INNOVATION MEET (ETM) 2026

Awards & Recognition

"Accelerating Energy Innovation: From Research to Commercialisation"

27-29 OCTOBER 2026 | URJA BHARAT CONVENTION CENTRE (UBCC), ATI-ONGC, GOA
UNDER THE AEGIS OF MOP&NG, GOVERNMENT OF INDIA

The ETM Awards recognise excellence in **refinery performance, energy efficiency, operational excellence, technological advancement and innovation** across the Indian hydrocarbon sector. They acknowledge the achievements of public and private sector refineries and R&D organisations, promote healthy competition and facilitate the sharing of best practices, reinforcing CHT's commitment to continuous improvement, technological self-reliance and a competitive, efficient and sustainable refining sector, in alignment with the vision of **Aatmanirbhar Bharat** and **Viksit Bharat**.

★ REFINERY PERFORMANCE AWARDS — 2025-26

Evaluated by an approved **Evaluation Committee** against prescribed parameters, with participation of all public and private sector refineries.

01	02	03
Refinery Performance Award	**Refinery Performance Award**	**Efficient Steam Management Award**
Design Capacity >3 MMTPA	Design Capacity ≤3 MMTPA	
AWARDEE	AWARDEE	AWARDEE
RIL-SEZ	**IOCL-Guwahati Refinery**	**IOCL-Haldia Refinery**

✦ INNOVATION AWARDS

Evaluated by the **Scientific Advisory Committee (SAC)** on merit, technological significance and potential contribution to the refining and downstream hydrocarbon sector.

#	CATEGORY	INNOVATION	COMPANY	AWARD
1	**Best Indigenously Developed Technology**	**CatAce-E-01:** Novel catalyst for production of High-Density Polyethylene (HDPE)	IOCL	JOINT AWARD
		KSM & API for Refinery Value Enhancement (KARVE) IBB: indigenous active pharma intermediate process technology for manufacture of Isobutyl Benzene	MRPL	JOINT AWARD
2	**Best Innovation in Refinery** (Refinery / Group / Individual)	**Closed-Loop Real-Time Optimization (CLRTO)** of Crude Distillation Units, from Kochi Refinery to industry-wide deployment	BPCL	JOINT AWARD
		REVEAL™ FCC: Indigenous closed-loop real-time optimizer	MRPL	JOINT AWARD
3	**Best Innovation in R&D Institute** (Institute / Group / Individual)	**Sodium-ion battery:** development & scale-up of in-house material, cell and battery	HPCL	

🏆 **Celebrating Excellence. Recognising Innovation. Advancing the Future of Energy.**

SECTION 03

Technical Abstracts

95 papers selected for ETM 2026, each presented on one page with the author's abstract as submitted and a visual summary of the technology.

24
Refining, Catalysts & Petrochemicals

15
Biofuels, CBG & Waste to Value

9
Carbon Capture & Decarbonisation

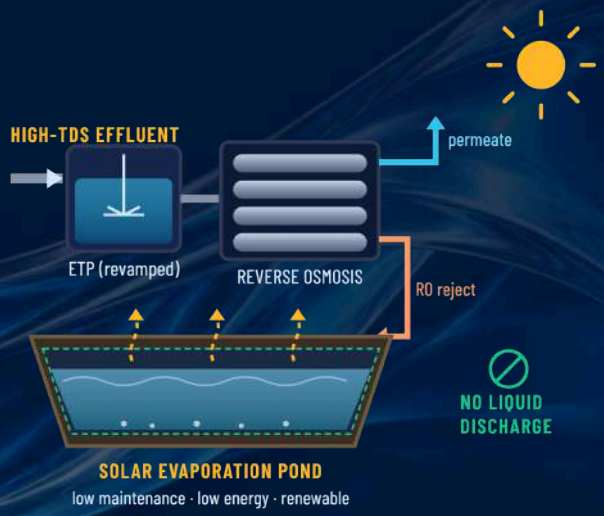
22
Digital, AI & Automation

12
Hydrogen & Fuel Cells

13
Energy Efficiency, Power & Reliability

ZERO LIQUID DISCHARGE | HIGH-TDS EFFLUENT · SOLAR EVAPORATION

Zero Liquid Discharge for High-TDS Industrial Effluent: A Techno-Economic Case for Reverse Osmosis with Solar Evaporation Ponds



R S Prasad
Engineers India Limited

ABSTRACT

Environmental clearance and consent-to-operate conditions for industrial plants in India require that effluent not be discharged outside the premises and instead be reused for gardening or horticulture. Where effluent carries very high total dissolved solids, such reuse is not feasible, making Zero Liquid Discharge (ZLD) facilities essential. While several ZLD technologies exist, including reverse osmosis, multiple effect evaporators, mechanical vapor recompression, electrodialysis reversal and membrane distillation, this study also examined solar evaporation for its low maintenance, low energy demand and use of renewable energy. The methodology comprised collection of historical effluent flow and quality data, a site visit, review of design documents and drawings, study of the existing effluent segregation scheme, and evaluation of treatment processes to develop a ZLD system. Three configurations were compared: (1) Effluent Treatment Plant (ETP) with Mechanical Vapor Compression (MVC); (2) ETP with Reverse Osmosis (RO) and MVC; and (3) ETP with RO and a solar pond. Capital costs were USD 10.70 million, 7.45 million and 4.83 million, and annual operating costs were USD 11.23 million, 9.12 million and 5.09 million, respectively. The revamped ETP with RO and solar pond therefore emerged as the most optimum option, **cutting both capital and operating cost by roughly 55%** compared with ETP and MVC while achieving no liquid discharge. Solar evaporation is already deployed at the Rajasthan Refinery and Petrochemical Project, India, where three ponds handle rejects and high-TDS water, confirming its practical viability. This paper presents the technological evaluation, cost comparison, and sizing and design details of the solar pond, demonstrating that solar evaporation is a viable, sustainable and low-cost route to achieving zero liquid discharge for high-TDS industrial effluents.

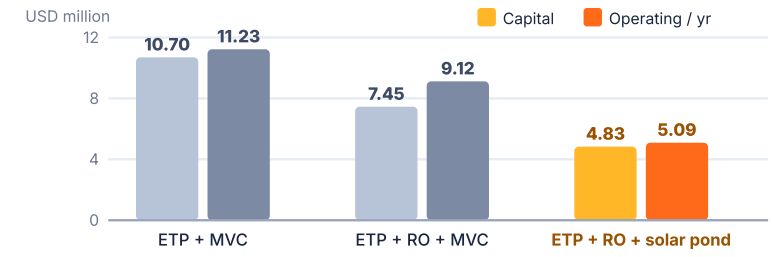
~55%
lower capital and operating cost vs ETP + MVC

4.83 USD M
capital cost, ETP + RO + solar pond

5.09 USD M/yr
annual operating cost, ETP + RO + solar pond

3 ponds
already in use at Rajasthan Refinery and Petrochemical Project

Cost of the three ZLD configurations (USD million)



Configurations compared

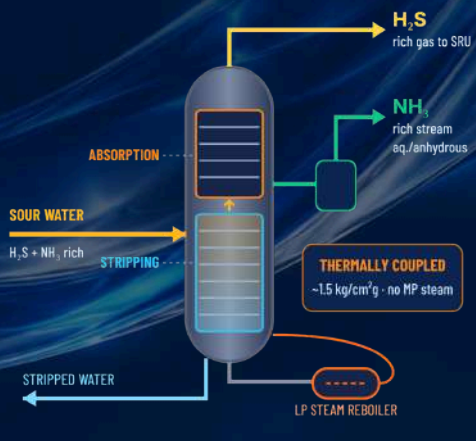
1. **ETP + MVC** — mechanical vapor compression
2. **ETP + RO + MVC** — reverse osmosis ahead of MVC
3. **ETP + RO + solar pond** — most optimum option, no liquid discharge

HOW IT WORKS

1. High-TDS effluent — not fit for reuse
2. Revamped ETP — effluent treatment
3. Reverse osmosis — recovers water
4. Solar pond — evaporates rejects

SOUR WATER STRIPPING | ENERGY EFFICIENCY · BROWNFIELD READY

Eng-SWäS: A Low-Pressure, Energy-Efficient Sour Water Stripping-Absorption System for Enhanced H_2S/NH_3 Separation



Ramayya Gorle
Engineers India Limited

ABSTRACT

Refineries are increasingly challenged by rising concentrations of ammonia (NH_3) and hydrogen sulfide (H_2S) in sour water systems, driven by the processing of a wide range of crude oils, including heavier and opportunity crudes. Conventional sour water stripper (SWS) configurations, whether single-stage or two-stage, face challenges in balancing contaminant segregation, energy efficiency, and operational simplicity. While single-stage systems offer lower energy consumption and simpler operation, they generally fail to achieve effective separation of H_2S and NH_3, resulting in ammonia contamination of sulfur-rich gas streams. This may adversely impact downstream sulfur recovery units (SRUs) through ammonia salt deposition, corrosion, sulfur condenser fouling, and operational instability. At the same time, ammonia represents a potential value-added byproduct in the form of aqueous or anhydrous ammonia. Conversely, two-stage systems achieve improved separation but require elevated operating pressures, higher steam quality, and increased process intensity.

This paper introduces **Eng-SWäS** (स्वास- Sour Water Stripper), a novel hybrid sour water stripping-absorption configuration developed to achieve effective H_2S and NH_3 segregation under low-pressure operating conditions. The system combines thermally coupled stripping and absorption sections, enabling internal handling of intermediate vapors and eliminating the need for conventional high-pressure first-stage operation and associated utilities.

The case study demonstrates that Eng-SWäS can operate at near-atmospheric to low pressures (~1-2.5 kg/cm²g), enabling the use of LP steam while reducing energy consumption. The configuration achieves near-complete separation of H_2S and NH_3 streams suitable for downstream processing while meeting stringent stripped water specifications. It also offers strong potential for brownfield implementation with minimal modifications, making it an attractive solution for refineries.

A detailed study was carried out for a refinery sour water stream of approximately 76,550 kg/h. The proposed Eng-SWäS configuration achieved effective H_2S and NH_3 segregation while operating at approximately 1.5 kg/cm²g, compared with about 7 kg/cm²g for a conventional two-stage sour water stripper. The low-pressure operating philosophy eliminated the medium-pressure steam requirement of the first-stage stripper and reduced the low-pressure steam demand of the second stage. Overall, the configuration reduced utility demand by **~6.7 MMkcal/h** (3.3 MMkcal/h MP+ 3.4 MMkcal/h LP), equivalent to an annual energy saving of about 53,600 MMkcal, corresponding to nearly 5,360 t/y fuel oil equivalent, an estimated **INR 14 crore/year reduction in operating cost**, and ~17,000 t/y CO_2 emission reduction. The study further demonstrated the potential to achieve stringent stripped sour water specifications while producing H_2S-rich and NH_3-rich streams suitable for downstream sulfur recovery and ammonia handling (e.g., anhydrous/aqueous ammonia production) applications.

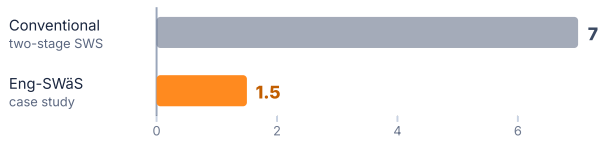
~1.5 kg/cm²g
operating pressure vs about 7 kg/cm²g for conventional two-stage SWS

~6.7 MMkcal/h
utility demand reduced (3.3 MP + 3.4 LP)

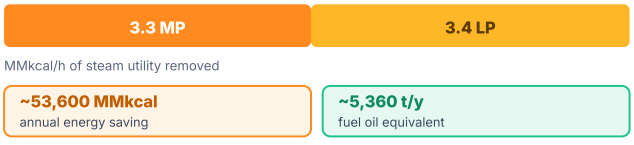
INR 14 crore/year
estimated reduction in operating cost

~17,000 t/y
CO_2 emission reduction

Operating pressure (kg/cm²g)



Utility saving ~6.7 MMkcal/h



HOW IT WORKS

1. **Sour water** ~76,550 kg/h feed
2. **Absorb + strip** thermally coupled sections
3. **LP steam only** ~1.5 kg/cm²g
4. **Two streams** H_2S to SRU · NH_3 rich

KEYWORDS Sour Water Stripper | Low-Pressure Operation | Energy Efficiency | Thermally Coupled Separation | Utility Optimization

POLYPROPYLENE | NUCLEATING AGENT · INDIGENOUS TECHNOLOGY

PNX-23: Advanced Nucleation for Polypropylene

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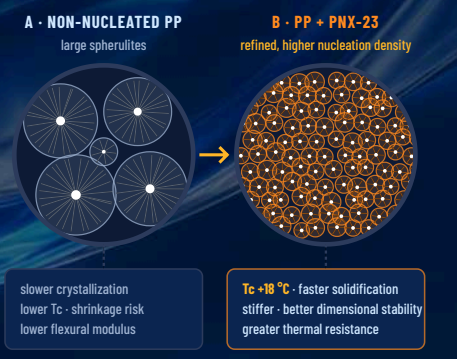


ABSTRACT

Polypropylene (PP) is a semi-crystalline thermoplastic widely utilized in high-volume applications due to its low density, chemical inertness, and excellent processability. The mechanical performance and processing behaviour of PP are primarily governed by its crystallization kinetics and the resulting crystalline morphology. However, conventional polypropylene, particularly homopolymer grades, exhibits inherent limitations including relatively low flexural modulus, limited impact resistance, lower crystallization temperature (Tc), and susceptibility to shrinkage and dimensional distortion during processing. These limitations restrict its performance in demanding structural and high-precision applications.

The incorporation of nucleating agents is a well-established strategy to modify crystallization behaviour by promoting heterogeneous nucleation, thereby increasing crystallization temperature, accelerating crystallization kinetics, and refining spherulitic morphology. In the present paper, an advanced nucleating agent, PNX-23 (Propel Xtra Performance Nucleating Agent), was synthesized and evaluated for its effectiveness in improving the structural, thermal, and processing characteristics of polypropylene.

The addition of PNX-23 to PP homopolymer resin resulted in significant improvements in both mechanical and thermal performance. The modified system exhibited **a ~25% increase in flexural modulus, ~75% enhancement in Izod impact strength, an 18 °C rise in crystallization temperature**, and a ~18% improvement in heat deflection temperature (HDT) compared to the unmodified polymer. These enhancements are attributed to the formation of a refined crystalline microstructure characterized by reduced spherulite size and increased nucleation density (Fig-1). The modified morphology contributes to improved stiffness, enhanced dimensional stability, and greater thermal resistance.

Figure 1, (A) Non-nucleated Polypropylene; (B) Nucleated PP with PNX-23

From a processing perspective, the elevated crystallization temperature facilitates faster polymer solidification during injection moulding, resulting in reduced cooling time and improved production efficiency. Processing trials indicate a **cycle time reduction of approximately ~5%**, accompanied by increase in output depending on mould geometry, article shape & size and processing parameters. The improved crystallization behaviour also enhances dimensional consistency and surface quality in moulded articles. The synthesis route for PNX-23 has been designed to be environmentally efficient, achieving greater than 98% reaction yield using water as the reaction medium, thereby minimizing solvent usage and process waste.

With significant polypropylene capacity expansions projected in India, total production capacity is expected to increase from approximately 6.5 million tonnes per year (2023-24) to 12-14 million tonnes per year by 2030, driven by rising demand from packaging, automotive, and healthcare sectors. Consequently, the consumption of performance additives such as nucleating agents is also anticipated to increase substantially. Commercial-scale implementation of this indigenously developed nucleating technology can reduce dependence on imports while strengthening the domestic petrochemical value chain, supporting the objectives of the Atmanirbhar Bharat (Self-Reliant India) initiative.

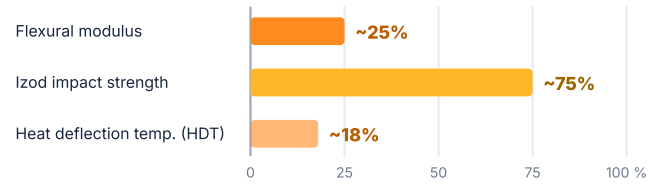
+18 °C
rise in crystallization temperature (Tc)

~75%
enhancement in Izod impact strength

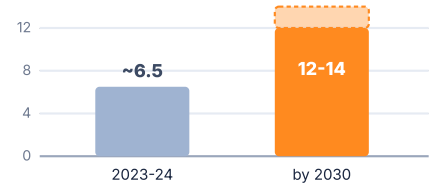
~5%
cycle time reduction in processing trials

>98%
reaction yield, water as reaction medium

PP homopolymer + PNX-23 · improvement vs unmodified polymer



India PP capacity · Mt per year



KEYWORDS Nucleating agent | Polypropylene | Modulus | Crystallization

FLOATING SOLAR | GREEN POWER · SCOPE 2 REDUCTION

Floating Solar Power plant on Rainwater Harvesting Pond

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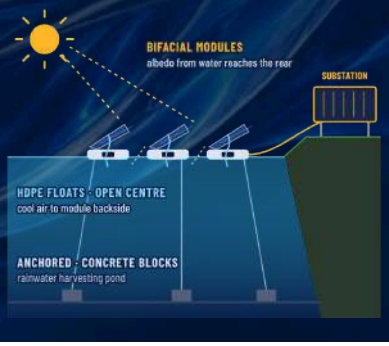


ABSTRACT

1. BASIC INFORMATION

Location of Implementation: BPCL Kochi Refinery
Status: Commissioned

Topic categorised: ✔ Changing Energy Landscape ✔ Aligning Refineries towards Net zero ✔ Environment management ✔ Energy Efficiency improvement ✔ Developments in alternative source of energy

Brief Description / Synopsis: BPCL-Kochi Refinery has nearly **18 acres of Rainwater harvesting pond** inside the refinery. A floating solar plant of **4.6 MW DC / 3.2 MW AC** was installed on water surface covering 60% of surface area to convert solar energy to electrical energy. This resulted in generation of green electrical energy and reduction of water evaporation losses and reduction in SCOPE-2 emissions.

2. ADVANTAGES OF FLOATING SOLAR PLANT

- Space Efficiency / Water surface used for solar panel installation.
- Enhanced Efficiency i.e. due to cooling effect from water
- Albedo Effect i.e. Due to reflection of irradiation from water surface
- Water Conservation
- Reduced Algae Growth
- Reduced Installation Costs

3. METHODOLOGY

Floating solar is the smart combination of floats (for supporting solar panels, cables and inverters) and solar panels, the whole system being anchored at the bottom and to the bank with the help of concrete blocks.

Basic technologies involved in this job are:

- **Solar Panels:** These are central to floating solar farms, which house multiple PV solar cells capable of transforming sunlight into direct current (DC) electricity via the photovoltaic effect.
- **Floating Platforms:** These floating platforms are constructed from buoyant materials such as high-density polyethylene (HDPE) to accommodate the solar panels, cables etc. ensuring to remain afloat on the water's surface.
- **Anchoring System:** This is required to secure the floating platforms, averting any drifting instigated by wind or water currents, thereby guaranteeing the stability and precise positioning of the solar arrays upon the water body.
- **Inverter:** The DC electricity engendered by the solar panels necessitates conversion into alternating current (AC) to facilitate utilization in electrical systems.
- **Electrical Infrastructure:** This includes High tension, Low tension electrical panels, Transformer to step-up the voltage, SCADA system for control and monitoring of complete solar plant, RO plant for cleaning of modules, Metering system for accounting the guaranteed generation.

5. CHALLENGES

- **New and Emerging technology:** Floating solar is a new technology that too very less commissioned plants in India for knowledge transfer/sharing. We visited the floating solar plant that got recently commissioned to understand the difficulties faced, design of float system including buoyancy calculations and anchoring and mooring system
- **Limited vendors in market that can manufacture floats:** Very few float manufactures are available in market. With in-depth market analysis 3 float manufacturers were shortlisted.
- **Availability of Skilled manpower:** This job involves requirement of skilled manpower in multiple stages like launching of floats with modules, earthing of solar modules by going inside pond, working on water body for cabling and termination works. Skilled/experience contract workforce for working on floating solar project was limited and we have put great effort in mobilizing skilled manpower from various execution agencies
- **First containerized substation in BPCL-KR:** To minimize the project timelines, we had opted for containerized substation that houses LT, HT and metering panels.

6. IMPLEMENTATION

This completed floating solar plant was constructed in very fast track basis with an execution timeline of 8 months. Even though this new concept showcased with multiple difficulties during engineering and execution phase due to lack of experienced manpower, material availability and monsoon effects but those were successfully encountered and completed this green field project in proper timelines.

7. INNOVATION & UNIQUENESS

- Solar panel float with open space at centre: We have used special solar panel floats having open space at centre of it, so that cool air travel from water surface to backside of solar module. There by increasing the efficiency of solar module to the tune of 1 to 1.2% due to cooling effect.
- Usage of Bifacial solar modules: We have used Bifacial solar modules in this solar plant, so that solar energy can be harnessed from back side of solar module due to albedo effect from water body. With this the efficiency of solar module is increased to the tune of 0.5 to 1%.
- Usage of Handrails in walkways: For safe movement/walking of manpower on floating blocks, a handrail arrangement was introduced. This enhanced manpower confidence while walking on the floating blocks.
- Usage of Containerised substation: For fast and easiness of installation, we have considered an elevated containerised substation houses High-Tension, Low-Tension panels and Metering Cubicles.

4.6 MW DC
floating plant, 3.2 MW AC

18 acres
rainwater harvesting pond inside the refinery

60 %
of the pond surface area covered

8 months
fast track execution timeline

4. Solar power generation process · author's flow chart

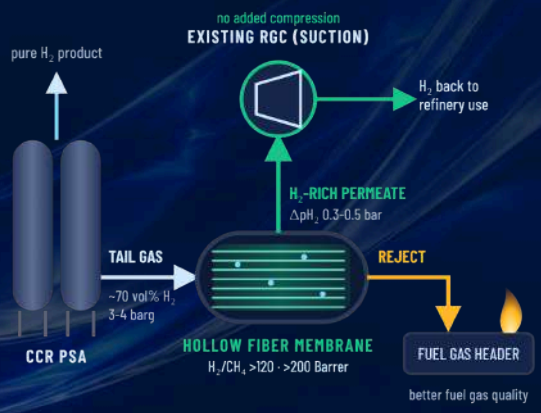
Solar cell → Solar module → String → String inverter → LT panel → Transformer → HT panel → Metering panel → BPCL-KR substation

DC | AC after the inverter

HYDROGEN RECOVERY

POLYMERIC MEMBRANES · INDIGENOUS TECHNOLOGY

Unlocking Hidden Hydrogen: A Waste-to-Resource Refinery Field Demonstration Using First-of-Its-Kind Indigenous Polymeric Membranes



Nitin Somkuwar[1], Abhishek Vashishta[2], Milind Dekate[2], Rajeev Kumar[1]

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ABSTRACT

Hydrogen management is a critical operational and decarbonization challenge for modern refineries. In Continuous Catalytic Reforming (CCR) units, Pressure Swing Adsorption (PSA) systems recover high-purity hydrogen; however, PSA tail gas still retains **up to ~70 vol% unrecovered hydrogen** mixed with light hydrocarbons. Due to ultra-low hydrogen partial pressure differentials, this stream is conventionally routed to the refinery fuel gas network, incurring significant hydrogen loss, elevated greenhouse gas (GHG) emissions, and adverse impacts on fired-heater performance including flame instability and burner degradation. Conventional recovery technologies are energy-intensive and economically unviable under such low-pressure conditions, a challenge no globally reputed membrane supplier has yet resolved.

This paper presents a ***first-of-its-kind*** refinery field demonstration of an advanced polymeric membrane process for hydrogen recovery from CCR-PSA tail gas at ultra-low partial pressure differentials (0.3-0.5 bar), conducted at the BPCL refinery.

The work addresses a globally relevant challenge in refinery hydrogen utilization and fuel gas quality management, offering a deployable, low-carbon solution for downstream operations. The membrane system is based on indigenously developed ultra-thin asymmetric polymeric hollow fiber membranes comprising a tailored polymers blend combined with optimized solvent/non-solvent formulations and nano-engineered fillers. This formulation delivers exceptional H_2/CH_4 selectivity (>120), high H_2 permeability (>200 Barrer), and robust mechanical stability under refinery conditions.

A key process innovation is the pressure-integrated system design: CCR-PSA tail gas at 3-4 barg is processed through the membrane module, and the hydrogen-enriched permeate is directly routed to the suction side of the existing recycle gas compressor (RGC) eliminating additional compression requirements. This integration leverages existing refinery infrastructure to achieve **negligible operating expenses (OPEX)**, a significant economic differentiator versus conventional recovery technologies. The field trial demonstrated consistent, stable operation with measurable outcomes: improved hydrogen recovery efficiency, enhanced fuel gas quality, reduced hydrogen losses, and quantifiable GHG emission reductions, all achieved with minimal process modifications.

Techno-economic analysis for a commercial-scale plant of ~120 MTPD capacity projects an annual economic benefit of approximately **USD 6.5 million, a payback period of under 5 months**, and a meaningful reduction in CO_2 emissions of up to **25,000 MTPA**, presenting a compelling financial and environmental value proposition rarely achieved simultaneously in refinery retrofit projects. The modular design offers compact footprint, scalability, and seamless retrofit compatibility. This demonstration establishes a commercially viable, energy-efficient pathway supporting refinery decarbonization and the industry-wide transition toward low-carbon hydrogen management.

~6.5 M USD/yr
annual economic benefit, ~120 MTPD commercial plant

<5 months
payback period

25,000 MTPA
CO_2 emission reduction (up to)

>120
H_2/CH_4 selectivity, with >200 Barrer H_2 permeability

Where PSA tail gas hydrogen goes · conventional vs membrane

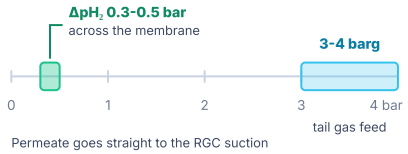
CONVENTIONAL

PSA tail gas — up to ~70 vol% H_2 → Fuel gas network — H_2 loss · higher GHG · flame instability, burner wear

WITH POLYMERIC MEMBRANE

Membrane — 3-4 barg feed → H_2 permeate to existing RGC suction — no added compression · negligible OPEX

Operating window · ultra-low driving force

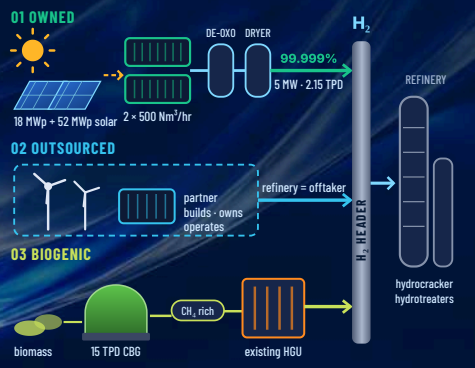


KEYWORDS Continuous Catalytic Reforming (CCR) · Pressure Swing Adsorption (PSA) · polymeric membrane · ultra-low partial pressure · OPEX · decarbonization

GREEN HYDROGEN | REFINERY DECARBONISATION · TRI-PATHWAY

Owned, Outsourced, and Biogenic: A Tri-Pathway Enabling Bina Refinery's Grey-to-Green Hydrogen Journey

Pathak Aman Ratan
Co-Authors: **Nilesh Zode, Anshul Gupta**
BPCL-Bina Refinery



ABSTRACT

In alignment with India's national commitment to achieving Net Zero emissions by 2070, Bharat Petroleum Corporation Limited (BPCL) has set a target of Net Zero in Scope 1 and Scope 2 by 2040. BPCL Bina Refinery, contributing nearly 30% of BPCL's total emissions, sits at the centre of this transition. Within the refinery, the Hydrogen Generation Unit (HGU) alone accounts for about 35% of total GHG emissions, making the replacement of grey hydrogen with green hydrogen the single most consequential lever in Bina's decarbonization strategy. **This paper presents the refinery's green hydrogen journey through three complementary pathways -Alkaline Water Electrolysis, Build-Own-Operate (BOO) green hydrogen plant, and hydrogen through biomass, each contributing distinctly to a common Net Zero destination of the nation.**

The first and most mature pathway is captive **green hydrogen production through alkaline water electrolysis**. Bina Refinery has commissioned **a 5 MW Green Hydrogen Plant producing 2.15 TPD of 99.999%-pure hydrogen** using two 500 Nm³/hr electrolysers. Hydrogen leaving the electrolysers at more than 99% purity is upgraded through De-oxo and Dryer units to ultra-high purity hydrogen, then fed directly into the refinery's hydrogen header for use in the hydrocracker, hydrotreaters, and hydrogenation units. The plant displaces 2,745 MTPA of naphtha consumption in the HGU, **cutting approximately 9,000 MTPA of CO_2 emissions annually**, while the conserved naphtha is redirected as feedstock to upcoming petrochemical units, extending the sustainability benefit beyond emissions reduction into resource efficiency. The facility draws renewable power from Bina's own Solar Power Plant of 18 MWp capacity at Bina and BPCL's a 52 MWp solar plant at Prayagraj UP. The future expansion of the Bina Refinery is also backed by upcoming 50 MW wind power project in Madhya Pradesh dedicated to the refinery's green hydrogen roadmap.

The second pathway will follow a **Build-Own-Operate (BOO) model**, under which renewable energy and green hydrogen infrastructure will be developed, owned, and operated by a specialised third-party partner, with the refinery serving as the offtaker. This asset-light structure keeps refinery capital free for core process investments, transfers technology and execution risk to developers with established expertise and allows capacity to scale faster than a fully captive build-out making it a natural complement to the refinery's owned assets rather than a competing alternative.

The third pathway **converts biomass into green hydrogen** through a 15 TPD Compressed Biogas (CBG) facility, Bina. Rather than building fresh hydrogen-generation capacity, this route repurposes the refinery's existing HGU assets, converting methane-rich compressed biogas into green hydrogen. This circular approach lowers capital intensity, diversifies feedstock away from grid power and electrolysis alone, and creates an economic link to the surrounding agrarian region through biomass sourcing.

Together, the three pathways- **owned, outsourced, and biogenic**, give Bina Refinery a diversified, de-risked route to displacing grey hydrogen at scale. This paper traces that journey from concept through construction, commissioning, and operationalisation of the 5 MW electrolysis plant, and outlines the roadmap by which the BOO and biomass pathways will extend this progress, reinforcing Bina Refinery's role as a flagship of BPCL's Net Zero 2040 ambition and India's wider energy transition.

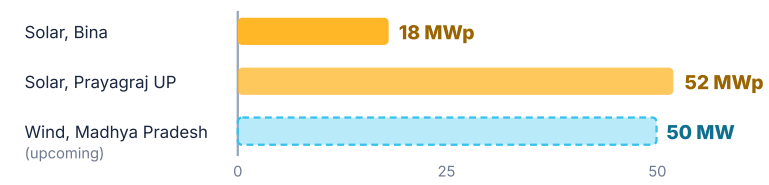
5 MW
green hydrogen plant, 2.15 TPD of 99.999%-pure hydrogen

~9,000 MTPA
CO_2 emissions cut annually

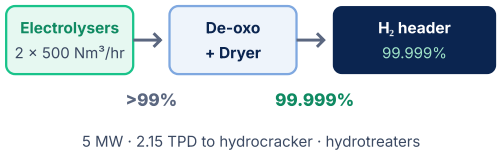
2,745 MTPA
naphtha consumption displaced in the HGU

35%
of refinery GHG emissions from the HGU alone

Renewable power behind the roadmap (capacity)



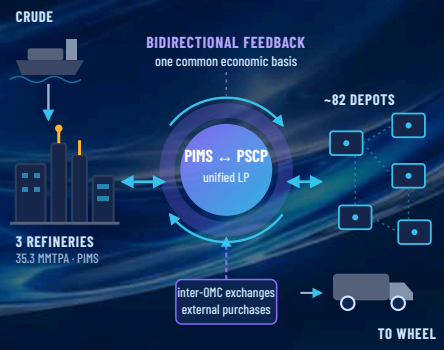
Owned pathway: purity chain



5 MW · 2.15 TPD to hydrocracker · hydrotreaters

DIGITAL PLANNING · LP OPTIMIZATION | REFINERY SUPPLY CHAIN

Eliminating Supply Chain Silos: Integrated Well-to-Wheel Refinery Optimization



Shekhar Gunwal
Bharat Petroleum Corporation Limited (BPCL)

ABSTRACT

Bharat Petroleum Corporation Limited (BPCL) operates three refineries with an installed refining capacity of 35.3 MMTPA and distributes petroleum products through a network of approximately 82 depots. In addition to its own refinery production, BPCL manages product exchanges with other Oil Marketing Companies (OMCs) and sources products from standalone refineries, including RIL, NEL, and MRPL.

Managing this interconnected value chain through conventional sequential planning created a significant optimization challenge. BPCL used Aspen PIMS for crude procurement and refinery production planning and Aspen Petroleum Supply Chain Planner (PSCP) for product distribution planning. Historically, refinery production was optimized first, after which the resulting product availability was passed to the distribution planning system. This siloed approach limited the ability of upstream refinery optimization to consider downstream demand, depot constraints, inter-OMC exchanges, external product purchases, and distribution economics simultaneously resulting in potential enterprise-wide value leakage.

To address this challenge, BPCL implemented an integrated Aspen Unified PIMS-PSCP optimization framework that enables iterative and bidirectional feedback between refinery production and product distribution planning engines. Unlike the conventional sequential approach, the integrated framework allows refinery production decisions to dynamically respond to downstream distribution requirements, while distribution and sourcing decisions continuously adapt to refinery economics and product availability.

The integrated optimization simultaneously evaluates the refinery product slate, crude selection, product sourcing, depot allocation, inter-OMC exchanges, external purchases, and distribution logistics, enabling decisions to be optimized on a common economic basis. This represents a fundamental shift from functional optimization to enterprise-wide value maximization, creating a digital planning capability spanning the complete Well-to-Wheel value chain.

The implementation delivered significant improvements in both planning efficiency and business value. Model execution speeds improved by **4.6×-16×**, model maintenance activities became 2-3× faster, and approximately 1,000 staff-hours are saved annually. The integrated framework also enabled dynamic allocation of approximately 50% of term crude based on refinery and downstream supply-chain economics. Most importantly, the enterprise-wide optimization delivered a quantified financial impact of approximately **Rs. 5.7 crore per month, equivalent to Rs. 68.4 crore annually**.

The platform is designed for future integration with Aspen Unified Scheduler (AUS), creating a pathway to link LP planning with day-to-day refinery scheduling and further strengthen BPCL's integrated, agile, and economically optimized Well-to-Wheel supply chain.

Parameter	Sequential / Siloed	Integrated PIMS-PSCP	Value Addition
Optimization Philosophy	Local Optimization (Refinery → Distribution)	Enterprise Optimization (PIMS ↔ PSCP)	Coordinated Value Maximization
Model Execution	Baseline	4.6×-16× faster	Rapid Scenario Analysis
Production, Product & Crude Optimization	Independent decisions based on operational flexibility	Integrated production, sourcing & distribution based on economics	~50% term crude dynamically allocated
Overall Impact	Local sub-optimization	Enterprise value maximization	**Rs. 5.7 Cr/month (Rs. 68.4 Cr/year)**

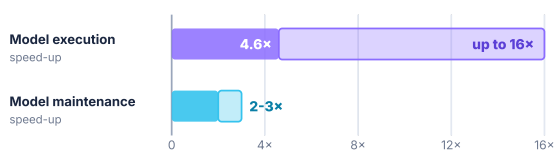
68.4 Rs. Cr/yr
financial impact, about Rs. 5.7 crore per month

4.6-16×
faster model execution

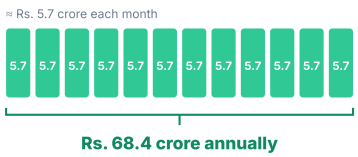
~1,000 hrs
staff-hours saved annually

~50 %
of term crude dynamically allocated

Planning efficiency gains

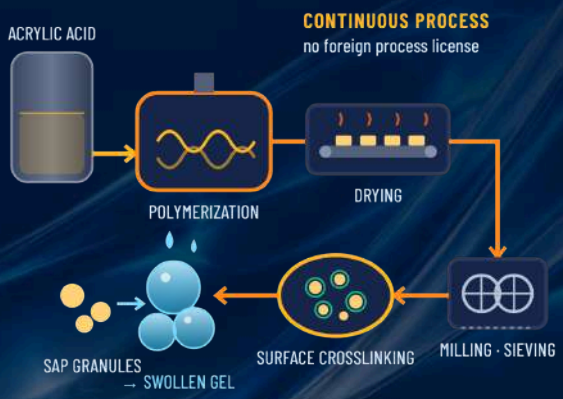


Enterprise value delivered



SPECIALTY PETROCHEMICALS | SAP · INDIGENOUS TECHNOLOGY

Development of Indigenous end to end technology for Production of Superabsorbent Polymer (SAP)



Jitendra Kumar Satyarthi, Rakesh Vankayala, Suvrajyoti Mishra, Ramesh karri, Seetaram Chebrolu, Pranab Kumar Rakshit, Saptarshi Ray

ABSTRACT

Superabsorbent Polymer (SAP) is a critical raw material for baby diapers, adult incontinence products, and feminine hygiene applications. Despite a growing domestic demand of about **60,000 TPA**, India remains fully dependent on imported SAP. To address this gap, Bharat Petroleum Corporation Ltd. (BPCL) developed and demonstrated an indigenous technology to produce hygiene-grade SAP from acrylic acid.

The key innovation lies in the development of a fully indigenous continuous SAP manufacturing process, covering polymerization, drying, milling, sieving, and surface-crosslinking technologies without reliance on any foreign process license. Advanced process and product design including polymerization recipe and post-treatments have enabled achievement of international hygiene-grade specifications with high absorbency under load, low residual monomer content, and low extractables.

A **200 TPA continuous technology demonstration plant** has been successfully commissioned, and the product has received positive validation from diaper and hygiene product manufacturers. The innovation is protected through multiple granted patents and forms the basis for a planned 20KTPA commercial plant.

This development establishes India's first indigenous SAP manufacturing capability, significantly reducing import dependence, strengthening the domestic hygiene products value chain, and demonstrating successful translation of in-house R&D into a commercially scalable specialty petrochemical technology.

Besides this BPCL is also working towards other application of Superabsorbent Polymer I n agriculture. Controlled trails of Bharat -Agri-SAP has shown Improved seed germination, **Nearly 20% increase in crop yield and Up to 30% water saving**.

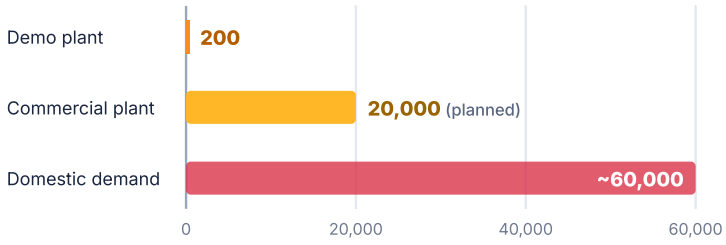
60,000 TPA
domestic SAP demand, fully met by imports today

200 TPA
continuous technology demonstration plant commissioned

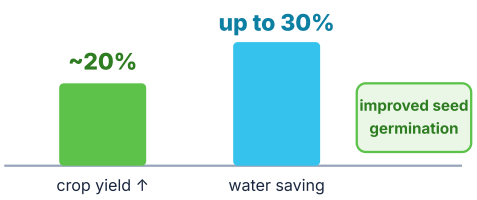
20 KTPA
planned commercial plant

~20 %
higher crop yield and up to 30% water saving with Bharat Agri-SAP

From demonstration to commercial scale · TPA



Bharat Agri-SAP field trials

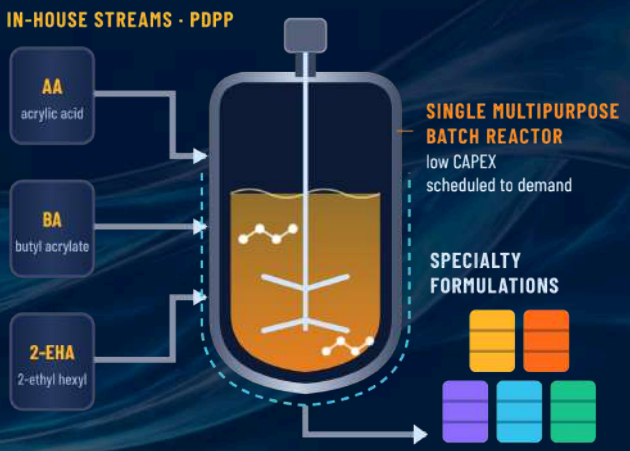


HOW IT WORKS

1. **Polymerization** — acrylic acid, continuous
2. **Drying · milling** — indigenous process
3. **Sieving** — hygiene-grade sizing
4. **Surface crosslinking** — high absorbency under load

SPECIALTY POLYMERS | PETROCHEMICALS · IMPORT SUBSTITUTION

Acrylic Acid to Value-Added Specialty Polymeric Formulations



Vaishakhi Singh
Bharat Petroleum Corporation Limited (BPCL)

ABSTRACT

The growing imperative for decarbonization is driving a global transition from conventional fuels toward alternative fuels and electrification. This transition is expected to reshape the demand landscape for conventional transportation fuels, necessitating a strategic shift in refinery business models beyond conventional fuel production. In this context, petrochemicals and downstream value-added products offer an important pathway for enhancing refinery sustainability and value creation.

Bharat Petroleum Corporation Limited (BPCL) has already established a presence in the niche petrochemical segment through its flagship Propylene Derivative Petrochemical Project (PDPP) at Kochi Refinery (KR). The PDPP produces acrylic acid along with its key derivatives, namely butyl acrylate and 2-ethyl hexyl acrylates. Acrylic acid and acrylate-based polymers have diverse applications in high-value specialty segments. BPCL R&D is actively engaged in developing **indigenous polymeric formulations** based on these in-house petrochemical streams for applications such as scale inhibition in industrial water treatment, including cooling towers and reverse osmosis systems, as well as detergents, binders, adhesives, coatings, and rheology modifiers for personal care products.

These products are majorly imported in India from global manufacturers. Indigenous development and commercialization of such products therefore offer opportunities for **import substitution, value addition to in-house petrochemical streams, and significant foreign exchange savings**. Importantly, the manufacturing of these formulations need relatively low CAPEX and **a single multipurpose batch reactor** can be used to manufacture different products with proper scheduling based on market demand, allowing flexible operations. Development of a diversified portfolio of acrylic-based specialty products can thus enable refineries to move beyond conventional fuels toward higher-value downstream chemicals and provide greater flexibility in navigating evolving market dynamics.

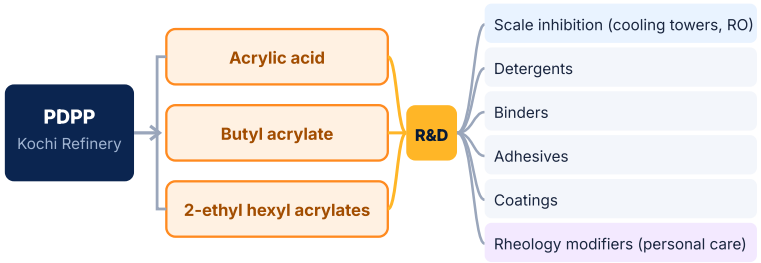
Indigenous
polymeric formulations from in-house petrochemical streams

Low CAPEX
relatively low CAPEX needed for manufacturing

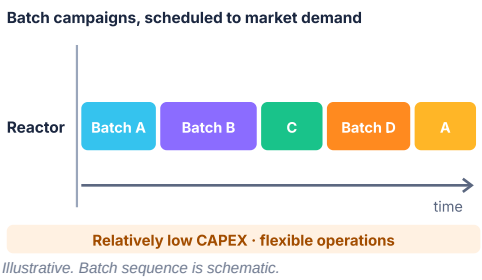
Single reactor
one multipurpose batch reactor for different products

Import substitution
and significant foreign exchange savings

From in-house streams to specialty applications



Flexible operation one reactor, many products



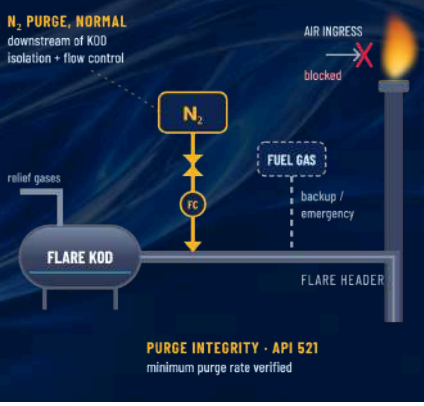
Illustrative. Batch sequence is schematic.

HOW IT WORKS

1. **In-house streams** — acrylic acid, BA, 2-EHA
2. **Indigenous R&D** — polymeric formulations
3. **Batch reactor** — single, multipurpose
4. **Specialty markets** — replace imports

FLARE SYSTEM SAFETY | FUEL GAS CONSERVATION · GHG REDUCTION

Provision of Nitrogen Purging in Flare Header Downstream of Flare KOD for Replacement of Fuel Gas as Flare Purge Medium delivering significant cost savings and Green House Gas emission reduction while ensuring flare system safety



Abhishek Swaroop Srivasta , Himanshu Chouksey, BPCL- Bina Refinery

ABSTRACT

A sustainable engineering initiative at BPCL Bina Refinery replacing Fuel Gas with Nitrogen as the continuous flare purge medium, delivering significant cost savings and Green House Gas emission reduction while ensuring flare system safety.

Background

In the BPCL Bina Refinery flare system, Fuel Gas (FG) was traditionally used as the continuous purge medium to prevent atmospheric air ingress through the flare tip during low-flow or no-flow conditions. Air ingress into the flare header can result in the formation of flammable or explosive hydrocarbon-air mixtures, making continuous purging essential for safe and reliable flare operation. However, the continuous use of Fuel Gas for purging led to significant Fuel Gas consumption, resulting in avoidable operating costs and associated greenhouse gas emissions.

Objective

To optimize flare system operation, conserve refinery Fuel Gas, and reduce environmental impact by replacing Fuel Gas with Nitrogen (N_2) as the normal continuous flare purge medium while ensuring compliance with safety and operational requirements.

Engineering Assessment

In-house purge integrity calculations were carried out in accordance with API 521 guidelines to determine the minimum purge rate and verify protection against atmospheric air ingress. The assessment considered the flare system configuration, operating conditions during low-flow and no-flow scenarios, and purge gas characteristics. The study confirmed that Nitrogen purging would adequately prevent air infiltration and eliminate the possibility of flammable mixture formation within the flare header and stack.

Implementation

A dedicated Nitrogen purging facility was installed in the flare header downstream of the Flare Knock-Out Drum (KOD). The modification included Nitrogen piping, isolation valves, and flow-control arrangements for controlled introduction of Nitrogen into the flare system. After successful commissioning, Nitrogen was established as the normal purge medium. The existing Fuel Gas purge arrangement was retained and reconfigured as a backup/emergency purge source in line with the approved operating philosophy.

Benefits Achieved

- Annual financial savings of approximately ₹11 crore through reduction in Fuel Gas consumption.
- GHG emission reduction: 6.9 TMT/year.
- Energy Intensity Index (EII) reduction: 0.28.
- Reduction in associated CO_2 emissions.
- Conservation of Fuel Gas for higher-value refinery applications.
- Sustained compliance with flare safety requirements and improved resource utilization.

Conclusion

The project successfully replaced Fuel Gas with Nitrogen as the primary flare purge medium while maintaining flare system safety and reliability. The modification demonstrates an effective approach for energy conservation, emission reduction, and cost optimization, delivering significant recurring financial and environmental benefits to BPCL Bina Refinery.

₹11 crore/yr
approx. annual savings from reduced Fuel Gas consumption

6.9 TMT/year
GHG emission reduction

0.28
Energy Intensity Index (EII) reduction

API 521
basis of in-house purge integrity calculations

Purge medium: before and after

BEFORE
Fuel Gas (FG)
continuous purge medium
operating cost · GHG emissions

→

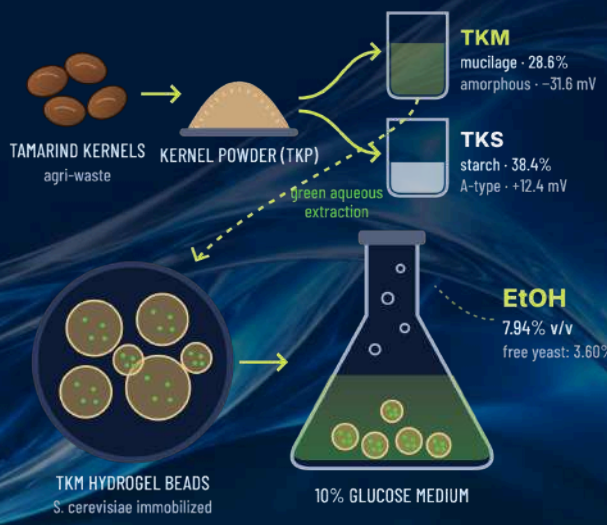
AFTER
Nitrogen (N_2)
normal continuous purge medium
Fuel Gas conserved for refinery use

Operating philosophy

1	Normal	Nitrogen purge, continuous
2	Control	isolation valves + flow control
3	Backup	Fuel Gas purge, backup/emergency

BIOMASS VALORIZATION | BIOETHANOL · BIOPOLYMERS

Valorization of tamarind kernel biomass into functional biopolymers for yeast immobilization and enhanced ethanol production



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BRIC-National Agri-Food and Biomanufacturing Institute (NABI), Sector-81, Sahibzada Ajit Singh Nagar, Mohali, Punjab, 140306, India

ABSTRACT

The valorization of agro-industrial residues into functional biopolymers aligns with circular economy principles and offers sustainable alternatives to synthetic materials in food and fermentation applications. This study investigated the potential application of tamarind kernel powder (TKP), an underutilized agri-waste, as a source of tamarind kernel mucilage (TKM) and tamarind kernel starch (TKS) for yeast immobilization for bioethanol production. Mucilage and starch were extracted via green aqueous media, yielding percentages of 28.6 ± 1.1% and 38.4 ± 1.6%, respectively. The biopolymers were characterized for their solubility, swelling, and water-holding capacity via thermal (TGA), morphological (SEM), structural (FTIR, XRD), and surface charge analyses. The TKM exhibited an amorphous structure, high hydrophilicity, and an anionic surface (−31.6 mV), whereas the TKS displayed A-type crystallinity and a positive charge (+12.4 mV), indicating gelling property with divalent cations and copolymers. *Saccharomyces cerevisiae* was successfully immobilized in TKM-based hydrogel beads (1 g/10 mL), with sodium alginate as a control, to form porous, mechanically stable beads. Fermentation trials in 10% glucose medium revealed that **immobilized yeast produced significantly more ethanol (7.94 ± 0.24% v/v) than free yeast (3.60 ± 0.08% v/v)**. These findings demonstrate the feasibility of tamarind-derived hydrocolloids as sustainable immobilization agents and support their broader application in fermentation and bioprocessing.

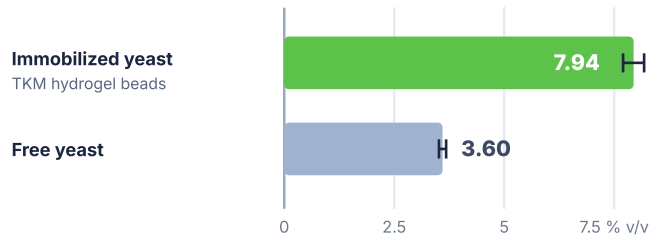
7.94 % v/v
ethanol with TKM-immobilized yeast (± 0.24)

3.60 % v/v
ethanol with free yeast (± 0.08)

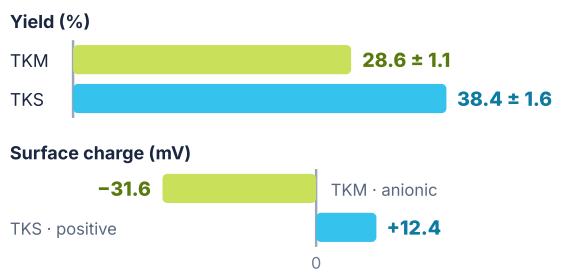
28.6 %
mucilage (TKM) yield, ± 1.1%

38.4 %
starch (TKS) yield, ± 1.6%

Ethanol in 10% glucose medium · % v/v, mean ± SD



Two biopolymers from TKP



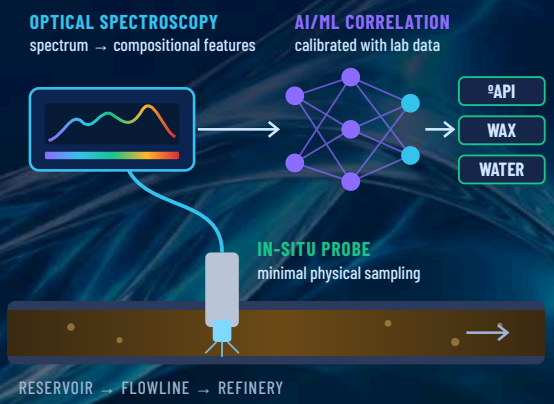
HOW IT WORKS

1. **Kernel powder** — underutilized agri-waste
2. **Green extraction** — aqueous media: TKM + TKS
3. **Bead formation** — yeast in TKM hydrogel
4. **Fermentation** — 10% glucose to ethanol

KEYWORDS Tamarind kernel | Yeast immobilization | Bioethanol | Biopolymers | Fermentation

CRUDE OIL CHARACTERIZATION | OPTICAL SPECTROSCOPY · AI/ML

Development of Correlation Algorithm from Molecular Characterization of Petroleum Crude Oil by Optical Spectroscopic Approach: Adoption for Futuristic Smart System Development in Petroleum Industry.



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ABSTRACT

Crude oil is a highly complex and heterogeneous mixture of hydrocarbons, commonly described in terms of Saturates, Aromatics, Resins, and Asphaltenes (SARA). As crude oil moves from the reservoir to surface facilities and subsequently to refineries, its composition does not remain constant. Variations in pressure and temperature, fluid expansion, phase separation, and interactions among different fractions lead to continuous physico-chemical changes and molecular rearrangements within the crude oil system. These changes directly influence important quality parameters such as ºAPI gravity, density range, wax content, water content, and the presence of impurities, which significantly affect processing behavior and flow assurance during production from sub-surface reservoirs, to processing units through production and flow pipelines and their follow-up transportation up-to refineries. Accurate compositional characterization of crude oil is therefore essential at multiple stages of the petroleum value chain. However, conventional laboratory-based techniques require extensive sample collection, preservation, transportation, and detailed laboratory preparation, making them time-consuming and costly. In practical scenarios, particularly at offshore platforms and remote production sites, routine sampling is often difficult or economically unfeasible. These limitations create a strong demand for rapid, in-situ or near-real-time analytical methods capable of providing reliable crude oil characterization with minimal physical sampling.

This study focuses on the **remote characterization of crude oil using optical spectroscopic approach**. The proposed methodology follows a standard petroleum workflow involving separation, characterization, and correlation. Spectroscopic data are analyzed to extract compositional features, which are then correlated with conventional laboratory measurements to develop predictive models. Although calibration with reference data remains necessary, the approach **significantly reduces analysis time and operational cost**. Furthermore, integration with artificial intelligence and machine-learning techniques offers strong potential for future automated, real-time, in-situ crude oil monitoring systems, supporting improved operational efficiency and faster decision-making.

SARA
Saturates, Aromatics, Resins and Asphaltenes

In-situ
near-real-time characterization with minimal physical sampling

Lower
analysis time and operational cost

AI/ML
for future automated, real-time crude oil monitoring

Laboratory route vs optical route

Conventional laboratory-based — time-consuming and costly

Sample collection → Preservation → Transportation → Lab preparation

Optical spectroscopic approach — rapid, minimal sampling

In-situ spectrum → Feature extraction → Correlate with lab → **Predictive model**

Composition changes along the value chain

Reservoir → Surface → Pipelines → Refinery

Quality parameters affected

ºAPI gravity | density | wax | water | impurities

HOW IT WORKS

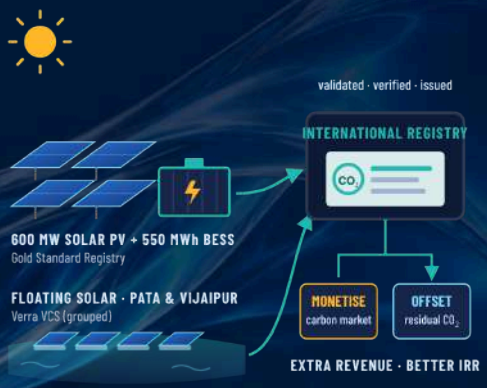
1. **Separation** — standard petroleum workflow
2. **Characterization** — optical spectroscopy
3. **Correlation** — spectral features vs lab data
4. **AI/ML** — real-time in-situ monitoring

KEYWORDS Crude Oil Characterization | Optical Spectroscopy | Molecular Characterization | Artificial Intelligence and Machine Learning | Real-Time In-Situ Analysis

CARBON MARKETS | RENEWABLE ENERGY · CARBON CREDITS

Leveraging International Carbon Markets for Decarbonisation: GAIL's Approach to Carbon Credit Accrual from Renewable Energy Projects

Mr. Sameer Virmani, CGM (SD), GAIL (India) Limited, Noida
Mr. Mukul Gupta, CM (SD), GAIL (India) Limited, Noida



ABSTRACT

The transition towards a low carbon energy system requires not only accelerated deployment of Renewable Energy but also innovative mechanisms for enhancing the financial viability of Decarbonisation projects. Carbon Markets can play an important role in this transition by converting verified GHG emission reductions into marketable Carbon Credits and thereby creating an additional revenue stream for clean-energy projects. In this context, GAIL (India) Limited is developing a structured approach for registration and monetisation of eligible Renewable Energy projects under Internationally recognised Carbon Credit mechanisms.

GAIL has set an ambitious target of achieving **3,600 MW of Renewable Energy capacity by 2035**, from its present installed RE capacity of ~154 MW, as a part of its Net Zero Emissions target. Accordingly, GAIL has undertaken detailed assessment of its Renewable Energy projects for their potential registration in Carbon Markets, both in the International / National Carbon Markets. Based on the assessment, 03 projects have been identified for registration under International Voluntary Carbon Market standards, as detailed:

(i) 600 MW Solar PV project integrated with a 550-MWh Battery Energy Storage System (BESS) at TUSCO Solar Park, Jhansi, proposed under the Gold Standard Registry.

(ii) 17.5 MW Floating Solar Project at Pata and (iii) 7.75 MW Floating Solar Project at Vijaipur, proposed as a grouped project under Verra Verified Carbon Standard (VCS) Registry

The above projects have potential of an average annual emission reduction of approximately **8.54 lakh tCO_2e** for the 600 MW RE+BESS project and approximately **42,000 tCO_2e** for the grouped Floating Solar projects.

The paper presents GAIL's approach to the end-to-end registration and monetization of Carbon Credit projects, covering project identification, selection of an appropriate International Registry, project documentation, Validation and Verification, Credit issuance and Monetisation/Offsetting, along with the cost-benefit analysis.

The accrued Carbon Credits to GAIL can either be monetised in the Carbon Market or utilised to Offset any residual emissions, as a step to achieve Net Zero Emissions targets.

A financial assessment of the identified projects indicates that Carbon Credit revenues can contribute to enhancing project economics and improving the commercial viability of Renewable Energy investments. For these capital-intensive projects, the additional revenue generated through Carbon Credits can provide an economic incentive for their deployment, supporting overall project financial viability and contributing to an incremental improvement in the Internal Rate of Return (IRR).

The paper demonstrates how integration of Carbon Market considerations at the project development stage can create an additional economic lever for RE-BESS / Floating Solar projects. It also provides a replicable framework for other energy-sector organisations seeking to leverage international Carbon Markets to support large-scale decarbonisation and Net Zero Emissions targets.

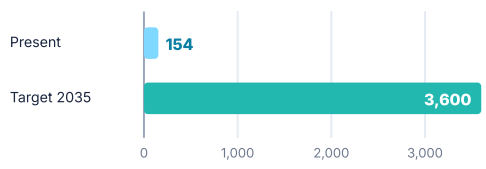
3,600 MW
Renewable Energy capacity target by 2035

~154 MW
present installed RE capacity

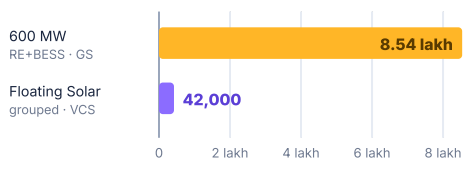
8.54 lakh tCO_2e/yr
approx. average annual reduction, 600 MW RE+BESS

~42,000 tCO_2e/yr
approx. grouped Floating Solar projects

GAIL Renewable Energy capacity · MW



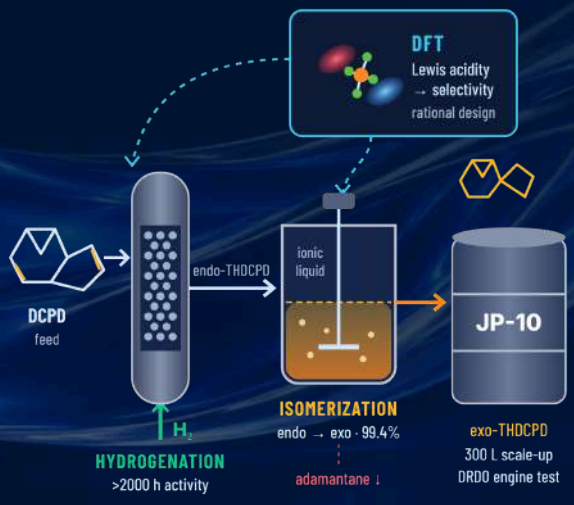
Average annual emission reduction · tCO_2e, approx.



KEYWORDS International Carbon Markets | Gold Standard | Verra VCS | Battery Energy Storage System | Floating Solar | Monetisation

SYNTHETIC DEFENSE FUELS | DFT CATALYST DESIGN · MAKE IN INDIA

First-Principles-Guided Catalyst Design for Indigenous JP-10 Production: Advancing High-Energy-Density Synthetic Fuels for Defense Applications



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ABSTRACT

JP-10 (exo-tetrahydrodicyclopentadiene, exo-THDCPD) is a high-energy-density synthetic fuel for defense applications, including short-range missiles and advanced aerospace systems. Its strained cyclic structure provides high volumetric energy density (39.6 MJ/L) and a low freezing point (−79 °C). The absence of indigenous manufacturing and high import costs highlight the need for domestic JP-10 production. HPCL Green R&D Centre has developed an indigenous catalytic process integrating first-principles-based catalyst design, experimental validation, and process scale-up. The heterogeneous catalysts developed for dicyclopentadiene (DCPD) hydrogenation demonstrated sustained activity for over 2000 hours in continuous pilot-plant operation. For the isomerization of endo-THDCPD to exo-THDCPD, tunable ionic-liquid-based catalysts achieved **99.4% selectivity** while significantly suppressing adamantane formation.

First-principles Density Functional Theory (DFT) calculations provided molecular-level insights into catalyst Lewis acidity and its influence on selectivity, guiding the rational design and optimization of the catalyst systems. This computational approach enabled scientifically informed catalyst development and reduced reliance on empirical screening. The process was successfully scaled up to 300 L, and DRDO engine evaluation demonstrated **a 13% improvement in volumetric efficiency** compared with aviation turbine fuel (ATF). The indigenous JP-10 achieved 99.4% purity, a freezing point of −79 °C, and a net heat of combustion of 43.9 MJ/kg. This work demonstrates how DFT-guided catalyst innovation can enable indigenous production of high-energy-density synthetic fuels for defense applications, advancing the Make in India initiative and India's strategic self-reliance.

99.4%
selectivity, endo to exo-THDCPD isomerization

>2000 h
sustained hydrogenation catalyst activity, continuous pilot plant

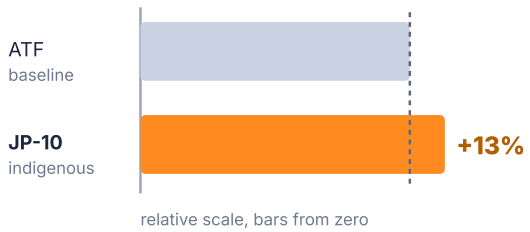
300 L
process scale-up achieved

13%
higher volumetric efficiency vs ATF (DRDO engine evaluation)

Indigenous JP-10: reported fuel properties

39.6 MJ/L	−79 °C	43.9 MJ/kg	99.4 %
volumetric energy density	freezing point	net heat of combustion	JP-10 purity

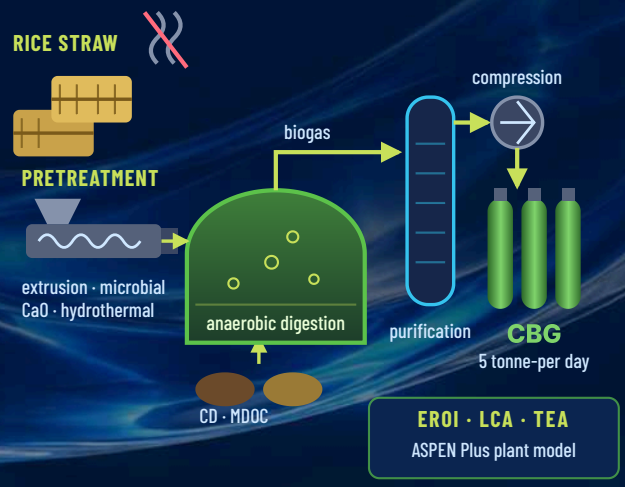
Volumetric efficiency (DRDO engine)



HOW IT WORKS
1. **DFT design** — Lewis acidity insights
2. **Hydrogenation** — DCPD, over 2000 h
3. **Isomerization** — endo to exo, ionic liquid
4. **Scale-up** — 300 L · DRDO engine test

COMPRESSED BIOGAS · RICE STRAW | EROI · LCA · TEA

From Pretreatments to Plant-scale Sustainability: Assessment of Rice straw-to-CBG systems



Amey Kulkarni
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ABSTRACT

Rice straw represents a significant yet underutilized renewable resource, with approximately **43.5 million tonnes** of surplus straw generated annually in India. A substantial fraction of this surplus is openly burned, contributing to environmental pollution and deterioration of air quality. Diverting rice straw for compressed biogas (CBG) production therefore offers dual benefit of sustainable residue management and renewable fuel generation. However, lignocellulosic nature of the straw, limits its biodegradability and makes it resistant to anaerobic digestion. Consequently, several pretreatment strategies have been investigated to improve the biodegradability of the straw; however, their implications for plant-scale energy performance, environmental impacts, and economic viability remain poorly understood.

In this study, we present an integrated framework linking laboratory-scale pretreatment performance with the above-mentioned plant-scale sustainability metrics. We experimentally evaluated four pretreatments (extrusion, microbial consortium, calcium oxide, and hydrothermal), for methane production from rice straw, co-digested with cow dung (CD) and mustard deoiled cake (MDOC). The best-performing pretreatments were subsequently integrated with ASPEN Plus simulation of downstream biogas purification and compression stages to model a 5 tonne-per day CBG producing facility. This modelled facility served as a common reference for evaluating net energy return on investment (EROI), cradle-to-gate life cycle assessment (LCA), and scenario-wide techno-economic assessment (TEA).

The results highlighted that extrusion pretreatment with both nitrogen supplements (CD and MDOC) and microbial consortium with CD showed significantly enhanced methane yields ranging from **87.37-175.61 mL CH_4/g TS**. These configurations also achieved a higher net EROI (1.90-4.15), lower life cycle impacts (1.92-3.25 kg CO_2/kg CBG) and economic rate of returns of up to **21.78 %**. The untreated plant configuration was unviable in all three metrics. These findings demonstrate that pretreatments can significantly improve the plant-scale sustainability of rice straw-to-CBG systems.

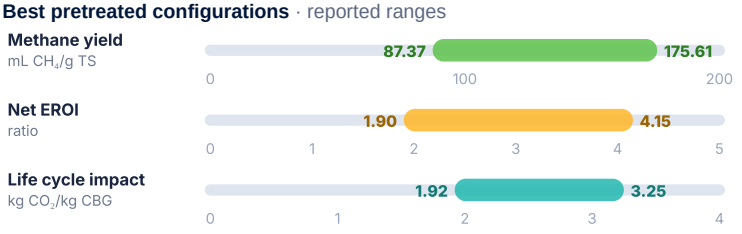
87.37-175.61
mL CH_4/g TS methane yield with best pretreatments

1.90-4.15
net EROI of pretreated configurations

1.92-3.25
kg CO_2/kg CBG life cycle impact

21.78%
economic rate of return, up to

Best pretreated configurations · reported ranges



Plant-scale verdict across three metrics

	EROI	LCA	TEA
Extrusion with CD · MDOC	✓	✓	✓
Microbial consortium with CD	✓	✓	✓
Untreated plant configuration	✗	✗	✗

HOW IT WORKS

1. **Pretreat straw** — 4 methods screened
2. **Co-digest** — with CD and MDOC
3. **Purify, compress** — ASPEN Plus, 5 TPD
4. **Assess** — EROI · LCA · TEA

CO₂ UTILISATION · CCUS | TECHNO-ECONOMIC ASSESSMENT

CO₂ to Value: A Techno-Economic Comparative Assessment of Carbon Utilization Pathways for Indian Refineries

D Hima Bindu*, Adhwarshu Bhattacharya, Mainak Sarkar, Karumanchi Ramesh, Sarvesh Kumar, Dr. Umish Srivastva
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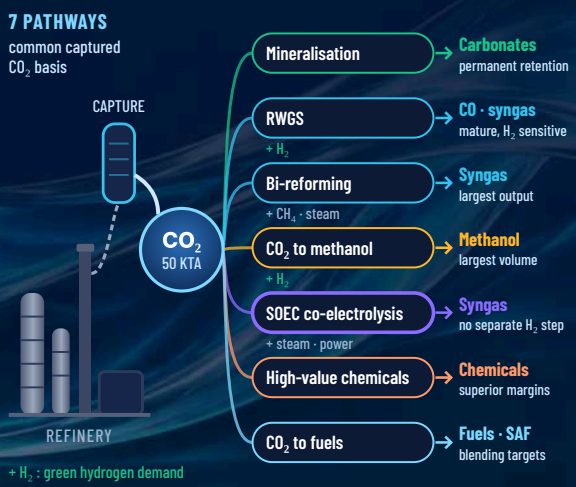

ABSTRACT

India's refining sector, with an installed capacity of approximately 267 MMTPA, faces the dual challenge of meeting rising fuel and petrochemical demand while progressing toward the national net-zero-by-2070 commitment. Carbon capture, utilisation and storage (CCUS) addresses residual, hard-to-abate emissions, but the strategic question is shifting from *how* CO_2 is captured to *where* it can create the greatest economic and decarbonisation value. This paper presents a comparative techno-economic assessment of seven CO_2 utilisation pathways relevant to Indian refineries: mineralisation, reverse water-gas shift (RWGS), bi-reforming of methane, CO_2-to-methanol, solid oxide electrolysis cell (SOEC) co-electrolysis, CO_2-to-high-value chemicals, and CO_2-to-fuels including sustainable aviation fuel (SAF). All pathways are evaluated on **a common 50 KTA captured-CO_2 basis**, comparing material balance, hydrogen and electricity demand, carbon-retention permanence, product value, technology readiness and refinery-integration potential.

The analysis finds that RWGS, though technologically mature, is constrained by high fresh-hydrogen demand, making its economics highly sensitive to green-hydrogen price. Bi-reforming yields the largest syngas output but derives most of its carbon and hydrogen from methane, limiting long-term decarbonisation value. CO_2-to-methanol represents India's largest volume opportunity, given ~98% import dependence, but requires green hydrogen at lower price to approach import-price competitiveness. **SOEC co-electrolysis emerges as the strongest long-term platform**, converting CO_2 and steam directly into syngas without a separate hydrogen-production step. High-value chemicals offer superior margins but limited absorptive market volume, while CO_2-to-SAF remains strategically vital despite a persistent cost gap, supported by India's phased SAF blending targets.

A weighted decision matrix and phased deployment roadmap are proposed, prioritising SOEC and methanol synthesis for near-to-medium-term development, mineralisation for permanent carbon retention, and CO_2-to-chemicals and SAF as longer-term value-diversification opportunities. The paper concludes that no single pathway is universally optimal; the recommended strategy is **an integrated refinery CO_2-to-value platform** combining multiple routes, supported by India's Green Hydrogen Mission, CCUS budget allocations and the Carbon Credit Trading Scheme.

7 — CO_2 utilisation pathways compared

50 KTA — common captured-CO_2 basis for all pathways

~98% — import dependence for methanol in India

267 MMTPA — installed refining capacity in India (approx.)

What the assessment found · per pathway

PATHWAY	STRENGTH	CONSTRAINT
Mineralisation	permanent carbon retention	
RWGS	technologically mature	high fresh H_2 demand
Bi-reforming	largest syngas output	C and H mostly from CH_4
CO_2 to methanol	largest volume opportunity	needs lower green H_2 price
SOEC co-electrolysis ★	strongest long-term platform	no separate H_2 step
High-value chemicals	superior margins	limited market volume
CO_2 to SAF	strategically vital	persistent cost gap

Phased deployment roadmap

NEAR TO MEDIUM TERM → LONGER TERM

- **SOEC · Methanol** — prioritised development
- **Mineralisation** — permanent retention
- **CO_2 to chemicals · SAF** — value diversification

ENABLERS: Green Hydrogen Mission · CCUS budget · CCTS

HOW IT WORKS

1. **Captured CO_2** — common 50 KTA basis
2. **Seven pathways** — mass, H_2, power, value, TRL
3. **Decision matrix** — weighted comparison
4. **CO_2-to-value platform** — phased, multiple routes

KEYWORDS CO_2 utilisation · CCUS · refinery decarbonisation · SOEC · RWGS · bi-reforming · methanol · sustainable aviation fuel · techno-economic analysis · India

FUEL QUALITY · ETHANOL BLENDING | CHLORIDE ANALYSIS · CORROSION

Comprehensive Assessment of Chloride Levels in Ethanol-Gasoline Blends for Enhanced Corrosion Resistance: Analytical Perspective. Challenges and opportunities

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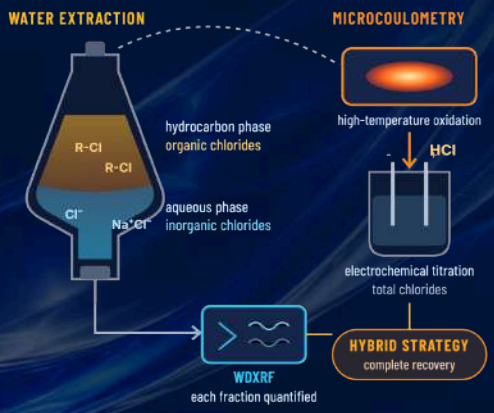


ABSTRACT

The increasing adoption of ethanol-gasoline blends as part of global biofuel strategies has raised important concerns regarding fuel system durability. Among the potential contaminants, **chloride ions** play a critical role in promoting corrosion of metallic components such as injectors, fuel pumps, and pipelines. Even trace concentrations can accelerate **pitting corrosion** and **stress corrosion cracking**, leading to severe mechanical failures and long-term vehicle damage. Given ethanol's polarity and hygroscopic nature, moisture ingress in ethanol-blended fuels creates a corrosive environment that is strongly exacerbated by chloride contamination. As a result, international regulatory frameworks impose strict maximum chloride limits in bio-ethanol to safeguard engine performance and ensure fuel-material compatibility. Accurate and reliable quantification of chloride content is therefore essential for both regulatory compliance and fuel system reliability.

This study presents a **comprehensive analytical framework for chloride determination in ethanol-gasoline blends**, with emphasis on differentiating between **organic and inorganic chlorides**, both of which influence corrosion pathways differently. Several analytical methodologies are examined, each with specific advantages and limitations. **Wavelength Dispersive X-Ray Fluorescence (WDXRF)**, a widely used technique, requires sample pre-treatment to address matrix complexity. A water-extraction method, similar to crude oil testing, enables phase separation: inorganic chlorides partition into the aqueous phase, while organic chlorides remain in the hydrocarbon phase. Each fraction can then be independently quantified by WDXRF. Alternatively, chemical transformation of the sample into a soluble matrix allows for WDXRF measurement, as demonstrated in chloride analysis of ionic liquids. While effective, these methods face challenges related to incomplete separation and ethanol-water interference.

Combustion microcoulometry offers a direct determination of total chlorides by oxidizing the fuel at high temperature, converting all organic and inorganic chlorides into hydrogen chloride (HCl), which is subsequently titrated electrochemically. However, its application to ethanol-gasoline blends is complicated by several factors: (i) ethanol and water interfere with high-temperature combustion; (ii) complex hydrocarbon structures, particularly unsaturated, branched, and cyclic species, reduce combustion efficiency; and (iii) soot formation during combustion can adsorb HCl, resulting in incomplete chlorine recovery. These limitations undermine accuracy, particularly for inorganic chloride quantification.

To overcome these challenges, the study proposes a **hybrid analytical strategy**: to detect inorganic chlorides and organic chlorides by reliable measurement analytical techniques, under optimized conditions. This combined approach **achieves complete chloride recovery, minimizes analytical artifacts, and ensures differentiation between chloride species**. By integrating complementary methodologies, the framework enables more robust chloride quantification compared to standalone techniques such as WDXRF or microcoulometry.

The outcomes of this work underscore the need for precise chloride analysis in ethanol-gasoline blends to guide **regulatory standards** and protect fuel system components from premature failure. Reliable quantification not only supports the enforcement of chloride limits in bio-ethanol but also provides critical insights for fuel formulation, material compatibility studies, and long-term storage assessments. In the context of increasing ethanol adoption in transport fuels, the proposed methodology enhances both scientific understanding and industrial practice, contributing to the safe and sustainable deployment of biofuels.

Trace
chloride concentrations can accelerate pitting and stress corrosion cracking

Organic + inorganic
chloride species differentiated

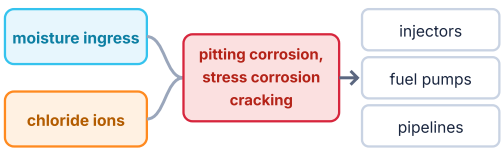
Complete
chloride recovery with the hybrid analytical strategy

Hybrid
more robust than standalone WDXRF or microcoulometry

Method comparison · as described in the abstract

	Species split	Main limitation / outcome
WDXRF water extraction	✓ separated	incomplete separation, ethanol-water interference
Microcoulometry combustion, total Cl	× total only	incomplete chlorine recovery: soot adsorbs HCl, ethanol and water
Hybrid strategy optimized conditions	✓ differentiated	complete chloride recovery, minimizes analytical artifacts

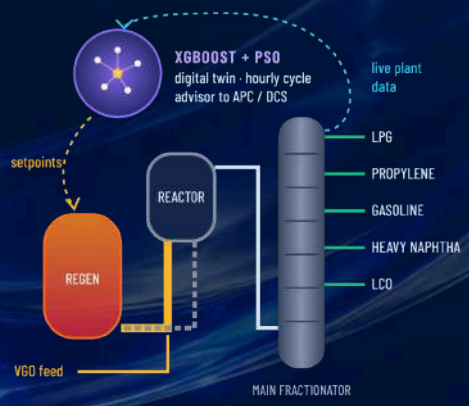
Why chloride matters



strict maximum chloride limits in bio-ethanol

AI · DIGITAL TWIN | FCC YIELD OPTIMIZATION

AI-Driven Fluidized Catalytic Cracking Unit (FCCU) Yield Optimization via Particle Swarm Optimization



Ayush Bathary
Indian Oil Corporation Limited (IOCL), Gurugram, Haryana, INDIA
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ABSTRACT

The Fluidized Catalytic Cracker (FCC) is a vital refinery unit that upgrades heavy vacuum gas oil into high-value products like LPG, gasoline, LCO, propylene, and heavy naphtha. With product prices changing frequently, realigning operating conditions can enhance profitability. A digital tool leveraging live operating data and updated prices supports operators in maximizing returns. Acting as an advisor in IOCL Mathura Refinery FCCU Advanced Process Controller (APC) and DCS, it enables data-driven, analytics-based decisions to optimize FCC performance and unlock greater monetary benefits.

In this study, we introduced a real-time, machine learning-driven digital twin and optimization framework for the FCC unit, designed to maximize profitability while maintaining safe and stable operations. The system predicts product yields and key quality indicators, such as Gasoline IBP and FBP, using live FCC plant data like Debutanizer top temp., Gas Con stripper temp., WGC suction pressure etc and catalysts properties and then recommends constraint-aware setpoints for controllable variables. By continuously adjusting these parameters, the FCC plant can increase the share of high-value products and improve overall revenue generation.

An advanced XGBoost Machine Learning regression model, enhanced through feature engineering and lagged input variables, is trained on three years of historical FCC plant data. This includes operating conditions, product yields, catalyst activity, and quality measurements, enabling accurate real-time predictions of FCC product distribution and quality. The predictive model feeds into an optimization module powered by PySwarms, which applies particle swarm optimization (an AI based algorithm) to determine plant setpoints in an economics-driven, constraint-sensitive manner.

To ensure practicality and operator acceptance, the framework includes intuitive dashboards and human-in-the-loop validation, allowing operators to review and confirm system recommendations while enforcing safety and quality limits. With hourly inference and optimization cycles, the solution continuously aligns FCC operations with current market conditions, delivering measurable gains in product yield, revenue, and operational efficiency without compromising compliance or stability.

The optimizer delivered **a steady 1-1.5% per-hour increase in product yield**, directly boosting revenue; key challenges encountered included irregular FCC Unit shutdown data, sensor drift and missing timestamps, multicollinearity and delayed process responses, enforcement of optimization constraints, computational latency, and operator acceptance. These were mitigated through a combination of rule-based preprocessing, ML-driven anomaly detection, timestamp reconciliation, regular model retraining, constraint-aware optimization, and human-in-the-loop validation to ensure safe, reliable, and operationally practical deployment.

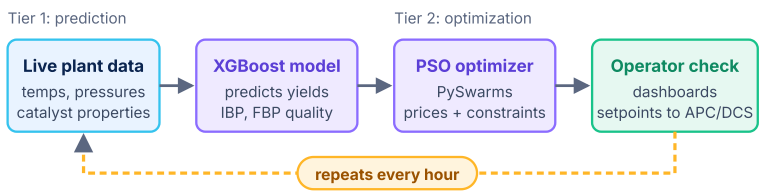
1-1.5 %/h
steady increase in product yield from the optimizer

3 years
of historical FCC plant data used for training

Hourly
inference and optimization cycles

Human in the loop
operators review and confirm recommendations

Prediction and optimization loop

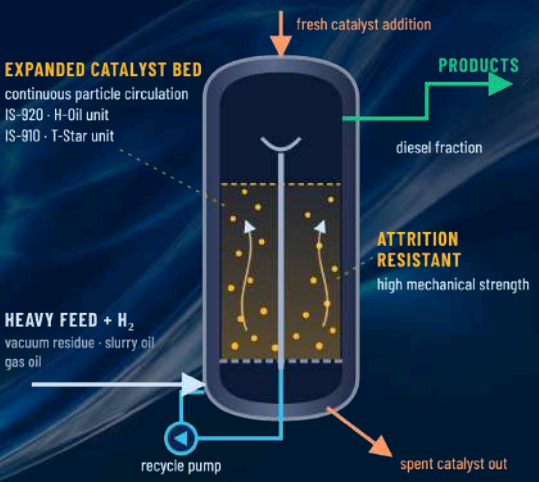


Challenges and mitigations

Challenge	Mitigation
Irregular shutdown data	Rule-based preprocessing
Sensor drift, timestamps	ML anomaly detection
Multicollinearity, delays	Timestamp reconciliation
Constraint enforcement	Regular model retraining
Computational latency	Constraint-aware optimization
Operator acceptance	Human-in-the-loop validation

EBULLATED-BED HYDROCRACKING | HEAVY FEEDSTOCKS · CATALYSTS

Industrial Application of Ebullated-Bed Hydrocracking Catalysts for Heavy Feedstocks



Anton Saraev, Head of Technical Support for Catalysts for Hydrogenation Processes and Regeneration,
Ishimbay Sorbents LLC

ABSTRACT

Ishimbay Sorbents LLC (IS LLC) presents its experience in the industrial application of its own ebullated-bed hydrocracking catalysts on operating units processing heavy feedstocks. The presentation will focus primarily on the practical operating results obtained with IS catalysts and on examples of their application in industrial H-Oil and T-Star units.

The presentation will discuss the results obtained with the IS-920 catalyst on an industrial H-Oil unit processing a blend of vacuum residue, catalytic cracking slurry oil, and light catalytic cracking gas oil. Under comparable operating conditions, replacement of the previously used catalyst resulted in **an increase in conversion of the 538 °C+ fraction from 53.34 to 61.41 wt.%** and **an increase in diesel fraction yield from 22.31 to 27.02 wt.%**, while maintaining the sediment content in the atmospheric column bottoms product at 0.56 wt.%. These results demonstrate the potential for increasing the depth of heavy-feedstock conversion in industrial operation using an IS catalyst.

The second industrial case concerns the application of the IS-910 catalyst in a T-Star ebullated-bed hydrocracking unit. Particular attention will be given to the catalyst's operating characteristics, including mechanical strength and resistance to attrition under conditions of continuous particle circulation. Industrial operating experience demonstrates the importance of these characteristics for maintaining stable operation of an ebullated-bed unit. The catalyst manufacturing technology was optimized jointly with the refining company to meet requirements for reducing attrition and particle degradation.

The presentation will also briefly describe Ishimbay Sorbents LLC's manufacturing experience in hydrocracking and hydrotreating catalysts. The company produces a full range of catalysts for different types of units and feedstocks, and its reference list includes more than 40 successful industrial implementations at refineries in Russia, Belarus, Kazakhstan, and the Middle East.

The industrial cases presented demonstrate the practical applicability of IS catalysts for heavy and challenging feedstocks and will be of interest to specialists in hydroprocessing, refinery process engineers, and professionals working to increase conversion depth and operating efficiency of ebullated-bed hydrocracking units.

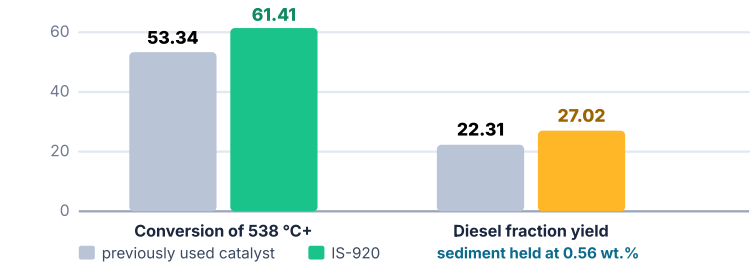
61.41 wt.%
conversion of 538 °C+ fraction with IS-920 (from 53.34)

27.02 wt.%
diesel fraction yield (from 22.31)

0.56 wt.%
sediment in atmospheric column bottoms, maintained

40+
industrial implementations: Russia, Belarus, Kazakhstan, Middle East

IS-920 on the H-Oil unit · previous catalyst vs IS-920, wt.%



Two industrial cases

IS-920 · H-Oil unit
vacuum residue, slurry oil and gas oil blend
deeper conversion · more diesel

IS-910 · T-Star unit
mechanical strength · attrition resistance
optimized jointly with the refiner

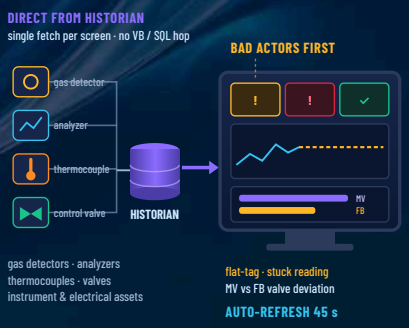
HOW IT WORKS

1. **Heavy feed + H_2** — residue, slurry oil, gas oil
2. **Ebullated bed** — continuous particle circulation
3. **IS catalyst** — IS-920 on H-Oil · IS-910 on T-Star
4. **Deeper conversion** — more diesel, stable operation

KEYWORDS ebullated-bed hydrocracking · ebullated-bed · hydrocracking catalysts · heavy feedstocks · industrial application · mechanical strength · attrition resistance · H-Oil · T-Star.

DIGITAL DASHBOARD | INSTRUMENT RELIABILITY · IN-HOUSE BUILD

Instrumentation Dashboard Modernization: Faster Visibility, Earlier Detection, Higher Instrument Availability



Deepthi K. M., Allen John
Department: Instrumentation Maintenance, MRPL

ABSTRACT

Why this was taken up:

The Instrumentation Dashboard is the refinery's common window into the health of field instrumentation: gas detectors, stack and process analyzers, thermocouples, control valves, calibration gas cylinders and electrical assets. Operations and maintenance teams use it to answer everyday questions. Which detectors are unhealthy? Which analyzer has stopped responding? Which valve is not following its command? What is due for calibration, and do we have the spares to carry it out?

Built in-house and extended year after year, prior to this modernisation dashboard screens values was dependent on back end visual basic program which updated the values into SQL database. Modernisation now fetches values directly from Historian without any dependency and hence data updation became seamless and faster. Implementation was done without altering any plant data and without interrupting the teams that depend on it.

What changed, in operational terms

1. Instrument health visible in seconds instead of minutes

Nine monitoring screens (Gas Detectors, Analyzers, Non-Stack Analyzers, Product Analyzers, Thermocouple, MV vs FB, Positioner Temperature, Instrumentation Assets, Electrical Assets) now retrieve all their historian data **in a single fetch rather than tag by tag**. Screens that were previously avoided mid-shift are now quick enough to form part of the daily routine, and trends open on the same screen so a deviation can be judged in context instead of through a separate exercise.

2. Early detection of silent failures:

The dashboard now surfaces conditions that raise no alarm but quietly erode reliability and safety:

1. Stuck or frozen readings. A thermocouple or analyzer that has stopped updating still looks perfectly healthy on a conventional display. Flat-tag detection identifies these, so the team knows a reading is no longer trustworthy before decisions are taken on it.
2. Control valve deviation. MV vs FB comparison highlights valves not reaching their demanded position, an early indication of stiction, air supply issues or positioner trouble that otherwise shows up first as loop instability and off-spec product.
3. Positioner temperature. Exposure trends that shorten field device life and lead to premature failure.
4. Calibration evaluation against the correct limits for each service, including separate threshold treatment for oxygen versus combustible and toxic gas detectors, so a detector that has drifted outside its safe band is visible as both a safety and a compliance item.

3. Management by exception: bad actors surface on their own

The landing screen now opens with status cards that place bad actors and attention items first. This changes how the dashboard is used. Instead of hunting through screens to locate problems, the problems present themselves, and effort concentrates on the small population of assets consuming most of the maintenance workload. The screen refreshes on its own **every 45 seconds**, so a display left open in the maintenance office stays current without anyone reloading it.

4. Preventive maintenance made workable:

The PM module, the largest and most heavily used part of the dashboard, was rebuilt end to end across seven staged rounds while it remained in daily service. The rebuilt module is more intuitive to work through.

5. Spares and consumables readiness:

Stock monitoring now updates directly from SAP and carries a reorder level. Instrument spares are visible against their reorder point, so PM jobs are less likely to be deferred for want of a a spare part. This closes a familiar gap between a plan that exists on paper and the material required to execute it.

6. Built for the way the work is actually done:

Large tables hold their headers and key columns in place while scrolling with filtering feature. Each tag can be viewed on its own scale so comparisons remain meaningful. A consistent industrial look, with safety-amber highlighting on items needing attention, keeps the reading of the screen unambiguous in the field.

Benefits delivered:

- Availability: Faster identification of faulty instruments; less time spent locating information, more time spent acting on it.
- Reliability: Stuck values, valve deviation and calibration drift detected earlier, before they progress to failure or unplanned shutdown.
- Safety and compliance: Gas detector health and calibration status evaluated against the correct limits for each service.
- Maintenance productivity: Bad actors prioritized automatically; PM planning and spares readiness available in one place.
- Data confidence: Frozen and untrustworthy readings identified, so operating decisions rest on live data.
- Continuity: Delivered in stages, with the system in continuous use throughout and no downtime for plant users.

9
monitoring screens loading all historian data in a single fetch

45 s
auto-refresh keeps an open display current

7
staged rounds to rebuild the PM module while in daily service

No downtime
for plant users; no plant data altered

Data path: before and now

Silent failures now surfaced

Stuck / frozen
flat-tag detection

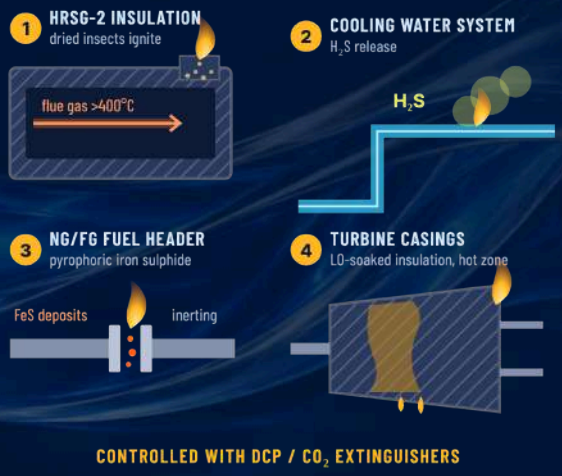
Valve deviation
MV vs FB comparison

Positioner temp.
exposure trends

Calibration drift
O_2 vs combustible/toxic

FIRE SAFETY · NEAR MISS | POWER & UTILITY · INCIDENT LEARNING

Invisible Hazards & Visible Lessons "Valuable Experiences & Learnings from the Rare, Unsafe & Hazardous Fire Incidents in our Power & Utility, NRL"



Dinesh Brahma, SM, Project Planning, Ex SIC, P&U
Numaligarh Refinery limited, NREP Project, NRL, Assam

ABSTRACT

In the course of day-to-day plant operations, certain rare and unforeseen fire incidents can challenge operational safety, test decision-making under pressure, and provide invaluable learning opportunities. This paper presents a compilation of four such rare but significant fire incidents encountered in the Power & Utility (P&U) areas of NRL, each demonstrating unique hazards, root causes, and critical lessons learned.

Incident-1 involved the **ignition of dried insects concealed within HRSG-2 insulation, triggered by contact with hot flue gas (>400°C)**. Incident-2 described a fire resulting from hydrogen sulphide (H_2S) release during cooling water system modification work - highlighting the dual hazard of flammability and toxicity. Incident-3 covered spontaneous ignition from pyrophoric iron sulphide (FeS) deposits in the NG/FG (Natural Gas/ Refinery Fuel Gas) fuel header during maintenance, emphasizing the importance of inerting and controlled opening procedures. Incident-4 detailed fire incidents caused by lubricating oil (LO)-soaked insulation around turbine casings, underscoring the risks of unnoticed oil leaks near high-temperature zones.

All the incidents were **promptly controlled through effective emergency response**, use of DCP/CO_2 extinguishers, and sound decision-making, preventing escalation or injury. Post-incident analysis led to the identification of root causes and the development of revised Standard Operating Procedures (SOPs) focusing on proactive inspection, improved housekeeping, better material selection, enhanced training, and readiness for emergency response.

These real-life experiences reinforce the importance of continuous vigilance, hazard anticipation, and knowledge sharing within plant operations. The insights gained serve as valuable references to strengthen fire prevention and safety preparedness across all operating areas of the refinery.

4
rare but significant fire incidents in P&U areas

>400°C
hot flue gas ignited dried insects in HRSG-2

H_2S
dual hazard of flammability and toxicity

FeS
spontaneous ignition from pyrophoric deposits

Four incidents at a glance

	LOCATION	HAZARD
1	**HRSG-2 insulation** during contact with hot flue gas	**Dried insects ignite** concealed within insulation, >400°C
2	**Cooling water system** during modification work	**H_2S release and fire** flammability and toxicity
3	**NG/FG fuel header** during maintenance	**Pyrophoric FeS deposits** inerting, controlled opening procedures
4	**Turbine casings** near high-temperature zones	**LO-soaked insulation** unnoticed oil leaks

Revised SOPs focus on

- ✓ Proactive inspection
- ✓ Improved housekeeping
- ✓ Better material selection
- ✓ Enhanced training
- ✓ Readiness for emergency response

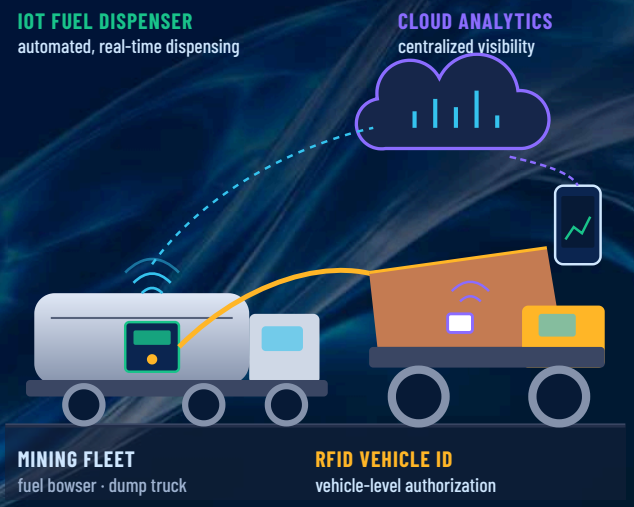
HOW IT WORKS

1. **Rare fire incident** — P&U areas of NRL
2. **Emergency response** — DCP/CO_2 extinguishers
3. **Root causes** — post-incident analysis
4. **Revised SOPs** — prevention, preparedness

KEYWORDS Fire Safety | Near Miss | HRSG | Hydrogen Sulphide | Pyrophoric Iron | Lubricating Oil | Power & Utility | NRL | Incident Learning | Process Safety

SMART FUEL MANAGEMENT | IOT · RFID · CLOUD ANALYTICS

Smart Fuel Ecosystem: Digital Transformation of Fuel Management for Energy Efficiency



Rajesha RL, Director & CEO
RETRACK AUTOMATION PRIVATE LIMITED

ABSTRACT

Fuel represents one of the largest operational expenditures in heavy industries, accounting for nearly **30-40% of total equipment operating costs**. However, conventional fuel management practices in many sectors still rely on manual processes, paper logs, and operator-dependent controls, resulting in fuel pilferage, inaccurate inventory management, inefficient vehicle utilization, excessive idling, and unplanned downtime.

This paper presents a **Smart Fuel Ecosystem**, digital transformation of fuel management using **IoT-enabled fuel automation, RFID-based vehicle identification**, wireless communication systems, and cloud-based analytics. The proposed system enables automated fuel dispensing, real-time monitoring of fuel transactions, vehicle-level authorization, fuel consumption analytics, and centralized operational visibility.

The study evaluates the deployment of the system in a mining environment and demonstrates measurable improvements in operational efficiency, **fuel accountability, and sustainability**. Results indicate **significant reductions in fuel losses, unauthorized fueling events, equipment idle time, and manual reconciliation efforts**. Additionally, optimized fuel usage contributes toward reduced carbon emissions and improved environmental compliance.

The paper highlights how digital fuel ecosystems can become a critical component of smart fuel infrastructure by integrating automation, telemetry, and data-driven decision-making into day-to-day fuel operations.

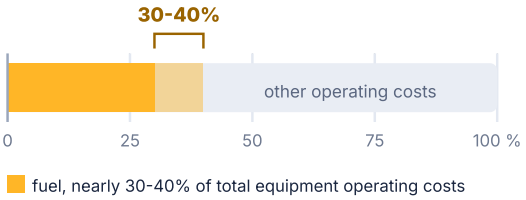
30-40%
of total equipment operating costs is fuel

RFID
vehicle identification for vehicle-level authorization

Real-time
monitoring of fuel transactions

Mining
deployment environment evaluated in the study

Fuel share of equipment operating cost



Conventional vs Smart Fuel Ecosystem

Conventional
- manual processes
- paper logs
- operator-dependent controls

pilferage, idling, downtime

→

Smart Fuel Ecosystem
- automated fuel dispensing
- real-time monitoring
- vehicle-level authorization
- fuel consumption analytics

Significant reductions in

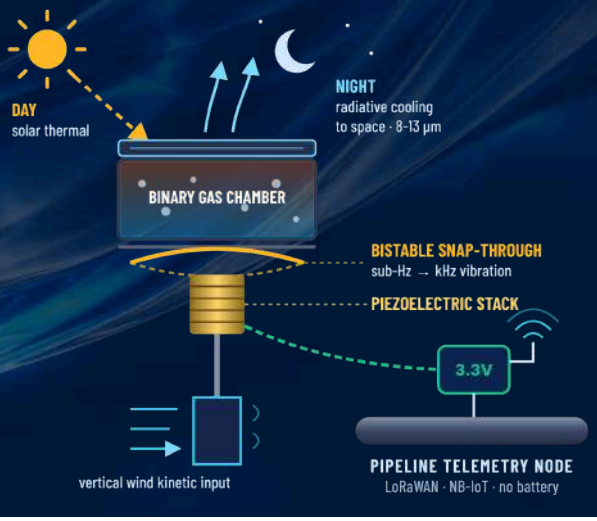
fuel losses | unauthorized fueling | idle time | manual reconciliation

HOW IT WORKS

1. **Identify** — RFID vehicle tag
2. **Authorize** — vehicle-level control
3. **Dispense** — IoT-enabled automation
4. **Analyze** — cloud-based analytics

BATTERY-LESS TELEMETRY | PIPELINES · EMERGING TECHNOLOGIES

Battery-less Autonomous Hybrid Micro-Power Infrastructure for Remote Pipeline Telemetry and Refinery Asset Monitoring



Shivang Rajwanshi
Modugen Innovations Private Limited

ABSTRACT

Modugen Innovations Private Limited presents a disruptive, hermetically sealed, non-rotating Dual-Input Sandwich Hybrid micro-power generator engineered to displace legacy chemical batteries across cross-country petroleum pipelines and isolated refinery telemetry nodes. Remote infrastructure monitoring loops face structural vulnerabilities due to the short lifespan of standard chemical batteries under extreme thermal shifts, causing data blind spots and recurring manual logistics replacement overheads. Traditional commercial solar configurations further degrade rapidly under high sand, dust, or snow accumulation parameters.

The Modugen architecture mitigates these industrial operational constraints by shifting away from conventional direct photon-to-electron conversion mechanics. Instead, the framework utilizes a responsive binary gas mixture enclosed within a specialized thermodynamic chamber coupled directly with a vertical wind kinetic system driving a shared central piezoelectric stack array. By optimizing sub-Hertz volumetric fluidic gas expansion via solar thermal tracking during diurnal phases, and matching it with passive outer space radiative cooling arrays exploiting the atmospheric transmission window (8-13 micrometers) during absolute darkness, a persistent thermal gradient is sustained. Slow thermodynamic cycles are systematically up-converted into high-frequency Kilohertz vibrations via a structural bistable snap-through buckling mechanism to deliver **a firmed, regulated continuous 3.3V power output (45-150 mW)**.

Operating at an ultra-low Bill of Materials footprint, this self-bootstrapping clean energy hardware engine directly interfaces with remote wireless LoRaWAN and NB-IoT telemetry nodes tracking pipeline pressure drop deviations, cathodic structural corrosion health indexes, and remote field tank variables without grid line additions or maintenance cycles. The asset-light IP implementation eliminates battery electronic waste hazards, ensuring uninterrupted pipeline field telemetry deployment security across thousands of kilometers of harsh environmental corridors under verified ESG compliance goals.

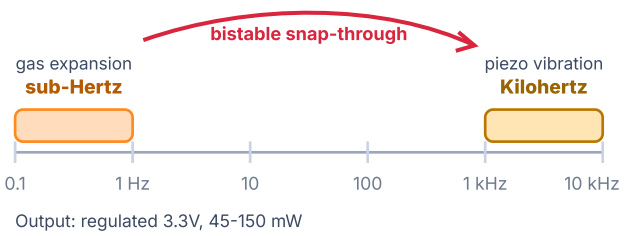
3.3 V
firmed, regulated continuous power output

45-150 mW
output power range

8-13 µm
atmospheric transmission window for night-time radiative cooling

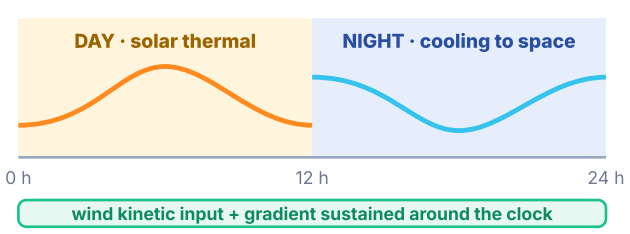
Battery-less
hermetically sealed, non-rotating; no battery e-waste

Frequency up-conversion · log scale



Band positions illustrative. Only "sub-Hertz" and "Kilohertz" are stated in the abstract.

Day and night inputs · persistent thermal gradient



Illustrative. Values not reported in the abstract.

HOW IT WORKS

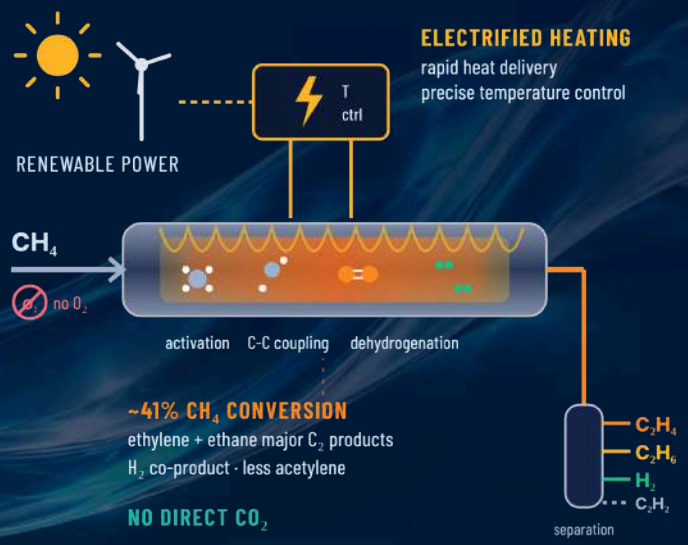
1. **Day / night** — solar heat · sky cooling
2. **Gas chamber** — sub-Hertz expansion
3. **Snap-through** — up-convert to kHz
4. **Piezo → 3.3V** — powers LoRaWAN node

KEYWORDS Battery-less Telemetry | Passive Radiative Cooling | Piezoelectric Upconversion | Bistable Buckling Mechanism | Pipeline Asset Monitoring | Cross-Country Asset Security

METHANE VALORISATION

ELECTRIFIED REACTOR · ETHYLENE + H_2

Non-Oxidative Conversion of Methane to Ethylene and Hydrogen



Dr. Sushant Kumar
Associate Professor, Department of Chemical and Biochemical Engineering,
IIT Patna, Bihta, Patna, Bihar 801 106

ABSTRACT

The direct conversion of methane into valuable chemicals and hydrogen is an important challenge in the transition toward more efficient utilization of natural gas. In this work, we explore non-oxidative methane conversion (NOCM) as a promising route for simultaneously producing ethylene and hydrogen **without using oxygen as a reactant and without direct CO_2 formation**. The approach relies on the high-temperature activation of methane, followed by C-C coupling and dehydrogenation to form C_2 hydrocarbons and H_2. Particular emphasis is placed on electrified heating, which offers rapid heat delivery and precise temperature control and provides an alternative to conventional furnace-based operation. Under optimized conditions, **methane conversion of approximately 41%** was achieved, with ethylene and ethane as the major C_2 hydrocarbon product, along with H_2 and smaller amounts of acetylene. The study also examines the energy requirement of the electrified reactor and the relationship between methane conversion, product distribution, and energy input. The results demonstrate the potential of electrified NOCM as a pathway for converting methane directly into ethylene, a major petrochemical building block, and hydrogen, while providing opportunities for integration with renewable electricity. The work highlights key challenges and opportunities for developing energy-efficient, scalable reactors for direct methane valorization.

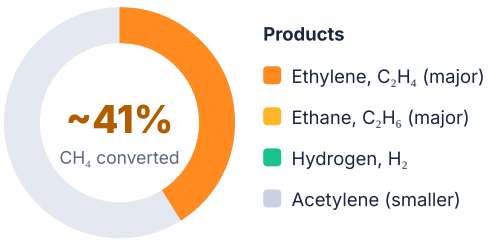
~41%
methane conversion under optimized conditions

$C_2H_4 + H_2$
ethylene and hydrogen produced simultaneously

No O_2
oxygen not used as a reactant

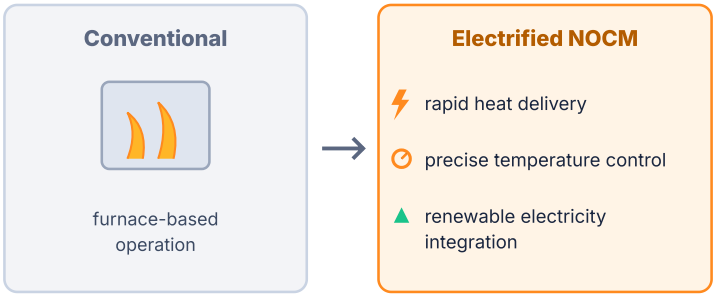
No CO_2
no direct CO_2 formation

Methane conversion (optimized)



Product split not quantified in the abstract.

Furnace vs electrified NOCM



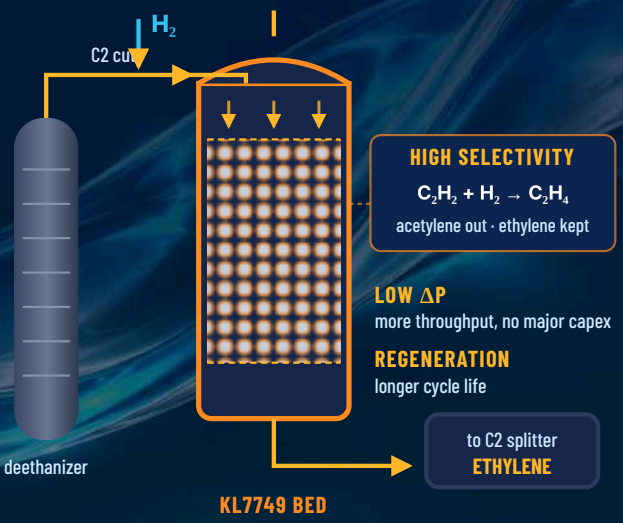
HOW IT WORKS

1. **Methane feed** — no oxygen reactant
2. **Electrified heating** — rapid, precise
3. **Activation** — C-C coupling, dehydrogenation
4. **Products** — C_2H_4, C_2H_6, H_2

CATALYSTS · ETHYLENE

ACETYLENE HYDROGENATION · DEBOTTLENECKING

Shell's Next Generation C2 Tail End Catalyst



Amir Taiyabi- Sales Manager
Shell Catalysts & Technologies

ABSTRACT

As the ethylene industry continues to seek production growth from existing assets, catalyst innovations that enable higher operating efficiency and greater capacity utilization have become increasingly important. Shell's next-generation C2 Tail End Catalyst, **KL7749**, has been developed to help ethylene producers to overcome the limitations of legacy and capacity-constrained ethylene units.

KL7749 delivers a differentiated value proposition through its combination of **high selectivity, low pressure drop, and enhanced regeneration flexibility**. The catalyst operates at high selectivity, improving acetylene conversion while maintaining ethylene yield. Its low-pressure-drop design minimizes hydraulic constraints across the reactor, creating opportunities for throughput increases and debottlenecking without major capital investment. Furthermore, improved regeneration capability extends catalyst cycle life and provides greater operational flexibility within existing equipment limitations. Together, these benefits enable ethylene producers to maximize asset value, increase production, and improve profitability from existing ethylene plant infrastructure.

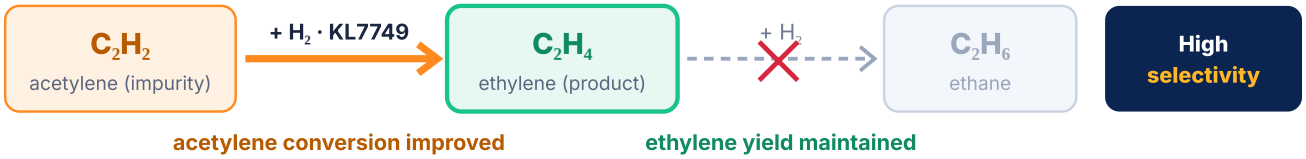
High
selectivity: acetylene conversion while maintaining ethylene yield

Low ΔP
pressure drop design minimizes hydraulic constraints

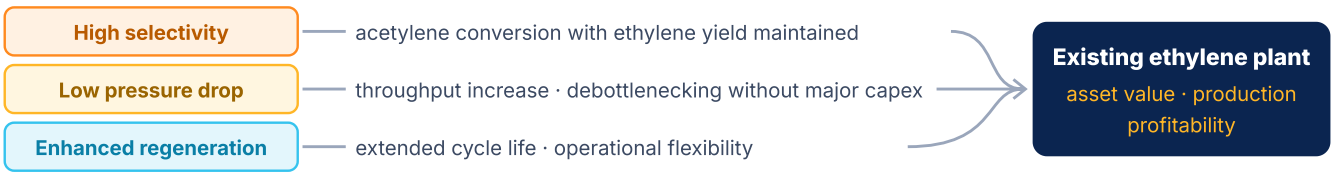
Enhanced
regeneration flexibility, extended catalyst cycle life

Existing
assets: debottlenecking without major capital investment

Selective hydrogenation in the tail end reactor · desired path solid, suppressed over-hydrogenation dashed



From catalyst attributes to plant value

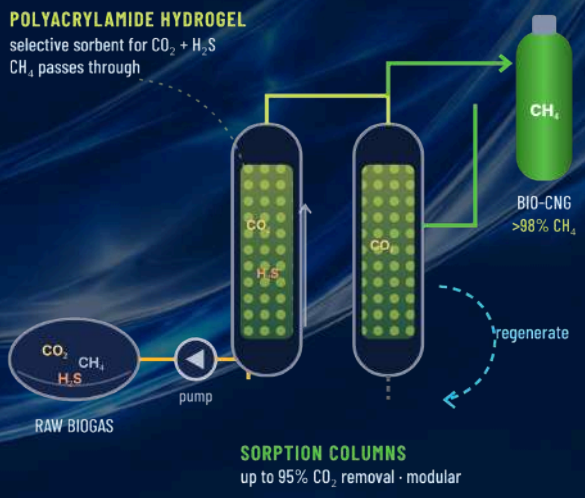


HOW IT WORKS

1. **Legacy unit** — capacity-constrained
2. **Load KL7749** — C2 tail end reactor
3. **Lower ΔP** — throughput, debottleneck
4. **Regenerate** — longer cycle life

BIOGAS UPGRADING · BIO-CNG | HYDROGEL SORBENT · CO_2 CAPTURE

Advanced Polymer-Nanocomposite Hydrogel Technology for High-Efficiency Biogas Upgrading and Bio-CNG Production



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ABSTRACT

The growing demand for clean and affordable renewable fuels has created a strong need for cost-effective technologies for upgrading biogas into bio-compressed natural gas (bio-CNG). Conventional biogas purification technologies can involve high capital investment, energy consumption, and operational complexity, limiting their adoption by small and medium-scale biogas producers. Gelcarbonix Private Limited is developing an innovative hydrogel-based biogas upgrading technology that addresses these challenges through an economical, regenerable, and energy-efficient purification system. The technology employs a polyacrylamide-based functional hydrogel as a selective sorbent for the removal of carbon dioxide (CO_2) and hydrogen sulfide (H_2S) from raw biogas while retaining and enriching methane (CH_4). Laboratory-scale continuous-flow experiments demonstrated **up to 95% CO_2 removal and enrichment of methane to above 98%** in the purified gas stream. The optimized hydrogel exhibited a **high CH_4/CO_2 selectivity of 32.75**, while thermodynamic analysis indicated favorable and spontaneous CO_2 sorption. Breakthrough studies demonstrated sustained purification performance under continuous operation, supporting the potential for integration into a scalable gas-upgrading process. The proposed technology is designed to provide a low-cost and alternative to conventional biogas upgrading systems, with potential applications in dairy farms, food-processing industries, municipal organic-waste plants, CBG industries, Ethanol producing industries and decentralized renewable-energy projects. Its modular configuration enables adaptation to different biogas production capacities, while the regenerable hydrogel has the potential to reduce consumable and operating costs. The technology therefore offers a pathway for converting locally generated biogas into higher-value biomethane/bio-CNG suitable for clean-energy applications, including transportation and industrial fuel. With ongoing development towards pilot-scale deployment, Gelcarbonix private Limited aims to commercialize the technology as an affordable, scalable, and energy-efficient biogas purification solution, contributing to waste-to-energy conversion, reduction of fossil-fuel dependence, and the development of a circular and low-carbon energy ecosystem.

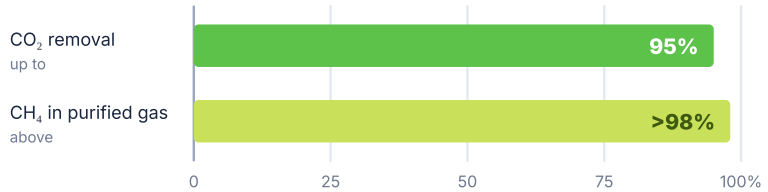
95%
CO_2 removal (up to), lab-scale continuous flow

>98%
methane in the purified gas stream

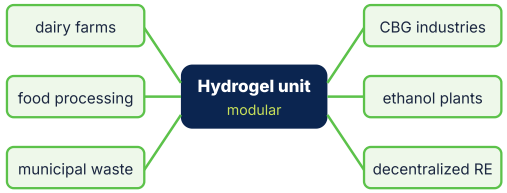
32.75
CH_4/CO_2 selectivity of the optimized hydrogel

Regenerable
hydrogel sorbent, modular configuration

Lab-scale upgrading performance · % of gas stream



Where it fits



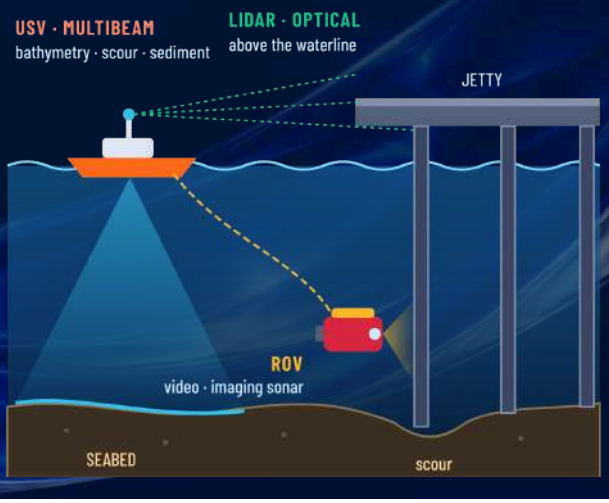
HOW IT WORKS

1. **Raw biogas** — CH_4 with CO_2 and H_2S
2. **Hydrogel sorption** — CO_2 + H_2S captured
3. **Biomethane** — CH_4 enriched above 98%
4. **Regenerate** — reuse the hydrogel

KEYWORDS Hydrogel | Biogas Upgrading | CO_2 Capture | H_2S Removal | Biomethane | Bio-CNG | Clean Energy | Sustainable Technology

MARINE ROBOTICS · USV / ROV | SUBSEA INSPECTION · LOW CAPEX

Low CAPEX Marine Robotics for Surface to Subsea Inspection and Seabed Studies



Satish Ramachandran
Vikra Ocean Tech Pvt. Ltd. | CHT 29th ETM 2026

ABSTRACT

Marine terminals, refinery water infrastructure and pipeline approaches require inspection methods that connect asset condition with surrounding seabed geometry. Vikra Ocean Tech proposes a modular marine robotics approach combining uncrewed surface vehicles (USVs), remotely operated vehicles (ROVs) and complementary sensors to support infrastructure assessment while **limiting customer capital expenditure through managed services, rental or leasing**.

The proposed workflow uses USV multibeam surveys to establish bathymetry, scour and sediment context, followed by targeted ROV video and imaging sonar inspection of selected structures and anomalies. Surface LiDAR and optical capture can extend observations above the waterline where configured. Integrated deployment offers shared mobilisation opportunities, while standalone systems accommodate site access and operational constraints. Positioned observations are combined into **a common spatial record linking assets, the waterline and seabed**.

Data reliability depends on sensor synchronisation, positioning uncertainty, sound velocity and water level corrections, alignment verification and traceable processing. Optical limitations and data gaps are recorded. Concurrent operations require an approved site specific plan addressing exclusion zones, tether routing, platform stability, battery reserves, acoustic interference, environmental limits and emergency recovery.

A proposed customer pilot at one jetty section or intake or outfall approach would validate readiness, acquisition quality and value against agreed acceptance criteria. Deliverables include bathymetric surfaces, aligned point clouds where feasible, indexed inspection evidence, anomaly locations and an operational record. Economic assessment would compare equivalent scopes using total cost per accepted survey area and inspected asset, including standby, processing and repeated work.

Potential benefits from shared support, fewer mobilisations and targeted inspection remain hypotheses for measurement, rather than demonstrated savings. Collaboration with CHT and an operator partner would establish the evaluation site, cost baseline, data ownership and acceptance thresholds. Successful validation would support repeat condition surveys and standardisation for wider deployment across energy infrastructure, subject to customer acceptance and site specific readiness.

Low CAPEX
through managed services, rental or leasing

USV + ROV
modular robotics with complementary sensors

Surface to subsea
one spatial record of assets, waterline and seabed

Pilot
proposed at one jetty section or intake or outfall approach

Surface to subsea workflow

1 · USV — multibeam survey bathymetry, scour sediment context
→ 2 · ROV — targeted video imaging sonar structures, anomalies
→ 3 · Surface — LiDAR, optical above waterline where configured
→ Spatial record — assets waterline seabed

Data reliability checks
sensor synchronisation | positioning uncertainty | sound velocity, water level | alignment verification

Proposed customer pilot

Deliverables
- Bathymetric surfaces
- Aligned point clouds, where feasible
- Indexed inspection evidence
- Anomaly locations
- Operational record

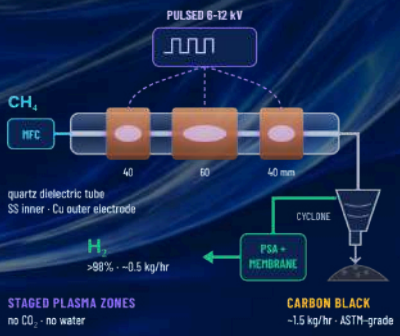
Total cost per accepted survey area and inspected asset

HOW IT WORKS
1 USV survey — multibeam bathymetry → 2 ROV inspection — video, imaging sonar → 3 Spatial record — asset, waterline, seabed → 4 Customer pilot — validate vs criteria

TURQUOISE HYDROGEN | PLASMA PYROLYSIS · CARBON BLACK

Plasma-Assisted Methane Pyrolysis for CO_2-Free Hydrogen and ASTM-Grade Carbon Black: Prototype Development and Results

Jayaraman Kandasamy, Hypersonic Technologies Pvt Ltd, Chennai



ABSTRACT

Introduction

The global energy transition requires disruptive technologies that can deliver clean hydrogen at scale while minimizing resource intensity and emissions. Conventional pathways such as electrolysis demand ~9 L of demineralized water per kg of hydrogen and ~50-60 kWh/kg H_2, while steam methane reforming (SMR) emits ~10 kg CO_2 per kg H_2 and requires costly carbon capture. Plasma-assisted methane pyrolysis offers a novel thermochemical route: direct decomposition of methane into hydrogen and solid carbon, eliminating CO_2 emissions and water dependency.

Hypersonic Technologies has developed a staged-plasma reactor that leverages non-thermal plasma chemistry to dissociate methane efficiently. The system simultaneously produces CO_2-free hydrogen and ASTM-grade carbon black, creating a dual-revenue model aligned with India's National Green Hydrogen Mission (NGHM) and import substitution goals for carbon black.

Methodology

The prototype reactor employs a multi-material tubular assembly: quartz dielectric tube, stainless steel inner electrode, and copper outer electrode. Staged plasma zones (40-60-40 mm) enable controlled decomposition and residence time management. Methane feedstock is metered via mass flow controllers, subjected to pulsed voltages (6-12 kV), and processed through cyclone separators for carbon removal. Downstream purification uses PSA and membrane systems to achieve hydrogen purity >98%. Diagnostics include gas chromatography (GC), oscilloscope monitoring, and LabVIEW integration for real-time plasma stability.

Results

- **Hydrogen output:** ~0.5 kg/hr at >98% purity (GC validated).
- **Carbon black output:** ~1.5 kg/hr, spherical morphology suitable for tyres, plastics, and composites.
- **Methane conversion:** Increased from ~17% at 6 kV to ~40% at 12 kV, with H_2/CH_4 ratio rising from 11.5% to 17%.
- **Energy efficiency:** Specific energy consumption ~25-50 kWh/kg H_2, competitive with electrolysis and approaching SMR efficiency without CO_2 emissions.
- **Carbon credits:** Each ton of hydrogen produced avoids ~12 tons CO_2 compared to SMR, enabling monetizable credits under compliance schemes (e.g., EU-CBAM).

Discussion

The prototype demonstrates **TRL 5 readiness**, with patent protection (No. 593785) and validated lab performance, approved by NRDC-NETRA, Govt of India. Compared to electrolysis, plasma pyrolysis reduces energy demand per mole H_2 and eliminates water dependency, critical in arid regions. Compared to SMR, it avoids CO_2 emissions and CCS infrastructure. The dual-revenue model, hydrogen plus ASTM-grade carbon black, creates structural cost advantages and resilience, directly addressing India's >90% import dependence on carbon black.

The modular design allows scaling from lab-scale (0.5 kg/hr) to pilot plants (5-10 kg/hr) and eventually industrial clusters (>500 kg/hr). Integration with renewable electricity further enhances sustainability.

Conclusion

Hypersonic's plasma pyrolysis reactor represents a scalable, modular pathway for clean hydrogen and sustainable advanced carbon black production. It aligns with ETM 2026's focus on green hydrogen integration, carbon capture alternatives, and startup innovation, while supporting industrial decarbonization and circular economy principles. Ongoing work focuses on pilot deployment, industrial partnerships, and regulatory alignment under NGHM.

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Hypersonic Technologies Patent No. 593785: "Hydrogen and Carbon Black Production via Staged Plasma Technology."

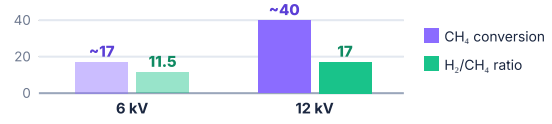
~0.5 kg/hr
hydrogen at >98% purity

~1.5 kg/hr
ASTM-grade carbon black

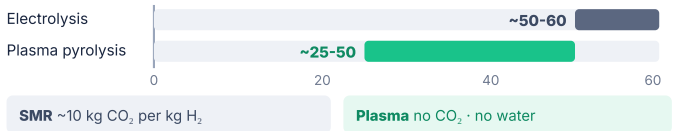
~40 %
CH_4 conversion at 12 kV

~12 t CO_2
avoided per t H_2 vs SMR

Effect of pulse voltage (%)



Energy & emissions per kg H_2



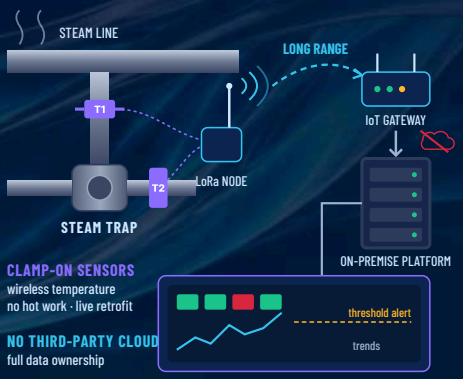
SMR ~10 kg CO_2 per kg H_2 | **Plasma** no CO_2 · no water

IIOT · STEAM TRAP MONITORING | ENERGY LOSS · IN-HOUSE PLATFORM

Sensors to Solutions: IoT based Steam Trap Monitoring System

A Scalable, Low-Cost In-House IIoT Platform at Substantially Lower Cost Than Market Solutions and Sub-Year Payback

Mr. Dipankar Chowdhury and Mr. Rahul V Wawle
Hindustan Petroleum Corporation Limited R&D Centre, India



ABSTRACT

Steam trap failures are a major source of unmonitored energy loss in refinery operations. The Digital Lab at HPGRDC has developed a LoRa (Long Range) based wireless, end-to-end IoT steam trap monitoring system, spanning field sensors, edge connectivity, an on-premise platform, and a custom analytics dashboard. The system achieves substantially lower cost and faster payback than typical market solutions, while establishing a reusable in-house technology base for plant-wide IoT deployment across multiple applications and industries.

Business Need

Manual steam trap inspection is infrequent and reactive, letting failures go undetected for months and causing avoidable energy loss, higher maintenance cost, and delayed corrective action. Real-time, connected monitoring closes this gap, without the high cost, cloud dependency, and vendor lock-in that typically come with commercial IoT offerings.

Solution & Technical Achievements

- End-to-end, from sensors to monitoring solution platform, hardware, firmware, communication, platform, and analytics
- Clamp-on wireless temperature sensors requiring no hot work, enabling fast, low-disruption retrofit on live steam traps.
- Wireless field communication network integrated with an on-premise IoT gateway and edge infrastructure, no third-party cloud or server dependency.
- Indigenously built on-premise IoT platform (device, data, application, and intelligence layers) ensuring full data ownership, privacy, and strong cybersecurity.
- Custom analytics dashboard covering device management, live steam-trap health monitoring, historical trend analysis, system configuration, and configurable threshold-based alerting.
- Modular, reusable “Multiple use cases, One Platform” architecture designed from the outset for extension to other IoT use cases and assets.

Cost & Business Impact

Benchmarked against typical market quotes for comparable commercial IoT monitoring solutions, this platform delivers a substantially lower capital cost per trap, **up to ~65-70% lower**, and eliminates recurring operating expense entirely. For a plant-wide rollout of 200 traps, this translates into **a simple payback period of approximately 6 months**, among the fastest achievable for an initiative of this scale, driven by low capex and near-zero lifecycle cost.

Future Scope

- Multi-sensor expansion on the same platform: pump vibration & condition monitoring, motor/equipment health, pipeline thickness, pressure relief valves, transformer health, energy monitoring, and water irrigation monitoring.
- Cross-industry scalability: the architecture is designed to extend beyond refining to any process industry requiring distributed asset health and condition monitoring.
- Cellular (LTE / NB-IoT) upgrade path: a planned parallel/redundant backhaul connectivity layer alongside the Ethernet connectivity to improve high availability and extend coverage to areas with limited network connectivity.

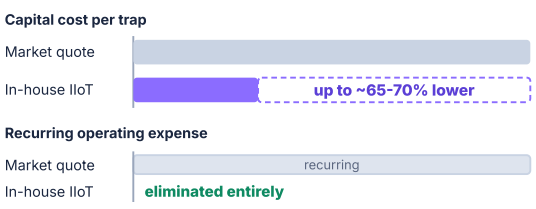
~65-70%
lower capital cost per trap vs typical market quotes

~6 months
simple payback, plant-wide rollout

200 traps
plant-wide rollout basis

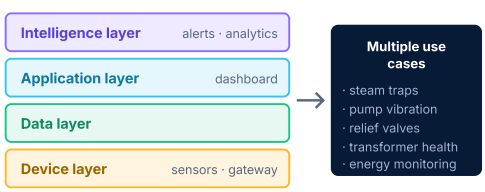
Zero
recurring operating expense

Cost vs typical market solution · per trap



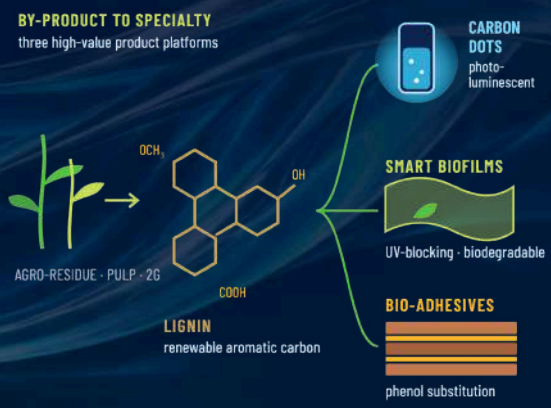
Relative bars. Only the reduction (up to ~65-70%) is reported in the abstract.

One platform, four layers



LIGNIN VALORIZATION | CIRCULAR BIOECONOMY · BIOREFINERY

Lignin Valorization for a Circular Bioeconomy: Global Outlook, Experimental Pathways and Economic Viability of High-Value Biorefinery By-Products



Sayanti Ghosh*, Vivek Rathore and Jaya Rawat
BPCL, Corporate Research & Development Centre, Greater Noida
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ABSTRACT

Lignin, the second most abundant natural biopolymer and the largest renewable source of aromatic carbon, is generated globally at 50-70 million tonnes annually as a by-product of the pulp, paper, and second-generation (2G) biorefinery industries, with Indian agro-residues contributing nearly 40 million tonnes each year. Despite its abundance, **over 97% of lignin is still combusted** for low-value process heat, representing a significant loss of renewable carbon and economic potential. With lignin-derived value chains projected to exceed USD 280 billion by 2030, lignin valorization presents a timely opportunity to advance India's Panchamrit commitments, Net-Zero 2070 targets, and Atmanirbhar Bharat vision through the development of sustainable, indigenous material supply chains.

This study presents a laboratory-validated lignin valorization framework integrating feedstock characterization, product development, and techno-economic assessment. Lignin from diverse industrial streams was successfully converted into three high-value product platforms. Lignin based Carbon Dots (CDs) synthesized via hydrothermal carbonization exhibited multicolour, excitation-dependent photoluminescence, with a novel correlation identified between carboxylic-acid valency and emission intensity. The resulting Carbon Dots demonstrated potential for bioimaging, sensing, anti-counterfeiting inks, and photocatalysis. Biodegradable lignin-starch-glycerol biofilms containing 0-1 wt% lignin showed enhanced UV-blocking performance, while incorporation of lignin-derived CDs imparted stable fluorescence, enabling smart and traceable packaging materials that fully biodegraded in soil within eight days. In parallel, bio-based phenolic adhesives produced through alkaline activation of lignin with PEG extenders and bio-crosslinkers achieved 30-50% phenol substitution, offering lower-VOC alternatives to conventional phenol-formaldehyde resins for engineered wood applications. Phase-separation behaviour observed in biorefinery-derived lignin highlighted fractionation as a key optimization pathway.

Preliminary techno-economic analysis revealed attractive **gross margins of approximately 79.5% for Carbon Dots**, 70% for biofilms, and 33% for adhesives. Notably, Carbon Dots production upgraded **lignin valued at ₹5-20/kg into specialty materials worth ₹5,000-25,000/g** at laboratory scale. These findings align with the rapidly growing global markets for Carbon Dots and biodegradable packaging. Beyond the demonstrated products, additional opportunities were identified for crude lignin in supercapacitor electrodes, 3D-printing photoresins, drug-delivery nanoparticles, structural-colour coatings, and solid polymer electrolytes, providing a practical pathway for scale-up within existing pulp mills, sugar factories, and bioethanol refineries.

Overall, this work establishes lignin, irrespective of source or purity, as a versatile and economically viable feedstock for producing high-value specialty materials. The findings demonstrate a clear pathway for transforming an underutilized industrial by-product into commercially relevant products, supporting the transition from research-driven innovation to large-scale commercialization within a circular bioeconomy.

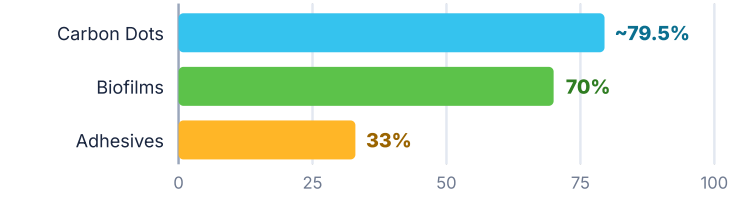
50-70 Mt/yr
lignin generated globally; ~40 Mt from Indian agro-residues

>97%
of lignin still combusted for low-value process heat

79.5%
gross margin for Carbon Dots (lab-scale TEA)

30-50%
phenol substitution in bio-based phenolic adhesives

Preliminary gross margin by product · %



Value uplift via Carbon Dots · lab scale

Lignin ₹5-20/kg → hydrothermal → Carbon Dots ₹5,000-25,000/g

Fate of lignin today
over 97% combusted for low-value process heat

KEYWORDS Biomass | Lignin Valorization | Circular Bioeconomy | Net-Zero

ENERGY EFFICIENCY | HOT OIL SYSTEM · PROCESS HEATING

Efficient Optimization of Refinery Energy Intensity and Life Cycle Cost Through Integrated Process Heating

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Numaligarh Refinery Limited (NRL), Golaghat, Assam
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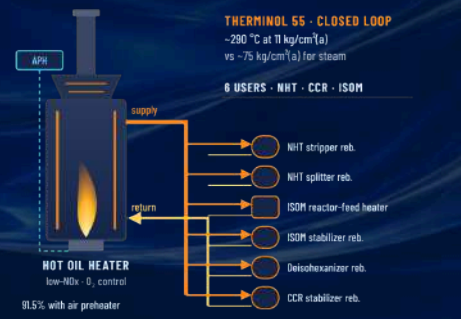


ABSTRACT

The decline in light crude reserves has increased reliance on abundant heavy crude resources, are several times higher than light oil reserves. NRL is expanding its crude-processing capacity from 3 MMTPA to 9 MMTPA by adding a new 6 MMTPA refinery train designed to process imported Arab crude. This predominantly heavy and high-sulphur crude mix reinforces the need for efficient generation, recovery and distribution of thermal energy. Refinery process units require continuous thermal energy for fractionation, stripping, stabilization, reboiling and reactor-feed temperature control. Conventionally, these duties are met through direct-fired heaters and steam utility systems. Steam remains a highly effective utility for low and medium-temperature process heating because of its high latent heat, non-flammability and favourable heat-transfer coefficient.

Nevertheless, high-temperature steam service requires high operating pressure and involves energy losses and auxiliary requirements related to blowdown, flash steam, deaeration, water treatment, steam traps and condensate recovery. Steam networks can also experience corrosion, scaling, erosion and water-hammer-related reliability concerns. Synthetic heat-transfer fluids offer an alternative for high-temperature heating because they can remain in the liquid phase and circulate at pressures substantially lower than steam at an equivalent temperature. Unlike the earlier Motor Spirit plant configuration in NRL, the new Motor Spirit Block introduces a centralized hot-oil system as a common thermal utility for multiple high-temperature indirect-heating duties. In comparison, the studied centralized hot-oil system uses **Therminol 55** in a closed circulation loop operating at approximately 290 °C and 11 kg/cm²(a). Achieving a similar temperature with saturated steam would require a pressure of approximately 75 kg/cm²(a), taking a significantly higher system design pressure. The centralized system supplies hot oil to six major process users across the Naphtha Hydrotreater (NHT), Continuous Catalytic Reforming (CCR) and Isomerization (ISOM) units, including two NHT reboilers, the CCR stabilizer reboiler, the first Isomerization reactor-feed heater, the stabilizer reboiler and the deisohexanizer reboiler. From the **fig.1**, the respective heat duties are 11.70 Gcal/h for the NHT stripper reboiler, 10.15 Gcal/h for the NHT splitter reboiler, 3.98 Gcal/h for the first Isomerization reactor-feed heater, 9.23 Gcal/h for the Isomerization stabilizer reboiler, 21.46 Gcal/h for the deisohexanizer reboiler and 7.22 Gcal/h for the CCR stabilizer reboiler. The total process-user duty is approximately 63.74 Gcal/h, closely matching the 64.04 Gcal/h (designed) absorbed duty of Hot Oil Heater. The heater has a reported fired duty of 69.2 Gcal/h and a thermal efficiency of approximately 91.5% with the air preheater. The high efficiency is achieved by recovering heat from the convection-section flue gas to preheat combustion air, thereby reducing stack heat loss and fuel demand. Low-NOx burners, oxygen-based combustion control, individual hot-oil flow regulation and closed-loop recirculation further support efficient heat generation and distribution. For the same heat duty, an equivalent saturated-steam system would require approximately 181.5 t/h of steam. Moreover, saturated steam at a comparable temperature would require pressure of the order of 75 kg/cm²(a), whereas the hot-oil circuit supplies the required temperature at about 11 kg/cm²(a), representing **a nominal pressure reduction of approximately 85%**. With the specified design margin, the alternative steam circuit and associated equipment would require a design pressure of approximately 83 to 85 kg/cm²(g), increasing the required pressure class, wall thickness and steel tonnage of piping, valves, reboilers and related facilities. The **CAPEX** benefit arises from avoiding an extensive 83 to 85 kg/cm²(g) steam-distribution network, high-pressure control stations, steam traps, condensate and flash-recovery systems, and the additional material required for high-pressure equipment and piping. The **OPEX** benefit arises from avoiding the continuous import of approximately 181.5 t/h of saturated steam, together with associated blowdown, deaeration, water-treatment, leakage and condensate-recovery costs, after accounting for hot-oil heater fuel, pumping electricity, Therminol makeup, nitrogen consumption and maintenance. Based on the preliminary equivalent-duty comparison, the hot-oil configuration is projected to deliver **an overall lifecycle-cost reduction of approximately 60%** relative to the corresponding high-pressure steam alternative.

The reduction in normalized utility-energy consumption is also expected to contribute positively to NRL's toward **Solomon Q1 Day 1** performance, with the final EII-point improvement to be established using NRL's official Solomon standard-energy denominator and configuration-specific normalization methodology. The innovation of the scheme lies in its centralized integration within NRL's new Motor Spirit Block, where one optimized thermal utility serves six consumers across three process units in Motor Spirit Block (NHT, CCR, ISOM). The system provides a replicable pathway for reducing utility intensity, lifecycle cost and combustion-related emissions in refinery process units. Thus, the centralized hot-oil system improves the utilization of fuel-derived heat, reduces dependence on very-high-pressure steam and provides a practical approach to efficient energy management across interconnected refinery process units.

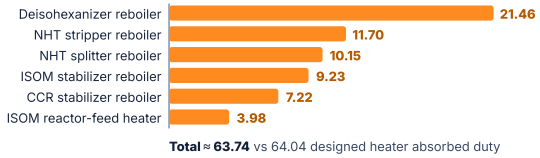
~85%
nominal pressure reduction: 11 vs 75 kg/cm²(a)

~60%
projected lifecycle-cost reduction vs high-pressure steam

181.5 t/h
saturated steam import avoided for the same duty

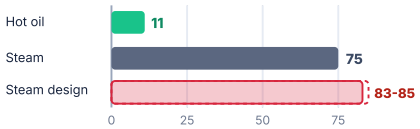
91.5%
hot oil heater thermal efficiency with air preheater

Hot oil users · heat duty, Gcal/h



Total ≈ 63.74 vs 64.04 designed heater absorbed duty

Loop pressure · for ~290 °C service



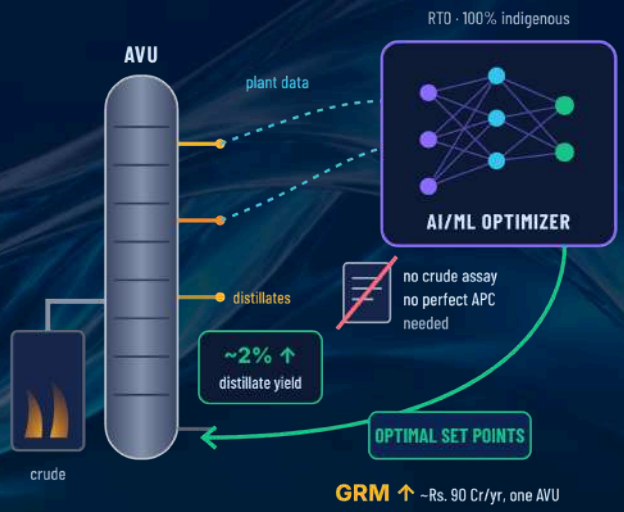
kg/cm²(a); steam design kg/cm²(g)

KEYWORDS: Synthetic Heat-Transfer Fluid | Hot Oil Heat Transfer System | Efficient Energy Management | Heavy and Light Crude | NHT | CCR | ISOM | CAPEX | OPEX

AI/ML · RTO OPTIMIZATION

GRM MAXIMIZATION · INDIGENOUS TECHNOLOGY

Innovative, 100% indigenously developed, digital, AI/ML solution for GRM maximization: proven in Indian refinery



Samir Gijre
BENCHMARK, Pune

ABSTRACT

This is about for sharing information on indigenously developed, innovative digital technology, proved in an Indian refinery, for GRM maximization, using AI/ML/RTO/optimization. All Indian refineries are currently and heavily interested, and either investing, planning to invest, implementing RTO already. Hence this topic is timely and relevant.

The innovative technology, **BENCHMARK**, complements current industry solutions, and helps refineries to achieve few times more benefit, and compresses the time to benefit to 1/4th of the typical RTO project. 100% Technology is developed by BENCHMARK, a 100% Indian company from Pune. The full paper has following content

1. What impacts refinery GRM most? 4 factors, of which major is **Distillate yield**, which has 54% impact on GRM. Reference- paper on www.benchmark1.in
2. Why do Indian refiners need RTO/optimizer, when PLANNING and APC are doing optimization? Technical, Engineering and Business reasons.
3. How BENCHMARK innovative technology compliments market RTO/Optimization technologies to increase project benefit by many times over, and compress time to benefit to 1/4th! 100% guarantee (not 10% PBG) -no benefit- don't pay!
4. Explain BENCHMARK technology in brief- (1) most accurate AI/ML technology-based optimizer (2) does not need crude assays/feed composition as input (3) does not need a perfect APC, (4) technology proved in an Indian refinery.
5. Case study of BENCHMARK technology proven in an Indian refinery, for one AVU. Order of magnitude benefit proved-about 2% increase in distillate yield, which is increase in GRM of about Rs. 90 Crore per year, for one AVU!
6. Needs CHT help to reach and share this technology to refining industry leaders.

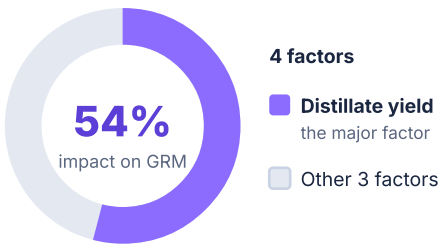
~Rs. 90 Cr/yr
increase in GRM, for one AVU

~2%
increase in distillate yield, Indian refinery case study

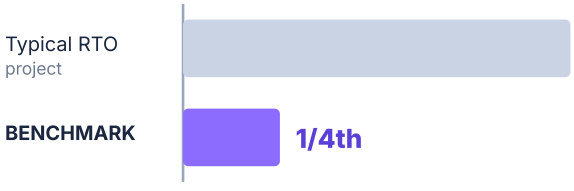
1/4th
time to benefit of the typical RTO project

100%
indigenous technology, Indian company from Pune

What impacts refinery GRM most



Time to benefit (relative)



100% guarantee: no benefit, don't pay

HOW IT WORKS

1. **Plant data** from the refinery unit
2. **AI/ML optimizer** no crude assay needed
3. **Optimal set points** back to the unit
4. **GRM up** ~2% distillate yield

MACHINE LEARNING · SOFT SENSORS | CCR · TOLUENE QUALITY

Machine Learning-Driven Real Time Prediction & Optimization of CCR Unit and Toluene Production

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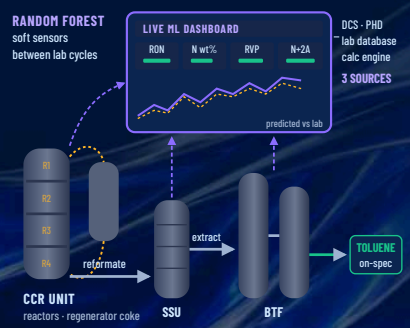


ABSTRACT

1. CCR Unit Live Performance Dashboard: Real-Time ML Predicted Soft-Sensors and Dynamic Economic Yield Optimization

In modern petroleum refining, Continuous Catalyst Reforming unit represents a highly dynamic system where maximizing high-value product yield and octane severity is critical to refinery profitability. However, key operational parameters such as Reformate Octane (RON), Reformate Naphthene (wt%), and Naphtha Feed quality rely on physical sample analysis, creating a significant blind spot between feedback cycles. This abstract presents the development and deployment of live CCR performance dashboard having adaptive Machine Learning predictors which are developed with datasets based on past performance of the unit and trained to establish a real-time, resilient monitoring and optimization mechanism.

The dashboard is structured across three major operational areas, prioritizing advanced predictive modelling:

a. Adaptive ML Soft-Sensors: Scikit-Learn Random Forest Regressors are deployed to continuously predict Reformate Octane (RON), Reformate naphthene (wt%), Reformate RVP and Feed N+2A (vol% naphthene and aromatics individually). The model input parameters are fetched automatically from **three distinct refinery data sources without any manual intervention**. The core operating variables, including loop pressures, feed throughput, and all reactor bed temperatures, are fetched in real-time from active plant DCS transmitters via Honeywell PHD. Bulk feed properties (IBP, 50% point, FBP) and compositions are retrieved dynamically from daily lab database. Finally, complex operational indicators such as bed-by-bed reactor Delta-Temperatures, debutanizer reflux ratios, and spent coke percentages are calculated inside the background calculations engine. These predictors values are compared with the lab metrices and are plotted in the dashboard for comparison.

b. Real-Time Unit Yield and Cost-Benefit Analysis Module: The system first converts raw DCS flow rate of feed and products to corrected mass flow rates and then utilizes these mass flow rates to calculate product yields in real-time. By comparing these active yields against the design, the module calculates the exact deviation. Fortnightly market prices for both Reformate and Hydrogen can be directly provided, and system instantly computes the net monetary impact and contrasts it with the previous day's average. This provides an immediate, quantifiable financial indicator of reactor severity adjustments, turning process parameters like WAIT and RON into tangible economic optimization vectors. Also, live product yields are plotted together to get better visualisation of performance of the unit.

c. CCR Regenerator Catalyst Coke Calculation: Spent catalyst coke content are calculated simultaneously through different independent methodologies: stoichiometric carbon-oxygen mass balance and licensor provided spent coke empirical correlation.

By deploying this hybrid framework, refinery has established a robust operational dashboard that provides continuous quality indicators, maintains prediction capabilities, and quantifies daily monetary impacts to maximize product recovery and economic yield.

2. Toluene Product: Real-Time Quality Prediction using ML Model and Operational Optimization for Producing On-Spec Product

Toluene is a high-value refinery product requiring stringent quality control, with a product specification of **Toluene Purity >99.8 wt% and non-aromatics <1000 wt. ppm**. In the process configuration considered, Shell Sulfolane Unit (SSU) produces extract (aromatic rich) which serves as the feed to Benzene-Toluene Fractionation (BTF) section. Since key quality parameters are primarily obtained through periodic laboratory analysis, delays between process changes and quality feedback can create a lag and increase the risk of off-specification production. This section presents the development of a real-time predictive quality monitoring dashboard integrating ML-based soft sensors for SSU and BTF sections.

SSU Extract Non-Aromatics predictor was developed to continuously monitor the quality of the extract feeding the BTF section. In parallel, ML predictors were developed for BTF Toluene Purity and Non-Aromatics content using historical process operating and laboratory data. The predicted quality parameters are continuously monitored against the specified product limits, providing real-time visibility between laboratory analysis cycles.

An Operational Recommendation Window was also developed using historical periods of successful on-specification toluene production. Operating ranges of key process parameters corresponding to acceptable Toluene Purity and Non-Aromatics levels were identified and incorporated into the dashboard to provide data-driven guidance for plant parameter adjustments.

The integrated dashboard combines extract non-aromatics prediction, toluene product quality prediction and historical operating-window analysis on a single platform. The system enables and supports proactive adjustment of operating parameters, thereby improving consistency in production of specification-compliant toluene and facilitating data-driven operation of the SSU-BTF process.

>99.8 wt%
toluene purity specification

<1000 wt. ppm
non-aromatics in toluene, specification

3
refinery data sources feed the models, no manual intervention

Real-time
yield deviation vs design and net monetary impact

Soft-sensor data pipeline

Toluene on-spec window

Schematic of the specification limits. Axes not to scale.

AI · ASSET INTEGRITY | START-UPS & EMERGING TECHNOLOGIES

The NextGen TIQ Asset Manager: A Standards-Grounded AI Layer for Refinery Asset Integrity

SRIJAN TIWARI
Co-founder , TIQWorld Pvt. Ltd. (Startup incubated at IIT Madras)
IIT Madras Alumni and Researcher (CNDE Lab, IIT Madras)

ABSTRACT

India's refineries are running into a widening asset integrity gap. Many units run well past their thirty-year design life, and about **30% of certified NDT personnel are already over 55** (ASNT,2023). Every fit-to-run decision still ends at one expert's judgment, over data scattered across disconnected systems.

The cost is measurable. A single turnaround extended by five days, at roughly $3 million per day of lost margin (AP-Networks,2024), erases tens of millions; our analysis puts the avoidable loss near **$3.35 million per asset each year** (TIQWorld analysis, 2026). Yet under 20% of field observations, recorded in unstructured Word, Excel and PDF reports, reach the risk-based inspection (RBI) system (TIQWorld customer discovery, 2026), and engineers spend over 50% assembling data rather than interpreting it (JPSE,2019).

The NextGen TIQ Asset Manager closes this data-to-decision gap. It is a standards-grounded AI layer, built on ASME, API and ISO codes, that does not ask engineers to change how they work, something earlier digitisation drives never achieved. Instead it takes the unstructured inputs they already produce, structures them, and reconciles them across ERP (SAP), RBI (such as GE Vernova, Meridium) and process historian systems to support a defensible residual-life and fit-to-run decision, with a qualified engineer accountable for every call. It advances in three stages: digital inspector, augmented inspector, and a semi-autonomous inspector inside the plant's digital twin.

Incubated at IIT Madras CNDE and DPIIT-recognised, TIQWorld has moved from research into commercialisation. Stage 1, its People's Capability and Digitalisation platform, is live with 500+ inspection professionals registered, in an asset-integrity market growing from $25.3 billion (2025) to $41 billion by 2034 at 6.35% annually (Fortune Business Insights, 2026).

Well-monitored assets also run more efficiently and leak less, cutting energy use and emissions, an indigenous route to safer, lower-emission refining.

References

• **ASNT (American Society for Nondestructive Testing).** Age profile of certified NDT personnel (about 30% over 55). asnt.org
• **AP-Networks.** Turnaround cost and extension benchmarks (about $3 million per day of lost margin). ap-networks.com
• **JPSE.** Share of engineer time spent finding and assembling data (over 50%); source abbreviation as cited in TIQWorld materials, full citation to be confirmed.
• **Fortune Business Insights (2026).** Asset Integrity Management Market: $25.3 billion (2025) to $41 billion (2034), 6.35% CAGR. fortunebusinessinsights.com
• **TIQWorld stakeholder discovery (2026).** Primary research across 30+ integrity leaders (under 20% of field observations reaching RBI).
• **TIQWorld analysis (2026).** Internal loss model (avoidable loss near $3.35 million per asset per year).

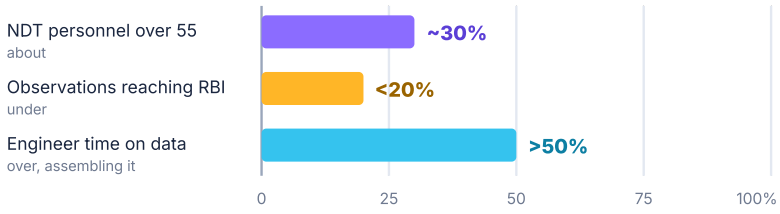
$3.35M
avoidable loss per asset each year (TIQWorld analysis)

<20%
of field observations reach the RBI system

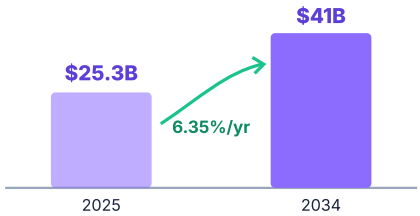
30%
of certified NDT personnel already over 55

500+
inspection professionals registered on Stage 1 platform

The data-to-decision gap · % as cited in the abstract



Asset-integrity market · USD billion

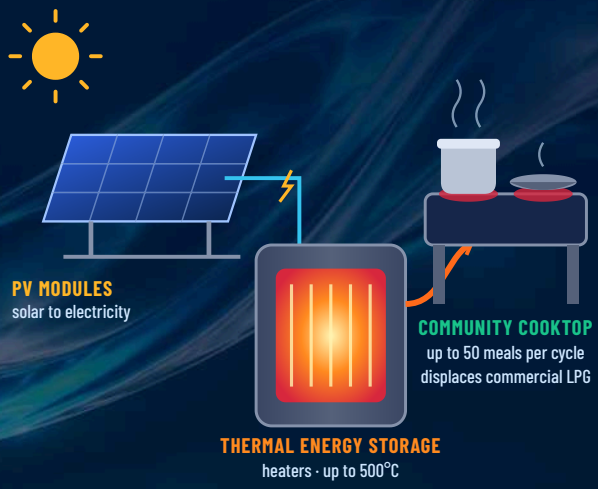


HOW IT WORKS
1 **Capture** Word, Excel, PDF as-is → 2 **Structure** standards-grounded AI → 3 **Reconcile** ERP, RBI, historian → 4 **Fit-to-run call** engineer accountable

SOLAR THERMAL STORAGE

CLEAN COOKING · INDIGENOUS TECHNOLOGY

Solar-Thermal Storage Based Community Cooking System: An Indigenous Solution for Mass Scale Clean Cooking



Manish Kumar
Solar Energy Department, IOCL R&D Centre

ABSTRACT

India's commercial cooking sector, comprising restaurants, catering services, industrial canteens, hostels, temple and community kitchens, relies predominantly on commercial LPG and PNG, creating exposure to fossil-fuel price volatility, imports and geopolitical uncertainties. There is a growing need for indigenous, reliable and scalable renewable-energy solutions for high-temperature cooking applications.

Building on its experience with the household Surya Nutan Indoor Solar Cooking System, Indian Oil Corporation Limited (IndianOil) is developing the Solar Nutan Community System (SNCS X50) for commercial and institutional cooking, designed to cater to **up to 50 meals per cooking cycle**.

The PV-based SNCS X50 converts solar energy into electrical energy through photovoltaic modules and subsequently into high-temperature thermal energy using specialized heaters. The thermal energy is stored in a Thermal Energy Storage (TES) system, enabling solar energy to be utilized according to the cooking demand and overcoming the intermittency of direct solar cooking. The system can achieve **temperatures of up to 500°C**, providing the required thermal flexibility for cooking operations such as boiling, sautéing, deep frying and roti baking.

The PV-TES configuration offers a practical pathway for displacing LPG consumption in community and institutional kitchens while providing greater operational flexibility and reliability. The technology can be deployed in canteens, hostels, restaurants, catering facilities, temples, schools and community kitchens, with potential benefits including reduced fossil-fuel dependence, lower emissions and improved energy security.

SNCS X50 represents an indigenous integration of solar PV, high-temperature thermal energy storage and commercial cooking, demonstrating the potential of renewable energy to support the decarbonization and transformation of India's commercial cooking sector.

This cooktop has an attractive payback period and also IRR when compared to the commercial LPG utilization. Additionally, also reduces the significant CO_2 emissions.

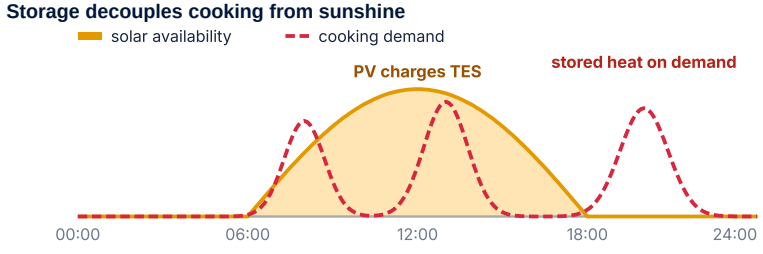
50 meals
per cooking cycle (SNCS X50)

500 °C
maximum temperature achievable

PV + TES
indigenous integration of solar PV and thermal storage

Payback + IRR
attractive vs commercial LPG, with lower CO_2

Storage decouples cooking from sunshine



Illustrative. Values not reported in the abstract.

Where it can be deployed

Canteens · Hostels · Restaurants · Catering · Temples · Schools · Community kitchens

Cooking operations supported

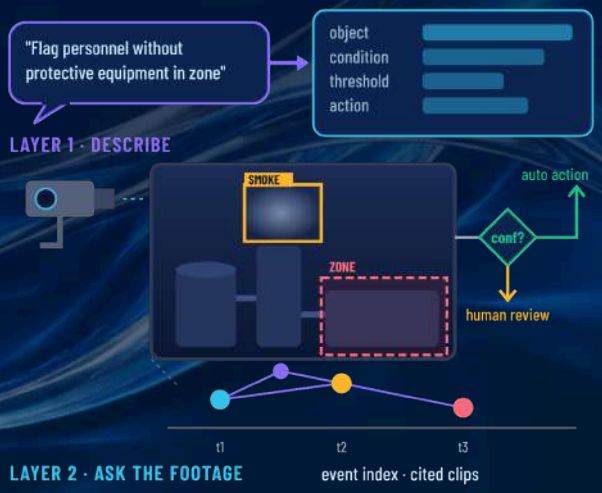
Boiling · Sautéing · Deep frying · Roti baking

HOW IT WORKS

1. **PV modules** — solar to electricity
2. **Heaters** — high-temperature heat
3. **TES** — stores up to 500°C
4. **Cooktop** — up to 50 meals/cycle

VISION AI · AGENTIC AI | INDUSTRIAL SAFETY MONITORING

From Prompt to Insight: A Natural-Language Vision Workflow and Agentic Investigation Framework for Real-Time Industrial Safety Monitoring



Siddharth Pai
Sahastranshu Technologies

ABSTRACT

Real-time visual monitoring of industrial operations safety-gear compliance, fire and smoke hazards, unauthorized zone entry usually requires either hand-configuring rule-based detection systems for each new condition or manually reviewing hours of footage after an incident to reconstruct what happened. Both approaches create a bottleneck between what a camera sees and what an operator can take action on. In this paper, we present **a two-layer framework** to bridge this gap by coupling natural-language workflow authoring with agentic video investigation.

The first layer allows an operator to describe a monitoring requirement in plain language, for example flagging personnel without required protective equipment in a defined zone. A language model interprets this into a structured, executable configuration (object, condition, threshold, and response action). If the description is incomplete, the model asks for clarification, instead of guessing at intent. The resulting workflow is shown to a human for review and editing, tested against sample footage, and only then put into production. In live operation, high-confidence detections automatically trigger the configured response; low-confidence or ambiguous cases are routed to a human reviewer, **preserving human oversight at the point of uncertainty** rather than either over-alerting or acting blindly.

The second layer is retrospective analysis. Rather than scrubbing footage manually, an operator can ask the system in natural language about past events like what happened, when, and in what order. It does this by indexing detected events and their evidence into a structured, queryable representation that connects objects, events, and their relationships in time. The retrieval and verification process grounds each answer in the particular footage it is derived from.

Combined, these layers bring together two operator needs that are usually handled by separate tools configuring what to look for, and investigating what has already happened into one coherent, auditable system. We describe the architecture, its deployment on cloud infrastructure, and its applicability to safety and process-monitoring use cases across industrial operations, providing a path from research prototype to deployable operational technology.

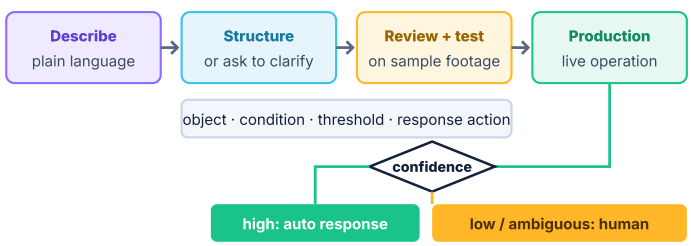
2 layers
natural-language workflow authoring + agentic video investigation

Plain language
to configure what to look for and to ask what happened

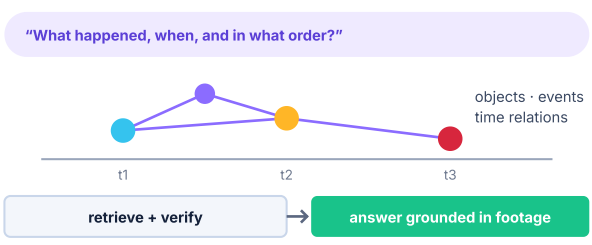
Human
review at the point of uncertainty: low-confidence cases routed to a reviewer

Grounded
every answer tied to the footage it is derived from; auditable

Layer 1: from prompt to a reviewed, live rule



Layer 2: ask the footage

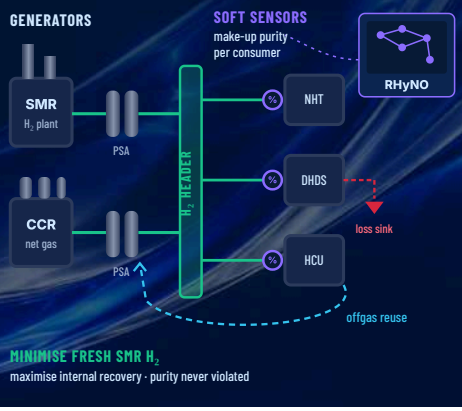


HOW IT WORKS

1. **Describe** what to watch, in plain language
2. **Configure** structured, reviewed rule
3. **Monitor live** confidence-gated response
4. **Investigate** ask about past events

REAL-TIME OPTIMIZATION · ML | REFINERY HYDROGEN NETWORK

Real-time Refinery Hydrogen Network Optimization



Raviraj S Nayak (Manager- Process, MRPL), **Ananyo Sengupta** (Chief Manager, MRPL)

ABSTRACT

Hydrogen is a key utility in the refining sector, which is used for upgradation of crude oil cuts into value added products via hydrotreating, hydrocracking processes. Of all the utilities used, hydrogen is the most cost intensive and has the maximum impact on the carbon footprint. The key sources of conventional hydrogen generation in refineries are traditional Steam Methane Reformers and Naphtha Catalytic Reformers. In view of the cost and environmental impact of hydrogen utility, management of each molecule of hydrogen generated, for efficient usage in the refining process, is a key driver for both profitability improvement and carbon footprint reduction. This paper proposes a novel approach for optimizing hydrogen generation and usage through **inhouse monitoring systems** which can provide **real time operator guidance** for hydrogen optimization (RHyNO).

Major hydrogen consumers in a refinery are hydro processing units like naphtha, diesel desulfurizers and hydrocrackers. These catalytic units operate at high hydrogen partial pressure, and the conversion efficiency is affected by the purity of hydrogen consumed. Not all units require the same level of hydrogen purity, and this provides a key handle for optimizing hydrogen distribution network. An in-house hydrogen optimizer has been developed for checking the impact of hydrogen generator routings on purity in real time basis by providing **soft sensors of make-up hydrogen purity** of each consumer. This enables plant operators to take informed decisions and derive the incremental benefits of hydrogen saving by maintaining optimal make up gas purity in respective hydro processing unit.

A comprehensive model has been built by mapping each consumer and generator distribution topology, based on **sequential directed flow propagation** for multi nodal component purity check and rationalization algorithms for system reconciliation. Further, a **Machine Learning model** is incorporated to identify the deviating flow transmitters as bad actors that need to be rectified. The reconciled network is analysed using a **multi-pass optimizer** for determining the optimal generator routing using **multi-parameter constraint minimization functions**.

The novelty of the model developed is with respect to rationalization of actual real-time hydrogen header purity-flow balance and identification of handles for reducing hydrogen let down via the loss sinks. It also provides real time hydrogen pinch and enables operators to have a visual understanding of the complete network. This model ensures that **the consumer unit purity targets are never violated while minimizing SMR hydrogen generation** for the dynamic hydrogen demand of the refinery processing units, thereby enabling energy savings on a continuous basis. The algorithm has a built-in flexibility for updating target purities of each consumer, thereby ensuring that the hydrogen optimization function is not in violation of the catalyst requirement throughout its life cycle.

Overall RHyNO (Real Time Hydrogen Network Optimizer) is a nodal topology driven mass-integration technique based multi-pass optimization engine coupled with Machine Learning based bad actor identifiers, to optimize the distribution network and thereby resulting in **reduction of hydrogen generation without sacrificing any process parameters**. By maximizing internal hydrogen recovery and circular reuse, a commensurate reduction in feed and energy cost is realised along with associated CO2 emissions.

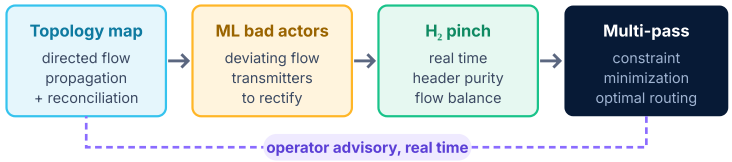
Real-time
operator guidance for hydrogen optimization

Soft sensors
make-up hydrogen purity of each consumer

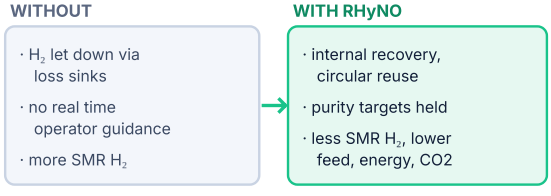
ML
identifies deviating flow transmitters as bad actors

Never
consumer unit purity targets violated

Inside the RHyNO engine



What the optimizer changes



BIO-BITUMEN | 2G ETHANOL RESIDUE · SUSTAINABLE ROADS

Durapave^{Bio}®: Indigenous Bio-Bitumen from 2G Ethanol process residue for sustainable roads

Irudayaraj Devotta*, Rabindra Kumar Padhan, Amol Ramakant Deorukhkar, Satyen Kumar Das, Kaushik Singha
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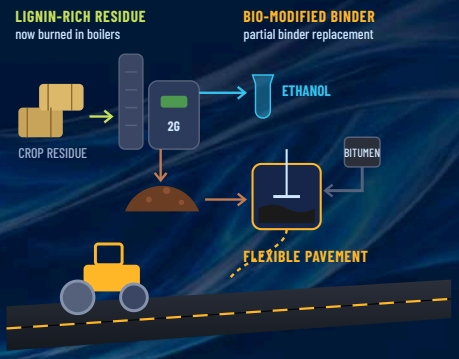


ABSTRACT

The growing demand for sustainable infrastructure necessitates the development of innovative construction materials that reduce reliance on fossil resources while promoting circular economy principles. India's expanding road network continues to drive significant consumption of paving bitumen, much of which is derived from finite petroleum resources. Concurrently, second-generation (2G) ethanol biorefineries generate substantial quantities of lignin-rich process residues that remain underutilized despite their inherent carbon-rich and natural binder-like characteristics. Valorisation of such residues into infrastructure materials presents an opportunity to create integrated solutions addressing both waste management and sustainable road construction.

Highlighting its broader significance, Shri Gadkari highlighted that bio-bitumen has the potential to convert agricultural waste into a valuable national resource, creating economic opportunities while addressing environmental challenges. He emphasized that large-scale adoption of bio-bitumen can help reduce pollution from crop residue burning, strengthen the circular economy, empower farmers, generate rural livelihoods, and reduce dependence on imported crude oil. One of the major advantages of bio-bitumen lies in its potential economic impact. India imports substantial quantities of crude oil and petroleum-based products, making the economy vulnerable to fluctuations in global energy markets. According to estimates, **a 15% blending of bio-bitumen could save nearly ₹4,500 crore annually** in foreign exchange. The technology also has the potential to replace imported bitumen worth ₹25,000-30,000 crore per year, contributing significantly to India's energy security and economic resilience. Beyond its economic benefits, bio-bitumen supports rural development by creating value from agricultural residues that are often discarded or burnt.

Huge quantity of lignin is generated (about six ton of lignin-rich residue generated per ton on ethanol produced) and is currently being burned in boilers. DurapaveBio is an indigenous technology developed for converting lignin-rich residue generated during 2G ethanol production into a value-added bio-bitumen component suitable for pavement applications. The technology leverages the aromatic and polymeric nature of lignin-containing residue to partially replace conventional petroleum-derived binder constituents, thereby creating a sustainable and resource-efficient paving material. Optimized processing and blending methodologies were employed to develop bio-modified binders capable of meeting the requirements of modern flexible pavements.

Comprehensive laboratory investigations demonstrated that incorporation of the bio-derived component **enhances binder stiffness and resistance to permanent deformation** while maintaining acceptable workability and processing characteristics. The technology establishes a synergistic linkage between biofuel production and transportation infrastructure by transforming a low-value industrial residue into a high-value construction material. Such integration not only improves resource utilization but also supports waste minimization and development of circular value chains.

Beyond technical performance, DurapaveBio offers significant environmental and strategic advantages, including reduced dependence on petroleum-derived materials, productive utilization of renewable carbon resources, and potential reduction in bitumen import requirements. Pilot-scale production and field implementation studies have demonstrated the practical applicability and scalability of the technology under real construction conditions. The innovation exemplifies industrial symbiosis between biorefineries and the road sector, creating a sustainable pathway for infrastructure development.

DurapaveBio represents a scalable indigenous solution aligned with national priorities of self-reliance, resource efficiency, and decarbonization. The technology highlights the potential of biorefinery residue valorisation to support the transition towards low-carbon, circular, and sustainable road infrastructure while creating additional value from renewable energy production system.

₹4,500 crore/yr — forex saving with 15% blending

15% — bio-bitumen blending

~6 t — residue per ton of ethanol

Pilot-scale — production and field studies

KEYWORDS Bio-bitumen | 2G Ethanol Residue | Lignin Valorisation

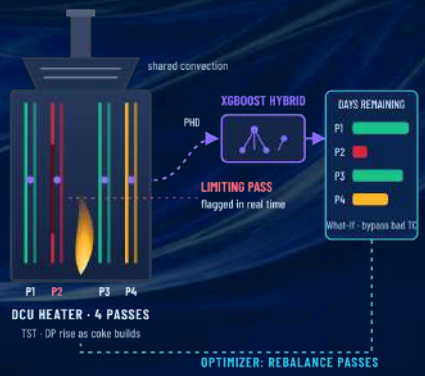
AI / ML · PREDICTIVE ANALYTICS

DELAYED COKER · HEATER RUN LENGTH

Extending DCU Heater Cycle Lengths through Real-Time Machine Learning and Predictive Analytics

Ajay Kumar K

Mangalore Refinery and Petrochemicals Limited (MRPL)



ABSTRACT

The profitability and operational efficiency of a Delayed Coker Unit (DCU) depend heavily on the run length of its fired heaters. Over time, thermal cracking causes coke to build up inside the heater tubes. This steadily raises Tube Skin Temperatures (TST) and Differential Pressure (DP) until safety and metallurgical limits force a shutdown for mechanical decoking (pigging). Traditionally, cycle lengths are managed using fixed schedules or simple linear extrapolation. Both approaches have drawbacks: fixed schedules often lead to premature shutdowns that waste valuable production time, while linear extrapolation can miss sudden, accelerated coking and result in unplanned outages.

This paper presents the development and deployment of a real-time AI optimization model that dynamically predicts **the remaining run length of each DCU heater pass**. The model uses a hybrid machine-learning architecture built around an XGBoost regressor. It is trained on extensive historical Distributed Control System (DCS) data, laboratory feed characterization data (such as MCR, Asphaltenes, Na, metals, SimDist etc), and Historical fouling rates.

MRPL DCU has two heaters with four passes each. Each pass has a separate radiant section while the convection section is common to all four passes. Hence pigging of any pass in a heater require a heater shutdown. A key operational challenge the model addresses is that fouling does not occur uniformly across all passes. In practice, only one or two passes typically become the limiting factor, forcing a shutdown of the entire heater even though the remaining passes may still have significant run length left. By providing continuous, pass-wise monitoring and prediction at the individual pass level, the system identifies these imbalances in real time. The Optimizer module then translates this insight into actionable recommendations, suggesting specific changes to individual pass operating parameters so that engineers can rebalance the passes on a continuous basis and safely extend the overall run length of the unit.

The core predictive engine works through an autoregressive, day-by-day simulation loop. It securely streams live plant sensor data directly from the Uniformance PHD historian database, continuously tracking the highest recorded (high-water mark) TST and DP degradation values for each pass. By simulating the non-linear physics of coke formation forward in time, the model calculates **the exact number of days remaining before each pass reaches its terminal limit**, across multiple heaters simultaneously.

The system is also built to be reliable in a real plant setting, with the option to re-calibrate using historical data after each pigging cycle to maintain accuracy over time. In addition, the interactive dashboard gives engineers the option to manually identify and bypass faulty thermocouples, removing them from the model's calculations so that prediction accuracy is preserved even when individual sensors fail. The model is deployed alongside an interactive What-If dashboard, which allows plant engineers to simulate hypothetical feed changes and operational adjustments in real time and see their predicted impact instantly.

Overall, this AI-driven framework enables refinery to move away from rigid, time-based maintenance and toward dynamic, condition-based pigging. This shift extends average cycle lengths, increases unit throughput, and delivers measurable improvements in overall unit economic margins.

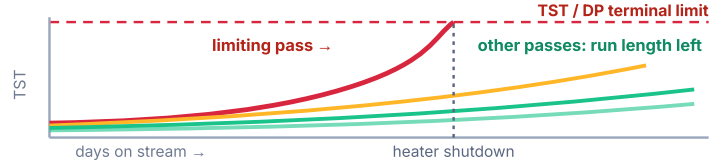
2 × 4
heaters × passes monitored, each with its own predicted run length

XGBoost
hybrid ML regressor on DCS, lab feed and fouling data

Day-by-day
autoregressive simulation to each pass's terminal limit

Pass-wise
real-time monitoring; condition-based pigging

Pass-wise coking · one pass limits the whole heater



Illustrative. Values not reported in the abstract.

From fixed schedules to condition-based pigging

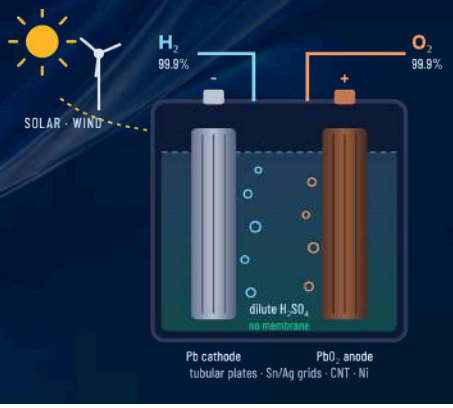
Fixed schedule
premature shutdowns

Linear extrapolation
misses sudden coking

AI pass-wise prediction + Optimizer
rebalance passes · longer cycles · higher throughput

GREEN HYDROGEN | ENERGY STORAGE · INDIGENOUS TECHNOLOGY

Indigenous, scalable lead acid hybrid battery for energy storage and cost - effective Hydrogen production



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ABSTRACT

Green hydrogen offers a sustainable pathway to achieving net-zero emissions, primarily through water electrolysis powered by renewable energy sources such as wind and solar. However, the widespread adoption of conventional electrolyzers is hindered by high capital costs, reliance on expensive electrode materials and membranes, limited working life, and the strict requirement for deionized water.

Recent advances from projects including the LoCel-H2 consortium and the Loughborough University research group have systematically addressed the electrode stability, efficiency, and scalability challenges inherent to lead acid battery based electrolyser system.

On the similar approach, this research, presents a cost-effective lead-acid battery-based system designed for simultaneous energy storage and green hydrogen production.

This hybrid "battolyser" system resolves the unpredictability of renewable power by storing daytime energy as electricity, while utilizing excess energy to produce green hydrogen. The system uses conventional lead-acid battery components, employing abundant and fully recyclable materials: a lead (Pb) cathode, a lead dioxide (PbO_2) anode, and a dilute sulfuric acid electrolyte. This approach eliminates the need for expensive traditional membranes, significantly lowering the overall capital cost.

To overcome historical challenges related to electrode stability and electrochemical efficiency, the system incorporates several targeted structural and chemical optimizations:

Tubular Plate Architecture: Replacing traditional flat plates with tubular plates securely confines the active mass within porous, inert gauntlets supported by a central Pb spine. This design prevents material shedding and structural collapse caused by the mechanical agitation of the hydrogen evolution reaction (HER), thereby ensuring a superior cycle life.

Corrosion-Resistant Grids: The integration of Tin (Sn) and Silver (Ag) into Pb-Ca or Pb-Sb grids creates a dense, conductive PbO_2/SnO_2 protective layer. This dramatically decreases the grid corrosion rate by reducing oxygen diffusion during prolonged oxygen evolution reactions (OER), with Ag acting synergistically to further stabilize the oxide layer.

Carbon Nanotube (CNT) Integration: Adding 0.01 to 0.3 wt% CNTs into the positive and negative plates increases electrical conductivity and minimizes internal resistance. This significantly reduces battery overpotential and power requirements for water splitting, yielding **a 6% reduction in top-of-charge voltage (TOCV) from 2.7 V to 2.55 V**.

Nickel (Ni) Catalysis: Introducing Ni into the negative active mass (NAM) shifts the HER voltage closer to the thermodynamic potential, substantially increasing hydrogen production efficiency during the overcharge phase.

Operating at a voltage of 2.1 to 2.6 V/cell, the optimized system successfully produces **99.9% pure hydrogen and 99.9% pure oxygen**. The high-purity hydrogen output is ideal for localized applications such as catalyst reduction, cooking, and industrial heating. When paired with a pressure booster and pressure swing adsorption (PSA), it can supply ~99.9999% pure hydrogen suitable for fuel cell buses. Ultimately, this hybrid technology offers a commercially viable, fully recyclable, and carbon-neutral solution to accelerate the green hydrogen economy.

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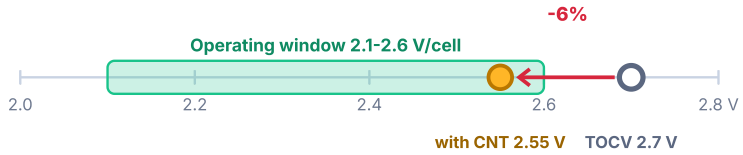
99.9%
pure hydrogen and 99.9% pure oxygen produced

2.1-2.6 V
operating voltage per cell

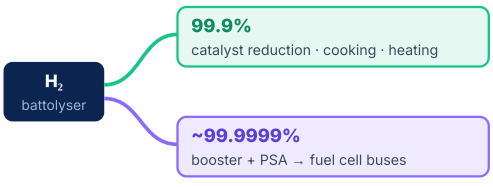
6%
lower top-of-charge voltage with CNT (2.7 → 2.55 V)

~99.9999%
hydrogen purity with pressure booster + PSA

Cell voltage map · CNT lowers the top-of-charge voltage



Where the hydrogen goes

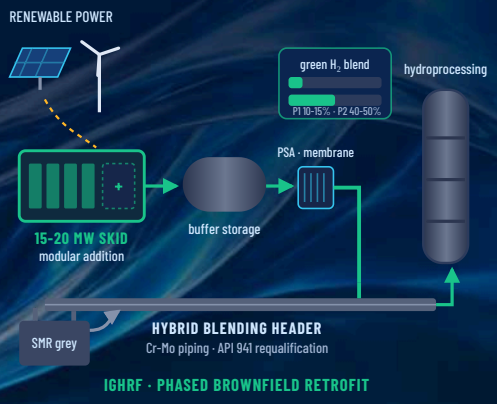


GREEN HYDROGEN · REFINERY INTEGRATION

BROWNFIELD RETROFIT · LCOH

Decarbonizing Downstream Assets: Techno-Economic and Engineering Pathways for Green Hydrogen Integration in Refinery Hydroprocessing Units

Author: **Abhishek Verma** (EIL) | Co-author: **Joseph Beski** (EIL)



ABSTRACT

India's National Green Hydrogen Mission (5 MMTPA by 2030) and its COP net-zero commitments require HPCL to displace grey hydrogen, currently $2.3-4/kg via steam methane reforming (SMR), across its Mumbai (9.5 MMTPA) and Visakhapatnam (15 MMTPA) refineries and JV assets (HMEL, HRRL, MRPL), in line with CHT's mandate for green hydrogen integration and indigenous technology development. Brownfield integration, however, confronts four engineering barriers: electrolyzer capacity factors of 25-35% against reformer baseloads above 90%, necessitating buffer storage at 15-20% of daily demand; PSA-train purity degrading from 99.9% to 96-97% under variable electrolyzer flow, requiring membrane-polishing retrofits; hydrogen embrittlement above 30 bar in existing Cr-Mo piping, requiring API 941 requalification; and electrolyzer balance-of-plant systems that must ride through ±3% grid-frequency excursions. To address these constraints, this paper presents a phased Indigenized Green Hydrogen Retrofit Framework (IGHRF), drawing on HPCL's operating experience and EIL's process-design capabilities: Phase-1 targets 10-15% green hydrogen blending via a 15-20 MW electrolyzer skid with buffer storage and a hybrid blending header, scaling to 40-50% in Phase-2 through modular electrolyzer addition.

The framework is benchmarked against HPCL's confirmed programme: a signed Green Hydrogen Purchase Agreement for 5 KTPA at Visakh Refinery, a 2040 Net Zero target, and 118 patents filed by the HPCL Green R&D Centre in FY 2025-26, building on its MoP&NG-recognized HP-COAT innovation (Best Innovation in R&D Award, 28th ETM). An H2A-style levelized-cost model shows **LCOH falling from $5.43/kg at 25% capacity factor to $3.31/kg at 75% (a 39% reduction)**, with electrolyzer CAPEX the dominant cost driver; layering SIGHT's declining incentive (Rs 50/40/30 per kg over three years) brings the effective LCOH to $2.70-2.94/kg, below grey hydrogen's $4/kg high case, though still above its $2.30/kg low case. At the standard SMR emission factor of 9-10 kg CO_2/kg H_2 displaced, the 5 KTPA GHPA volume alone would abate approximately **47,500 tonnes of CO_2 annually**. Together, these results indicate that a phased, brownfield-first retrofit pathway can bring green hydrogen blending within commercial reach of HPCL's existing hydroprocessing assets well ahead of full grid-parity electrolyzer economics.

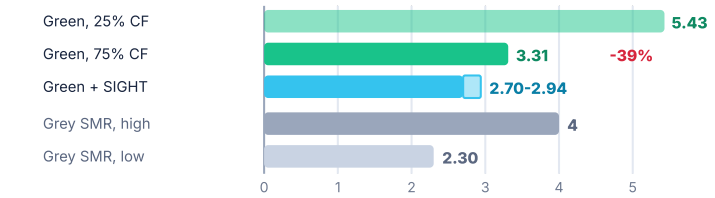
$5.43 → 3.31
LCOH per kg, 25% to 75% capacity factor (39% reduction)

$2.70-2.94
effective LCOH per kg with SIGHT incentive

~47,500 t/yr
CO_2 abated by the 5 KTPA GHPA volume alone

10-15 → 40-50 %
green hydrogen blending, Phase-1 to Phase-2

Levelized cost of hydrogen, $/kg



Four brownfield barriers

- **CF 25-35% vs baseload >90%** — buffer storage at 15-20% of daily demand
- **PSA purity 99.9% → 96-97%** — membrane-polishing retrofits
- **Embrittlement above 30 bar, Cr-Mo** — API 941 requalification
- **±3% grid-frequency excursions** — balance-of-plant ride-through

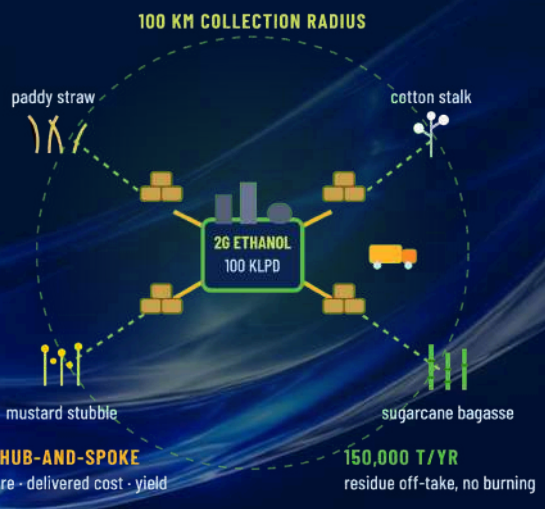
HOW IT WORKS

1. **Phase-1** — 15-20 MW skid, 10-15% blend
2. **Buffer + polish** — storage, membrane PSA
3. **Blend header** — green with grey H_2
4. **Phase-2** — modular scale to 40-50%

KEYWORDS Green Hydrogen Blending · LCOH Sensitivity Modelling · Brownfield Retrofit Framework (IGHRF) · Hydrogen Embrittlement · Refinery Decarbonization

2G ETHANOL · CBG | BIOMASS LOGISTICS · MILP OPTIMISATION

Scaling Multi-Feedstock Biofuels: A Quantitative Optimisation Framework for Regional Biomass Hubs



Joseph Beski S, AGM (EIL) | Co-author: **Abhishek Verma**, Dy. Mgr (EIL)

ABSTRACT

Meeting India's aggressive biofuel mandates requires state-owned refiners like Hindustan Petroleum Corporation Limited (HPCL) to tackle severe supply chain bottlenecks across their bioenergy assets, including the flagship 2G ethanol biorefinery in Bathinda and regional CBG projects like Budaun. Seasonal shortages, high logistics costs, and strict reliance on single crops like paddy straw routinely force plant slowdowns. To address these operational hurdles, a Multi-Feedstock Regional Biomass Hub Framework was formulated to transition HPCL away from single source dependency toward dynamic, multi crop aggregation.

Utilizing a mixed integer linear programming (MILP) optimisation model covering a 100 km collection radius, the framework balances supply across paddy straw, cotton stalk, mustard stubble, and sugarcane bagasse based on real time moisture quality, delivered cost, and conversion yields.

Benchmarked against a standard 100 KLPD single feedstock baseline, the hub model **cuts delivered raw material costs by 10.4%** (dropping from ₹2,850 to ₹2,553 per tonne) and lowers overall transport expenses by 14.3% through streamlined hub-and-spoke routes. Broadening the feedstock mix stretches annual run time from 225 to 250 days, pushing plant utilization up by 11.1%. As a result, unit production costs decline by 5.4%, **lifting annual modelled EBITDA by 26.2%** (from ₹48.5 Crore to ₹61.2 Crore) and shortening project payback from 6.3 to 5.0 years, a 20.6% improvement.

At full capacity, the 2G facility scales regional crop residue off-take to 150,000 tonnes annually, preventing open field burning and abating roughly **180,000 tonnes of CO_2 equivalent per year**. These findings confirm that HPCL's long term commercial viability in biofuels depends on supply flexibility, lower freight overheads, and higher asset uptime rather than relying on premium fuel pricing, providing a clear blueprint for future refinery retrofits and greenfield expansion.

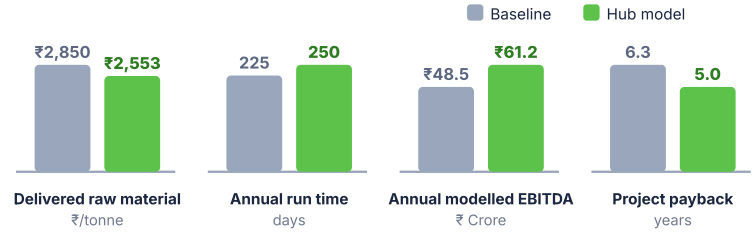
10.4%
lower delivered raw material cost (₹2,850 → ₹2,553/t)

26.2%
higher annual modelled EBITDA (₹48.5 → ₹61.2 Crore)

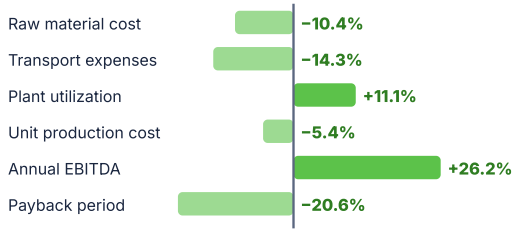
6.3 → 5.0 yr
project payback, a 20.6% improvement

~180,000 t
CO_2 equivalent abated per year at full capacity

Single feedstock baseline vs hub model · 100 KLPD



Change vs baseline

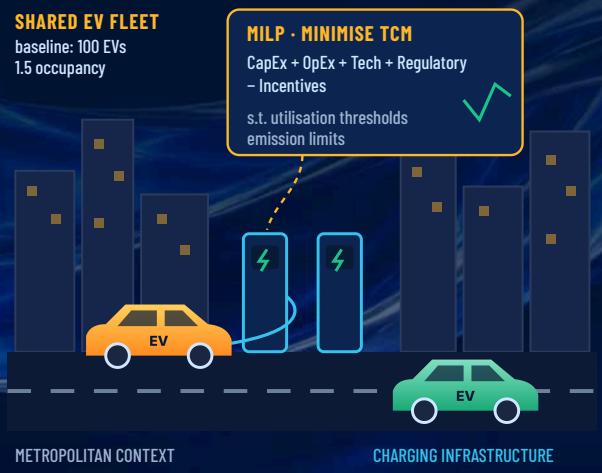


HOW IT WORKS
1. **Catchment** — 100 km collection radius
2. **Multi-crop mix** — straw, stalk, stubble, bagasse
3. **MILP allocation** — moisture, cost, yield
4. **Hub-and-spoke** — to the 2G biorefinery

KEYWORDS Multi-feedstock biofuels | biomass logistics | 2G ethanol | feedstock optimisation | biofuel economics | agricultural residues | techno-economic analysis

SHARED E-MOBILITY | MILP COST OPTIMISATION

Cost Optimisation Model for Shared E-Mobility in India



Author: **Joseph Beski S**, AGM (EIL) | Co-author: **Abhishek Verma**, Dy. Mgr (EIL)

ABSTRACT

India's pursuit of sustainable urban mobility is closely aligned with the electrification of transportation and the expansion of shared mobility services. However, the economic feasibility of shared electric vehicle (EV) fleets remains constrained by high upfront capital expenditure, volatile operational costs, and inadequate charging infrastructure. This study develops a cost optimisation model tailored to Indian metropolitan contexts to minimise the Total Cost of Mobility (TCM) while ensuring service reliability and meeting sustainability targets.

The model is planned using a mixed method research design, integrating qualitative interviews, a quantitative survey, with quantitative modelling through Mixed Integer Linear Programming (MILP). The optimisation framework incorporates annualised capital costs, operational costs, policy incentives and regulatory requirements while embedding constraints such as utilisation thresholds, and emission limits.

$$TCM = \sum(CapEx + OpEx + Tech + Regulatory - Incentives)$$

Baseline outcomes indicate that a fleet of 100 EVs incurs a total annualised cost of ₹63.9 million, yielding a per-passenger-km cost of ₹6.09 at 1.5 occupancy. Sensitivity analysis highlights utilisation as the most significant cost lever: **a 20% increase in vehicle utilisation reduces per-passenger-km cost by 18%** and shortens payback periods by 1.1 years. Tariff adjustment reduce costs by around 5%, while such operational measures improve payback time by 0.3 years. Future oriented scenarios suggest that driverless operations, which eliminate driver related costs, could **reduce operating expenses by nearly 38%**. This would achieve cost parity with internal combustion engine (ICE) fleet economics and substantially improve long-term financial sustainability.

The study concludes that improving utilisation, making driverless fleets, rationalising tariffs, and incentivising infrastructure are the most effective pathways to achieve cost competitiveness in shared EV mobility. Future research instructions include extending the model to autonomous fleets, two and three wheeler EV segments, and rural shared mobility ecosystems.

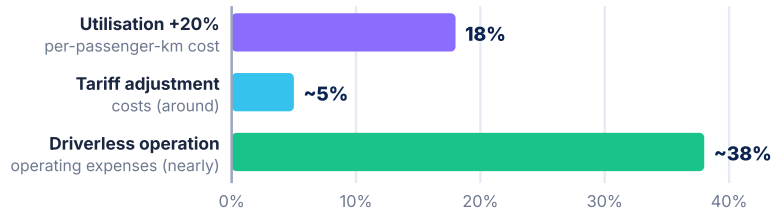
₹6.09
per passenger-km at 1.5 occupancy (baseline)

₹63.9 M/yr
total annualised cost, fleet of 100 EVs

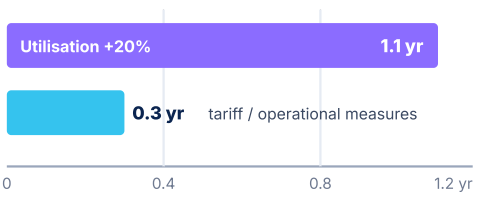
18%
lower per-pkm cost with 20% higher utilisation

~38%
lower operating expenses with driverless operation

Cost levers (reduction, base as stated)



Payback shortened by



HOW IT WORKS

1. **Survey + interviews** — mixed method inputs
2. **MILP model** — minimise TCM
3. **Sensitivity** — utilisation, tariff
4. **Scenarios** — driverless, ICE parity

KEYWORDS Shared Mobility | Electric Vehicle | Charging Infrastructure | Innovation | Smart Mobility

2G ETHANOL · WASTE TO VALUE

BIOMASS PELLETS · COAL SUBSTITUTION

Valorization of 2G Ethanol Plant Byproducts by Production of Biomass Pellets from Lignin Rich Wet Cake and Syrup

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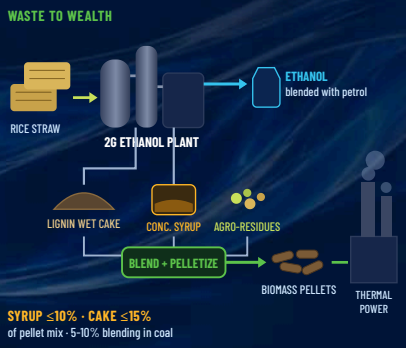
[1]General Manager (Technical Services), [2]Deputy General Manager (Technical Services) [3]Chief Manager (Technical Services), [4]&[5] Senior Technical Services Manager are posted at IOCL Panipat Refinery.



ABSTRACT

Indian Oil's 2G Ethanol Plant also called second generation ethanol plant installed at Panipat Refinery is first of its kind in world which utilizes over **2 lakh MT of rice straw annually to produce 3 crore liters of ethanol**. This plant uses surplus agricultural waste (rice straw) to produce ethanol, which is then blended with petrol. During commissioning and stabilization, several operational challenges emerged, primarily concerning the handling of rice straw, effluent processing and burning of lignin-rich wet cake/concentrated syrup. In-house innovations were implemented to sustain the operation and valorization of the waste. To overcome boiler combustion challenges and eliminate waste accumulation, the team innovatively developed a sustainable route to convert these by-products into biomass fuel pellets through optimized blending with agro-residues. This initiative not only ensures valorization of residues but also substitutes coal and opened gates for waste to wealth. Collectively, these efforts have stabilized operations and unlocked new revenue streams from waste-derived energy products making the 2G ethanol plant a national benchmark for sustainable refinery innovation and circular bioeconomy integration.

Brief About 2G Ethanol Plant Process:

The plant consists of Biomass handling section, pre-treatment section, enzymatic hydrolysis, co-fermentation, distillation, residue handling section, evaporators and effluent treatment section.

Challenges and implemented Solutions:

1. Challenges in burning byproducts from a 2G Ethanol plant:

2G Ethanol production process generates significant volumes of by-products, primarily lignin-rich wet cake (363.6 TPD) and concentrated syrup (217.3 TPD). According to the design philosophy, lignin cake and concentrated syrup are to be burned in the boiler to produce steam. However, combustion of these byproducts begins only once the boiler furnace temperature reaches 650°C for which shredded rice straw is to be fired as primary fuel. Since lignin and syrup are being burned in the boiler for the first time, some operational challenges have emerged which includes break down of single-line conveyors, shredders, formation of clinkers, pile up ash (ash was unsuitable for brick manufacturing and cement industries), pile up of concentrated syrup/Lignin rich wet cake and inconsistent steam supply to pre-treatment section. Steam line (~2Km) from refinery helped to sustain pre-treatment section but pile up of lignin rich wetcake and concentrated syrup forced for value-realization as both fractions possess reasonable calorific value and have been utilized in the manufacture of biomass pellets after lots of rejections in view of high moisture (~50%), offering a sustainable solution aligned with India's clean energy transition.

I. Lignin Rich Wet Cake & Concentrated Syrup Properties:

Product	Composition	Calorific Value kcal/kg	Role in Pellets
Lignin Rich Wet Cake: Solid residue generated from Solid Liquid Separation (SLS) section.	Predominantly lignin, residual cellulose/ hemicellulose, and moisture.	~2,000-2,250 (wet basis)	• Primary solid matrix • Imparting density • Add Strength
Concentrated Syrup Liquid residue generated from Evaporation section.	Soluble organic compounds, sugars, and residual solids.	~2,000-3,000 (wet basis)	• Natural binder • Enhancer of calorific content, • Improving combustion efficiency.

Both by-products are energy-dense but posed operational challenges when directly fired in boilers. To address this, an innovative route of pelletization has been developed via trials with many customers, converting these streams into high-quality biomass pellets for supply to thermal power plants.

II. Making of Biomass Pellets:

Between syrup and lignin cake, syrup posed greater challenges due to its viscous nature, tendency to solidify at ambient temperature, and limited tank capacity. The low ullage in the syrup tank constrained the evaporation and distillation processes, limiting production because of restricted syrup storage.

Contacted 100+ vendors in segments such as brick kilns, bio-mass fuel manufacturers, and industrial fuel users for utilization of lignin rich wet cake/Concentrated syrup. After extensive trials and adjustments, the process for producing biomass pellets has been successfully developed. To utilize the concentrated syrup and lignin-rich wet cake from the 2G Ethanol plant, their moisture content needs to be reduced. This is achieved by blending with other biomass-based waste available (Rice husk, cotton cobs, bird droppings, charcoal dust, saw dust, pulverized wheat, rice straw, bagasse, groundnut shells and mustard cakes).

The maximum allowable proportion of concentrated syrup in the biomass pellet mix is **10% by weight, while lignin cake can be added up to 15%**. Exceeding these limits increases the moisture content in the final pellets, which can lead to rejection by end users due to compromised quality and combustion efficiency. Currently, using 5-10% blending in coal for firing in the thermal power plants.

III. Biomass Pellet Properties:

Details	Values	Remarks
Shape	Cylindrical pellets: Usually 6-10 mm diameter, 20-30 mm length	-
Bulk Density	600-750 kg/m³	Compact for efficient storage & feeding
Moisture Content	≤ 10% (preferably 5-8%)	Low moisture improves combustion efficiency
Ash Content	≤ 5% (target < 3%)	Lower ash reduces clinker formation in boilers
Color	Brown to dark brown	Depends on feedstock (paddy straw, [source page 4+ not supplied]

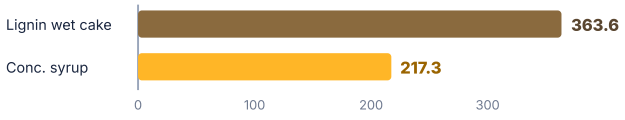
2 lakh MT/yr
rice straw used to produce 3 crore liters of ethanol

363.6 TPD
lignin-rich wet cake by-product

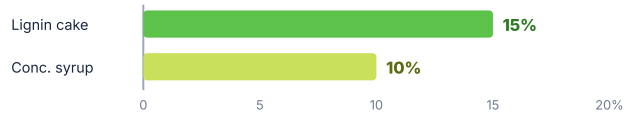
217.3 TPD
concentrated syrup by-product

100+
vendors contacted for utilization of wet cake and syrup

By-product generation (TPD)

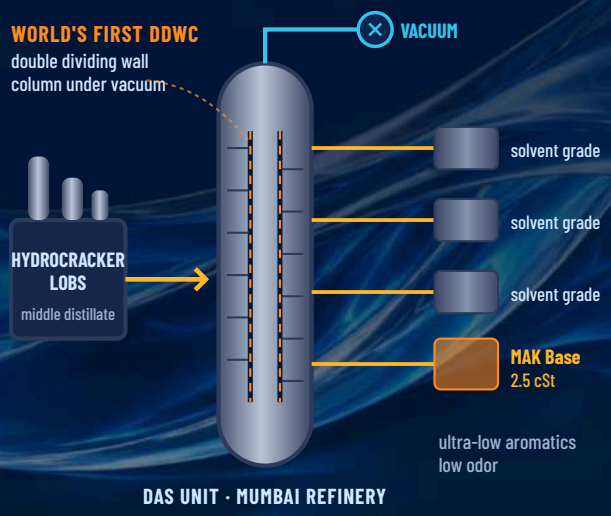


Maximum share in pellet mix (% by weight)



SPECIALTY SOLVENTS | ATMANIRBHAR BHARAT · DRILLING FLUIDS

India's First De-Aromatised Solvent Unit at Mumbai Refinery: Driving Self-Reliance and Enabling Drilling Fluid Applications



Arun Rajagopal (Dy General Manager), **Vivek V** (Chief Manager)
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ABSTRACT

The commissioning of the De-Aromatised Solvent (DAS) unit at BPCL Mumbai Refinery marks a significant milestone in India's pursuit of Atmanirbhar Bharat by enabling indigenous production of high-value specialty solvents. Traditionally import-dependent, de-aromatised solvents are characterized by ultra-low aromatic content, low odor, and superior environmental performance, making them suitable for applications in paints, coatings, and chemicals.

The DAS unit, integrated with the Hydrocracker-LOBS configuration, has advanced separation technology, in form of **the world's first Double Dividing Wall Column (DDWC) operating under vacuum**. This innovation enables simultaneous production of multiple solvent grades with improved energy efficiency, reduced emissions, and optimized capital and operating costs.

Another key achievement of this initiative is the production of **drilling fluid base oil (MAK Base 2.5 cSt)** using refinery middle distillate. This product, meeting stringent low aromatic specifications, offers an environmentally friendly alternative for drilling operations and has received industry acceptance.

The project not only enhances value realization by upgrading refinery streams but also strengthens domestic supply chains and reduces foreign exchange outflow

Overall, the DAS unit exemplifies technological innovation, sustainability, and strategic value addition, positioning Mumbai Refinery as a pioneer in specialty solvent production and contributing significantly to India's self-reliance and energy transition objectives.

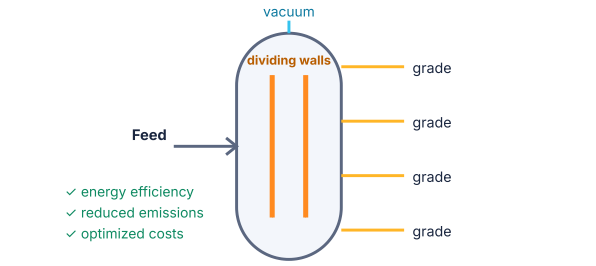
India's 1st
De-Aromatised Solvent unit, BPCL Mumbai Refinery

World's 1st
Double Dividing Wall Column under vacuum

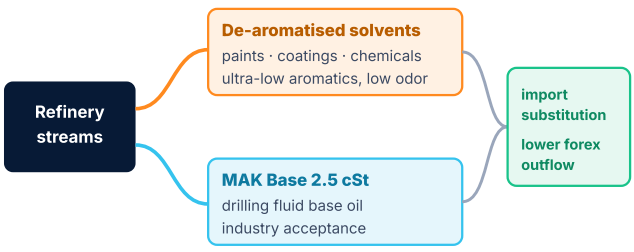
2.5 cSt
MAK Base drilling fluid base oil from middle distillate

Multiple
solvent grades produced simultaneously

Double Dividing Wall Column · one shell, many grades



From refinery streams to markets



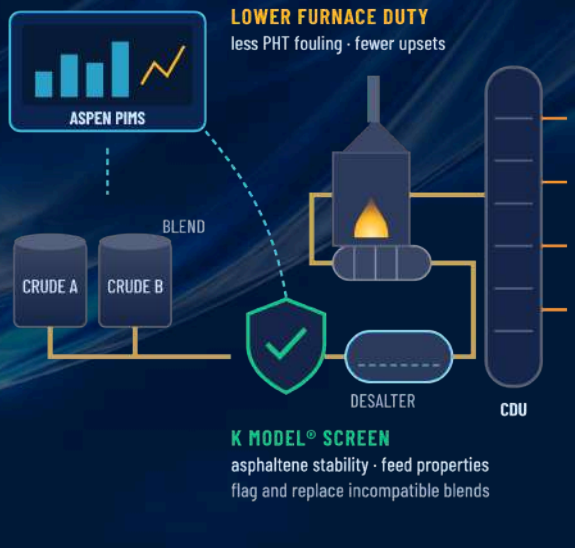
HOW IT WORKS

1. **Refinery streams** — Hydrocracker-LOBS
2. **DDWC under vacuum** — multiple grades at once
3. **Low aromatic products** — solvents, MAK Base 2.5 cSt
4. **Markets** — paints, coatings, drilling

KEYWORDS Dearomatised Solvent | Drillol | MAK Base 2.5 cSt | BPCL | Make In India | Atmanirbhar Bharat

CRUDE COMPATIBILITY | REFINERY PLANNING · ASPEN PIMS

Beyond Economic Optimization: Embedding Crude Compatibility Intelligence into Aspen PIMS for reliable refinery operation



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ABSTRACT

Crude oil selection and blending critically influence refinery profitability and operational reliability. Conventional planning tools optimise crude selection primarily on economic and process parameters, without explicitly addressing blend compatibility. Incompatible crude blends can trigger desalter upsets, accelerated preheat train (PHT) fouling, elevated furnace duty, higher fuel consumption, and increased CO_2 emissions eroding the very economic gains planning tools seek to achieve. Embedding compatibility intelligence into planning therefore offers a dual opportunity to enhance economic and operational performance simultaneously.

This work presents the integration of BPCL's proprietary K Model®, a crude compatibility prediction tool, with the Aspen PIMS planning module to embed blend compatibility within planning-level optimisation. K Model® evaluates proposed crude blends using asphaltene stability and crude feed property parameters. Every blend generated by the planning module is screened through K Model®; high-risk or incompatible combinations are flagged and replaced with compatible alternatives and associated risks with desalter upset potential and PHT fouling propensity are fed back into planning scenarios.

The methodology was validated against CDU operating data, comparing actual crude scheduling with compatibility-based rescheduling. The compatibility-driven approach substantially increased compatible crude processing, delivering **2-3% lower furnace duty, over 40% reduction in desalter-related upsets**, reduced PHT fouling, improved operating stability, and significant fuel-firing cost savings demonstrating a practical pathway to more reliable and efficient refinery operation.

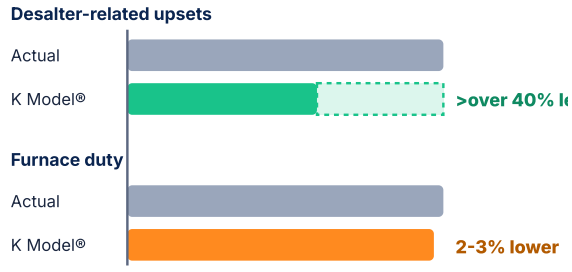
2-3%
lower furnace duty with compatibility-based rescheduling

>40%
reduction in desalter-related upsets

Every blend
from the planning module screened through K Model®

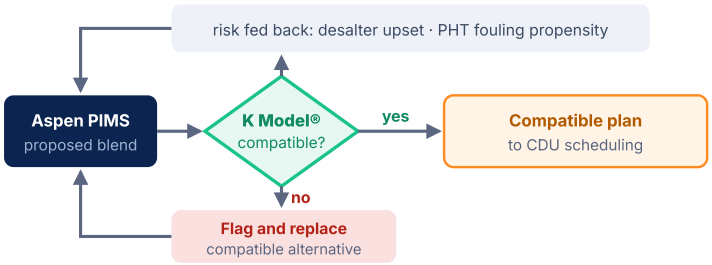
CDU data
methodology validated against actual crude scheduling

Actual vs compatibility-based scheduling



Bar lengths relative to actual scheduling (= full bar); only the % changes are reported.

K Model® inside the planning loop



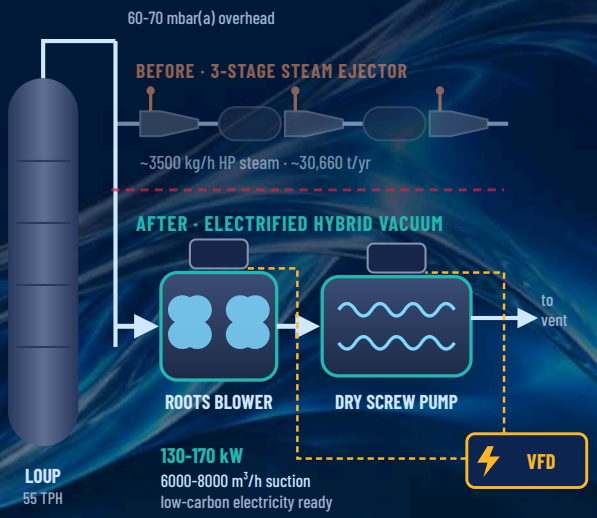
HOW IT WORKS

1. **Plan** — Aspen PIMS crude blend
2. **Screen** — K Model® compatibility
3. **Replace** — flag high-risk blends
4. **Validate** — CDU operating data

KEYWORDS Crude Compatibility · Asphaltene Stability · Refinery Planning Optimisation · Aspen PIMS · K Model® · Desalter Upset · Preheat Train Fouling · Crude Scheduling

UTILITY ELECTRIFICATION | DECARBONISATION · VACUUM SYSTEMS

Decarbonising Refinery Utilities: From Steam-Driven Vacuum to Electrified Systems: Towards Net Zero Pathways



Harmeet Singh
HPCL Mumbai Refinery

ABSTRACT

Refinery vacuum systems are critical for processing high-boiling hydrocarbons but can be significant energy consumers when vacuum is generated using steam ejectors. This study presents a process-driven approach to decarbonising an existing refinery vacuum system through electrification, using a Lube Oil Upgradation Project (LOUP) as a case study.

The study evaluates replacement of a conventional three-stage steam ejector system with a hybrid mechanical vacuum system comprising a Roots blower and dry screw vacuum pump. The assessment is based on actual operating conditions of a 55 TPH LOUP unit operating at 60-70 mbar(a). Process load estimation indicates a design non-condensable load of approximately 300 kg/h and a required suction capacity of 6000-8000 m³/h, with an estimated electrical power requirement of 130-170 kW.

The existing ejector system consumes approximately 3500 kg/h of high-pressure steam, equivalent to nearly 30,660 tonnes annually. At an assumed steam cost of ₹2.5/kg, the annual steam-related operating expenditure is approximately ₹7.66 crore. The proposed mechanical system is estimated to reduce annual operating expenditure to approximately ₹1.25-1.5 crore, indicating **potential annual savings of ₹6.1-6.4 crore and a payback period of less than two years**.

Using an emission factor of 0.2 tCO_2/t steam, the avoided steam demand corresponds to **a potential reduction of approximately 6132 tCO_2/year**. Beyond economic benefits, the proposed electrification reduces dependence on fossil-fuel-derived steam, provides VFD-based operational flexibility, and offers a pathway for progressively integrating low-carbon electricity.

The study demonstrates that decarbonisation need not be limited to new technologies or greenfield projects. Strategic electrification of legacy refinery utilities can provide measurable energy, economic and carbon benefits while supporting the transition of existing assets towards long-term net-zero pathways.

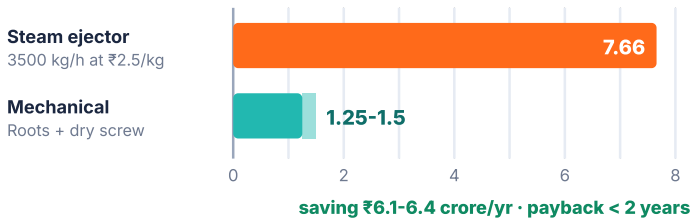
₹6.1-6.4 crore/yr
potential annual savings

~6132 tCO_2/yr
potential emission reduction (0.2 tCO_2/t steam)

<2 years
payback period

3500 kg/h
high-pressure steam no longer needed (~30,660 t/yr)

Annual operating expenditure · ₹ crore



saving ₹6.1-6.4 crore/yr · payback < 2 years

Avoided steam → avoided CO_2

30,660 t steam / year × 0.2 tCO_2 / t steam = ~6132 tCO_2 / year

from ~3500 kg/h of high-pressure steam

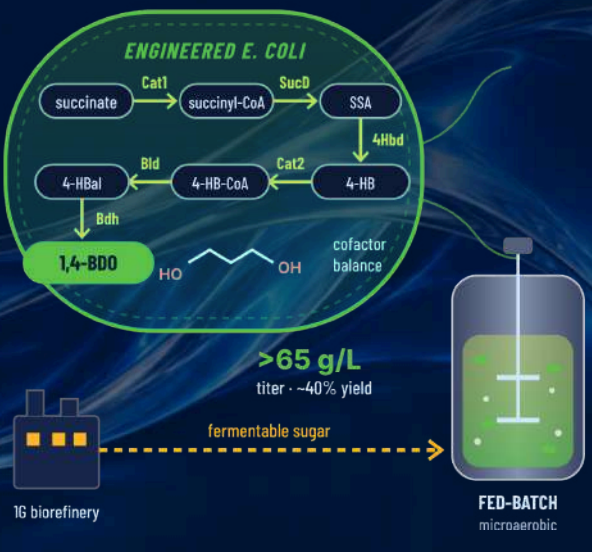
HOW IT WORKS

1. **LOUP vacuum** — 55 TPH at 60-70 mbar(a)
2. **Roots blower** — 6000-8000 m³/h suction
3. **Dry screw pump** — ~300 kg/h non-condensables
4. **VFD drive** — 130-170 kW electricity

BIO-BASED CHEMICALS

METABOLIC ENGINEERING · 1G BIOREFINERY

High-Yield Sustainable Production of 1,4-Butanediol: A Metabolically Engineered *E. coli* Approach



Bhawna Madan, Syed Shams Yazdani, Payal Gupta, Parmeshwar Patil, Vivek Rathore, Jaya Rawat, Bharat Newalkar

ABSTRACT

1,4-Butanediol (1,4-BDO) is an industrially important platform chemical used in the production of fibers, engineering plastics, and solvents. The global 1,4-BDO market is projected to reach USD 14.5 billion by 2026, growing at a CAGR of 7.9%. This scale of opportunity makes the shift from petrochemical feedstocks to first-generation (1G) biorefineries especially compelling. Realizing this potential, however, requires overcoming a persistent challenge in metabolic engineering: achieving high product titers while maintaining metabolic efficiency and cofactor balance. In this study, *Escherichia coli* was metabolically engineered to enable direct biosynthesis of 1,4-BDO through the introduction of a complete heterologous pathway consisting of succinate CoA-transferase (Cat1), CoA-dependent succinic semialdehyde dehydrogenase (SucD), 4-hydroxybutyrate dehydrogenase (4Hbd), 4-hydroxybutyryl-CoA transferase (Cat2), aldehyde dehydrogenase (Bld), and alcohol/butanol dehydrogenase (Bdh) for enhanced product formation. Metabolic flux was systematically redirected toward the 1,4-BDO pathway while maintaining cofactor balance to support pathway efficiency. Under microaerobic fed-batch fermentation, the engineered strain achieved **a notably high titer exceeding 65 g/L**, corresponding to a sugar-to-product yield of approximately 40%. A mass-balance and revenue analysis of a representative 230 TPD rice-grain-based 1G ethanol biorefinery showed that diverting 50% of the fermentable sugar stream toward 1,4-BDO production at this yield could **raise overall plant revenue by more than 20%** relative to conventional all-ethanol operation. These results demonstrate the potential of integrating this optimized bioprocess into 1G biorefinery platforms as a scalable and economically viable route toward greener chemical manufacturing.

>65 g/L
1,4-BDO titer, microaerobic fed-batch fermentation

~40 %
sugar-to-product yield

>20 %
higher plant revenue vs all-ethanol operation

USD 14.5 bn
projected global 1,4-BDO market by 2026

Integration case: 230 TPD rice-grain 1G ethanol biorefinery

Fermentable sugar stream

Overall plant revenue (relative)

Revenue bars illustrative of the reported uplift (more than 20%).

1,4-BDO market (projected)

CAGR 7.9%

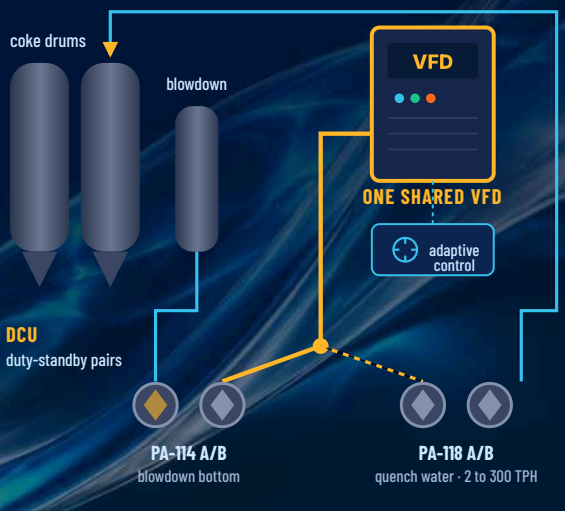
Used in
- fibers
- engineering plastics
- solvents

HOW IT WORKS

1. **Engineer E. coli** — complete BDO pathway
2. **Redirect flux** — keep cofactor balance
3. **Fed-batch** — titer above 65 g/L
4. **1G biorefinery** — revenue up more than 20%

ENERGY EFFICIENCY · VFD | ADAPTIVE INTELLIGENT CONTROL

Reinventing VFD Economics: A Shared VFD Architecture with Adaptive Intelligent Control for Refinery Pumps



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ABSTRACT

Variable Frequency Drives (VFDs) improve pump energy efficiency under variable operating conditions; however, installing dedicated VFDs for critical refinery pumps often involves high capital investment, making several energy-efficiency projects economically marginal. BPCL Bina Refinery addressed this challenge in its Delayed Coker Unit (DCU) through an innovative Shared VFD Architecture integrated with Adaptive Real-Time Intelligent Control.

The solution was developed for two duty-standby pump systems, PA-114 Blowdown Bottom Pumps and PA-118 Coke Drum Quench Water Pumps, having variable hydraulic requirements. PA-114 serves multiple process destinations, while PA-118 experiences flow variation from approximately 2 to 300 TPH during the coking cycle. Instead of installing dedicated VFDs, a single VFD was engineered to be shared between the two duty-standby pumps, while maintaining required reliability, redundancy and operational flexibility. This reduced **VFD CAPEX by approximately 44%**.

An adaptive control philosophy was developed to continuously evaluate multiple process demands, identify the governing hydraulic requirement and automatically determine the optimum pump speed. This minimized over-pumping and throttling losses while reducing dependence on manual VFD optimization.

The system was implemented and validated under actual DCU operating conditions across the complete coking cycle. It maintained required flow and pressure under different operating modes and delivered approximately **34% electrical energy savings**, with around 33% higher savings compared with conventional manual VFD optimization. The combined CAPEX and OPEX benefits improved **project IRR from 15.6% to 37.1%**, with a payback period of 1.94 years.

The concept is scalable and replicable across similar refinery or industries pump systems with cyclic or variable hydraulic demand, offering a practical pathway for simultaneous CAPEX reduction, energy conservation and digital process optimization. providing a practical and scalable pathway for economically viable refinery energy-efficiency improvement.

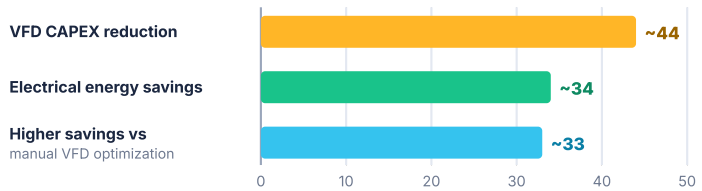
~44%
lower VFD CAPEX with one shared drive

~34%
electrical energy savings

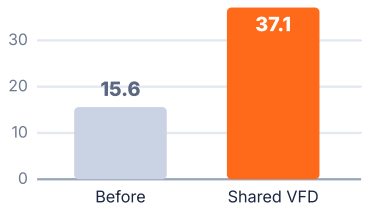
15.6 → 37.1%
project IRR improvement

1.94 years
payback period

Validated benefits across the coking cycle, %



Project IRR, %



1.94 yr
payback

HOW IT WORKS

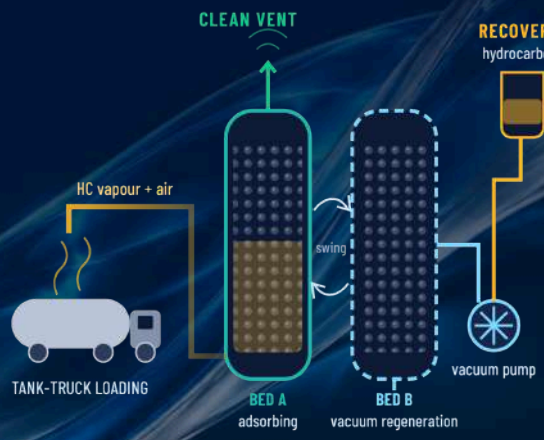
1. **Sense demands** — multiple process destinations
2. **Find governing** — hydraulic requirement
3. **Set speed** — optimum pump speed
4. **One VFD** — shared by duty-standby pumps

KEYWORDS Shared VFD Architecture | Adaptive Intelligent Control | Refinery Energy Optimization | Digital Process Optimization

VAPOUR RECOVERY · EMISSIONS

ACTIVATED CARBON · INDIGENOUS TECHNOLOGY

Indigenous Development and Commercialization of HP-VRU Technology: A Cost-Effective and Energy-Efficient Vapour Recovery Solution



Prashant Mishra, Neha Kumari Agarwal, Bollu Amulyasri, Annaji Rajiv Kumar Tompala, Bhaskarjyoti Baruah
HP Green R&D Centre, Hindustan Petroleum Corporation Limited, Bengaluru-560067

ABSTRACT

Vapour Recovery Units (VRUs) have become mandatory across Indian oil marketing terminals and depots to comply with emission norms mandated by the CPCB, NGT, and the Supreme Court of India. However, VRU technology has historically remained proprietary, with only a handful of foreign licensors controlling the underlying intellectual property. Indian equipment vendors have had to enter licensing tie-ups with these foreign technology holders to obtain the Basic Design Engineering Package (BDEP) before fabrication and supply, resulting in recurring license fees that inflate project CAPEX. This dependency has also constrained after-sales technical support, as Indian vendors, themselves reliant on the foreign licensor for troubleshooting, are often unable to provide prompt, reliable support to end users of commercial plants.

To address this strategic gap, Hindustan Petroleum Corporation Limited (HPCL), though its in-house R&D efforts, has developed HP-VRU, a fully indigenous hydrocarbon vapour recovery technology based on activated-carbon adsorption coupled with vacuum-swing regeneration. A key R&D differentiator lies in the activated carbon's pore structure, which has been specifically tuned and tailor-made for the targeted hydrocarbon components, rather than adopting a generic adsorbent. This tailored pore architecture delivers faster adsorption-desorption kinetics, enabling shorter cycle times, a smaller adsorbent bed volume for a given throughput, and, critically, a lower regeneration energy requirement, making HP-VRU a more energy-efficient technology overall, alongside its CAPEX advantage.

The technology has been successfully commercialized, with the **first industrial-scale HP-VRU plant commissioned in 2024** at HPCL's Hassan Marketing Terminal, designed for a feed capacity of 2,100 m³/hr, achieving a product specification of **<5 g/m³ for Gasoline & Naphtha and <20 mg/m³ for Benzene**. The unit has been in continuous, trouble-free operation for over two years, consistently meeting these emission targets and validating the tailored-adsorbent design under real field conditions. HP-VRU technology is also capable of handling heavier petrochemical vapour streams, Benzene, Toluene, Xylene, and Ethylbenzene (BTXE), widening its applicability to petrochemical complexes and aromatics-handling facilities.

By combining a tailored, kinetically-optimized adsorbent with in-house indigenous design, HP-VRU offers lower CAPEX, reduced regeneration energy, and faster, more reliable technical support. This paper presents the technology's working principle, adsorbent design rationale, and HPCL's Hassan Terminal's two-year field performance, reinforcing India's Atmanirbhar Bharat vision in downstream petroleum technology.

2,100 m³/hr
feed capacity, Hassan Marketing Terminal (commissioned 2024)

<5 g/m³
product specification for Gasoline & Naphtha

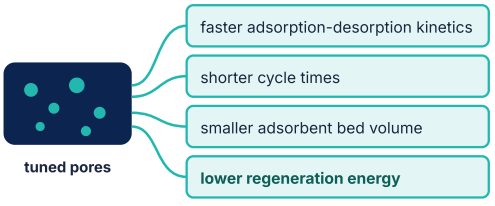
<20 mg/m³
product specification for Benzene

2+ years
continuous, trouble-free operation

Licensed VRU vs indigenous HP-VRU · qualitative, from the abstract

Foreign-licensed VRU	HP-VRU
× BDEP via licensing tie-up	✓ fully indigenous design
× recurring license fees, CAPEX	✓ lower CAPEX
× generic adsorbent	✓ tailored pore activated carbon
× support via foreign licensor	✓ faster, reliable support

Tailored pore architecture delivers

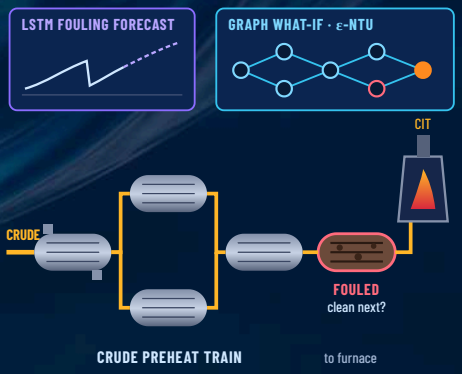


HOW IT WORKS

1. **Vapour capture** — terminal loading vapours
2. **Adsorption** — tailored activated carbon
3. **Vacuum swing** — bed regeneration
4. **Recovery** — hydrocarbon returned

DIGITAL TWIN · LSTM | CRUDE PREHEAT TRAIN FOULING

A Comprehensive suite for Crude Preheat Heat Exchanger performance management using Time Series Forecasting models, Bayesian Regression and Graph-based simulation



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ABSTRACT

Crude-distillation-unit preheat trains are tightly coupled thermal networks whose performance degrades as exchanger's tube surfaces foul. The effectiveness of the preheat network deteriorates over time as fouling increases the heat transfer resistance. A common practice in refinery is to identify exchangers and clean them. However, this decision is taken based on present fouling factor calculations. FLUX is a monitoring system developed in-house which reconciles imperfect measurements, quantify thermal resistance, forecast its evolution over time, translate that forecast into an optimized maintenance sequence, distinguish crude-blend effects from equipment effects, and estimate how a proposed cleaning propagates through the complete network.

The forecasting subsystem uses an exchanger-specific LSTM-based models to forecast fouling factor trend and change. Four-hour reconciled fouling-resistance observations are transformed into lag, rolling-statistic, trend and calendar features. A stacked long short-term memory network recursively predicts either the next resistance or its increment, using the model, input scaler, output scaler, and metadata exported together during training.

The cleaning-planning subsystem converts each predicted fouling trajectory into time-dependent exchanger duty, crude-preheat recovery, outage loss, fuel displacement, cleaning cost, and net campaign value. Cleaning duration, crew availability, campaign size, fuel properties, throughput, and attainable post-clean heat-transfer coefficient are explicit assumptions, which are considered as user inputs. It also assumes that each exchanger begins re-fouling immediately after return to service and because later gains compete for a finite network sensible-heat opportunity. A **sequence-aware beam search** has been used to explore feasible permutations and combinations of exchangers which can be cleaned based on user-defined assumptions to get the most optimized sequence.

The crude-inlet-temperature subsystem uses Bayesian regression models, and uses user-defined crude assay and composition to predict change in Crude inlet temperature. The model uses major drivers such as crude properties, distillate yields, current CIT, etc., to predict change in CIT lending an insight into effect of change of crude composition of furnace load.

The cleaning what-if subsystem creates a directed graph from configured exchanger connections and shared process tags. On top of the graph, Kahn's algorithm is applied to determine the crude-path solution order, product-side recycles are converged by sequential modular iteration, and an equation-oriented alternative solves the affine network simultaneously, while using an epsilon-NTU solver. Paired present-U and cleaned-U solves, isolate the causal temperature change and display it on a network anchored to reconciled measurements.

The result is an integrated layered system where deep learning models predict degradation in performance, optimizer plans cleaning schedule, crude-based CIT prediction subsystem explains achievable performance for future crude mixes, and first-principle graph simulation quantifies the thermal consequence of selected cleaning actions. The system has been **implemented across two CDU units in Mumbai and Visakh Refinery, with three more CDUs in pipeline**.

4 subsystems
forecast, cleaning plan, CIT prediction, what-if

4 hour
reconciled fouling-resistance observations

2 CDUs
implemented, Mumbai and Visakh Refinery

+3 CDUs
more in pipeline

FLUX: an integrated layered system

Forecast
stacked LSTM
fouling trend
per exchanger

→

Cleaning plan
beam search
net campaign
value

→

CIT prediction
Bayesian
regression
crude assay

→

What-if
directed graph
Kahn's algorithm
epsilon-NTU

Fouling, cleaning, re-fouling

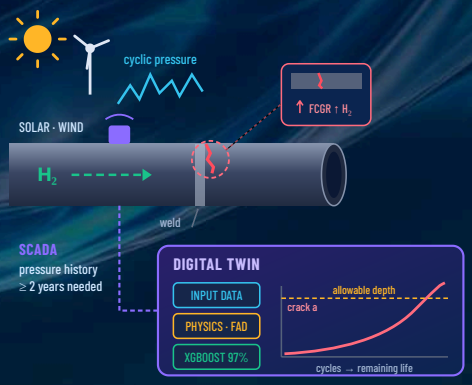
Illustrative. Values not reported in the abstract.

KEYWORDS heat-exchanger fouling | crude preheat train | LSTM | recursive forecasting | data reconciliation | maintenance optimization | CIT | graph algorithms | Kahn's algorithm | sequential modular simulation | equation-oriented simulation | epsilon-NTU

DIGITAL TWIN · MACHINE LEARNING | HYDROGEN PIPELINE INTEGRITY

Digital Twin Platform for Real-Time Fatigue Damage Monitoring and Remaining Life Assessment of High-Pressure Hydrogen Pipelines

Balaji Srinivasan
Engineers India Limited



ABSTRACT

The global transition towards clean energy has positioned green hydrogen as a critical fuel of the future, with high-pressure pipelines serving as the most efficient means of large-scale transportation. However, hydrogen pipelines face severe structural integrity challenges owing to hydrogen embrittlement and accelerated fatigue crack growth rates (FCGR), which are significantly higher than those observed in conventional natural gas pipelines. The intermittent nature of renewable energy sources such as solar and wind introduces variable cyclic pressure loading, further aggravating fatigue damage progression and reducing pipeline service life.

This paper presents a Digital Twin (DT) platform developed for real-time fatigue damage monitoring and remaining life assessment of high-pressure hydrogen pipelines, implemented using the Python programming language. The platform is structured around three integrated components. The first is an Input Data Module that synthesises cyclic pressure time-history data based on realistic assumptions reflecting renewable energy-driven hydrogen production, employing the Peak-Valley counting method to extract individual load cycles while preserving loading sequence. The module is designed for seamless future integration with live SCADA systems. The second is a Physics-Based Model developed in full compliance with ASME B31.12 Performance-Based Design Option B and API 579-1 Level 2 fitness-for-service codes, incorporating the Failure Assessment Diagram (FAD) approach and hydrogen-environment FCGR formulations including ASME B31 Code Case 220. The model accounts for initial crack size variability, residual stress effects, weld conditions, and allowable crack depth limits per ASME BPVC Section VIII Division 3, Article KD-412. The third component is a Machine Learning Surrogate Model built on XGBoost, trained on physics-model-generated synthetic data, achieving **97% prediction accuracy for remaining life estimation** while substantially reducing computational overhead.

The platform was validated against published numerical case studies from API 579-2/ASME PTB-14 and Ishikawa et al. (2022), demonstrating excellent agreement. Three case studies were conducted covering API 5L X52, X65, and X70 pipeline steels across varying class locations, initial crack depths representing design and start-of-life conditions, and random variable-amplitude pressure histories simulating 25-80% of maximum operating pressure fluctuations. What-if scenario analyses were incorporated to evaluate the impact of unexpected pressure excursions on fatigue life and support proactive maintenance decision-making. Results confirm that lower class location pipelines with higher design factors exhibit significantly faster crack propagation, and that initial flaw size has a pronounced influence on remaining life estimates. Integration with a Recurrent Neural Network (RNN) model demonstrated that **a minimum of two years of real-time SCADA pressure data** is necessary for reliable remaining life prediction.

The developed Digital Twin bridges the gap between prescriptive pipeline design practices and real-world operational demands of emerging green hydrogen infrastructure, offering pipeline operators a condition-based predictive maintenance framework that minimises operational expenditure and reduces the risk of catastrophic failure.

97%
XGBoost surrogate accuracy for remaining life estimation

≥2 years
real-time SCADA pressure data needed for reliable RNN prediction

3
case studies: API 5L X52, X65 and X70 steels

25-80%
of maximum operating pressure, simulated fluctuations

Digital Twin architecture

1 · Input Data
pressure time-history
Peak-Valley counting
SCADA-ready

→

2 · Physics-Based Model
ASME B31.12 Option B · CC 220
API 579-1 Level 2 FAD
BPVC VIII-3 KD-412 limits

→

3 · ML Surrogate
XGBoost on synthetic physics data
97% accuracy

remaining life · what-if scenarios · predictive maintenance

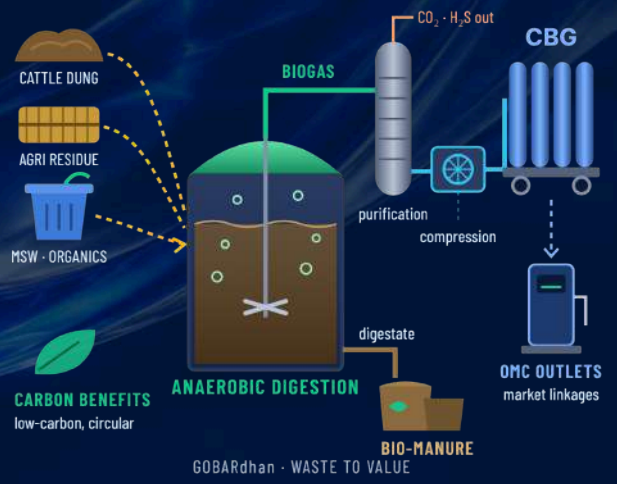
Variable-amplitude pressure history (% MOP)

Illustrative waveform. Only the 25-80% band is from the abstract.

KEYWORDS High-Pressure Hydrogen Pipeline | Digital Twin | Fatigue Crack Growth | Remaining Life Assessment | ASME B31.12 | Predictive Maintenance | Machine Learning

GOBARDHAN · CBG | BIOMASS VALORIZATION

From Waste to Value: GOBARdhan and the Emerging Landscape of Biomass Valorization



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ABSTRACT

India's diverse biomass resources offer a significant opportunity to simultaneously address organic waste management, energy security, rural development and decarbonization. The GOBARdhan initiative of the Government of India provides an enabling framework for converting cattle dung, agricultural residues, municipal solid wastes and other organic wastes into valuable products such as **Compressed Biogas (CBG), bio-manure and other bio-based products**. The transition from waste management to resource valorization can play an important role in building India's circular and low-carbon energy economy.

This paper presents a global outlook on biomass valorization and examines the emerging technological pathways for converting biomass into energy and value-added products. These include anaerobic digestion, gasification, thermochemical conversion and other advanced biofuel pathways. Particular emphasis is placed on understanding the suitability of different pathways for India's heterogeneous biomass resources and their potential for scale-up. Key factors influencing successful deployment include feedstock quality and consistency, methane yield, technology selection, plant scale, logistics, energy consumption, product recovery and end-use integration. Hence, evaluating the CBG value chain from feedstock characterization, aggregation and logistics through anaerobic digestion, biogas purification, compression, transportation and digestate utilization is of paramount importance.

The paper further evaluates the technical, environmental and economic dimensions of biomass valorization and highlights the importance of **multiple value streams, including CBG, bio-manure and carbon benefits**, for improving the project sustainability. The potential role of Oil Marketing Companies in developing market linkages and accelerating the integration of CBG into the energy ecosystem is also explored. It proposes a "Waste-to-Value" perspective for GOBARdhan, highlighting how appropriate technology pathways, effective feedstock ecosystems and integrated value creation can transform India's biomass challenge into a significant opportunity for clean energy, circularity and sustainable growth.

CBG
Compressed Biogas from cattle dung, residues and MSW

Bio-manure
value stream from digestate utilization

Carbon
benefits as a third value stream

OMCs
market linkages to integrate CBG into the energy ecosystem

CBG value chain · stages evaluated in the paper

1 Feedstock characterization → 2 Aggregation and logistics → 3 Anaerobic digestion → 4 Biogas purification → 5 Compression → 6 Transport to end use

3 Anaerobic digestion → Digestate utilization · bio-manure

Multiple value streams: CBG | Bio-manure | Carbon benefits

Key factors for successful deployment

- Feedstock quality and consistency
- Methane yield
- Technology selection
- Plant scale
- Logistics
- Energy consumption
- Product recovery
- End-use integration

HOW IT WORKS

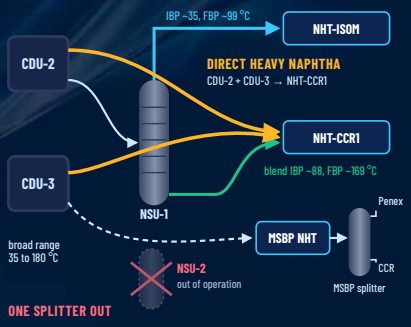
1 **Feedstock** dung, residues, MSW, organics → 2 **Conversion pathways** digestion, gasification → 3 **Upgrade** purification and compression → 4 **Value streams** CBG, bio-manure, carbon benefits

KEYWORDS GOBARdhan | CBG | Anaerobic Digestion | Digestate

NAPHTHA PROCESSING | PROCESS OPTIMIZATION · ENERGY EFFICIENCY

Naphtha Splitter Reconfiguration for Operational Simplification and NSU-2 Shutdown at BPCL Kochi Refinery

Himanshu Kumar Gupta, Raju Mondal, Mohammed Swalih
BPCL (Bharat Petroleum Corporation Limited), Kochi Refinery



ABSTRACT

Integrated refinery naphtha systems often involve multiple fractionation steps to distribute feedstocks to isomerization, catalytic reforming and motor-spirit processing units. At BPCL Kochi Refinery, a detailed process review identified an opportunity to simplify the naphtha routing by eliminating an intermediate fractionation step while maintaining the required downstream feed quality.

A network-level process simulation using rigorous distillation-column modelling with the Peng-Robinson thermodynamic package was carried out to evaluate the revised routing. The study covered naphtha streams from CDU-2, CDU-3, NSU-1 and the MSBP section, with validation based on boiling-range distribution, throughput and key hydrocarbon properties. The analysis established that the existing CDU heavy naphtha streams could be directly integrated with the NHT-CCR1 feed. CDU-2 heavy naphtha (IBP ~100°C, FBP ~180°C) and CDU-3 heavy naphtha (IBP ~85°C, FBP ~180°C) were routed directly to NHT-CCR1 along with NSU-1 bottoms, producing a blended feed with IBP ~88°C and FBP ~169°C. NSU-1 overhead, with an IBP of ~35°C and FBP of ~99°C, continued to meet the requirement of NHT-ISOM. The broad-boiling-range naphtha routed to MSBP NHT (IBP ~35°C, FBP ~180°C) was subsequently fractionated in the MSBP splitter to generate the required Penex and CCR feeds.

The simulation demonstrated that the NSU-2 fractionation step was not essential within the evaluated operating envelope, as its separation duty could be replaced through direct routing and better integration of existing streams. Based on the simulation findings, the revised routing was implemented in the refinery, followed by stabilization and monitoring of the modified operating configuration. Subsequently, **NSU-2 was taken out of normal operation**, eliminating its associated fractionation duty. **The implemented configuration resulted in an estimated MP steam saving of approximately 6.5 TPH and power saving of approximately 100 kW, equivalent to approx. 33.6 Cr per annum** while maintaining the required downstream boiling-range specifications.

The work demonstrates a practical refinery process-engineering approach wherein simulation-led network optimization, boiling-range alignment and process integration were translated into an actual plant modification, enabling energy reduction and operational simplification without major equipment modification.

3. BASIS FOR RECONFIGURATION: PROCESS INTEGRATION OPPORTUNITY

Analysis of the crude distillation products showed that the natural boiling-range cuts from CDU-2 and CDU-3 align well with downstream unit requirements:

- **CDU-2 Heavy Naphtha (IBP 100°C, FBP 180°C):** Nearly perfect match for NHT-CCR1 feed requirement (IBP 88°C, FBP 173°C)
- **CDU-3 Heavy Naphtha (IBP 85°C, FBP 180°C):** Suitable for direct blending to NHT-CCR1
- **NSU-1 Light Overhead (IBP 35°C, FBP ~98°C):** Optimal for NHT-ISOM (IBP 35°C, FBP 100°C)

11. CONCLUSION

The naphtha routing reconfiguration at BPCL Kochi Refinery demonstrates a practical and validated method for simplifying an integrated refinery naphtha fractionation network. By aligning feed cut-points with the location of downstream separation requirements, and by eliminating an intermediate split/recombine step, the revised routing achieves:

- **Energy Efficiency:** Approximately 6.5 TPH reduction in MP steam consumption and an estimated cost saving of 33.6 Cr
- **Operational Simplicity:** Removal of NSU-2 from normal service reduces control interactions and operating complexity
- **Maintained Quality:** Thermodynamic network simulation validates that all downstream feed specifications (IBP, FBP, benzene, etc.) continue to be met
- **Enhanced Flexibility:** Dynamic allocation of NSU-1 light naphtha between NHT-ISOM and MSBP NHT decouples unit operation from demand fluctuation
- **Transferability:** The methodology is applicable to other refineries with similar multi-column naphtha processing arrangements

Condensed from the author's abstract for this one-page compendium.

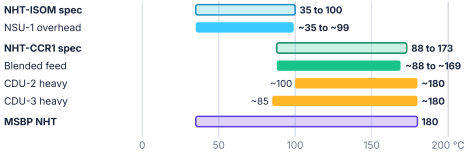
~6.5 TPH
MP steam saving after NSU-2 shutdown

~100 kW
power saving

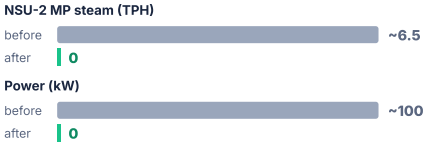
33.6 Cr
approx. saving per annum

NSU-2
taken out of normal operation

Boiling-range alignment · IBP to FBP, °C



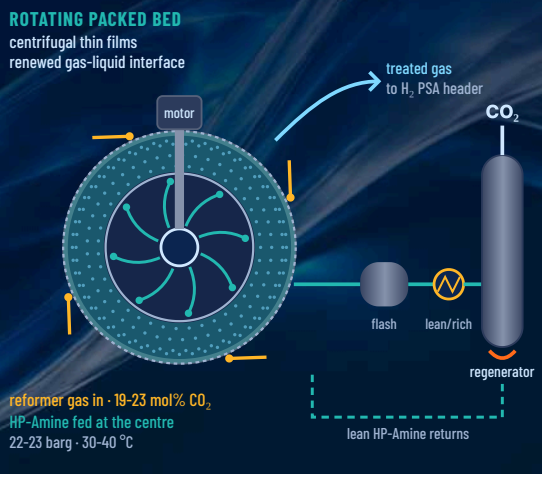
NSU-2: before → after · estimated saving



KEYWORDS Naphtha splitter | NSU column | refinery integration | routing optimization | energy efficiency | NSU-2 shutdown | thermodynamic simulation | mass balance validation | NHT | catalytic reforming | isomerization | Penex | MSBP | process intensification

CARBON CAPTURE · BLUE HYDROGEN | RPB · INDIGENOUS

Development & Commercialization of Indigenous HP-BH2 Technology for Carbon Capture and Blue Hydrogen



K. Vijaya Durga, J. Shankar, T. A. Rajiv Kumar, Bhaskarjyoti Baruah
HP Green R&D Centre, Hindustan Petroleum Corporation Limited Bangalore-560067

ABSTRACT

Large absorber size and high solvent-regeneration energy are major constraints when integrating amine-based CO_2 capture into operating refineries. Hindustan Petroleum Corporation Limited (HPCL) developed a first-of-its-kind, indigenous HP-BH2 technology to address these constraints by integrating its proprietary rotating packed bed (RPB) absorber with HP-Amine, an aqueous amine blend developed in-house. In the RPB, centrifugal acceleration drives the solvent radially outward through the packing against inward-flowing gas, generating thin films and droplets that continuously renew the gas-liquid interface and enhance mass transfer. The absorber operates within a closed-loop process incorporating pressure flashing, lean/rich heat exchange and thermal solvent regeneration.

The technology was developed through laboratory studies, bench-scale and pilot-scale testing, followed by engineering scale-up and refinery implementation. Gas and liquid throughputs were increased approximately fivefold from bench to pilot scale to evaluate scale-up behaviour. Laboratory studies demonstrated that HP-Amine achieved approximately 40-45% higher net cyclic CO_2 loading than the conventional amine solvent evaluated. RPB design was modified to address the higher-pressure requirements. The resulting design maintained mechanical integrity, with vibration levels remaining within permissible limits during operation.

A demonstration unit designed to capture 24 KTPA of CO_2, was commissioned at HPCL Visakh Refinery in 2026. The unit treated a slipstream of reformer gas upstream of the hydrogen PSA and returned the treated gas to the feed header. The unit processed gas containing 19-23 mol% CO_2 at 22-23 barg and 30-40 °C. Periodic inlet and outlet gas analyses indicated **an average CO_2 capture efficiency above 86%**, exceeding the design target of 85%. Cumulative CO_2 capture exceeded 700 tonnes, while **the average solvent-regeneration energy observed during operation was approximately 35% lower** than that reported for conventional amines systems.

HPCL developed the process design, basic engineering package, proprietary RPB absorber and solvent in-house, establishing indigenous capability across the technology-development and deployment stages. The refinery demonstration validates the integrated operation of RPB absorption and solvent regeneration under the tested industrial conditions and establishes an operating reference for wider deployment in refineries, hydrogen production plants and other industrial CO_2 capture systems.

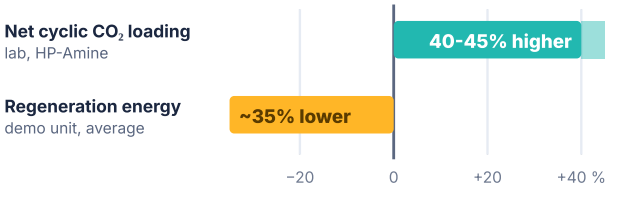
>86%
average CO_2 capture efficiency (design target 85%)

~35%
lower solvent-regeneration energy vs conventional amines

24 KTPA
CO_2 demonstration unit, HPCL Visakh Refinery, 2026

>700 t
cumulative CO_2 captured

HP-BH2 vs conventional amine · % change



Visakh demonstration · capture efficiency

19-23	22-23	30-40
mol% CO_2	barg	°C

HOW IT WORKS

1. **Reformer gas** — slipstream before H2 PSA
2. **RPB absorber** — HP-Amine, thin films
3. **Flash + exchange** — lean/rich heat exchange
4. **Regeneration** — ~35% lower energy

UNDERGROUND ENERGY STORAGE

ENERGY SECURITY · ATMANIRBHAR

Underground Energy Storage: A Pathway to Atmanirbhar Energy Security

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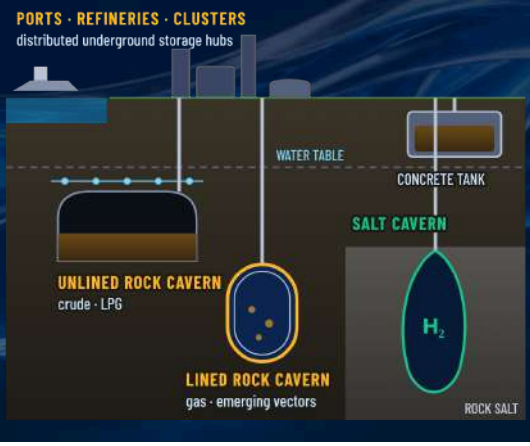


ABSTRACT

India's growing energy demand, dependence on imported hydrocarbons, and transition towards low-carbon energy systems necessitate the development of resilient and flexible energy-storage infrastructure. Underground Energy Storage (UES) offers a strategic pathway for strengthening India's energy security by enabling **large-scale, safe and geographically distributed storage** of Crude Oil, Diesel, Aviation Turbine Fuel (ATF), LPG, Natural Gas and emerging energy vectors such as Hydrogen. This study examines the role of UES in reducing import vulnerability, enhancing supply resilience, supporting the energy transition, and enabling India to evolve as a regional energy hub.

An integrated techno-strategic framework is adopted, combining subsurface engineering considerations with energy-system planning to assess the potential deployment of UES across major energy hubs in India. The study evaluates the applicability of different underground storage technologies, including Unlined Rock Caverns (URCs), Lined Rock Caverns (LRCs), solution-mined Salt Caverns, and underground Concrete Tanks, for strategic storage of conventional hydrocarbons and emerging energy carriers. The assessment considers key parameters such as geological suitability, site-specific engineering requirements, proximity to refineries, ports and industrial clusters, storage capacity, infrastructure connectivity and strategic relevance.

Building upon India's experience in strategic crude oil and LPG storage, together with emerging global developments, the study proposes an integrated subsurface energy-storage framework linking conventional and future energy-storage systems. The analysis indicates that UES can evolve beyond its conventional role as an emergency strategic reserve into a **multifunctional national energy asset** supporting energy resilience, import-risk mitigation, energy transition and regional energy integration.

India's diverse geological conditions, extensive coastline, established petroleum infrastructure and expanding energy corridors provide opportunities for developing distributed underground storage hubs integrated with ports, refineries, industrial clusters and cross-border energy networks. Such a network could enhance the resilience of domestic energy supply while creating opportunities for regional energy cooperation and trade.

The study concludes that Underground Energy Storage can serve as a critical infrastructure bridge between energy security and the energy transition. A coordinated national approach to geological assessment, technology selection, infrastructure integration and phased development of UES could contribute significantly to India's pathway towards a more resilient, self-reliant and future-ready energy system.

Crude to H_2
Crude Oil, Diesel, ATF, LPG, Natural Gas and Hydrogen

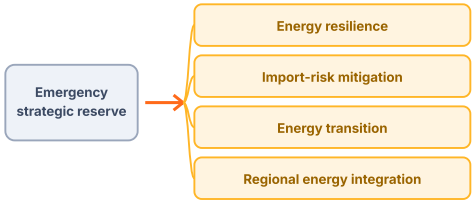
URC · LRC
plus solution-mined Salt Caverns and underground Concrete Tanks

Distributed
large-scale, safe, geographically distributed storage hubs

Atmanirbhar
reduced import vulnerability, resilient and self-reliant supply

Site and technology assessment parameters

From strategic reserve to national energy asset



HOW IT WORKS

1. **Geology** — geological assessment
2. **Technology** — URC, LRC, salt cavern, tank
3. **Integration** — ports, refineries, clusters
4. **Phased build** — national UES network

KEYWORDS Energy · Atmanirbhar · Underground · Hydrocarbons · Refinery

DIGITALIZATION · IIOT | FLARE EMISSION REDUCTION

Bridging the Net-Zero Gap: Acoustic IIoT Detection of Hidden Hydrocarbon Loss in Refinery Flare Systems

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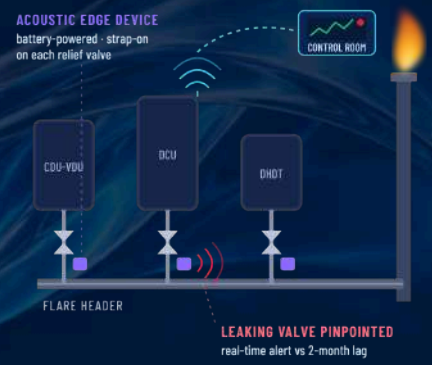


ABSTRACT

Relief valve leakage across India's refineries represents a hidden, largely unaccounted loss of hydrocarbons, for a typical 9 MMTPA refinery, this study estimates the figure at **2,500 tonnes per annum** calculated for CDU-VDU, MS Block, PFCCU, DCU and DHDT units. As India's refining sector expands towards a projected national capacity of ~300 MMTPA by end-2027, and pursues its 2070 net-zero commitment under the Panchamrit goals announced at COP-26 (which also targets a 1-billion-tonne cut in carbon emissions between 2021 and 2030), this preventable loss is a significant, underexploited opportunity. Flare systems are among the largest sources of refinery emissions and fall under Scope 1 emissions, therefore, addressing chronic leakage within them will add fillip to decarbonisation efforts.

Flaring during process upsets is well recognised, but chronic leakage across flare system components, principally relief valves, the primary source, causes a steady loss that rarely shows up in any emission inventory. IIoT-based edge devices for hydrocarbon leak detection enable prompt identification of the specific leaking valve, minimising emissions and losses while supporting both environmental and operational goals.

This paper adopts a multifaceted approach: (a) the IIoT technological framework, (b) estimation of relief valve leakage, (c) economic impact, and (d) implementation challenges.

a. Technological framework

Battery-powered edge devices using acoustic detection are installed on relief valves to identify passing. Wireless infrastructure, a key facet of IIoT, carries leakage data to a centralised location such as the control room.

b. Estimation of leakage

Flare flowmeters at unit battery limits are inaccurate at the low flows typical of leakage and cannot identify the source. IIoT devices, installed downstream of each safety valve, pinpoint the specific malfunctioning valve. The methodology considers relief capacities across all safety valves in a unit along with assumed leakage incidence and severity. Across the units studied, CDU-VDU, DCU, DHDT, MS block and FCCU, approximately 360 relief valves were considered. Conservatively, 5% (≈18 valves) are taken to develop minor leaks at 0.02% of rated capacity, and 1% (≈4 valves) major leaks at 1%. Detection time under conventional practice is taken as two months, the period over which each leak persists unchecked. On this basis, leakage across the studied units works out to 2,500 tonnes per annum.

c. Financial impact

A detailed cost estimate has been developed for plants both with and without existing wireless infrastructure. **Payback works out to 4 months** where wireless infrastructure already exists, and 5 months where it must be established.

d. Implementation challenges

Being strap-on devices, the sensors avoid several installation interface problems. However, factors such as battery refresh intervals and wireless network density are critical to performance and are discussed in detail.

Conclusion

Relief valve leakage is a quantifiable, correctable loss rather than an inevitable cost of refining. A modest 6% incidence of leaking valves accounts for 2,500 tonnes of hydrocarbon loss annually at a typical 9 MMTPA refinery. By collapsing the two-month detection lag into a real-time alert, the proposed IIoT framework converts this invisible loss into an actionable one, with a payback of 4-5 months, an economic case strong enough to stand on its own alongside the emissions benefit.

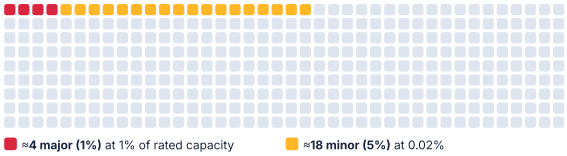
2,500 t/yr
hidden hydrocarbon loss, typical 9 MMTPA refinery

~360
relief valves studied (CDU-VDU, DCU, DHDT, MS block, FCCU)

6 %
incidence of leaking valves assumed

4-5 months
payback period

Leak assumption across ~360 relief valves

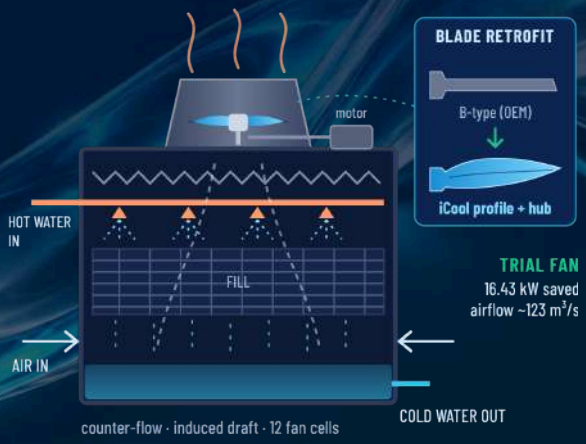


Payback & detection

KEYWORDS: Flare Gas Recovery / Flare Emission Reduction | Relief Valve Leakage | IIoT | Industrial Internet of Things) | Acoustic aLeak Detection | Scope 1 Emissions

ENERGY EFFICIENCY | COOLING TOWER FANS · RETROFIT

Energy Efficiency Enhancement of Induced Draft Cooling Tower Fans through Replacement of Conventional B-Type Blades with High-Efficiency iCool Profile Blades



Ambarish Mahajan, Sunil Khare, Saurabh Nautiyal, Vishesh Parwar, Ashwani
Presenter: **Vishesh Parwar**, Asistant Manager
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ABSTRACT

Cooling towers are essential utilities in process industries and refineries for maintaining the required cooling water temperature for various process and auxiliary equipment. Since cooling tower fans operate continuously and constitute a significant portion of the cooling tower auxiliary power consumption, improvement in fan efficiency offers considerable potential for energy conservation.

The Captive Power Plant, BPCL-BR cooling tower under consideration is a counter-flow induced draft cooling tower comprising twelve (12) fan cells. The existing cooling tower fans are equipped with conventional B-type profile fan blades supplied by the Original Equipment Manufacturer (OEM), M/s Parag Fans & Cooling Systems Ltd. As part of the energy efficiency improvement initiative, we initiate for the replacement of the existing B-type fan blades and compatible hubs with newly developed high-efficiency "iCool" profile fan assemblies.

To assess the effectiveness of the proposed modification, a trial installation of the high-efficiency iCool fan assembly was carried out in 1 fan of Cooling Tower. The performance evaluation of the modified fan demonstrated significant improvement in energy efficiency. The trial resulted in a measured power saving of **16.43 kW**, corresponding to an energy reduction of **more than 20%**, while simultaneously increasing the fan airflow to approximately **123 m³/s**.

The trial results demonstrate that the replacement of conventional B-type fan blades with high-efficiency iCool profile blades can achieve substantial energy savings without compromising cooling tower airflow performance. Based on the successful trial, implementation of the high-efficiency fan assembly in the remaining cooling tower fans has significant potential to reduce auxiliary power consumption and improve the overall energy performance of the CPP cooling tower system.

This paper presents the technical approach, trial methodology, measured performance improvement, energy-saving potential, and the benefits associated with the proposed full-scale implementation of high-efficiency cooling tower fan technology.

Projected Energy Saving

If the 16.43 kW saving is achieved on all 12 fans:

Total potential power saving = 16.43 × 12 = 197.16 kW

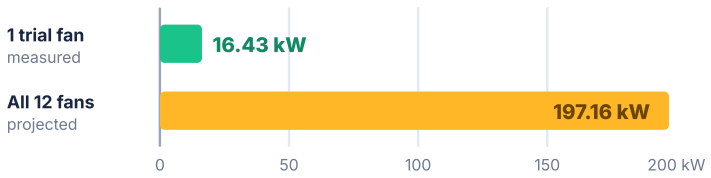
16.43 kW
measured power saving on the trial fan

>20 %
energy reduction on the modified fan

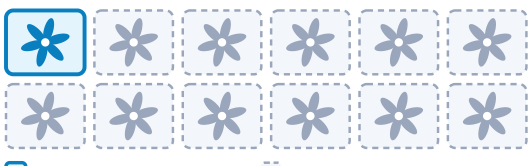
~123 m³/s
fan airflow after the iCool retrofit

197.16 kW
potential saving if achieved on all 12 fans

Power saving · trial fan vs all 12 fans



12 fan cells · trial and rollout



HOW IT WORKS

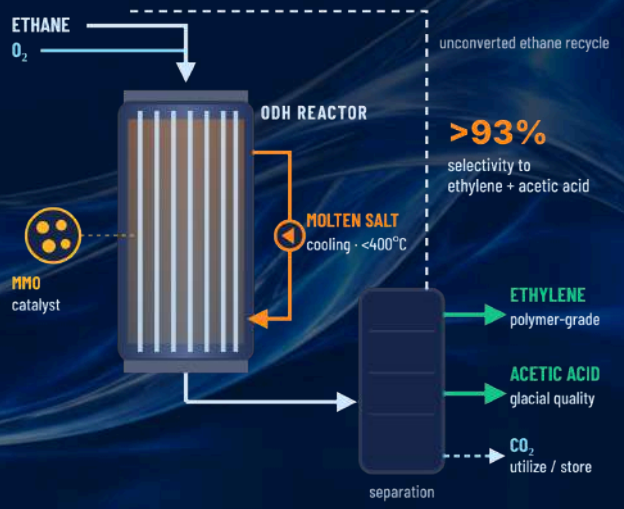
1. **Existing fans** — B-type blades, 12 cells
2. **Trial retrofit** — iCool blades + hub on 1 fan
3. **Measured** — 16.43 kW saved, ~123 m³/s
4. **Full scale** — remaining fans, 197.16 kW

KEYWORDS Cooling Tower | Induced Draft Fan | Energy Efficiency | iCool Profile Blades | B-Type Fan Blades | Fan Performance | Auxiliary Power Reduction | Energy Conservation | Airflow Optimization | Cooling Tower Performance | Power Saving | Retrofit | Captive Power Plant | Sustainable Energy

PETROCHEMICALS · ETHYLENE

OXIDATIVE DEHYDROGENATION · LOW CO_2

Linde EDHOX™ Ethylene Technology: Combined Ethylene & Acetic Acid Production Avoiding CO_2 Emissions



Suneel Koul
Business Development Manager
Linde Engineering India

ABSTRACT

Linde's EDHOX™ technology is the first commercial process to produce polymer-grade ethylene and acetic acid of glacial quality by the oxidative dehydrogenation of ethane. The process is operated at relatively mild temperature (<400°C) and achieves **an overall selectivity above 93%** towards the valuable products ethylene and acetic acid. Moreover, EDHOX™ produces less by-products than the conventional state-of-the-art ethane steam cracking (E-SC) technology, which allows for simplified cryogenic separation of the ethylene product.

In addition to reduced CAPEX and more than three times lower specific energy consumption than conventional E-SC, the technology also offers **a CO_2 emissions reduction of about 60%** compared to the combined emissions of the conventional production routes for ethylene and acetic acid. If the CO_2 emissions directly captured from the process are utilized or stored, the proprietary process becomes a zero Scope 1 solution. As the process is delivered fully electrified, zero Scope 2 emissions can be achieved if renewable electric power is applied.

To develop the mixed-metal oxide catalyst for EDHOX™ technology, Linde has partnered with the well-known catalyst manufacturer Clariant. The EDHOX™ catalyst has been successfully scaled up and trial-produced in tonnage scale on Clariant's commercial scale production facility. Besides catalyst lab scale testing by Clariant and Linde, the performance of the commercial catalyst has also been verified in Linde's pilot plant under commercial conditions..

The pilot facility comprises a reactor equipped with a commercial-size reactor tube and molten salt cooling, as well as a separation and purification unit that allows closed-loop operation, i.e. the recycling of unconverted ethane. This setup enables direct scale-up of the EDHOX™ technology to commercial-scale application..

P.S : It was awarded as "Best Petrochemical Technology 2025" by Gulf Energy Information, a U.S.-based publisher known for leading industry titles such as Hydrocarbon Processing and World Oil.

>93%
overall selectivity to ethylene and acetic acid

~60%
lower CO_2 vs combined conventional routes

>3×
lower specific energy consumption than E-SC

<400°C
relatively mild operating temperature

EDHOX™ vs conventional routes · relative

CO_2 emissions

Conventional — full bar

EDHOX™ — **about 60% lower**

Specific energy consumption

E-SC — full bar

EDHOX™ — **more than 3× lower**

Bars scaled to the stated ratios (conventional = full bar); energy bar drawn at the 3× bound.

Route to zero Scope 1 and Scope 2

Zero Scope 1
captured process CO_2 utilized or stored

Zero Scope 2
fully electrified process + renewable electric power

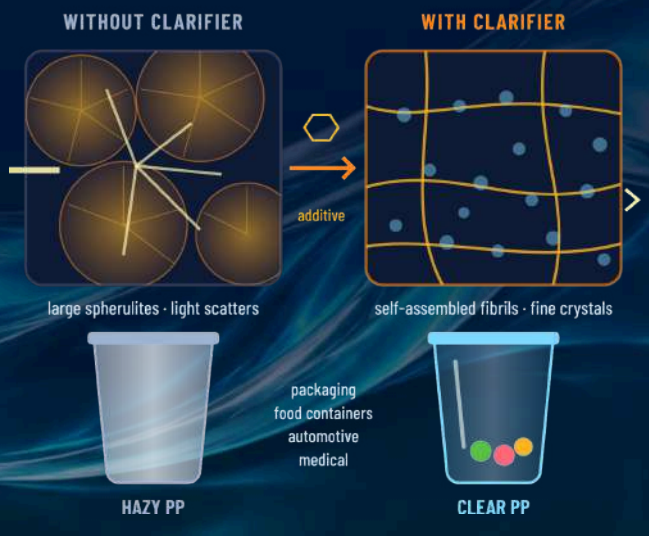
HOW IT WORKS

1. **Ethane + O_2** — oxidative dehydrogenation
2. **MMO catalyst** — <400°C, molten salt cooled
3. **Separation** — simplified cryogenic step
4. **Two products** — ethylene + acetic acid

POLYPROPYLENE ADDITIVES

CLARIFYING AGENTS · INDIGENOUS DEVELOPMENT

Clarifying Agents in Polypropylene: Growth Strategies & Future Outlook



Amardeep Singh*, Rajasekhar Tota, Priyanka Luthra, Vishal Goel, Gurmeet Singh, Rajesh Badhe, Alex C Pullikottil
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ABSTRACT

The growing global and domestic demand for highly transparent, lightweight and high-performance polypropylene (PP) has accelerated the need for advanced self-assembling agents. PP offers significant advantages in terms of low density, chemical resistance, cost effectiveness and ease of processing. However, PP has lower transparency compared to Polyethylene terephthalate (PET), Polycarbonate (PC) and glass, limiting its application in high-clarity packaging, food containers, automotive and medical uses etc. The Self-assembling agents are specialized nucleating/clarifying additives used mainly to improve optical clarity and transparency of the PP without compromising mechanical and thermal properties.

In this direction, the industry has evolved from first-generation dibenzylidene sorbitol (DBS) to advanced fourth-generation nonitol and organophosphate, trisamide based systems. The global market for these additives was valued at approximately USD 1.05 billion in 2025 and is **projected to reach USD 1.85 billion by 2034**, representing a compound annual growth rate (CAGR) of 6.4%. The Asia-Pacific region **accounting for approximately 48% of global consumption**, with China and India emerging as major manufacturing and consumption hubs. Thus, given the substantial PP production capacity and the dependency on imported specialty additives, development of indigenous self-assembling clarifying-agents is of considerable strategic and commercial significance.

References:

1. Sha, X.; Duan, J.; Feng, J. Comparative Investigation on the Crystallization Behaviour of Polypropylene Nucleated by Sorbitol-Based Nucleating Agents. **Macromolecules, 2025.** 58 (7): 3622-3634.

2. Sha, X., Wang, Y., Wu, R., et al. Comparative study on the nucleation and crystal growth behaviors of polypropylene induced by two reinforcing nucleating agents. ***Polymer* 2026;** 361: 130407.

3. Galatini, M., Baouch, Z., Carmeli, E., Caelers, H., & Cavallo, D. Solubility diagrams and nucleation efficiency of sorbitol- and nonitol-based nucleating agents in isotactic polypropylene, *Polymer* 2026; 360: 130360.

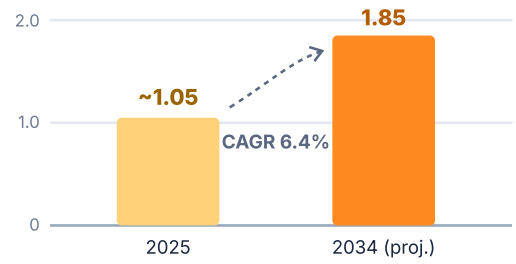
USD 1.85 bn
projected global market by 2034 (USD 1.05 bn in 2025)

6.4%
compound annual growth rate (CAGR)

~48%
of global consumption in Asia-Pacific

4th gen
nonitol, organophosphate, trisamide based systems

Clarifying additive market (USD billion)



Evolution of self-assembling clarifiers

Today: dependency on imported specialty additives

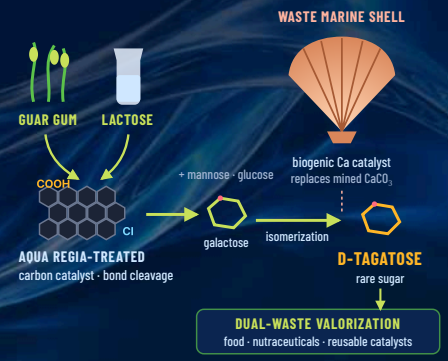
HOW IT WORKS

1. **PP limitation** — lower transparency
2. **Clarifier** — self-assembling additive
3. **Clear PP** — optical clarity, properties kept
4. **Indigenous** — reduce import dependency

RARE SUGARS · TAGATOSE

WASTE-DERIVED HETEROGENEOUS CATALYSTS

Integrated Approach for the High-value Functional Sugars Production Using Heterogeneous Catalysts



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ABSTRACT

The sustainable production of high-value sugars from waste and renewable carbon resources is central to green chemistry and a circular bioeconomy. This work develops functional, reusable heterogeneous catalysts to transform bio-derived feedstocks and waste streams into new classes of chemicals, contributing to UN Sustainable Development Goals (SDG) 3 (Good Health and Well-Being), 9 (Industry, Innovation and Infrastructure), 12 (Responsible Consumption and Production), and 13 (Climate Action). A major focus is the sustainable production of D-tagatose, a rare sugar important for food and nutraceutical applications. We developed a dual-waste valorization strategy in which galactose obtainable from bio-derived resources (such as guar gum and lactose) is converted to tagatose using calcium-based catalysts prepared from waste marine shells, thereby replacing conventionally mined $CaCO_3$ with a biogenic resource.[1] The scallop-shell catalyst showed the highest activity and retained **>60% selectivity over four cycles**. Sustainability assessment yielded an E-factor of 3.23, ~93% atom economy, and a process mass intensity of 4.23, while life-cycle assessment indicated lower mining-related impacts than those of commercial $CaCO_3$. These results provide measurable evidence of the environmental benefits of integrating waste-derived catalysts into rare-sugar (tagatose) production. To make the upstream production of galactose sustainable, we developed functionalized carbon catalysts treated with various acids, and we found that the aqua regia-treated catalyst shows better cleavage of glycosidic bonds present in carbohydrates among all other acid treatments, thereby concluding that the aqua regia-treated carbon catalyst has carboxylic acid as the catalytic sites and chlorine as the binding sites, which is important for the depolymerization of carbohydrates. Guar gum, an abundant galactomannan, was converted to galactose and mannose with **90% selectivity**,[2] while lactose, a food-industry by-product, achieved complete conversion with **>99% selectivity to glucose and galactose at 150 °C**.[3] Mechanistic and kinetic investigations established the roles of surface binding and catalytic sites in substrate adsorption and glycosidic-bond cleavage, providing fundamental insights for rational catalyst design. Together, these studies establish an integrated catalytic pathway in which widely available bio-derived carbohydrates provide the galactose precursor, while marine shell waste serves as the catalyst for its subsequent transformation into the high-value rare sugar tagatose. The use of widely available renewable feedstocks, waste-derived, recyclable catalysts, and adaptable catalytic processes provides translational potential across rare sugars, biorefineries, food, and nutraceutical manufacturing, offering a scalable pathway toward resource-efficient, circular chemical manufacturing.

References:

(1) Nayak, R. R.; Gupta, N. K. Waste Scallop Shell as a Sustainable Basic Catalyst for Galactose Isomerization to Tagatose. *RSC Sustainability* 2026. https://doi.org/10.1039/d6su00410e.

(2) Nayak, R. R.; Gupta, N. K. Tailoring Carbon Nanostructure for Selective Guar Gum Conversion: Unveiling the Interplay between Structure and Surface Functionalities in Galactose and Mannose Production. *ACS Sustainable Chem. Eng.* 2024, 12 (51), 18445-18453. https://doi.org/10.1021/acssuschemeng.4c08126.

(3) Nayak, R. R.; Gupta, N. K. Non-Enzymatic, Scalable Selective Depolymerization of Lactose to Monomeric Sugars Using Surface-Engineered Carbon Catalyst via a Low-Energy Pathway. *Bioresource Technology Reports* 2026, 35, 102880. https://doi.org/10.1016/j.biteb.2026.102880.

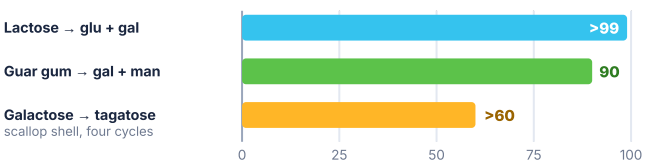
>60%
tagatose selectivity retained over four cycles, scallop-shell catalyst

~93%
atom economy (E-factor 3.23, PMI 4.23)

90%
selectivity, guar gum to galactose and mannose

>99%
selectivity, lactose to glucose and galactose at 150 °C

Selectivity across the integrated pathway, %



Green metrics, tagatose step

3.23
E-factor

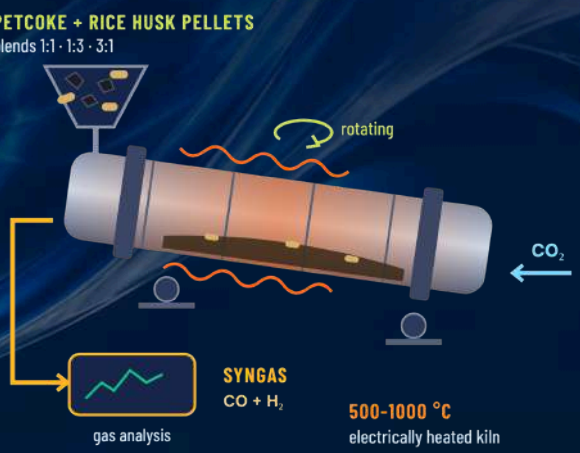
4.23
process mass intensity

atom economy

KEYWORDS Integrated approach · Tagatose · Galactose · Lactose · Heterogeneous Catalyst · Waste marine shells · Sustainability

CO-GASIFICATION · SYNGAS | PETCOKE + BIOMASS · ROTARY KILN

Co-gasification of Petroleum Coke and Rice Husk Pellets in a Novel Rotary Kiln-type Reactor System



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[1]Department of Chemical Engineering, Motilal Nehru National Institute of Technology Allahabad, Prayagraj, Uttar Pradesh, 211004, India
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ABSTRACT

As a consequence of recent developments worldwide, petroleum refineries are indirectly forced to explore various options to meet an ever-increasing demand of products. Therefore, practical approaches for efficient utilization of both fossil-based and bioenergy sources together, are being extensively investigated to leverage the energy content of both, more effectively. It may be noted that delayed coking process is still the most preferred choice of petroleum refiners for processing vacuum distillation residue. This process generates a significant amount of a solid by-product, known as petroleum coke, i.e. petcoke, while maximizing yield of liquid hydrocarbons. There is a scope in deriving energy from fuel-grade petcoke, which is obtained by processing heavy crude oil, through co-gasification with biomass pellets. In the present work, petcoke was co-gasified with rice husk pellets in an in-house designed rotary kiln reactor in the temperature range of **500-1000 °C by employing CO_2 as a gasifying agent**. To start with, gasification of individual carbonaceous material, i.e. petcoke and rice husk pellets was conducted in a thermogravimetric analyzer (STA-6000, PerkinElmer) with CO_2 as a gasifying medium. Furthermore, the co-gasification experiments were carried out at three different blending ratios, viz. 1:1, 1:3, and 3:1. The syngas yield and composition at six temperatures in the studied temperature range was analyzed. Results revealed that **syngas fraction was richer in CO and H_2 at lower temperatures of co-gasification, however, higher overall syngas yield was obtained at higher temperatures**. Kinetic parameters for co-gasification were evaluated by employing model-free isoconversional methods. Further research work for scale-up of rotary kiln systems, based on the results obtained is on, for possible twinning of petroleum refinery operations in a bio-refinery.

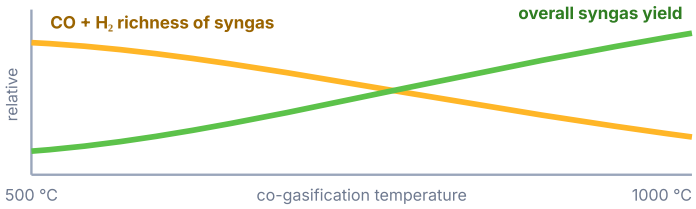
500-1000 °C
co-gasification temperature range in the rotary kiln

CO_2
gasifying agent, also in the thermogravimetric runs

3 blends
blending ratios 1:1, 1:3 and 3:1

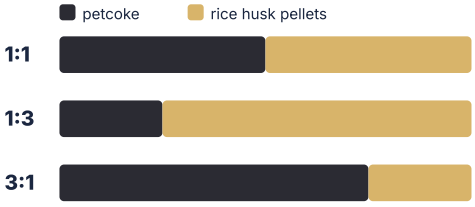
6 temps
syngas yield and composition analysed

Temperature trade-off · syngas quality vs quantity



Illustrative. Values not reported in the abstract.

Blending ratios studied · petcoke : rice husk pellets



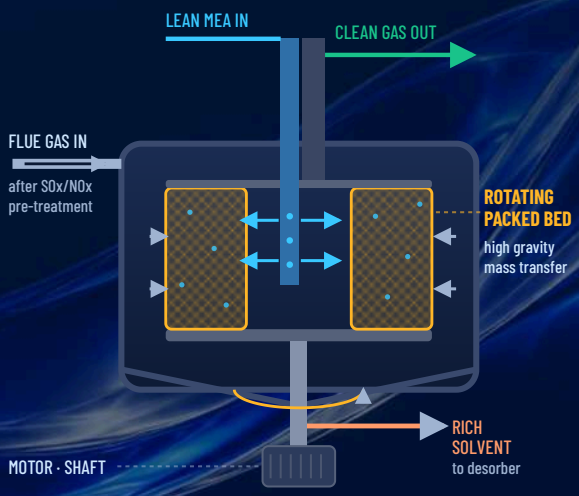
kinetics: model-free isoconversional methods

HOW IT WORKS
1. **Single fuels** — thermogravimetric, CO_2
2. **Blend** — ratios 1:1, 1:3, 3:1
3. **Rotary kiln** — 500-1000 °C with CO_2
4. **Syngas + kinetics** — yield, CO and H_2

KEYWORDS Petroleum coke | Rice husk pellets | Co-gasification | Synergistic effect | Synthesis gas and purification

CO₂ CAPTURE · CCUS | PROCESS INTENSIFICATION · HIGEE RPB

Process Intensification for Energy-Efficient SOx, NOx & CO_2 Capture Using High-Gravity Rotating Packed Bed Technology: From Pilot Demonstration to Industrial Scale-Up



Dr. Srikanth Kutla, Senior Process Engineer · **Mr. Ramesh Mehta**, Founder & CEO
Trilok Corporation, Mumbai
srikanth.higeetrilok@gmail.com · rcmehta1@gmail.com

ABSTRACT

This study presents the development and industrial evaluation of process-intensified post-combustion CO_2 capture using High-Gravity Rotating Packed Bed (HiGee RPB) technology under realistic flue-gas conditions containing acid-gas impurities, demonstrating its potential for enhanced mass transfer, compact equipment design, reduced energy consumption, and efficient CO_2 capture. HiGee systems incorporate sequential SOx/NOx pre-treatment, chemical absorption, and thermal desorption. While the conventional column is restricted to 30 wt% monoethanolamine (MEA), the HiGee RPB successfully operates with 50 wt% MEA, enabled by its high mass-transfer rates, enhanced gas liquid slip velocity and ultra-short gas-liquid residence times, mitigating viscosity and corrosion limitations associated with conventional columns.

The HiGee system provides improved control of absorption kinetics, minimizing undesirable co-absorption of O_2, SOx with CO_2 and thereby reducing solvent degradation and downstream impurities. The conventional absorber requires 8-20 times greater volume than the RPB. Using the steam generated through a conventional reboiler for stripping, the specific regeneration energy is reduced from **3.3-4.4 GJ/t CO_2 to 2.7-3.0 GJ/t CO_2** using HiGee. Despite the mechanical power requirement of the rotating bed, the intensified system demonstrates 9-15% CAPEX savings and a total annualized capture cost of approximately US$40-50/t CO_2.

The industrial applicability of the technology has been demonstrated by Trilok Corporation through a HiGee CO_2 capture installation at a thermal power plant in southern India, achieving **>95% CO_2 capture efficiency and approximately 99.3% CO_2 product purity**. The captured CO_2 is further utilized for methanol production. In another industrial application at a large petroleum refinery, HiGee technology treated fuel gas containing approximately 70,000 ppm H_2S, achieving **>99% H_2S removal** with outlet concentrations below 20 ppm.

The work highlights design methodology, scale-up, commissioning experience, operating performance, and engineering challenges, and demonstrates the potential of HiGee technology for compact, energy-efficient CO_2 capture, acid-gas treatment, and integrated CO_2-to-methanol systems.

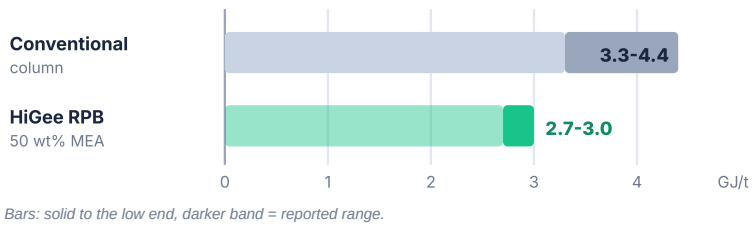
>95%
CO_2 capture efficiency at a thermal power plant

99.3%
CO_2 product purity (approx.), used for methanol

9-15%
CAPEX savings vs conventional

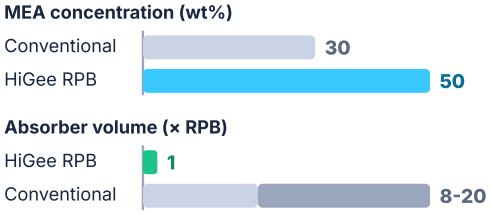
>99%
H_2S removal from refinery fuel gas

Specific regeneration energy · GJ/t CO_2



Bars: solid to the low end, darker band = reported range.

Conventional vs HiGee RPB



HOW IT WORKS

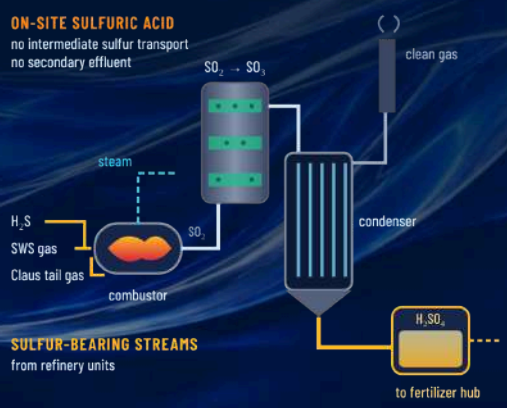
1. **SOx/NOx pre-treatment** — acid-gas impurities removed
2. **Chemical absorption** — HiGee RPB · 50 wt% MEA
3. **Thermal desorption** — steam from conventional reboiler
4. **CO_2 to methanol** — captured CO_2 utilized

KEYWORDS HiGee | Rotating Packed Bed (RPB) | Process Intensification | CO_2 Capture | H_2S Removal | SOx/NOx Removal | Regeneration Energy | CCUS | Industrial Demonstration | Process Scale-Up

SULFUR RECOVERY · SULFUR ACID

REFINERY · FERTILIZER INTEGRATION

Driving Refining Toward a Sustainable Future: Redefining Sulfur Recovery in India Through On-Site Sulfuric Acid Production



By: **Sagar Shukla**, Account Manager Sales India
Topsoe

ABSTRACT

China's decision to restrict sulfur and Sulfuric Acid exports in 2026, amid tightening global supply and increasing geopolitical uncertainty, highlights the strategic importance of sulfur-based value chains. Recent regional conflict and Iran-related war conditions have also disrupted trade routes and led several countries to restrict or control sulfuric acid exports, increasing supply risks for import-dependent nations such as India. These developments demonstrate that sulfur is no longer merely a refinery by-product; it is a critical feedstock for sulfuric acid, fertilizers, chemicals, metals, batteries, textiles, and pharmaceuticals.

This paper presents a new approach to sulfur recovery based on Topsoe Sulfuric Acid technology. Traditionally, refineries have used Claus units to recover elemental sulfur from acid gas and sulfur water stripper (SWS) gas. The sulfur is then transported to external sulfur burners, where it is converted into sulfuric acid. This conventional model leaves the refinery with the lower-value product while transferring the conversion margin and associated energy benefits to downstream facilities.

Topsoe Sulfuric Acid technology enables refineries to convert sulfur-bearing streams, including Claus tail gas, hydrogen sulfide, and SWS gas, directly into commercial-grade sulfuric acid on-site. This approach eliminates an intermediate transportation and conversion step, creates additional acid value for refiners, and improves supply resilience for nearby fertilizer and chemical plants. The process also offers low operating costs, high energy efficiency, and no secondary effluent generation.

The opportunity is particularly significant in India, where refinery and phosphate-fertilizer assets are frequently located within shared industrial hubs. Direct refinery-fertilizer integration could reduce dependence on imported sulfuric acid and strengthen local industrial value chains. In the Paradip hub alone, coordinated planning could potentially avoid **approximately 1,200 tonnes per day of sulfuric acid imports**. Reference-case estimates indicate that integration across suitable Indian hubs could deliver **annual foreign-exchange savings of approximately USD 250 million**, including energy savings and avoided imports, while reducing emissions by an estimated 1,000 ktpa of CO_2 and 10 ktpa of SOx.

By shifting the focus from sulfur recovery to sulfuric acid value creation, Topsoe technology offers India a pathway toward more sustainable, resilient, and economically integrated refining. It can support future refinery expansions, reduce import exposure, improve energy utilization, and align refinery operations with national priorities for industrial self-reliance and decarbonization.

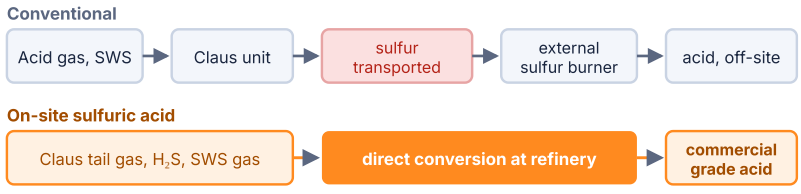
~1,200 t/d
sulfuric acid imports avoidable, Paradip hub alone

~USD 250 M/yr
foreign-exchange savings across suitable Indian hubs

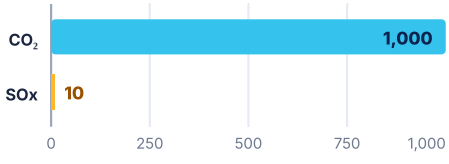
1,000 ktpa
estimated CO_2 emission reduction

10 ktpa
estimated SOx emission reduction

Sulfur route: conventional vs on-site acid



Estimated emission reduction (ktpa)



KEYWORDS sulfur recovery · sulfuric acid · refinery sustainability · Topsoe technology · import substitution · fertilizer integration · energy efficiency · India

DIGITALIZATION · PYTHON AUTOMATION

GHG EMISSIONS REPORTING · BEE

Automation of Greenhouse Emissions Index (GEI) Calculations Using Python and BEE Methodology

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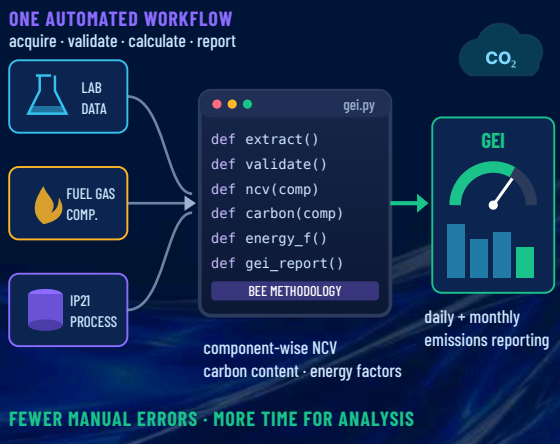


ABSTRACT

The Greenhouse Emissions Index (GEI) is a key performance indicator used for monitoring refinery energy performance and greenhouse gas emissions. Traditionally, GEI calculations involved extensive manual data collection, validation, component analysis, calculation of fuel properties, determination of energy factors, and spreadsheet-based computations. This approach was time-intensive, prone to manual errors, and required significant effort for daily and monthly reporting activities.

To address these challenges, a Python-based automation solution was developed to streamline the GEI calculation workflow in accordance with the Bureau of Energy Efficiency (BEE) methodology. The solution automatically extracts laboratory analysis data from the company's internal systems, processes fuel gas composition data, performs component-wise calculations, and generates Net Calorific Value (NCV), Carbon Content data and processes IP21 data required for determination of energy factors and other critical GEI inputs.

The developed application integrates data acquisition, validation, calculation, and reporting functions **into a single workflow, significantly reducing manual intervention**. Automated processing ensures consistent application of calculation logic, minimizes data handling errors, and improves data reliability. The tool also assists users in rapidly generating the inputs required for daily and monthly emissions reporting.

Implementation of the project resulted in **a substantial improvement in reporting efficiency**, increasing process automation while significantly reducing manual effort and report preparation time. The initiative enhanced productivity, improved data accuracy, and enabled energy professionals to focus more on analysis and performance improvement activities rather than repetitive data processing.

This project demonstrates how digital tools and automation can be effectively leveraged to improve sustainability reporting, support energy management initiatives, and accelerate digital transformation within refinery operations.

Python
automation of the full GEI calculation workflow

BEE
Bureau of Energy Efficiency methodology applied consistently

1 workflow
data acquisition, validation, calculation and reporting integrated

Daily + monthly
emissions reporting inputs generated rapidly

Before and after automation

BEFORE · MANUAL
- data collection
- validation
- component analysis
- fuel properties
- energy factors
- spreadsheet computations

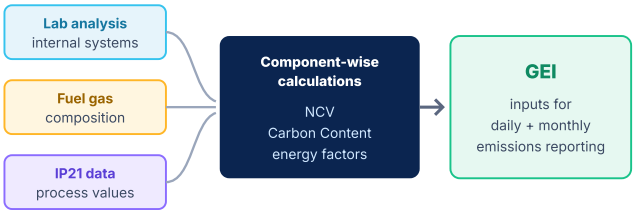
time-intensive · error-prone

→

AFTER · PYTHON
- single integrated workflow
- consistent calculation logic
- fewer data handling errors
- improved data reliability
- less report preparation time
- focus on analysis

substantial efficiency gain

GEI data pipeline (BEE methodology)



HOW IT WORKS

1. **Acquire** — lab, fuel gas, IP21 data
2. **Validate** — consistent logic
3. **Calculate** — NCV · carbon · energy factors
4. **Report** — daily + monthly GEI

KEYWORDS Greenhouse Emissions Index (GEI) · Python Automation · Bureau of Energy Efficiency (BEE) · IP21 · Carbon Content · Net Calorific Value (NCV) · Digitalization · Energy Management · Digital Transformation · Sustainability Reporting

RUBBER PROCESS OIL · TDAE | LOW PAH · IMPORT SUBSTITUTION

Production of Low PAH Treated Distillate Aromatic Extract-Rubber Process Oil: Selective Multistage Separation to Low PAH High Aromatic Extract Streams

N. Seshubabu, P. Mohana Sundaram, Ravi Prakash Gupta, Alex Pulikottil, Umish Srivastva
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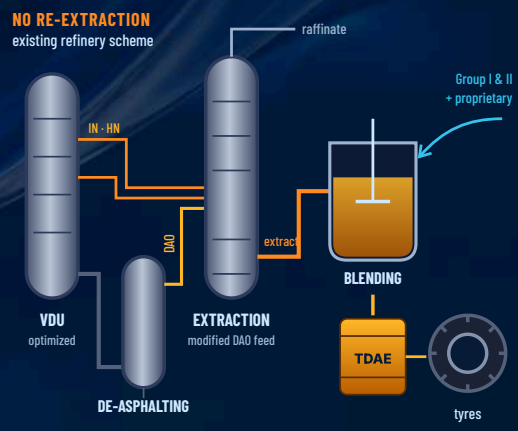


ABSTRACT

Low polycyclic aromatic hydrocarbon (PAH) rubber process oil (RPO) or also called Treated Distillate Aromatic Extract (TDAE) is mainly used in the tyre manufacturing industry while strictly adhering to REACH compliance. Traditionally, distillate aromatic extract oils are historically favored for their excellent rubber compatibility, however these oils contain high levels of carcinogenic PAHs. Therefore, these are being aggressively phased out globally in favor of safe, low-PAH alternatives. In this context, there is a need to produce TDAE due to REACH compliance and strict environment regulations. Currently, TDAE demand in India is estimated about 15-20 KTPA and is expected to double in next five years. Furthermore, TDAE attracts cost premium of about Rs.30,000-50,000 per MT over the normal grade. As per market estimates, TDAE has potential to generate revenues of Rs.270-375 crores/year. Currently, TDAE is imported from foreign countries.

Therefore, it is essential to produce TDAE to reduce import dependency thus it is enabled to build Indigenous capabilities in the niche rubber process oil. In view of this, a process has been designed and developed to produce TDAE by **utilizing the existing refinery process schemes without additional capex**. In general, TDAE is produced from re-extraction routes which involve additional capex as well as operating cost. However, the IOCL TDAE process involves optimization of vacuum distillation column (VDU) along with de-asphalting and aromatic extraction units. The modified DAO (Partial IN and HN feed stock along with DAO) is subsequently processed through extraction column to get the low PAH aromatic extract streams with the help of aromatic extraction/hydrotreating unit. Thus, produced modified aromatic extract is suitably blended with other cutter stock base oils to manage viscosity and pour point requirement for producing TDAE with low PAH. A careful base oil combination is necessary to achieve all the critical properties of TDAE. Therefore, solvent processed base oil (Group I & II) along with proprietary components in the desired proportion need to be added to processed modified aromatic extract to meet the TDAE specifications. The final formulated TDAE has **the PAH content is less than 10 ppm (mass) and Benzo(a) pyrene content less than 1 ppm (mass)** while meeting all other critical parameters like lower PCA content, aniline point etc. TDAE developed by Indian Oil is commercialized and supplying to rubber manufacturing industry.

<10 ppm — PAH content (mass) in final formulated TDAE

<1 ppm — Benzo(a) pyrene content (mass)

15-20 KTPA — TDAE demand in India, expected to double in five years

Rs.270-375 cr/yr — revenue potential as per market estimates

TDAE market in India

Demand (KTPA)

Cost premium over normal grade: **Rs.30,000-50,000** /MT

Revenue potential: **Rs.270-375** crores/year

Final formulated TDAE · key limits met

TRADITIONAL DISTILLATE AROMATIC EXTRACT OILS
high levels of carcinogenic PAHs · being phased out

IOCL TDAE
- **PAH < 10 ppm** (mass)
- **BaP < 1 ppm** Benzo(a) pyrene (mass)

HOW IT WORKS

1. **Optimized VDU** — IN and HN cuts, residue
2. **De-asphalting** — DAO, modified DAO feed
3. **Extraction** — low PAH aromatic extract
4. **Blending** — Group I & II + proprietary

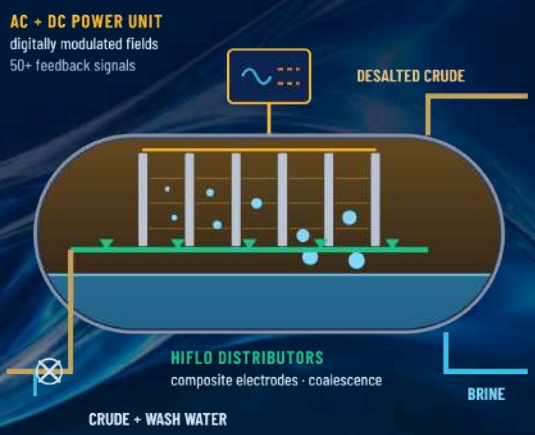
KEYWORDS Treated Distillate Aromatic Extract | Low PAH RPO | Tyre Manufacturing | De-asphalted oil | Aromatic extract

CRUDE DESALTING

ELECTROSTATIC SEPARATION · DIGITAL CONTROLS

Advanced Desalting for Challenging Crudes: SLB Dual Frequency Technology

Mehulee Patra, Pradeepkumar Muthuswamy
Schlumberger



ABSTRACT

As refineries process heavier and more opportunity crudes with elevated water and salt contamination levels, the demand for robust dehydration and desalting solutions continues to grow. Inadequate removal of salts and water can adversely impact downstream equipment through corrosion, fouling, and reduced operating efficiency. At the same time, refinery expansion opportunities are often limited by footprint and infrastructure constraints. Modern desalter technologies must not only achieve superior separation performance but also deliver greater reliability, flexibility, and capacity within existing refinery footprints.

This paper presents SLB's Dual Frequency (DF) Desalter technology, an advanced electrostatic desalting solution developed to address the limitations of conventional AC-field systems when processing increasingly challenging crude oils. Unlike traditional dehydrators that rely solely on alternating current, the Dual Frequency system **combines AC and DC electrostatic fields** to promote electrophoretic movement and enhanced coalescence of water droplets. Through digitally controlled, modulated electrostatic fields tuned to resonant frequency oscillation, the technology delivers stronger and more stable separation performance while maintaining flexibility across a wide range of crude blends and operating conditions.

Over years of field application and continuous development, the Dual Frequency platform has evolved into a highly intelligent system incorporating advanced digital controls, communication capabilities, anomaly detection, predictive maintenance features, and more than fifty operational feedback signals. The design includes HiFlo distributors that direct crude oil efficiently into the active electrostatic treatment zone, maximizing droplet coalescence and achieving near-complete vessel hydraulic efficiency. This minimizes flow bypassing and parasitic circulation, ensuring effective utilization of the entire vessel volume.

The technology further incorporates composite electrode designs capable of handling highly conductive emulsions and elevated water cuts. These electrodes generate graduated electrostatic fields that enhance droplet growth, reduce untreated flow paths associated with electrical arcing, and increase retention time within the treatment zone. Combined with an optimized wash-water injection system that improves mixing efficiency and water distribution, the result is **superior desalting and dehydration performance with lower wash-water and chemical requirements**. The stronger electrostatic field enables treatment of difficult-to-separate crudes while significantly increasing vessel throughput, reducing equipment footprint, lowering operating temperatures, decreasing power and fuel consumption, and consistently achieving stringent BS&W and salt specifications. Through retrofit and greenfield applications alike, Dual Frequency technology provides refiners with a practical pathway to increase capacity, improve reliability, and reduce total operating expenditure.

AC + DC
electrostatic fields combined for electrophoretic coalescence

>50
operational feedback signals in the digital platform

Lower
wash-water and chemical requirements

Retrofit
and greenfield applications alike

Conventional AC vs Dual Frequency

- relies solely on alternating current
- limits with challenging crudes

- resonant frequency modulation
- composite electrodes, high water cut
- HiFlo distributors, full vessel use
- anomaly detection, predictive maint.

Waveforms are schematic. Values not reported in the abstract.

Reported operating benefits · direction of change

↑ Vessel throughput	↑ Capacity · reliability
↓ Equipment footprint	↓ Operating temperature
↓ Power and fuel use	↓ Wash water · chemicals

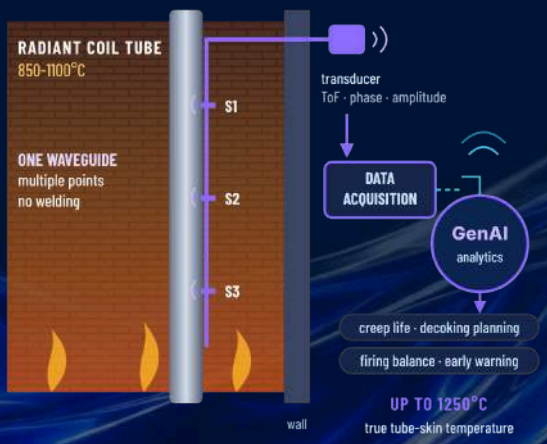
✓ Stringent BS&W and salt specifications, consistently

HOW IT WORKS

1. **Mix** — optimized wash-water injection
2. **Distribute** — HiFlo into treatment zone
3. **Coalesce** — AC + DC graduated fields
4. **Separate** — BS&W and salt on spec

GENAI · IIOT SENSING | FURNACE TUBE-SKIN TEMPERATURE

GenAI-Powered Continuous True-Skin Temperature Monitoring & Predictive Asset Management Using Patented µTMapS Ultrasonic Waveguide Sensors



Yogesh Kumar, Nitesh Rai, Satya Prakash Pasi, and Ramachandran Balasubramaniyan
Indian Oil Corporation Limited (IOCL), Panipat Refinery & Petrochemical Complex in collaboration with XYMA Analytics Pvt. Ltd.

ABSTRACT

Executive Summary:

- This is **an indigenously developed, breakthrough IIoT and artificial intelligence sensing platform deployed at the IOCL Panipat Naphtha Cracker Complex (1st Pilot NCU Heater),IOCL Mathura Refinery (HGU-Reformer), and IOCL Gujrat Refinery (DCU Heater).**
- Operating in extreme radiant **environments (850-1100°C),** traditional monitoring techniques (infrared pyrometry, manual optical peephole readings, and single-point welded thermocouples) suffer from emissivity distortions, heavy flue-gas interference, sensor drift, and fear of severe personnel burn hazards
- To solve these persistent operational bottlenecks, **an advanced solution integrating patented µTMapS Ultrasonic Waveguide Sensors** (IIT Madras incubated) **with a Generative AI predictive analytics engine was engineered and deployed**. The system delivers continuous, **multi-point true tube-skin temperature measurements up to 1250°C** directly from radiant coil tubes **without requiring welding or structural furnace modifications.**
- The deployment demonstrated immediate, game-changing operational results: **a 95% improvement in accuracy**, uncovering a +28°C systemic measurement offset hidden by legacy methods; **a 75% reduction in manual data correlation time**; a 40% reduction in maintenance costs; and reduction of high-risk manual furnace inspections.

Working Principle: A transducer creates high-frequency ultrasonic waves. The waves travel along the length of a solid metallic rod called a waveguide. The waveguide features intentional geometric markers i.e. notches, or reflective discontinuities at specific intervals for reflection of waves with change in surrounding medium (such as extreme heat, fluid viscosity, or material density) alters the local material properties and velocity of the waveguide at those specific points. The system measures the exact Time-of-Flight (ToF), phase shifts, frequency changes, and signal amplitudes of the reflected waves.

Empirical Correlations:

Temperature Offset : a systemic +28°C offset achieved, successfully ruling out the tube temperature uncertainty by 20-40°C.

Feed Rate Synchronization: Validated that sensor traces (S1, S2, S3) precisely track dynamic plant feed rates from 56-70 TPH with zero signal lag.

Coil Efficiency Diagnostics: Identified internal coking and heat absorption variances after data revealed **Coil 3 ran 13.5°C cooler than Coil 1** under identical firing loads.

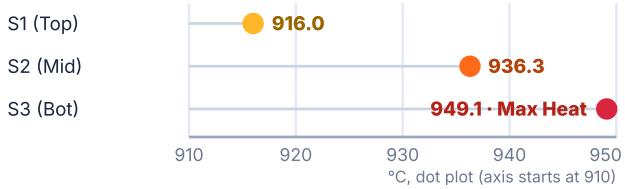
95% improvement in accuracy

+28°C systemic measurement offset uncovered

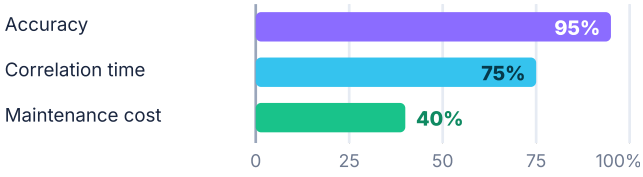
75% less manual data correlation time

40% reduction in maintenance costs

Heater H-200 · multi-point skin temperature, °C



Deployment results · % improvement / reduction



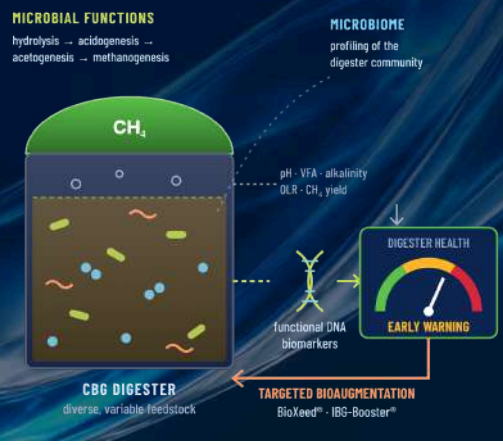
HOW IT WORKS

1. **Transducer** — high-frequency ultrasonic waves
2. **Waveguide notches** — reflect at each point
3. **ToF · phase · amplitude** — multi-point skin temp
4. **GenAI engine** — predictive actions

CBG · BIOMETHANATION

MICROBIOME BIOMARKERS · PREDICTIVE MONITORING

From Microbiome to Methane: Functional Microbial Biomarkers for Predictive Monitoring and Process Stability in CBG Production



Manoj Kumar*, Sandipam Srikanth, Ravi P Gupta, Umish Srivastva
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ABSTRACT

Commercial compressed biogas (CBG) plants process diverse organic feedstocks whose composition, biodegradability and nutrient characteristics can vary significantly with source, season and operating conditions. Such variability can disturb the complex microbial interactions governing hydrolysis, acidogenesis, acetogenesis and methanogenesis, resulting in volatile fatty acid accumulation, reduced methane productivity and process instability. Conventional monitoring based on pH, alkalinity, volatile fatty acids and gas production often identifies process deterioration only after microbial imbalance has already developed. This work proposes a microbiome-guided approach for moving CBG operation **from reactive process correction towards predictive monitoring** and targeted biological intervention.

The approach focuses on identifying functional microbial biomarkers associated with key anaerobic-digestion functions, including biomass hydrolysis, acidogenesis, syntrophic conversion, acetoclastic and hydrogenotrophic methanogenesis, and microbial responses to process stress. Changes in these functional signatures are correlated with conventional process parameters such as organic loading rate, volatile fatty acids, alkalinity, ammonia, volatile-solids reduction, methane concentration and specific methane yield. Establishing such microbiome-performance relationships can enable **detection of microbial shifts before significant deterioration** in digester performance becomes evident through conventional operating parameters.

IndianOil R&D has developed indigenous microbial solutions for biomethanation, including BioXeed® and IBG-Booster®, designed as feedstock-agnostic biological interventions for improving degradation of complex organic substrates and supporting stable biomethanation. Integration of these microbial solutions with functional biomarker-based monitoring offers a pathway for targeted bioaugmentation based on the biological condition of the digester rather than only routine or post-upset dosing.

The proposed framework integrates microbiome profiling, functional DNA biomarkers, conventional digester analytics and plant-performance data to generate actionable information on digester health. For CBG producers, such a system can provide early warning of emerging biological imbalance, support timely intervention before significant loss in methane production, improve response to feedstock changes, reduce prolonged process upsets and enable more rational use of microbial and process additives. Over time, accumulation of microbiome and operational datasets can support development of digester-health indices and predictive alerts for identifying instability and guiding corrective actions.

The work presents a pathway towards precision biomethanation, where feedstock-agnostic microbial augmentation using BioXeed® and IBG-Booster® is combined with biomarker-guided process monitoring. This approach can improve feedstock flexibility, process resilience, methane-production stability and plant availability, thereby supporting more reliable and economically sustainable operation of commercial CBG plants.

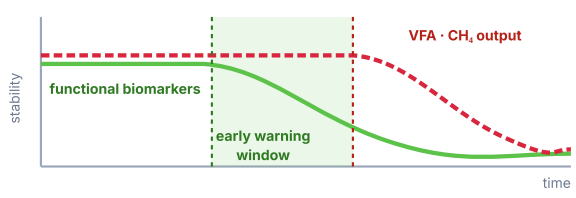
Predictive
monitoring instead of reactive process correction

Early
warning of emerging biological imbalance

Indigenous
microbial solutions: BioXeed® and IBG-Booster®

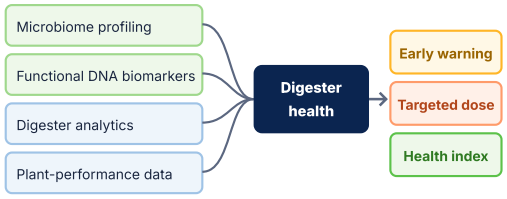
Feedstock-agnostic
biological interventions for stable biomethanation

Biomarkers see the drift first (concept)



Illustrative. Values not reported in the abstract.

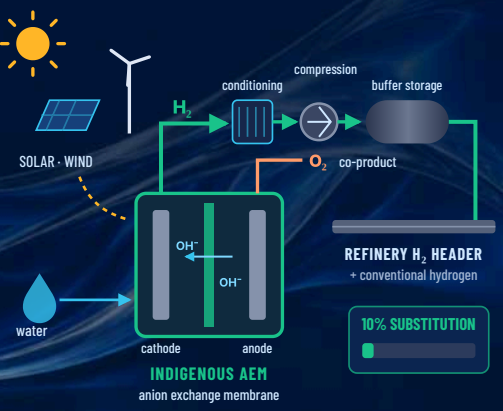
Framework: data to decisions



GREEN HYDROGEN · AEM | REFINERY INTEGRATION

FROM PILOT TO REFINERY SCALE: A TECHNO-ECONOMIC FRAMEWORK FOR INTEGRATING INDIGENOUS AEM ELECTROLYSIS-BASED GREEN HYDROGEN INTO REFINERY OPERATIONS

Kanisetty K Uday
Hindustan Petroleum Corporation Limited (HPCL)



ABSTRACT

The decarbonisation of refinery hydrogen represents a significant opportunity for reducing the carbon intensity of petroleum refining while maintaining the reliability, safety and flexibility demanded by continuous-process operations. This study proposes a refinery-integrated framework for replacing a portion of conventionally produced hydrogen with renewable green hydrogen generated through **indigenous Anion Exchange Membrane (AEM) electrolysis**. Unlike approaches that consider green hydrogen production as an isolated utility, the proposed framework addresses the complete integration pathway from renewable electricity generation to electrolyser operation, water management, hydrogen conditioning, compression, buffer storage and refinery hydrogen-header utilisation.

A representative refinery hydrogen-demand scenario is developed to evaluate a **10% green-hydrogen substitution pathway**. The proposed model couples renewable-power availability with electrolyser sizing, dynamic operation and hydrogen storage to address the mismatch between intermittent renewable generation and continuous refinery hydrogen demand. Technical assessment includes electrolyser utilisation, specific energy consumption, renewable-power requirement, water consumption, hydrogen quality, compression and storage requirements, while techno-economic evaluation considers Levelized Cost of Hydrogen (LCOH), capital expenditure, operating expenditure, avoided greenhouse-gas emissions and sensitivity to electricity price, electrolyser cost, renewable capacity factor and utilisation.

The framework further evaluates potential value creation through carbon-emission reduction and applicable carbon-credit mechanisms, subject to prevailing regulations, eligible methodologies, monitoring, reporting and verification requirements. Potential utilisation of the oxygen co-product and existing refinery infrastructure is also considered as an additional pathway for improving overall system economics. Safety, operability and brownfield integration are incorporated through consideration of hydrogen handling, pressure management, isolation requirements and process-hazard assessment.

A phased implementation strategy is proposed, progressing from pilot-scale validation to multi-megawatt refinery deployment. A dynamic optimisation approach is envisaged to coordinate renewable-power availability, electrolyser loading, hydrogen storage and refinery hydrogen demand, thereby improving system flexibility and utilisation. The indigenous AEM pathway is particularly relevant to India's emerging domestic electrolyser ecosystem and the development of locally manufacturable hydrogen technologies.

The proposed methodology provides a practical decision-support platform linking process integration, techno-economic optimisation, carbon-value assessment, safety and commercialisation. It aims to establish a replicable pathway for Indian refineries to transition from pilot-scale green-hydrogen demonstrations towards scalable, economically informed and lower-carbon refinery operations.

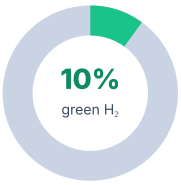
10%
green-hydrogen substitution pathway evaluated

Indigenous
Anion Exchange Membrane (AEM) electrolysis

Pilot → MW
phased: pilot-scale validation to multi-megawatt deployment

O_2 + CO_2
oxygen co-product and carbon-credit value pathways

Refinery hydrogen demand scenario



- **Green H_2** via indigenous AEM
- **Conventional** hydrogen

LCOH sensitivity to:
· electricity price · electrolyser cost
· renewable capacity factor · utilisation

plus CAPEX, OPEX and avoided GHG emissions

Four lenses of the decision-support platform

Process integration
power · electrolyser · water storage · H_2 header

Techno-economics
LCOH · CAPEX · OPEX dynamic optimisation

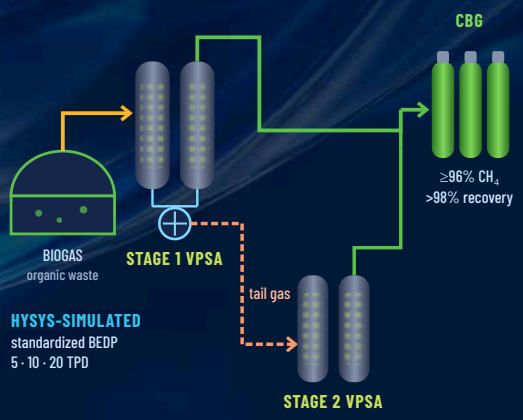
Carbon value
emission reduction · credits MRV requirements

Safety · operability
pressure · isolation process-hazard assessment

COMPRESSED BIO-GAS · CBG

DUAL-STAGE VPSA · INDIGENOUS TECHNOLOGY

From Waste to Wealth: HPCL's Indigenous Dual Stage HP-CBG-VPSA Technology



Vijaya Laxmi Anand*, T A Rajiv Kumar, Prashant Mishra, Bhaskarjyoti Baruah
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ABSTRACT

India is transitioning towards a circular and low-carbon energy economy and it requires scalable, efficient and indigenous technologies for converting organic waste into renewable fuels. In response to this opportunity, Hindustan Petroleum Corporation Limited (HPCL) has developed and standardized an indigenous dual-stage Vacuum Pressure Swing Adsorption (VPSA) technology for biogas upgradation to high-purity Compressed Bio-Gas (CBG).

The key novelty in this is the development of a dual stage Vacuum Pressure Swing Adsorption process. Entire process is simulated in Hysys and standardized for VPSA technology that moves beyond project-specific designs towards a replicable in-house technology solution. The technology has been progressively standardized across 5 TPD, 10 TPD and 20 TPD CBG capacities, culminating in the development of a comprehensive engineering design packages.

The technology achieves **≥96% methane purity and >98% methane recovery**. The 20 TPD plant can produce approximately 6,600 tonnes of CBG annually at 330 operating days. With the newly approved GOBARdhan CBG price of approximately ₹ 100 - 105/kg (₹2,110/MMBTU), the 20 TPD plant represents a potential gross CBG revenue of approximately **₹ 66 - 69 crore per year**, subject to plant operation, offtake and scheme conditions. The new GOBARdhan policy also provides eligible greenfield projects with capital assistance of up to ₹2 crore/TPD, potentially amounting to ₹40 crore for a 20 TPD project, subject to eligibility.

From an environment perspective, the 6,600 tonnes/year of renewable CBG can displace an equivalent energy quantity of fossil natural gas. On fossil-fuel displacement basis, by using the IPCC default natural-gas combustion emission factor, this corresponds to approximately **18,500 tonnes of CO_2 emissions avoided annually**. The figure presents avoided fossil CO_2 from fuel substitution and should be distinguished from a full lifecycle CO_2e assessment.

HP-CBG-VPSA technology also creates significant value through indigenous engineering capability. Standardized in-house BEDPs reduce dependence on external engineering/licensing support, with a minimum estimated ₹0.5-0.75 crore potential saving per plant from in-house BEDP development, in addition to potential technology/licensing savings. At multiple-project deployment, these savings can translate into a substantial numbers and cumulative business benefit of nearly ₹2-3 crore per plant.

By combining indigenous VPSA technology, process simulation and engineering standardization HPCL has established a pathway for replicable commercial-scale CBG projects, aligned with the newly strengthened national GOBARdhan framework for accelerating domestic CBG production. The initiative demonstrates how "Engineering Innovation, Indigenous Technology and Standardization can lead to Green Revenue" and can create measurable value for both HPCL and India's low-carbon energy ecosystem aligning with India's Atamnirbhar Bharat Mission.

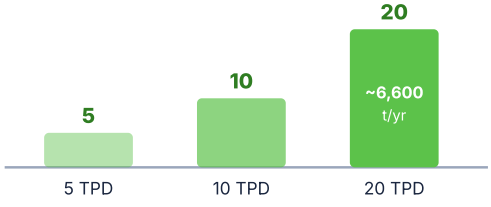
≥96%
methane purity, with >98% methane recovery

~6,600 t/yr
CBG from the 20 TPD plant at 330 operating days

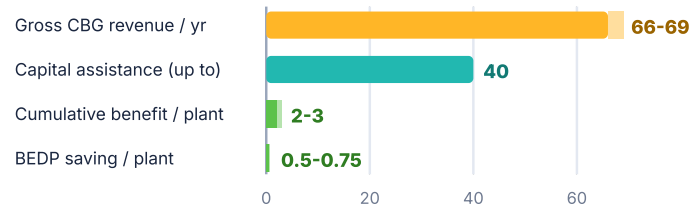
₹66-69 crore/yr
potential gross CBG revenue, 20 TPD plant

~18,500 t
CO_2 emissions avoided annually (fossil-fuel displacement)

Standardized capacities · TPD CBG



20 TPD plant value · ₹ crore



NAPHTHA VALORISATION | HIGH-PURITY PENTANE · PLANT TRIAL

Beyond the Naphtha Pool: Simulation-Guided Process Design to Plant-Scale Production of High-Purity Pentane Product

Anushka Shrivastava, Rameshprabu V, Dr Lavanya M

Research & Development (R&D), Chennai Petroleum Corporation Limited (CPCL), Chennai, TN, India

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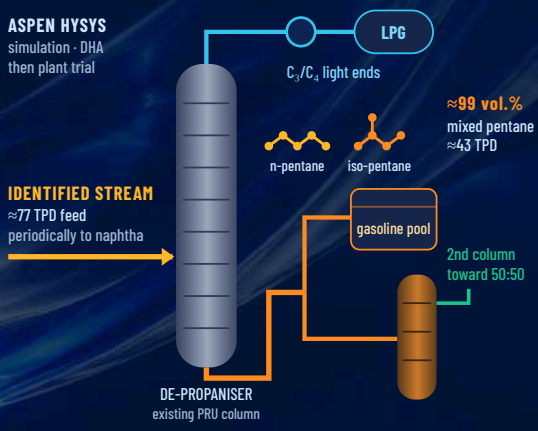


ABSTRACT

The transition towards a resource-efficient and economically sustainable energy sector requires innovative approaches that maximise value recovery from existing refinery assets. In line with this, Chennai Petroleum Corporation Limited (CPCL) undertook a refinery-scale initiative to upgrade a stream, periodically diverted to naphtha because of vapour-pressure limits on gasoline blending into a stabilised, high-purity mixed pentane product. The study demonstrates a structured pathway from research to commercially viable industrial solutions.

The work combined detailed hydrocarbon analysis (DHA) characterisation of the identified stream, process simulation using Aspen HYSYS, operating-strategy development using existing Propane Recovery Unit (PRU) and executing a plant trial. A stable operating conditions were established at the existing de-propaniser column of PRU, removing C_3/C_4 light ends to LPG and delivering **mixed pentane of ≈99 vol.% average purity at a ≈70:30 iso/n-pentane ratio**, with stable column hydraulics under varying crude slates.

The trial processed approximately 77 TPD of feed, yielding **about 43 TPD of pentane product**.

The recovered pentane-rich stream was successfully routed to the gasoline pool without any observed adverse impact on product quality which demonstrated the feasibility of integrating pentane recovery with existing refinery operations.

Further process optimization was undertaken to develop a market-oriented iso/n-pentane blend targeting a 50:50 composition. The subsequent trials demonstrated the capability of the existing system in the same PRU utilising a second column to achieve a composition approaching the desired ratio, while also identifying the process intensification required for further improvement towards the 50:50 target.

The study highlights a CPCL R&D-led approach to naphtha valorisation, refinery process integration and value creation through innovative utilization of existing assets.

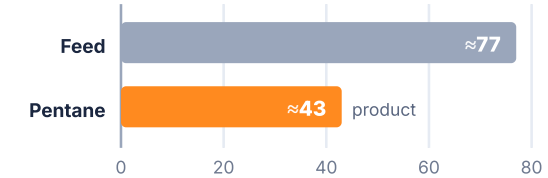
≈99 vol.%
average purity of mixed pentane

≈43 TPD
pentane product from ≈77 TPD feed

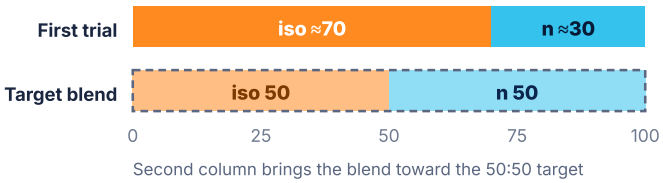
≈70:30
iso/n-pentane ratio in first trial

50:50
market-oriented blend targeted with a second column

Plant trial throughput (TPD)



iso/n-pentane composition (%)



Second column brings the blend toward the 50:50 target

HOW IT WORKS

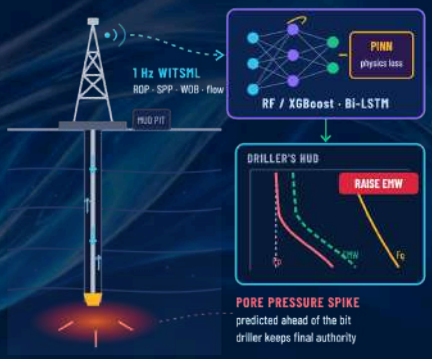
1. **DHA** — characterise the stream
2. **Aspen HYSYS** — simulate the PRU
3. **Plant trial** — de-propaniser column
4. **Optimise** — second column, 50:50

KEYWORDS Refinery Stream Upgradation · Naphtha Valorisation · Process Simulation · Process Optimisation · Plant Trial Validation · Hydrocarbon Recovery · Mixed Pentane · Petrochemical Integration · Value Addition · Asset Utilisation · Industrial Innovation

AI/ML · PHYSICS-INFORMED | DRILLING · WELL CONTROL

Real-Time Physics-Informed Machine Learning Framework for Dynamic Drilling Fluid Density Optimization and Downhole Pore Pressure Prediction

Sanskruti Thakur
Pandit Deendayal Energy University (PDEU)



ABSTRACT

During deep oil and gas well construction, subsurface formation pore pressure uncertainties frequently trigger formation fluid influxes ("well kicks"), resulting in significant Non-Productive Time (NPT), expensive drilling mud losses, or severe blowout hazards. Conventional mud weight management relies on static pre-drill geological predictions and lagged surface circulation data, leaving rig operators reactive to sudden pressure fluctuations.

This paper proposes an automated **Machine Learning (ML) framework for real-time drilling fluid density optimization.** By continuously ingesting high-frequency surface drilling telemetry, including Rate of Penetration (ROP), Standpipe Pressure (SPP), Hook Load, Weight on Bit (WOB), and differential mud flow rates, the framework models downhole compaction trends continuously. An ensemble machine learning model combining Long Short-Term Memory (LSTM) time-series networks with Random Forest feature importance algorithms predicts pore pressure spikes ahead of the drill bit, automatically recommending dynamic Equivalent Mud Weight (EMW) adjustments within a safe operational window.

The proposed machine learning framework replaces conventional, periodic mud logging with an end-to-end, automated predictive workflow. The system operates through five integrated modules: Data Ingestion, Preprocessing & Feature Engineering, Hybrid Machine Learning Engine, Automated Recommendation Engine, and Rig-Floor Decision Execution.

The ingestion layer continuously streams high-frequency surface drilling parameters recorded via WITSML (Wellsite Information Transfer Standard Markup Language) protocol at **1 Hz intervals**.

- **Feature Importance & Ranking (Random Forest / XGBoost):** Evaluates non-linear correlations across 15+ surface parameters, assigning dynamic weights to key indicators (such as ROP breaks, SPP drops, and flow-line gas spikes).
- **Time-Series Deep Learning (Bidirectional LSTM):** A 2-layer Bidirectional Long Short-Term Memory (Bi-LSTM) neural network processes sequential sliding windows of depth and time data (e.g., past 50 ft / 10 minutes of drilling).

By incorporating hydrostatic pressure equations and compaction laws directly into the model's loss function, physical boundary conditions are strictly enforced. The model is physically constrained from predicting pore pressure values below normal hydrostatic gradients (**0.433 psi/ft or 8.33 ppg equivalent**) or above overburden rock stress, preventing catastrophic algorithm divergence in unmapped geological formations.

The system functions under a strict Human-In-The-Loop (HITL) architecture. Rather than executing automated mud dosing autonomously, the engine displays explainable confidence intervals and feature contribution plots (using SHAP values) directly on the Driller's Heads-Up Display (HUD). The driller retains final authority to validate and execute the recommended mud weight adjustment, bridging digital predictions with seasoned operational expertise.

6.2 Economic Efficiency & NPT Reduction

Non-Productive Time (NPT) resulting from well-control events, lost circulation, and stuck pipe can **exceed $100,000 daily** in deep drilling operations. By dynamically maintaining the equivalent circulating density strictly within the optimal drilling margin window, this system optimizes Rate of Penetration (ROP), minimizes chemical mud loss, and reduces total well construction expenditures.

7. Conclusion

This paper demonstrates a physics-informed, machine learning-driven framework for dynamic drilling fluid density optimization. By integrating high-frequency surface sensor telemetry, dc-exponent compaction trend analysis, and a Bidirectional LSTM neural network constrained by physical hydrostatic laws, the system converts conventional, reactive mud weight adjustments into a proactive, automated workflow. This digital innovation significantly enhances operational safety, reduces costly Non-Productive Time, and advances sustainable engineering practices across the energy sector.

Condensed from the author's abstract for this one-page compendium.

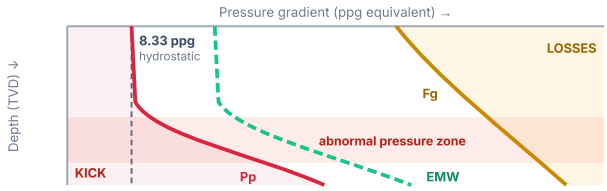
1 Hz
WITSML surface telemetry streamed continuously

15+
surface parameters ranked by Random Forest / XGBoost

8.33 ppg
PINN floor: normal hydrostatic, 0.433 psi/ft

$100,000 /day
NPT cost can exceed this in deep drilling

Dynamic drilling margin window · pressure vs depth



Illustrative. Values not reported in the abstract, except the 8.33 ppg hydrostatic floor.

Five integrated modules · end-to-end workflow

1. **Data Ingestion** — WITSML at 1 Hz
2. **Preprocessing & Feature Engineering**
3. **Hybrid Machine Learning Engine** — RF / XGBoost · Bi-LSTM · physics loss
4. **Automated Recommendation Engine** — dynamic EMW
5. **Rig-Floor Decision Execution** — HUD · SHAP · driller decides

MEMBRANE SEPARATION

ETHYLENE RECOVERY · PATENTED TECHNOLOGY

Next-Generation Energy-Efficient Process for Ethylene Recovery from FCC Off-Gas

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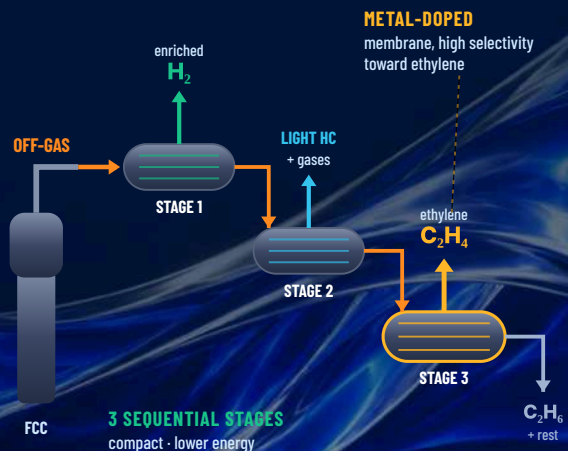
[1]Mangalore Refinery and Petrochemicals Limited (MRPL), Mangalore, Karnataka - 575030

[2]Indian Institute of Chemical Technology (CSIR-IICT), Hyderabad - 500007



ABSTRACT

Fluid catalytic cracking (FCC) is a major refinery process that produces off-gas containing rich hydrocarbons such as Hydrogen, Nitrogen, Ethane and Ethylene. Despite often being used as refinery fuel or processed by conventional methods, this stream contains valuable olefins, particularly ethylene. Their efficient recovery can enhance resource utilization, reduce fuel losses, and lower the energy demand of downstream separation processes. The recovery of ethylene from FCC off-gas is technically challenging as it is in the form of highly multicomponent mixture and exhibits physical and molecular characteristics similar to those of ethane. The close molecular dimensions, boiling points, and transport properties of ethylene and ethane make their separation particularly difficult. Conventional technologies for light hydrocarbon separation, such as cryogenic distillation involve substantial energy consumption, refrigeration requirements, equipment size, and operational complexity.

These limitations have driven the development of membrane based separation technologies as potentially more compact and energy efficient alternatives to conventional separation processes. Membrane systems can enable continuous separation with relatively low mechanical complexity and, when appropriately integrated with existing refinery operations, offer the potential to reduce the energy intensity and carbon footprint of gas processing.

In this context, MRPL R&D in collaboration with CSIR-IICT, has **developed and patented membrane based technology** for the separation and recovery of ethylene from FCC off-gas. The integrated process comprises three sequential separation stages. In the first stage, a proprietary membrane selectively enriches hydrogen from the FCC off-gas. In the second stage, other light hydrocarbons and gaseous components are selectively separated to further concentrate the stream. In the third stage, a **metal-doped membrane with high selectivity toward ethylene** enables the selective separation of ethylene from ethane and the remaining hydrocarbon mixture. The technology offers the potential for a more compact process configuration, lower energy consumption, and reduced environmental footprint, making it a promising approach for ethylene recovery from refinery FCC off-gas.

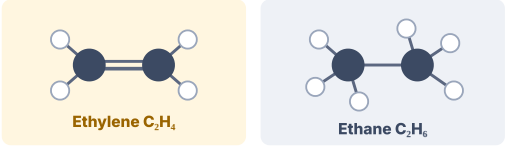
3 stages
sequential membrane separation: H_2, light gases, then ethylene

Patented
membrane technology by MRPL R&D with CSIR-IICT

Metal-doped
final-stage membrane with high selectivity toward ethylene

Compact
potentially lower energy consumption and environmental footprint

Why it is hard: ethylene vs ethane



close molecular dimensions · boiling points · transport properties · multicomponent mixture

Cryogenic distillation vs membrane route

CONVENTIONAL	MRPL · CSIR-IICT
Cryogenic distillation	**3-stage membrane**
· substantial energy consumption	· compact configuration
· refrigeration requirements	· continuous separation
· large equipment size	· low mechanical complexity
· operational complexity	· lower energy intensity
	· reduced carbon footprint

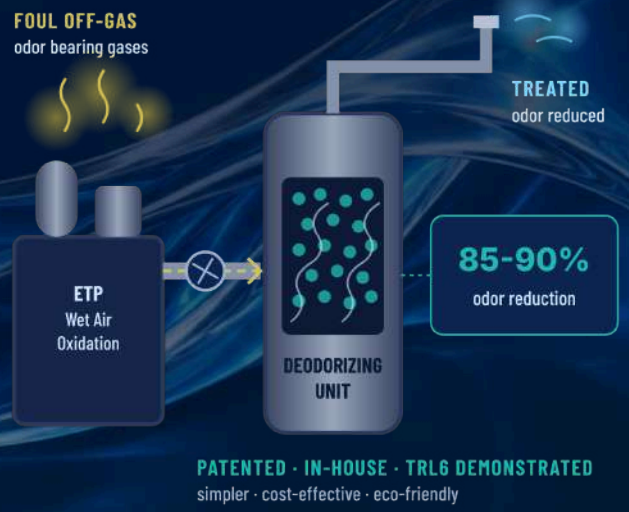
HOW IT WORKS

1. **FCC off-gas** — H_2, N_2, ethane, ethylene
2. **Stage 1** — hydrogen enriched
3. **Stage 2** — light HC + gases out
4. **Stage 3** — C_2H_4 split from C_2H_6

KEYWORDS FCC off gas · ethylene recovery · membrane separation

ODOR CONTROL · OFF-GAS | PATENTED · INDIGENOUS

Deodoring Technology: An Indigenous Innovation for Odorless Process Industries



Pramod Kumar Hegde, Karthick R, Manjunatha M G, Nirmal Ganesh S
Mangalore Refinery and Petrochemicals Limited (MRPL), Mangalore, Karnataka - 575030

PATENTED · IN-HOUSE · TRL6 DEMONSTRATED
simpler · cost-effective · eco-friendly

ABSTRACT

While eliminating contamination from crude oil to produce value added products in a refinery, there can be emission of unpleasant odor bearing gases. Conventional odor control methods, such as scrubbing, incineration, chemical neutralization and photo-catalytic decomposition are commonly used to mitigate these odors. However, these techniques are inefficient, cost intensive and can have negative impact on environment over a long term. This invention seeks to address the limitations of current methods by developing a simpler, more cost-effective, and eco-friendly process for reducing odors from petroleum refinery off-gases. The proposed solution focuses on creating a streamlined and effective system that significantly reduces odors in foul off-gas streams while minimizing environmental impact, offering a practical alternative to existing approaches.

Under this patented invention, an in-house developed technology designed to address odor emissions from off-gas streams is presented. The journey began in 2018 with a proof-of-concept (POC) investigation, followed by the filing of a provisional patent application on August 8, 2018. A mini pilot-scale study was subsequently conducted to understand the reaction kinetics. Subseqeuntly, a demonstration-level reactor was developed, reaching Technology Readiness Level 6 (TRL6), and an extensive study was carried out. On September 13, 2023, the Indian Patent Office granted the patent for this technology. Building on the insights gained from the demonstration study, a Deodorizing unit was designed and implemented in the ETP Wet Air Oxidation (WAO) offgas application. Further a Basic Design and Engineering Package (BDEP) was developed, which formed the basis for in-house execution of detailed engineering, procurement, fabrication, and construction of the Deodorizing unit. The unit stands successfully operating demonstrating **odor reduction efficiency of 85% to 90%**. This innovative solution offers a sustainable and efficient approach to odor control in industrial processes.

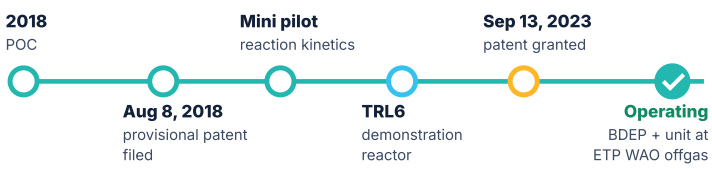
85-90%
odor reduction efficiency, unit in operation

TRL6
demonstration-level reactor

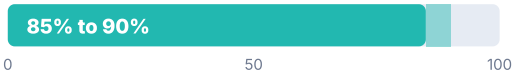
2023
patent granted by the Indian Patent Office (September 13)

In-house
BDEP, detailed engineering, procurement, fabrication, construction

From proof of concept to operating unit



Odor reduction efficiency · %



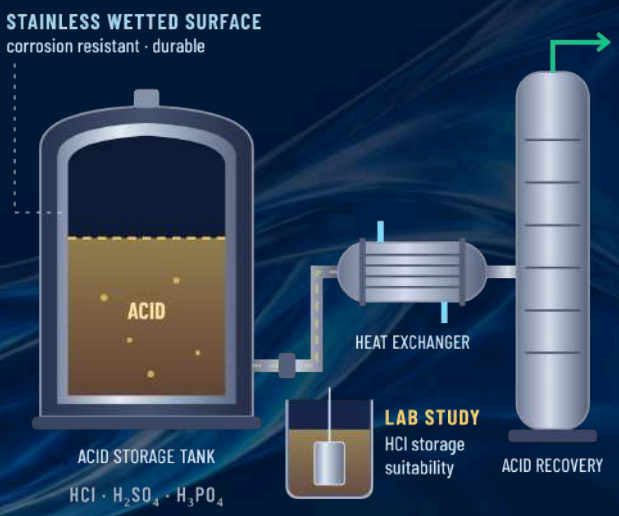
CONVENTIONAL METHODS
scrubbing · incineration · chemical neutralization
photo-catalytic decomposition
inefficient · cost intensive · long-term impact

HOW IT WORKS
1. **Foul off-gas** — ETP WAO odor bearing gases
2. **Deodorizing unit** — patented in-house process
3. **Odor reduced** — 85% to 90% efficiency
4. **In-house build** — BDEP, engineering, fabrication

KEYWORDS Deodoring | Off-gas streams | Process Industry

MATERIALS · CORROSION | ACID SERVICE · STAINLESS STEEL

Stainless Steel Material Solutions for Hydrochloric, Sulphuric, and Phosphoric Acid Service Applications



Lalatendu Panda
Jindal Stainless

ABSTRACT

Material selection is critical for ensuring safety, reliability, and lifecycle cost optimization in acid handling and processing facilities. Stainless steels offer **effective corrosion-resistant solutions** for a wide range of acidic environments encountered in chemical, fertilizer, mining, and refining industries. Specialized stainless steels and alloyed grades provide excellent performance in hydrochloric, sulphuric, and phosphoric acid applications under specific concentration and temperature conditions.

The presentation will provide corrosion challenges associated with these acid services and highlights the role of stainless steel as a sustainable and cost-effective material solution. Case studies and industry practices are presented for storage tanks, process vessels, piping systems, heat exchangers, and acid recovery units. The lab study on material suitability for Hydrochloric Acid storage for refinery application will also be showcased in the presentation.

The presentation will further examine opportunities to replace conventional materials with advanced stainless steel solutions to **enhance process efficiency, reduce downtime, and lower lifecycle costs**. By combining corrosion resistance, durability, and recyclability, stainless steel emerges as a key material for safe and sustainable acid-processing infrastructure, supporting long-term operational excellence across diverse industrial sectors.

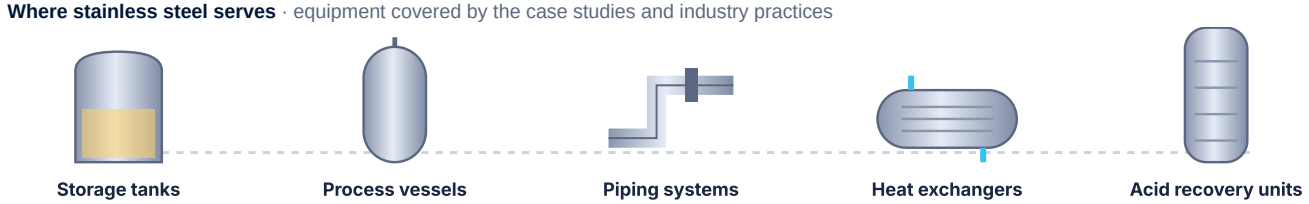
$HCl \cdot H_2SO_4$ H_3PO_4
hydrochloric, sulphuric and phosphoric acid service

Lab study
material suitability for HCl storage, refinery application

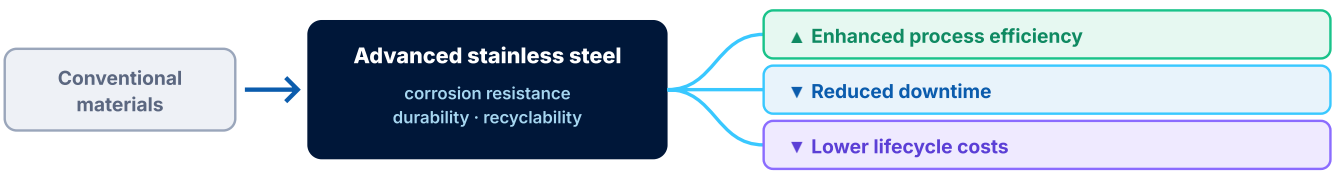
Recyclable
corrosion resistance and durability combined with recyclability

Lifecycle cost
lower, with reduced downtime and better process efficiency

Where stainless steel serves · equipment covered by the case studies and industry practices



Replacing conventional materials · with advanced stainless steel solutions



HOW IT WORKS

1. **Acid service** — HCl, sulphuric, phosphoric
2. **Corrosion challenge** — concentration, temperature
3. **Material selection** — specialized stainless grades
4. **Outcome** — safe, reliable, lower cost

AEM WATER ELECTROLYSIS

GREEN HYDROGEN · TRANSPORT MODELLING

Transport modelling of the anion exchange membrane electrolyser: mechanistic insights and performance analysis

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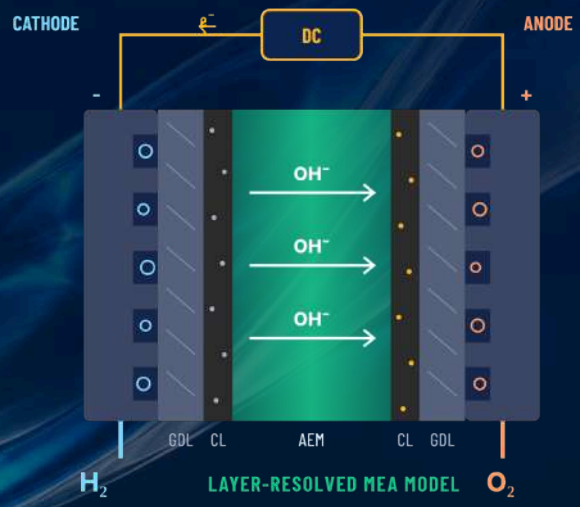


ABSTRACT

Anion exchange membrane (AEM) water electrolysis offers a promising route for cost-effective green hydrogen production, with performance governed by coupled electrochemical and transport processes within the membrane-electrode assembly (MEA). A first-principles multiphysics model is developed to resolve individual MEA layers and quantify activation, ohmic, and transport losses. The model shows good agreement with experimental polarization data over 40-70 °C. Increasing temperature enhances hydroxide-ion conductivity and reaction kinetics, resulting in **a 34% increase in current density at 1.9 V**. Parametric analysis demonstrates that higher exchange current densities reduce activation losses, with greater sensitivity observed at the anode. Ionic potential analysis reveals that membrane thicknesses above 50 µm substantially increase ohmic losses. The catalyst layer thickness is optimized within approximately 10-50 µm, providing a balance between reaction kinetics and transport resistance. Increasing electrolyte concentration improves performance up to approximately 0.3 M, beyond which performance gains become marginal. Carbonation is found to have a non-negligible impact, reducing performance by approximately 1%. Overall energy efficiency decreases from **approximately 96.9% at 1.5 V to 46.8% at 1.9 V**, highlighting the trade-off between hydrogen production rate and energy efficiency. The developed framework provides useful insights for MEA optimization and AEM electrolyzer design.

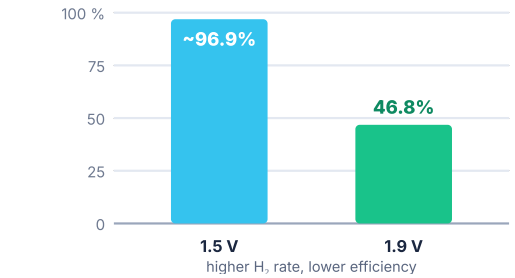
+34%
current density at 1.9 V with higher temperature (40-70 °C)

96.9 → 46.8%
overall energy efficiency, 1.5 V vs 1.9 V

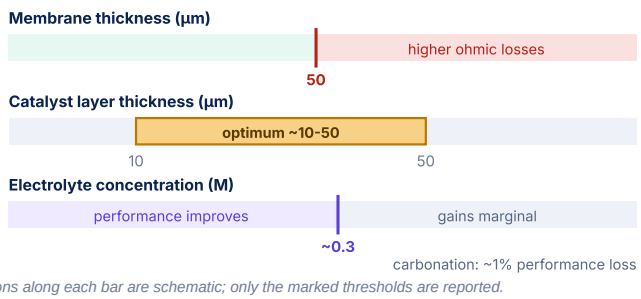
10-50 µm
optimized catalyst layer thickness

~0.3 M
electrolyte concentration beyond which gains are marginal

Energy efficiency vs cell voltage



MEA design window from the model



Positions along each bar are schematic; only the marked thresholds are reported.

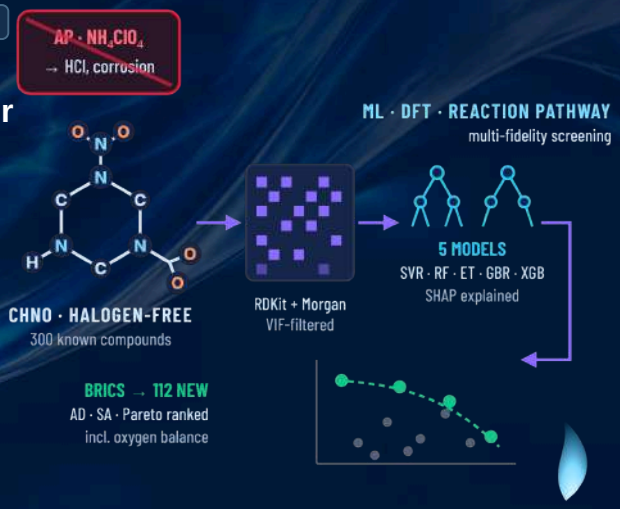
HOW IT WORKS

1. **Model** — layer-resolved MEA physics
2. **Validate** — polarization data, 40-70 °C
3. **Analyse** — activation, ohmic, transport
4. **Optimize** — membrane, CL, electrolyte

KEYWORDS Anion exchange membrane · water electrolysis · hydrogen production · charge transport · mathematical modelling

AI / ML · MOLECULAR SCREENING | HALOGEN-FREE ENERGY MATERIALS

Halogen-Free Energy Materials Identified Using Machine-Learning: A Multi-Fidelity ML-DFT Approach for Improved Combustion Systems



Yashasvi Singh, Vaibhav Pathak, Snehasish Panigrahy
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ABSTRACT

Halogen-based oxidizers like ammonium perchlorate (AP) generate HCl and other chlorinated species upon combustion causing corrosion, toxic impact, and safety concerns. Thus, halogen-free, high-nitrogen-content materials are desirable. Searching for materials via experimentation is time- and cost-consuming. In this paper, we propose a new framework of multi-fidelity ML-DFT-reaction pathway analysis for accelerated and more efficient identification and prioritization of halogen-free (CHNO) energetic materials. A dataset of 300 experimentally studied compounds was represented using RDKit descriptors and Morgan fingerprints, and redundancy of features was eliminated using VIF analysis. Then, five regression models (SVR, RF, ExtraTrees, GBR, and XGBoost) were optimized using randomized search with cross-validation and validated using independent test dataset. All the models demonstrated **good prediction quality with R^2 = 0.84–0.98 (R^2 = 0.95 for enthalpy of formation)**. Prediction of safety-related sensitivity characteristics proved challenging (R^2 = 0.30). Novel compounds were generated using the BRICS fragment recombination approach **yielding 112 novel molecules**. They were ranked using applicability domain checking, synthetic accessibility ranking, Pareto optimization and multi-objective scoring including oxygen balance. Interpretable models were developed using SHAP and permutation importance approaches.This pipeline can be used again for identifying fuel additives, high energy density and sustainable aviation fuels, or any other form of energy molecule. This can be accomplished quickly and inexpensively.

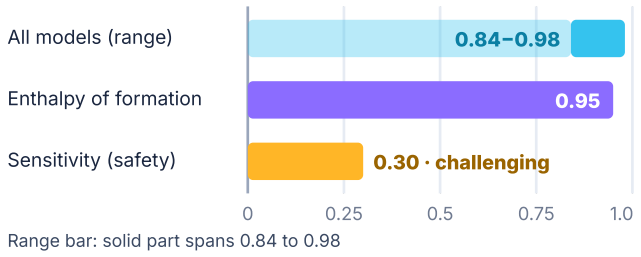
300
experimentally studied compounds in the dataset

0.84–0.98
R^2 across five regression models (0.95 for enthalpy of formation)

112
novel molecules generated by BRICS fragment recombination

5
models: SVR, RF, ExtraTrees, GBR, XGBoost

Prediction quality · R^2 on independent test data



Range bar: solid part spans 0.84 to 0.98

Screening funnel

300 compounds · 5 models
RDKit + Morgan · VIF · randomized search CV

112 novel molecules
BRICS fragment recombination

Ranked candidates
AD · SA · Pareto · oxygen balance

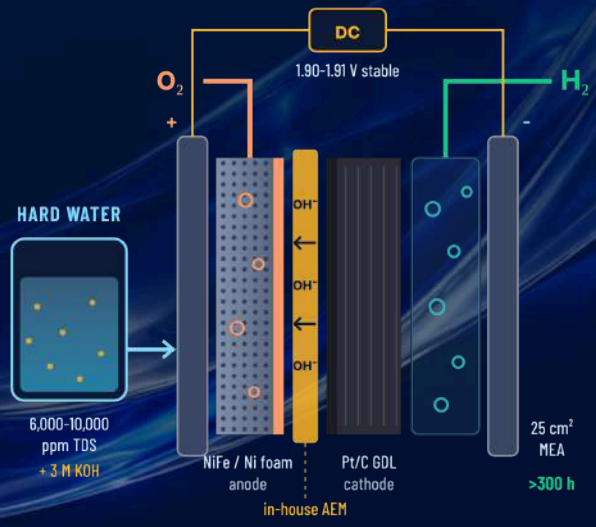
HOW IT WORKS

1. **Encode** — RDKit + Morgan, VIF
2. **Train 5 models** — randomized search CV
3. **Generate** — BRICS: 112 molecules
4. **Rank** — Pareto + oxygen balance

KEYWORDS Machine learning · molecular screening · halogen-free energy materials · clean combustion · AI in energy

GREEN HYDROGEN | AEM ELECTROLYSER · HARD WATER

Direct Green Hydrogen Production from Hard Water Using a Cost-Effective Electrolyser System



Prashant Suryawanshi, and Ravindra Joshi*
*Tridiagonal Solutions Pvt. Ltd. (TSPL), Shirwal, Tal. Satara, Maharashtra, India

ABSTRACT

Water availability is one of the major barriers to the widespread deployment of green hydrogen technologies because conventional proton exchange membrane (PEM) electrolyzers require high-purity deionized water. This work presents the development and validation of a hard-water-compatible Anion Exchange Membrane (AEM) electrolyser capable of producing green hydrogen directly from **water containing 6,000-10,000 ppm total dissolved solids (TDS)**. The prototype employs a 25 cm² membrane electrode assembly (MEA) consisting of an in-house alkaline AEM, NiFe-coated nickel foam anode, and Pt/C gas diffusion cathode, operating with 3 M KOH electrolyte.

A continuous durability investigation **exceeding 300 hours** was performed under ambient conditions. The system maintained a stable operating voltage of 1.90-1.91 V, while current, current density, power consumption and hydrogen production gradually decreased due to expected long-term electrode and membrane ageing. Despite the progressive reduction in current, continuous hydrogen evolution was sustained throughout the test without catastrophic membrane failure or electrolyte instability.

The proposed architecture significantly reduces dependence on freshwater purification, lowers capital and operating costs compared with conventional PEM systems, and provides a scalable platform for decentralized hydrogen generation. The technology demonstrates strong potential for renewable hydrogen production, green ammonia, fertilizer manufacturing and industrial hydrogen applications, and future commercialization of low-cost AEM electrolyser systems.

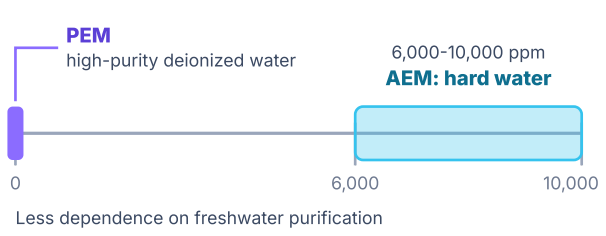
6,000-10,000 ppm TDS in the feed water, used directly

>300 h continuous durability test, ambient conditions

1.90-1.91 V stable operating voltage

25 cm² MEA prototype, 3 M KOH electrolyte

Feed water the cell accepts (TDS, ppm)



Durability run (>300 h, ambient)

Illustrative. Values not reported in the abstract.

HOW IT WORKS

1. **Hard water** — 6,000-10,000 ppm TDS + KOH
2. **AEM cell** — NiFe anode · Pt/C cathode
3. **Electrolysis** — stable 1.90-1.91 V
4. **Green H_2** — ammonia, fertilizer, industry

KEYWORDS Green hydrogen · Anion Exchange Membrane · Hard water electrolysis · AEM electrolyser · NiFe catalyst · Hydrogen durability · Sustainable electrolysis · etc.

BIOMASS VALORIZATION | NANOCELLULOSE · CMF

Scalable Co-Production of Nanocellulose and Chloromethyl Furfural from Lignocellulosic Biomass: Process Technology and Applications

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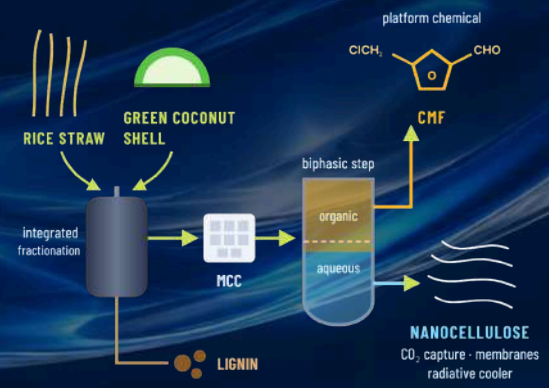

ABSTRACT

Utilization of lignocellulosic biomass remains constrained by challenges supply-chain management, feedstock heterogeneity, process complexity, and production economics. These challenges become particularly critical in the production of bioethanol from lignocellulosic biomass. Lignocellulosic biomass such as rice straw and green coconut shell, is a structurally complex renewable resource with its composition and physicochemical properties varying significantly. To address the limitations of existing approaches, we have developed and patented a series of **integrated, and scalable methods** for converting agricultural and biomass residues into high-value products- **nanocellulose and chloromethyl furfural**. Nanocellulose finds vivid applications in CO_2 capture, drilling fluid, radiative cooler, pharmaceuticals, electronic devices, membranes, and others. Chloromethyl furfural is a platform chemical and finds vivid applications.

Our process-development strategy is guided by the principles of Atom Economy, Step Economy, Energy Economy, and Cost Economy. The patented technology platform includes:

- Integrated production of microcrystalline cellulose (MCC) and lignin from rice straw and green coconut shell.
- **Co-production of nanocellulose and chloromethyl furfural (CMF)** from microcrystalline cellulose.
- **PFD** for microcrystalline cellulose production.
- **PFD** for nanocellulose and chloromethyl furfural production.

The developed platform offers a scalable pathway for converting underutilized agricultural residues into high-value renewable materials and platform chemicals, thereby supporting circular bioeconomy, and creating new opportunities for decentralized biomass-based manufacturing.

References:

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D. Panda, and coworkers, “Integrated Upcycling of Rice Straw into Electrospun Nanocellulose Chemiresistors and Lignin Nanoparticles with Superior Photoprotection” Biomacromolecules (2026) In Press

D. Panda, and coworkers, “Transparent, Fluorophore-doped Cellulose Nanocrystals Film prepared from Crop-Residue: Superior Radiative Cooler and Organic Photodetector” ACS Sustainable Chemistry & Engineering (2025) 13, 2086-2096

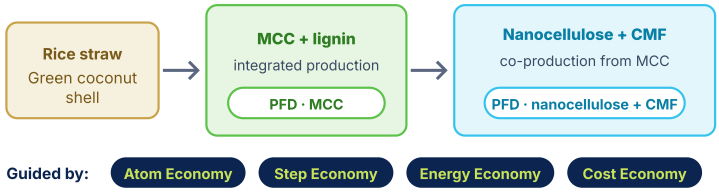
Patented
series of integrated, scalable methods for residue conversion

MCC + lignin
integrated production from rice straw and green coconut shell

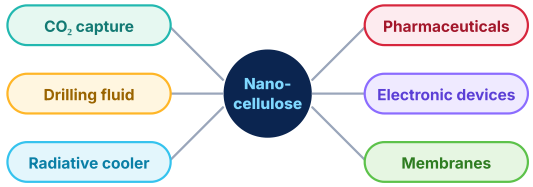
CMF
platform chemical co-produced with nanocellulose from MCC

Decentralized
biomass-based manufacturing opportunities

Patented technology platform



Where nanocellulose goes



HOW IT WORKS

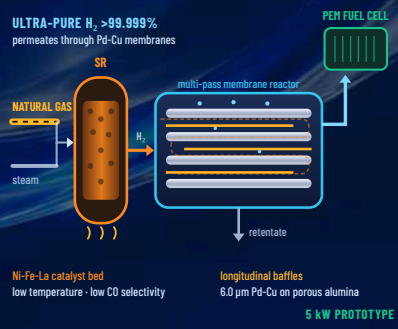
1. **Agri residues** — rice straw, coconut shell
2. **Fractionate** — MCC and lignin
3. **Co-produce** — nanocellulose + CMF
4. **Apply** — materials, platform chemical

KEYWORDS Biomass | Nanocellulose | Chloromethyl Furfural | Integrated valorization

ON-SITE HYDROGEN | MEMBRANE REFORMER · NATURAL GAS

Natural Gas-based Membrane Reformer for 'On-Site' Production of Ultra-Pure Hydrogen

Rahul Sharma
GAIL (India) Ltd, in association with IIT BHU, Varanasi



ABSTRACT

Oil and gas companies face twin-challenging role that requires them to provide secure, affordable energy to consumers and customers worldwide while also acknowledging the critical need to address climate change.

To meet the pressing challenges of adverse climate change , Indian oil and gas are widely working towards developing their Net-Zero roadmaps in align with country's target of reducing CO_2 emissions by 50% by 2050 and reaching net zero by 2070.

A widespread and effective development of green hydrogen requires a notable amount of renewable electricity, which may be a problem in the short term, since renewable energy sources are already needed to decarbonize existing electricity demand. For this reason, blue hydrogen can represent a useful option on the short and medium term, by helping in paving the way for green hydrogen at a later stage

On-site hydrogen production using compact reformer is believed to be an important stepping-stone technology in the transition to a hydrogen-based infrastructure. Compact reformer proposes an on-site hydrogen production system that converts natural gas to high-purity hydrogen for remote areas without convenient access to hydrogen. It includes a pressurized steam reformer (SR) to produce H_2-rich gas followed by multi-pass membrane reactor (MR) to promote H_2-producing reactions and permeate ultra-pure hydrogen.

In this aspect, as one of the pioneer of natural gas economy in India, GAIL (India) Ltd in association with IIT BHU, Varanasi has developed a Natural Gas-based Membrane Reformer for 'On-Site' Production of **Ultra-Pure Hydrogen(>99.999%)**.

In current R&D work with IIT BHU, tri-metallic catalyst supported on Al_2O_3 and CeO_2 was synthesized by using wet impregnation method. The results show that La promoted tri-metallic catalyst on alumina support gives high conversion and low CO selectivity even at low temperature. Further, Pd-Cu membrane supported on porous alumina tube was synthesized for H_2 separation from reformate gases. Results show highest membrane selectivity for highest purity of hydrogen.

In first part, Pd/Pd-alloy membranes were synthesized by using hybrid approach by combining electroless plating (ELP) and physical vapor deposition (PVD) method. The thickness of dense membrane prepared by hybrid approach is **6.0 microns**. Hence, membrane prepared by hybrid approach is thinner and provides more hydrogen flux compared to the conventional membranes. Further, the membrane life was also tested for 7 days with mixture gases ($50H_2$:$50N_2$) at 723 K temperature and 400 kPa pressure. It was found that membrane performance is stable for all the time. This shows that the membrane prepared has a good life and no pin hole formation was detected for the tested period. The membrane separator design was optimized to achieve the maximum hydrogen recovery and minimize the concentration polarization. It was found that membrane arrangement significantly affects the hydrogen recovery and an optimal membrane separator design was found by using the longitudinal baffles which also helped in minimizing concentration polarization. Hence, multi-pass membrane separation module is used for the separation of hydrogen from the mixture gases. Figure 1 shows the membrane synthesized by hybrid approach

Fig. 1 Characterization and testing of Pd-Cu membrane prepared through hybrid methodology

In second part of the work a low temperature and low CO selective catalyst was synthesized. Ni based mono, bi and tri-metallic catalysts were synthesized on alumina and ceria supports. Fe, and La are used as a promotor to enhance the reforming activity and minimize the startup time and CO selectivity. Synthesized catalysts were characterized by using BET, XRD, SEM, TEM, etc. The synthesized catalysts were tested in a conventional packed bed reactor to optimize the operating parameters (temperature, pressure, steam to methane ratio, W/F ratio) and test the catalyst activity. Ni-Fe-La based catalyst was found suitable which showed maximum conversion, low CO selectivity low startup time and high catalyst life. Figure 2 shows the performance of optimized Ni (75)-Fe (15)-La (10) catalyst on alumina support

Fig. 2 Characterization and testing of Pd-Cu membrane prepared through hybrid methodology

Finally, both catalyst and membranes were integrated in a single unit called 'Membrane Reformer (MR).' The performance of both membrane reformer (MR) and 'Multi-pass Membrane Reformer (MMR)' was tested for different operating conditions like temperature, pressure, membrane to baffle ratio, steam to methane ratio, etc. Finally, a prototype was designed to generate 5kW power and the same was tested with the natural gas. The prototype was tested at different temperature, pressure, W/F ratio and membrane arrangement. For 5kW power generation **600 gm catalyst and 28 membranes** were used. The performance of traditional reformer (TR) was compared with the MR and MMR in terms of conversion and hydrogen recovery (shown in Figure 4), and hence, MMR is found suitable for the on-site generation of ultra-pure hydrogen.

By utilizing the natural gas infrastructure, compact Membrane reformer can produce high purity hydrogen effectively and make it more accessible for wide range of applications to generate power when combined with PEM fuel cells for both mobile (vehicle) and stationary applications like household generators, power supply to mobile towers, EVs, malls/shop generators, etc. In addition, portable unit can be installed at CNG station to mix hydrogen with CNG to reduce the tailpipe emissions.

>99.999%
ultra-pure hydrogen produced on-site from natural gas

6.0 µm
dense Pd/Pd-alloy membrane by hybrid ELP + PVD

7 days
stable membrane life test at 723 K and 400 kPa, no pin holes

5 kW
prototype with 600 gm catalyst and 28 membranes

From lab to prototype · catalyst and membrane integrated in one unit

Catalyst
Ni(75)-Fe(15)-La(10) / Al_2O_3

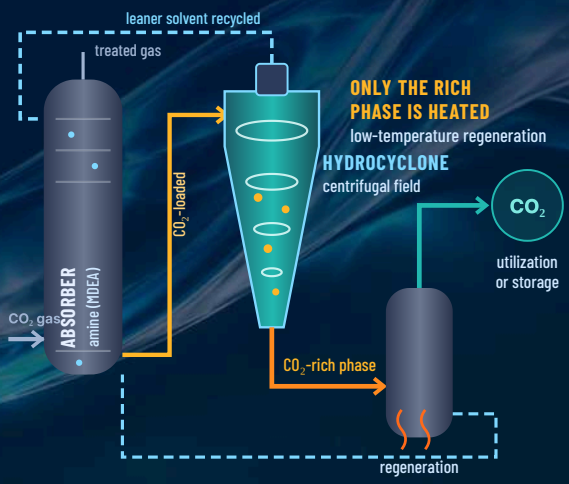
Membrane
Pd-Cu · ELP + PVD · 6.0 µm

→ **MR → MMR**
multi-pass, baffled

→ **5 kW prototype**
600 gm catalyst
28 membranes · natural gas

CO_2 CAPTURE | AMINE SOLVENT · HYDROCYCLONE

Low-Energy CO_2 Capture through Hydrocyclone-Assisted Amine Separation



Josvita Sequeira, Omsat Mohanty, Karthick R, Pramod Kumar Hegde, Manjunatha MG

Mangalore Refinery and Petrochemicals Limited (MRPL), Mangalore, Karnataka - 575030

ABSTRACT

A mine-based solvents, particularly conventional methyldiethanolamine (MDEA), have been extensively investigated for post-combustion CO_2 capture and direct air capture (DAC) owing to their favorable absorption characteristics and established processability. However, several challenges, including high regeneration energy requirements, solvent degradation, foaming, amine losses, and inefficient separation of CO_2-rich phase from the bulk solvent, remain significant barriers to their widespread practical application. These limitations are primarily associated with the requirement to heat and regenerate a large quantity of solvent, resulting in substantial energy consumption.

The present study proposes a hydrocyclone-assisted selective separation approach for low-energy CO_2 capture and regeneration. Following CO_2 absorption, the CO_2-loaded solvent is introduced into a hydrocyclone, where tangential flow generates a centrifugal field that promotes the separation of the CO_2-rich phase from the bulk amine solvent. A key feature of the proposed process is the formation of a distinct CO_2-rich phase upon sufficient CO_2 loading, enabling its selective separation from the remaining leaner solvent. The hydrocyclone facilitates rapid phase separation and directs the CO_2-rich fraction toward a downstream regeneration unit.

Unlike conventional amine-based systems, where the entire solvent inventory must be heated during regeneration, the proposed configuration **selectively regenerates only the separated CO_2-rich phase**. Following regeneration, the resulting lean solvent is recycled to the absorption column, while the recovered CO_2 is directed toward subsequent utilization or storage. This selective regeneration strategy can **substantially reduce the solvent circulation rate through the regeneration section and, consequently, the thermal energy requirement**.

Overall, the proposed system integrates high CO_2 loading capacity, rapid absorption kinetics, low-temperature regeneration, hydrocyclone-assisted phase separation, and reduced solvent circulation. By selectively separating and regenerating the CO_2-rich phase rather than the entire solvent stream, the process offers a promising pathway toward reducing regeneration energy, improving solvent management, and enhancing the overall efficiency of conventional amine-based CO_2 capture systems.

CO_2-rich phase only
selectively regenerated, not the entire solvent inventory

Reduced
solvent circulation through the regeneration section

Lower
thermal energy requirement for regeneration

Low-temp.
regeneration with high CO_2 loading capacity

What gets heated in regeneration

Conventional entire solvent inventory	all solvent heated and regenerated
Hydrocyclone-assisted CO_2-rich phase only	CO_2-rich: heated | leaner solvent: recycled, not heated

less solvent circulated through regeneration → lower thermal energy

Illustrative. Values not reported in the abstract.

Barriers addressed

- high regeneration energy
- solvent degradation
- foaming
- amine losses
- inefficient separation of CO_2-rich phase from bulk solvent

conventional amine (MDEA) capture, post-combustion and DAC

HOW IT WORKS

1. **Absorption** — amine takes up CO_2
2. **Hydrocyclone** — centrifugal phase split
3. **Selective regeneration** — CO_2-rich phase only
4. **Recycle** — lean solvent back

KEYWORDS CO_2 capture | Low energy | Hydrocyclone

HYDROGEN FUEL CELL · PEMFC

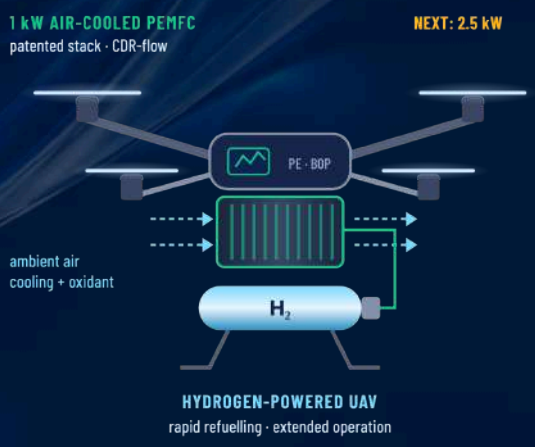
AERIAL MOBILITY · INDIGENOUS TECHNOLOGY

Powering the Next Mile: Indigenous PEMFC Technology for Hydrogen-Powered Fuel Cell applications.

Ashutosh Behera, Mrityunjay Kumar, Shruthikumar Ramasagar[1], Chinmay Chaudhari, Meenakshi Sundarraman, Kapil Sonkar, Dr. Sauhard Singh, Dr. Tapan Bera, Rajesh Badhe, Dr. Umish Srivastva[2]

[1] Hypace Solution Limited

[2] Indian Oil Corporation Limited, R&D Centre, Sector-13, Faridabad



ABSTRACT

Polymer Electrolyte Membrane Fuel Cell (PEMFC) technology offers a practical pathway for clean mobility requiring long operating duration, high energy utilisation and rapid refuelling. As hydrogen mobility expands across logistics, aerial systems and other high-utilisation applications, fuel-cell powertrains can create new and distributed demand for hydrogen, supporting India's emerging hydrogen ecosystem. However, mobile platforms require compact and lightweight systems, effective thermal and flow management, and reliable power delivery. To address these needs, Hypace Solutions has indigenously developed in India a compact air-cooled PEMFC system featuring a patented stack architecture, design-protected features and CDR-flow technology for improved flow management, thermal control and integration.

The development has resulted in **a 1 kW air-cooled PEMFC stack, successfully integrated and operated in a hydrogen-powered UAV**. The working system establishes the application of indigenously developed fuel-cell technology in aerial mobility and provides a platform for evaluating performance, endurance and reliability under practical operating conditions, supporting further optimisation for demanding missions.

Hydrogen-powered UAVs are particularly relevant for last-mile logistics, time-sensitive delivery, defence and surveillance, and remote operations. Extended operation with rapid refuelling can reduce downtime and improve vehicle utilisation, making hydrogen suitable for applications where endurance and mission flexibility are important.

Building on the 1 kW system, Hypace Solutions is **developing a 2.5 kW fuel-cell system** and exploring additional power levels for diverse mobility requirements. The broader objective is to establish a scalable, India-developed hydrogen powertrain platform for UAVs across 15-100 kg MTOW classes, while extending the technology towards hydrogen-powered 2- and 3-wheeler land logistics. Scaling these applications can create growing domestic demand for green hydrogen, enable onsite hydrogen generation and utilisation, strengthen energy security and global competitiveness, and accelerate the localisation of fuel-cell technology, with Hypace's indigenously developed fuel-cell technology contributing to the broader goals of the National Green Hydrogen Mission (NGHM).

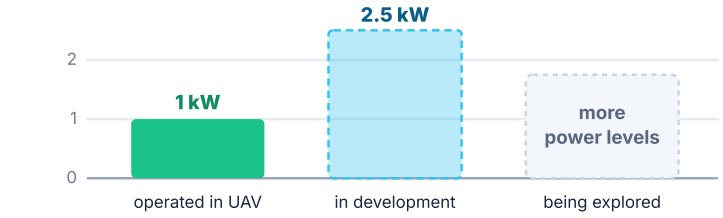
1 kW
air-cooled PEMFC stack, operated in a hydrogen-powered UAV

2.5 kW
fuel-cell system in development

15-100 kg
UAV MTOW classes targeted for the platform

2/3 wheelers
hydrogen-powered land logistics, next extension

Fuel-cell system power roadmap (kW)



Target applications

UAVs, 15-100 kg MTOW

- Last-mile logistics
- Time-sensitive delivery
- Defence, surveillance
- Remote operations

Land logistics

- Hydrogen-powered 2- and 3-wheelers

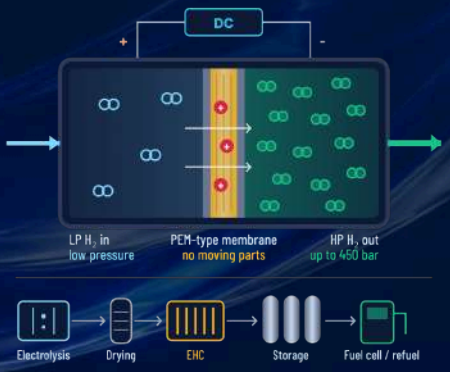
HOW IT WORKS

1. **H_2 storage** — on-board cylinder
2. **Air-cooled stack** — CDR-flow, patented
3. **Power delivery** — to UAV powertrain
4. **Scale up** — 2.5 kW, 2/3-wheelers

KEYWORDS PEMFC · Hydrogen Fuel Cell · Air-Cooled Fuel Cell · Hydrogen UAV · Aerial Mobility · CDR Flow · Last-Mile Logistics · Hydrogen Powertrain · Clean Mobility · MTOW · Green Hydrogen · NGHM

HYDROGEN STORAGE · COMPRESSION | REFINERIES · REMOTE MICROGRIDS

Next-Generation Zero-Moving-Parts Electrochemical Compression and Modular Hybrid Storage: Advancing Energy Autonomy for Critical Hydrocarbon Infrastructure, Refineries, and Remote Tactical Microgrids



Eisen Picardo
Zeus and Hachiman P Ltd, 301, Mahant Chambers, Rd No 34, Wagle Estate, Thane 400604 · On behalf of: A European deep-tech hydrogen infrastructure company (name withheld pending technology transfer)
eisen@zeushachiman.com

ABSTRACT

Executive Summary

As India accelerates its transition toward green energy self-reliance and net-zero operational targets within the hydrocarbon and defence sectors, decentralized hydrogen logistics and high-pressure storage remain primary engineering bottlenecks. Traditional mechanical compressors used in refinery hydrogen booster lines and remote distribution networks suffer from high energy parasitism, noise footprints, mechanical wear, and risks of lubricant-induced gas contamination.

This abstract presents a **field-proven, patented electrochemical hydrogen compression and storage platform** designed for decentralised, long-duration energy storage. The technology addresses a critical gap in India's hydrogen ecosystem: the absence of a **standardised, bankable, locally deployable unit** that converts surplus renewable electricity into stored hydrogen and dispatches it on demand - without mechanical compressors, without logistics, and without carbon emissions- integrated with a modular hybrid energy platform (combining short-term battery power smoothing, on-site water electrolysis, and **high-pressure storage up to 450 bar with native Class-6 / 99.9999% purity output)**.

The platform has been deployed in **12 units across Europe**, including at a Global Automotive OEM- Europe and the Paris 2024 Olympics, accumulating approximately 10,000 hours of operating experience.

The Technology: Quokka Decentralised Long-Duration Energy Platform

The platform is a **containerised hydrogen energy storage unit** that integrates:

- **Electrolysis:** Splits water into hydrogen using surplus solar, wind, or grid electricity.
- **Electrochemical compression:** A patented, solid-state compression system with **no moving parts**. It achieves 20× compression ratios, up to 450 bar (expandable to 1,000 bar), and produces ISO 14687 Grade 6 hydrogen natively.
- **Storage:** High-pressure hydrogen storage integrated into the unit.
- **Fuel cell (optional):** Converts stored hydrogen back to electricity for off-grid autonomy.

Pressure logic: Stationary storage typically 300-450 bar; re-fueling configurations can combine 450 bar storage with 350 bar dispensing.

Field Proof and Endorsements

Toyota Motor Europe - Paris 2024 Olympics

Deployment: 3 units deployed · 50 vehicles powered · 1-minute refills

Economic Case: Bankable Returns Today

Total Cost of Ownership (10 MWh backup over 25 years):

Configuration	TCO
100% LFP Battery	€5,000k
5% LFP + 95% H_2 (Quokka)	€800k

6× cost advantage for long-duration applications.

Conclusion: The Missing Layer of Energy Infrastructure

Refinery & Midstream Integration: In petroleum refineries and petrochemical complexes, where hydrogen purity and reliability are paramount, electrochemical compression eliminates oil contamination risks, minimizes maintenance down-time, and provides an inherently safe, scalable pathway for midstream hydrogen boosting and utility management.

High-Altitude & Remote Defence Microgrids: For isolated defence and border outposts where conventional fuel supply chains face severe logistical vulnerabilities, the modular system decouples power from duration - utilizing stored hydrogen mass to guarantee 12 to 48+ hours of continuous, silent, emission-free power without relying on fragile grid extensions or vulnerable diesel supply loops.

This technology represents the missing layer of energy infrastructure: a standardised, bankable, long-duration energy storage unit that is decentralised, decarbonised, and deployable at scale. It has been proven in Europe with Tier-1 clients (Toyota, Paris 2024, Groupama). It holds 4 patent families and 50 R&D person-years. It is now ready for technology transfer and manufacturing localisation in India.

Condensed from the author's abstract for this one-page compendium.

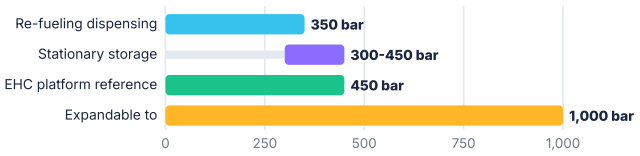
450 bar
high-pressure storage, expandable to 1,000 bar

99.9999 %
native Class-6 hydrogen purity output

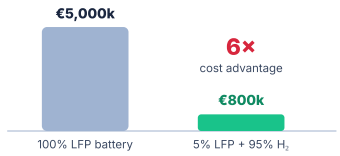
12
units deployed across Europe, incl. Paris 2024 Olympics

~10,000 h
operating experience · 4 patent families

Hydrogen pressure chain · bar

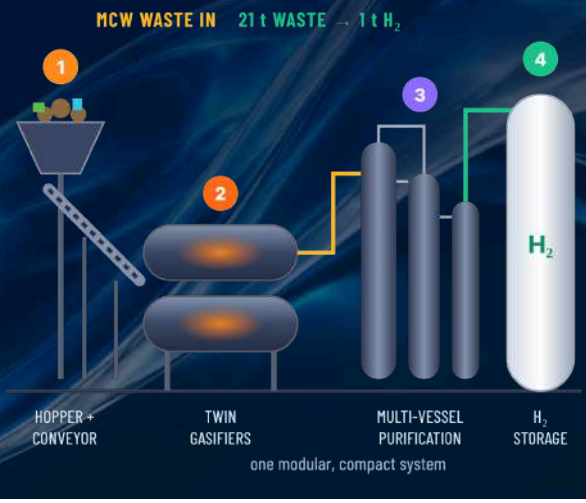


TCO, 10 MWh backup over 25 years



WASTE TO HYDROGEN | GASIFICATION · MODULAR SYSTEM

Integrated Waste (MCW, Municipal Corporation Waste) to Hydrogen Production System



Omkar V Shinde
Shivaji Institute of Engineering

ABSTRACT

Project: Integrated Waste-to-Hydrogen Production System.

The growing need for sustainable waste management and clean energy solutions presents an opportunity to combine MCW waste processing and hydrogen production into an integrated system. The combined Waste-to-Hydrogen Production System addresses many challenges by combining MCW waste, waste feeding, gasification, gas purification and hydrogen storage.

The system consists of four integrated stages. 1. A vertically arranged waste-feeding section includes a hopper and an inclined conveyor mechanism to introduce the MCW waste into the system. 2. A dual horizontal cylindrical gasification reactor configuration is used for processing the material. 3. The purification and separation section consists of multiple vertically oriented cylindrical vessels connected by piping systems. 4. The separated hydrogen is routed in a continuous pipeline to a vertically positioned cylindrical hydrogen storage. **To produce 1 ton (1,000 kg) of pure hydrogen, the gasification machine requires 21 tons of MCW waste**

The Novelty of the concept lies in the modular arrangement of the individual process stages in a single system. The design provides a compact industrial layout, effective utilisation of the installation space, scalability, maintainability, and unique configuration for commercial deployment. The vertically aligned feeding arrangement, twin-reactor configuration, multi-vessel purification module, and integrated hydrogen storage arrangement are combined into **a unified system architecture**.

The proposed system is aimed at organisations and industries to introduce a combined approach to waste processing and hydrogen generation, when a compact and scalable infrastructure is beneficial. The modular architecture can be expanded and adapted.

The project is supported by a design application for the Integrated Waste-to-Hydrogen Production System, with the novelty of the design lying in its visual shape, configuration, arrangement, and ornamental appearance. The integrated approach combines multiple systems into a single industrial system.

Ultimately, the system is to contribute to the development of clean energy, enhanced waste utilisation and sustainable industrial infrastructure. By introducing a combined waste processing and hydrogen-generation system that is compact and scalable, the project supports the overarching goals of sustainability and clean-energy development.

21 t
of MCW waste to produce 1 ton (1,000 kg) of pure hydrogen

4 stages
feeding, gasification, purification, hydrogen storage

Twin
dual horizontal cylindrical gasification reactors

Modular
compact, scalable layout that can be expanded and adapted

Waste to hydrogen (tons)

21 t MCW waste
each square = 1 ton

1 t (1,000 kg) pure H_2

Novelty of the modular layout

- **Compact layout** — effective use of installation space
- **Scalability** — modules expanded and adapted
- **Maintainability** — stages arranged as modules
- **Unified architecture** — four stages in a single system
- **Supported by a design application** — shape, configuration, arrangement, ornamental appearance

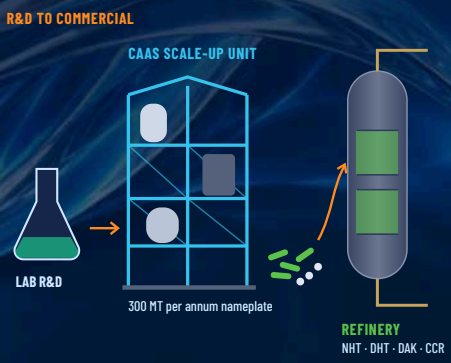
HOW IT WORKS

1. **Feed** — hopper + inclined conveyor
2. **Gasify** — twin horizontal reactors
3. **Purify** — multi-vessel separation
4. **Store** — vertical H_2 storage

REFINERY CATALYSTS | MAKE IN INDIA · CATALYST SCALE-UP

Indigenous Hydro Processing-Based Refinery Catalyst Manufacturing for Make in India: From R&D to Commercialization

Dr. Narasimharao Kanna, Dr. Santhosh Kotni, Dr. Vasudev Shetti, Dr. G. Valavarasu, Mr. Sriram S, Mr. V K Maheshwari
HP Green R&D Centre, Hindustan Petroleum Corporation Limited, Bengaluru-560067



ABSTRACT

Refinery catalysts are critical enablers of efficient and reliable refinery operations, while dependence on imported catalyst technologies and products can pose challenges related to supply security, cost competitiveness and technological self-reliance. In the context of Make in India and Atmanirbhar Bharat, development of indigenous catalyst technologies and their successful scale-up from R&D to manufacturing scale is therefore of strategic importance

This paper presents the journey of in-house development, scale-up and manufacturing of hydroprocessing-based refinery catalysts at HPCL, demonstrating the transition from R&D innovation to industrial-scale catalyst production. The work encompasses the establishment and utilization of an in-house **Catalyst and Adsorbent Scale-up Unit** (CAAS) for translating laboratory developed catalyst technologies into larger scale manufacturing.

A key achievement of the atmanirbharta has been the successful scale-up and in-house manufacturing of **30 MT of Naphtha Hydrotreating (HP-NHT) catalyst and 30 MT of Diesel Hydrotreating (HP-DHT) catalyst**, addressing two critical catalyst requirements in a modern refinery. NHT catalysts play an essential role in removing sulphur, nitrogen and other contaminants from naphtha streams, thereby producing suitable feed for downstream catalytic reforming and other refinery processes while protecting downstream catalysts. DHT catalysts are fundamental to the production of low-sulphur diesel and enable refineries to meet stringent fuel-quality and environmental requirements through effective removal of sulphur and other undesirable heteroatom-containing compounds. The in-house manufacturing of these catalysts therefore contributes directly to refinery reliability, fuel-quality compliance and security of catalyst supply.

The programme was further extended to the manufacture of **10 MT** of **HP-DAK** catalyst, supporting the production of de-aromatised kerosene/solvent products. De-aromatisation technology is important for producing specialty hydrocarbon streams with improved product characteristics and reduced aromatic content, thereby enabling value addition from refinery streams. In addition, **1 MT** scale-up of **CCR** catalyst has been undertaken, demonstrating the capability of the indigenous scale-up infrastructure to extend beyond conventional hydrotreating applications to catalysts supporting continuous catalytic reforming (CCR), an important refinery process for production of high-octane reformate and hydrogen.

For a rapidly growing refining nation such as India, indigenous manufacturing of refinery catalysts has strategic importance beyond the catalyst itself. Catalysts are continuously consumed and replaced in refinery operations, making assured availability, supply-chain resilience, cost competitiveness and timely catalyst deployment important for maintaining refinery throughput and operational flexibility. Developing domestic manufacturing capability reduces dependence on imported catalysts and associated external supply-chain risks, while creating an indigenous ecosystem encompassing catalyst R&D, process scale-up, manufacturing, quality assurance and refinery application. The successful scale-up of **NHT, DHT, HP-DAK and CCR** catalysts therefore represents more than a manufacturing achievement; it demonstrates a research-to-commercialization pathway for building indigenous technology capability and strengthening India's self-reliance in critical refinery technologies, in line with the objectives of Make in India and Atmanirbhar Bharat.

The Catalyst and Adsorbent Scale-up (CAAS) plant, with a **nameplate capacity of 300 MT per annum**, provides an important bridge between laboratory-scale catalyst development and industrial-scale manufacturing. The facility enables systematic scale-up and production of different refinery catalysts while maintaining consistency and quality at larger scales. This indigenous infrastructure strengthens the R&D-to-commercialization pipeline and provides a platform for translating internally developed catalyst technologies into commercially relevant quantities

The work represents an important step towards technology self-reliance in refinery catalysts, reducing dependence on imported products and supporting India's objectives of Make in India, Atmanirbhar Bharat and technology-led growth of the refining sector.

30 MT
HP-NHT catalyst manufactured

30 MT
HP-DHT catalyst manufactured

10 MT
HP-DAK catalyst · 1 MT CCR

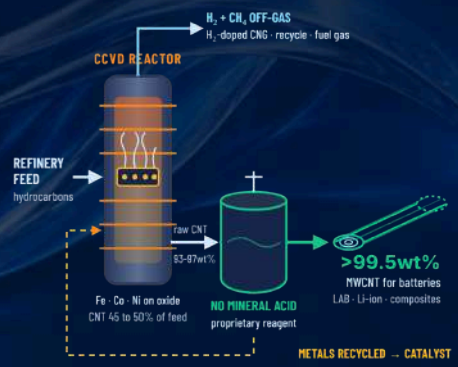
300 MT/yr
CAAS plant nameplate capacity

Indigenous catalyst scale-up · MT manufactured at HPCL

KEYWORDS Indigenous catalyst technology | Make in India | Atmanirbhar Bharat | hydroprocessing catalysts | naphtha hydrotreating | diesel hydrotreating | de-aromatisation | catalyst scale-up | catalyst manufacturing | research to commercialization

CARBON NANOTUBES | BATTERY MATERIALS · REFINERY FEEDSTOCKS

Scalable Synthesis and Industrial Non-mineral Acid Purification of High Purity Multiwall Carbon Nanotubes from Refinery Feedstocks



P. Mohana Sundaram, S. Bhanu Murthy, N. Seshubabu, Ravi Prakash Gupta, Alex Pulikottil, Umish Srivastava
Indian Oil Corporation Limited R&D Centre, Sector-13, Faridabad, Haryana

ABSTRACT

The discovery of novel carbon allotrope, carbon nanotube (CNT) has opened up variety of applications because of its unique and extraordinary properties. Indian Oil R&D Centre has developed an innovative, sustainable technology for the large-scale production of high-purity Multi-Walled Carbon Nanotubes (MWCNTs) from hydrocarbon streams. This proprietary process transitions low value hydrocarbon feedstocks into valuable carbon nanomaterials. The detailed technology summary covering synthesis, purification, catalyst recycling, and its application across industrial energy sectors. Due to exceptional electrical, mechanical, and thermal properties, CNTs are preferred materials for numerous applications such as Energy storage devices like lithium-ion batteries, Lead acid batteries, hydrogen storage, and other applications in electronic devices, chemical/electrochemical and biosensors, transistors, electron field emitters, electrostatic discharge (ESD), electrical-shielding applications.

In-house Development of MWCNT Process Technology

MWCNTs are grown by modified catalytic chemical vapor deposition (CCVD), where a hydrocarbon feedstock is decomposed over a supported transition-metal catalyst (typically Fe, Co, Ni, or combinations, on a support oxides) at high temperature. Indigenizing this catalyst rather than importing is selecting active metals and support chemistry to control tube diameter, wall number, and yield by optimizing metal-loading and calcination conditions to maximize carbon yield per gram of catalyst & tailoring catalyst particle size/morphology for the CVD reactor configuration used. The process yields **CNT 45 to 50% with respect to feed quantity**, and the valuable by-products are Hydrogen and Methane, and some fraction of lighter hydrocarbons. The methane and hydrogen combinedly used as Hydrogen doped CNG after compression, or this gas stream can be recycled back into the reactor to enhance the CNT yield. Alternatively, the off gases of CNT process can be integrated to refinery heating application as fuel gas. The obtained CNT is of 93-97wt% purity depends on process conditions, catalyst type, and feedstock selection. The as produced MWCNTs having residual catalyst impurities, and these must be removed for battery electrode applications.

CNT Purification

IOCL's process adopted new approach to purify the raw CNTs without using any mineral acid-based treatment employing proprietary reagent at optimal process conditions to yield **purified CNTs with purity >99.5wt%**.

Catalyst Recycling

The value proposition is process economics rather than treating spent catalyst/metal residue as waste. The dissolved metal streams emanated from purification streams recovered and recycled for catalyst preparation. This has led to lower both raw-material cost and minimizing the waste generation. By this loop, the process is sustainable and eco-friendly compared to available metal-intensive CVD process.

MWCNTs for Advanced Batteries

Lead-acid batteries (LAB): When MWCNTs added as a conductive additive in the negative active material (NAM), performance shown is high charge-transfer activity and improved cycle life.

Li-ion batteries: MWCNTs added in cathodes of Li-ion shown improved performance of high-rate capability (Fast Charging, high-rate discharge), and improved cycle life.

Polymer composites: MWCNTs disperse in polymer matrices enabling their use as reinforcing/conductive fillers in engineering plastics and composites for high thermal conductive and electrical conductive applications.

MWCNT Market Potential In India

In India, Li ion battery cell manufacturing is emerging to cater the Indian EV market, growing data centers, BEES integration to solar farms, and other electronic applications. India's domestic Li-ion cell manufacturing capacity is projected to reach between 150 GWh and 220 GWh annually by 2030, driven by government incentives and private investments. Hence MWCNT is expected to gain significant demand (~300-600 Tons per annum) to cater only Li-ion applications.

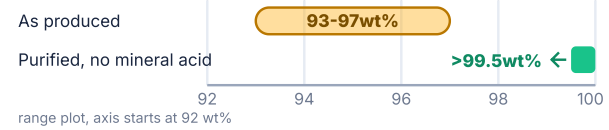
45-50%
CNT yield with respect to feed quantity

>99.5wt%
purity after non-mineral acid purification

150-220 GWh
India Li-ion cell capacity by 2030

~300-600 TPA
MWCNT demand, Li-ion only

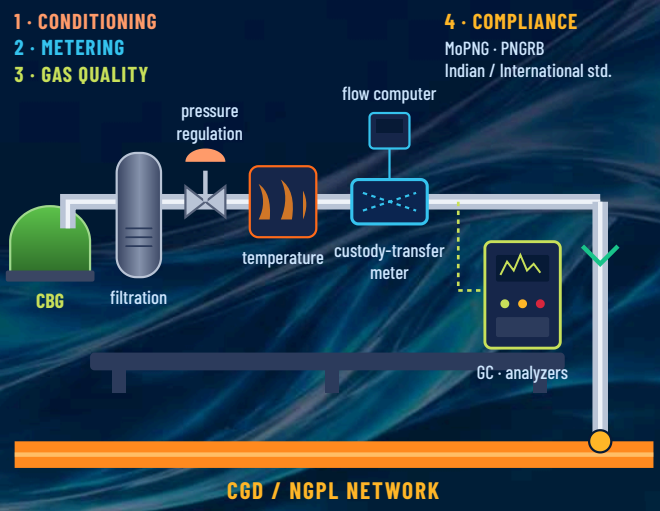
MWCNT purity · wt%



Where the feed goes · CCVD outputs

CBG · GAS GRID INJECTION | CUSTODY TRANSFER · GAS QUALITY

CBG Injection into CGD/NGPL Networks: Technology, Measurement & Quality Assurance



Deepak Purohit, Business Director, Emerson Process Management
Stephen R Bhowmick, Associate Director-Sales, Emerson Process Management
Sanjeev Rai, Sr Manager- Sales, Emerson Process Management

ABSTRACT

India is expanding the use of Compressed Biogas (CBG) as a renewable gaseous fuel, with increasing focus on integrating CBG into existing natural gas infrastructure. The successful integration of CBG requires particular attention to **gas conditioning, custody-transfer metering and gas-quality measurement** to ensure safe, reliable, and compliant injection.

This paper focuses on the key considerations for CBG injection into CGD and NGPL networks, covering:

- **Gas Conditioning**: filtration, pressure regulation, maintaining temperature required for pipeline-injection.
- **Custody-Transfer Metering**: accurate flow measurement, meter selection and sizing, metering skid configuration, flow computers, energy measurement, calibration/proving and uncertainty management, Metrology Approvals.
- **Gas Quality Measurement**: online BTU/Energy measurement and Monitoring of Impurities; selection and integration of GCs and dedicated gas analyzers; measurement performance, calibration/validation, and data management.
- Regulatory Compliance & Best Practices: alignment with applicable MoPNG, PNGRB and relevant Indian/International standards, together with practical implementation experience.

The paper will present **a recommended system architecture and practical implementation approach** for reliable CBG injection, with emphasis on maintaining gas quality, measurement integrity, operational safety and long-term reliability of the existing CGD/NGPL infrastructure.

Safe
reliable and compliant injection into existing gas networks

Custody transfer
metering: flow computers, energy measurement, proving

Online BTU
energy measurement and monitoring of impurities

MoPNG · PNGRB
alignment with Indian/International standards

Recommended injection architecture

CBG plant → Gas conditioning (filter · P · T) → Custody transfer (meter · FC) → Gas quality (GC · analyzers) → CGD / NGPL

calibration · validation · data management

Regulatory compliance: MoPNG · PNGRB · Indian / International standards

Emphasis of the approach

- **Gas quality** — energy · impurities
- **Measurement integrity** — uncertainty · proving
- **Operational safety** — safe, compliant injection
- **Long-term reliability** — existing CGD/NGPL assets

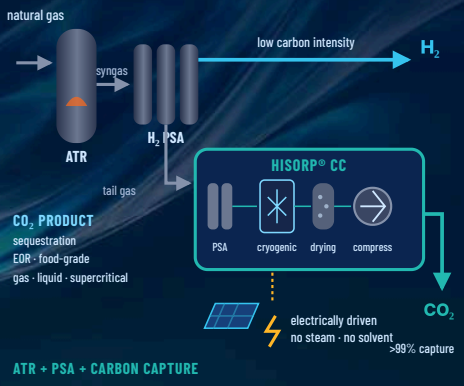
HOW IT WORKS

1. **Condition** — filter, regulate, temperature
2. **Meter** — custody-transfer flow, energy
3. **Analyse** — GC, impurity analyzers
4. **Inject** — into CGD / NGPL networks

CARBON CAPTURE · CCS | LOW-CARBON HYDROGEN

Powering India's Low-Carbon Future with Carbon Capture

Sumit Ghiya and Ujjaval Modi (Linde)



ABSTRACT

Despite the increasing efforts to harness renewable energy, the global economy remains heavily reliant on fossil fuels, leading to a continuous rise in global CO_2 emissions. To mitigate these emissions and curb climate change, carbon capture and storage (CCS) emerges as a pivotal measure. It is crucial for industry segments such as oil & gas, (petro-) chemicals, and steel production, as well as for hard-to-abate sectors like cement production and waste incineration.

In this talk, we focus on hydrogen production with low carbon intensity by utilizing CCS and discuss valuable insights from two world-scale carbon capture projects currently under execution, where Linde is providing its innovative HISORP® CC technology for removing and purifying CO_2 with minimal total costs of ownership.

The first project is the recently announced DOW's Path2Zero project in Alberta, Canada, for decarbonization of ethylene production. It aims to achieve a **CO_2 removal of over 2 million tons per annum (tpa)**. The applied hydrogen production is based on autothermal reforming (ATR), the HISORP® CC unit is placed downstream of the hydrogen purification pressure swing adsorption plant (PSA), achieving superior **CO_2 capture rates of over 99%**. This setup ensures maximum availability of hydrogen production and the lowest hydrogen carbon intensity, with the option of additional hydrogen production.

The second project demonstrates the effectiveness of HISORP® CC for parallel H_2 and CO_2 recovery and purification in the oil & gas upstream sector, such as sour gas treatment plants, as recently demonstrated in ADNOC's Hail & Ghasha project in the UAE. This project targets to capture 1.5 million tpa, contributing to ADNOC's goal of net zero emissions.

In both projects, the HISORP® CC technology was the most competitive solution in benchmarking for the CO_2 capture unit. Originally designed to minimize the carbon footprint of hydrogen production plants, it combines proven technologies such as PSA, cryogenic purification, drying, and compression.

Above examples demonstrate that HISORP® CC is highly adaptable to various feed gas sources, capable of handling different CO_2 concentrations and flows, and producing CO_2 in gaseous, liquid, or supercritical states with purities ranging from low (e.g. for enhanced oil recovery (EOR)) to high (e.g. for sequestration) or food-grade quality.

One of the main advantages of HISORP® CC is its electrically driven carbon capturing approach, which can be powered entirely by renewable energy. It exhibits high reliability and stability against feed gas changes in composition and flows due to the use of proven technologies and yields high cost-benefits by optimal low CAPEX and OPEX compared to other carbon capture technologies. Additionally, HISORP® CC does not require steam for solvent regeneration, eliminating the need for solvent make-up, handling, and solvent decomposition removal and waste treatment.

In summary, HISORP® CC is a versatile and efficient solution for decarbonizing hydrogen production and combined H_2 and CO_2 recovery from sour gas treatment, making it a perfect technology for industries aiming to reduce their carbon footprint and contribute to a sustainable future.

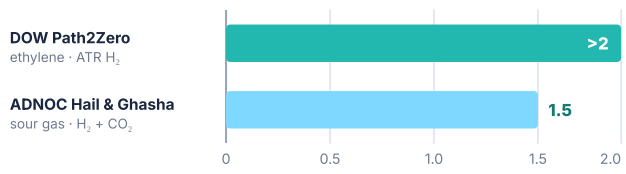
>2 million tpa
CO_2 removal, DOW's Path2Zero, Alberta, Canada

>99 %
CO_2 capture rate downstream of hydrogen PSA

1.5 million tpa
CO_2 capture target, ADNOC's Hail & Ghasha, UAE

No steam
electrically driven; no solvent regeneration

Two world-scale projects, CO_2 million tpa



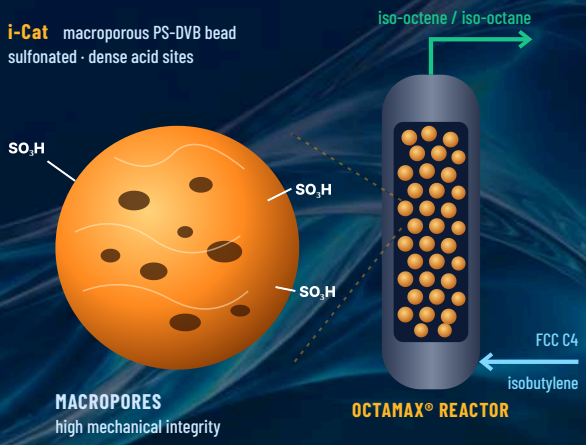
Flexible CO_2 product

KEYWORDS Carbon Capturing | low carbon intensive hydrogen | low carbon solutions

REFINING CATALYST · C4 UPGRADING

OCTAMAX® · INDIGENOUS TECHNOLOGY

Commercialization of i-Cat^{OM}: Indigenous Solid-Acid Dimerization Catalyst for the Octamax® Process



Vishal Goel, Prosenjit Maji, Priyanka Luthra, Pushkar Varshney, Gurmeet Singh, S. Saravanan, Rajesh M Badhe, S. K. Das, Alex C Pulikottil, Kaushik Singha

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ABSTRACT

Upgrading low-value refinery C4 streams into high-octane gasoline blendstocks without hazardous liquid acids (such as HF or H_2SO_4) is critical for complying with stringent, low-olefin, low-aromatic fuel mandates like BS-VI and Euro-VI. To address this, IndianOil R&D developed the novel **Octamax®** process, which selectively dimerizes fluid catalytic cracking (FCC) light olefins, primarily isobutylene, into ultra-high-octane iso-octene/iso-octane.

A key challenge remained in replacing imported solid-acid catalysts to eliminate single-vendor dependency, secure the supply chain, and enhance unit economics. This work highlights the indigenous development, structured scale-up, and commercial validation of **i-Cat^{OM}**, a proprietary and patented sulfonated macroporous poly(styrene-co-divinylbenzene) catalyst tailored specifically for the Octamax® environment.

Catalyst Synthesis and Scale-Up Architecture

- **Tailored Synthesis:** Fabricated via a two-stage route comprising precision suspension polymerization to yield macroporous base beads with high mechanical integrity, followed by controlled sulfonation to incorporate dense active sulfonic acid (-SO_3H) sites.
- **Stage-Gate Scale-Up:** Successfully progressed from bench-scale optimization to a 200 L pilot batch, culminating in commercial-scale 8 m³ production with a domestic toll manufacturing partner.
- **Property Assurance:** Physicochemical metrics, such as cross-linking density, surface area, pore size distribution, mechanical crush strength, and total acid site capacity, were benchmarked to guarantee operational longevity and resist fouling under industrial flux.

Commercial Performance at Mathura Refinery

Deployed in the commercial Octamax® unit at IndianOil's Mathura Refinery, the i-Cat^{OM} catalyst processed over 110 thousand metric tonnes (TMT) of feed with robust operational stability:

- **Yield:** Achieved **20.4 wt%** product yield, exceeding the design specification of 18.1 wt%.
- **Product Quality:** Delivered a blend product Research Octane Number (RON) of **119.5**, significantly outperforming the 113.8 design baseline.
- **Economic Advantage:** Reduced catalyst procurement expenditure by approximately **22%**.

By commercializing i-Cat^{OM}, IndianOil established a fully indigenized process-and-catalyst technology bundle, reinforcing national self-reliance (*Atmanirbhar Bharat*) while creating a robust technical blueprint for adjacent solid-acid downstream transformations.

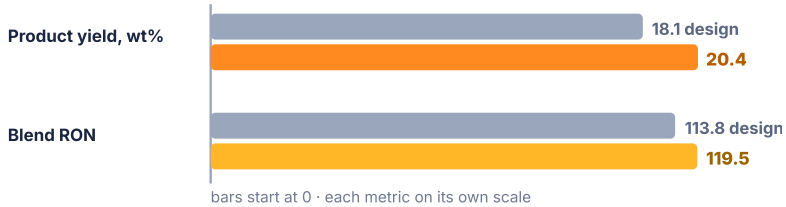
20.4 wt%
product yield vs 18.1 wt% design specification

119.5 RON
blend product octane vs 113.8 design baseline

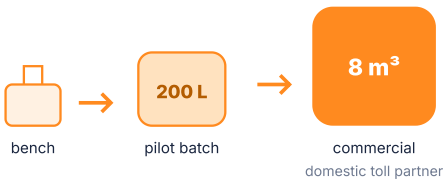
~22 %
lower catalyst procurement expenditure

>110 TMT
feed processed at Mathura Refinery

Mathura commercial unit vs design



Stage-gate scale-up



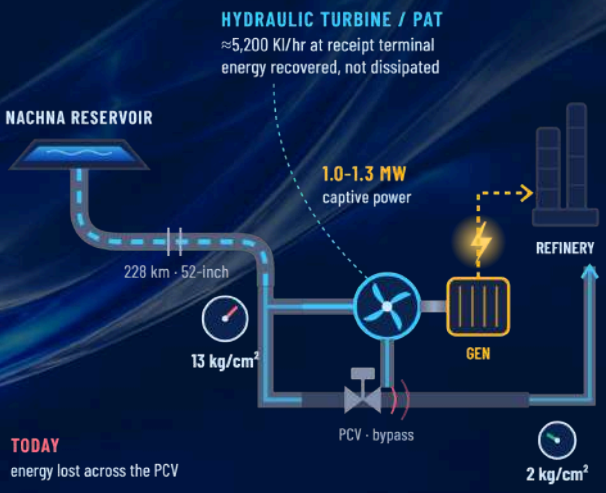
HOW IT WORKS

1. **Polymerization** — macroporous PS-DVB beads
2. **Sulfonation** — dense -SO_3H acid sites
3. **Scale-up** — 200 L pilot to 8 m³
4. **Dimerization** — C4 olefins to iso-octene

ENERGY EFFICIENCY

HYDRAULIC ENERGY RECOVERY · CAPTIVE POWER

HYDRAULIC ENERGY RECOVERY FROM A LONG-DISTANCE RAW WATER PIPELINE FOR CAPTIVE POWER GENERATION



Mohit Bayar, Ramkrishna Singh & Aishwary Singhal
HPCL Rajasthan Refinery Limited (HRRL)

ABSTRACT

Industrial water transmission systems dissipate substantial hydraulic energy across pressure control valves (PCVs), which regulate downstream pressure without recovering the available energy. This paper presents a concept for harnessing this otherwise wasted energy through a hydraulic turbine or pump-as-turbine (PAT) system at the terminal pressure-control location of HPCL Rajasthan Refinery Limited (HRRL).

HPCL Rajasthan Refinery Ltd. (HRRL) is a greenfield 9 MMTPA refinery with an integrated petrochemical complex at Pachpadra, Barmer (Rajasthan). HRRL operates a 228 km long, 52-inch raw water pipeline from Nachna Reservoir to the refinery. The designed flow rate is approximately 5,200Kl/hr. with pressure reduced from 13 kg/cm² to 2 kg/cm² across the Pressure control valve at Receipt terminal. Based on these parameters, the theoretical hydraulic power available is **approximately 1.5 MW**. Considering an overall turbine-generator efficiency of 70-85%, the preliminary electrical generation potential is estimated at **1.0-1.3 MW**, subject to detailed hydraulic assessment and equipment performance validation.

Results and Economic Assessment

Parameter	Estimated result
Theoretical hydraulic power	**1.5 MW**
Expected electrical generation	**1.0-1.3 MW**
Electricity cost	**₹6.50/unit**
Gross annual electricity cost saving	**₹5.0 crore**
Estimated capital investment	**₹3.0-6.0 crore**
Simple payback period	**7-14 months**
First-year gross ROI	**85-175%**

These estimates exclude operating and maintenance costs, taxes and financing expenses and require validation through a detailed feasibility study.

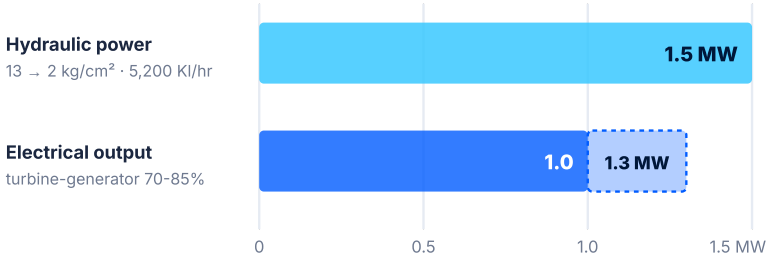
1.5 MW
theoretical hydraulic power available

1.0-1.3 MW
expected electrical generation (turbine-generator efficiency 70-85%)

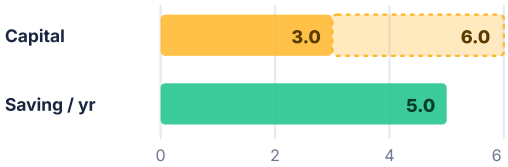
₹5.0 crore
gross annual electricity cost saving at ₹6.50/unit

7-14 months
simple payback period

From pressure to power · per the abstract estimates



Investment vs annual saving · ₹ crore



Simple payback **7-14 months**

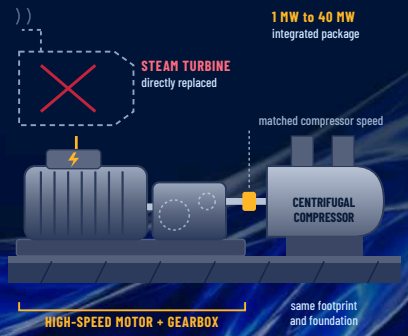
First-year gross ROI **85-175%**

HOW IT WORKS

1. **Nachna Reservoir** — 228 km, 52-inch pipeline
2. **Receipt terminal** — 13 to 2 kg/cm² pressure drop
3. **Turbine or PAT** — instead of PCV dissipation
4. **Captive power** — 1.0-1.3 MW for the refinery

ELECTRIFICATION · NET ZERO | COMPRESSOR DRIVES · BROWNFIELD

Integrated High-Speed Motor Solution for Brownfield Electrification of Compressor Drives in Refineries: A Step Towards Net Zero



By: **Christian Honold**, Senior Product Manager, Voith BHS Turbo Gears, Germany
Rajdeep Roy, DGM, Industry Sales, Voith Turbo India

ABSTRACT

The global drive toward decarbonization, improved energy efficiency, and sustainable energy utilization is accelerating the adoption of innovative technologies across the Oil & Gas industry. As refinery operators pursue ambitious Net Zero targets, the electrification of energy-intensive process equipment is emerging as a key strategic initiative.

Among the major power consumers in downstream refineries and petrochemical complexes, centrifugal compressors account for a significant share of overall energy consumption, second only to process heaters. Electrifying existing compressor drive trains currently powered by steam turbines presents a substantial opportunity to improve plant efficiency, reduce greenhouse gas emissions, and lower operating costs.

Leading Indian Oil & Gas companies, including IOCL, BPCL, HPCL, and MRPL, are actively evaluating the replacement of steam turbine-driven compressor trains with electric drive systems. Based on current market trends, an estimated **25-30 compressor drive electrification projects are expected across India over the next 4-5 years**, representing a significant opportunity in the refinery modernization and decarbonization space.

Key Requirements for Brownfield Compressor Drive Conversion

Successful electrification of existing compressor trains requires a solution capable of addressing several critical project constraints:

- The electric drive system must directly replace the existing steam turbine while fitting within the available footprint and existing foundation geometry, requiring minimal civil or mechanical modifications.
- The solution should match the compressor operating speed without introducing additional equipment into the drive train.
- Project execution must align with the turnaround schedule of the process unit, demanding a compact design, simplified installation, and minimal downtime.

Voith E-Pack DS: Enabling Efficient Brownfield Electrification

Voith addresses these challenges through its **E-Pack DS Integrated High-Speed Motor Solution**, designed specifically for seamless replacement of steam turbine drives in brownfield applications.

The Voith E-Pack DS combines **a high-speed electric motor and precision gearbox into a fully integrated synchronized package**, delivering the required compressor speed while maintaining a compact footprint. This approach minimizes modifications to existing foundations, piping, and auxiliary systems, significantly reducing implementation complexity and project risk.

Key Advantages

- Direct steam turbine replacement with minimal plant modifications
- Compact integrated design suitable for space-constrained brownfield installations
- Reduced technical interfaces, resulting in improved reliability and simplified project execution
- Lower total installed cost through a streamlined drive train architecture against complex high speed motor technology
- High operational efficiency, supporting refinery decarbonization objectives
- Power range from 1 MW to 40 MW, suitable for a wide range of centrifugal compressor applications
- Shorter turnaround execution time, enabling installation within planned shutdown windows

Supporting the Net Zero Journey

By replacing steam turbine-driven compressors with high-efficiency electric drive technology, refinery operators can significantly reduce steam demand, improve overall energy utilization, and support corporate sustainability goals. The Voith E-Pack DS provides a practical and technically robust pathway for brownfield electrification, helping refiners accelerate their transition toward lower-carbon operations while maintaining process reliability and operational flexibility.

Voith's integrated high-speed motor technology represents a future-ready solution for refinery compressor modernization, combining performance, simplicity, and sustainability in a single package.

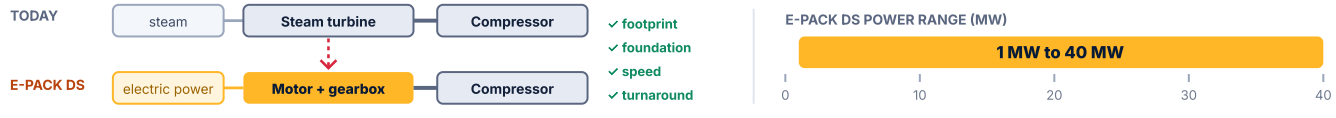
25-30
compressor drive electrification projects expected in India

4-5 years
window for these projects

1-40 MW
E-Pack DS power range

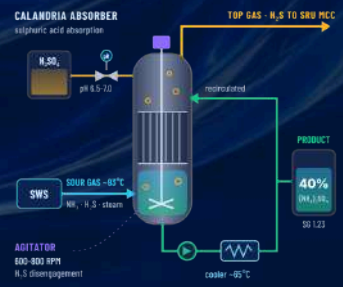
Direct
steam turbine replacement, minimal plant modifications

Brownfield conversion · same foundation, same speed · power range 1 MW to 40 MW



SOUR GAS · AMMONIA RECOVERY | SRU RELIABILITY · WASTE TO VALUE

Recovery of Ammonia from Sour Gas and Conversion to 40% Ammonium Sulphate (Value-Added Product)



S. ARUN, B.Sc., B.Tech., DQCI
Process Engineering / Operations, Gujarat Refinery

ABSTRACT

Petroleum refineries generate substantial quantities of sour gas from Sour Water Stripper (SWS) units containing ammonia, hydrogen sulphide, steam, and traces of hydrocarbons. Conventionally, the ammonia-bearing sour gas is routed to Sulphur Recovery Units (SRU), where ammonia destruction creates operational challenges such as elevated Main Combustion Chamber (MCC) temperature, exchanger choking, increased back pressure, catalyst poisoning, corrosion, and occasional unit trips.

The present work proposes and validates an innovative process for recovering ammonia from sour gas and converting it into a value-added product in the form of 40% liquid ammonium sulphate using sulphuric acid absorption. Pilot-scale studies demonstrated efficient ammonia absorption under controlled pH, temperature, and circulation conditions. The developed process eliminates solid handling complexity associated with conventional ammonium sulphate crystallization routes while simultaneously improving SRU reliability.

Economic analysis indicates a potential annual revenue of approximately **₹116 crore with a net profit of nearly ₹92 crore** for **Gujarat Refinery** operating conditions. The process offers significant environmental and operational advantages including waste vaporization, reduced thermal stress on SRU systems, reduction in ammonium sulphide deposition, and improved refinery throughput.

Chemical Reaction

The process is based on the following exothermic reaction:

$$2NH_3 + H_2SO_4 \rightarrow (NH_4)_2SO_4 \ (\Delta H = -687 \ kJ/mol)$$

Process Description

- Sour gas at ~93°C enters a **calandria-type absorption tower**
- Gas is contacted with **sulphuric acid**
- Ammonia reacts to form **ammonium sulphate solution**
- Bottom liquid (~40%) is:
  - Cooled to ~65°C
  - Recirculated to absorber
  - Partially bled as product by using gravity valve.

Economic Analysis

Operating Cost

- Sulphuric acid: ₹19.2 Cr/year
- Utilities: ₹2.3 Cr/year
- Other costs: ₹2.6 Cr/year
- Total Cost: ~₹24.1 Cr/year

Net Profit → ~₹92 Cr/year

Capital Investment → ~₹32 Cr

Payback Period → **~0.35 years (~4 months)**

Key Innovations & Simulation Results;

These findings indicate that temperature and agitation are critical parameters governing H_2S removal efficiency in the proposed ammonium sulphate production process. Based on pilot observations, maintaining absorber temperature near 60-65°C with adequate agitation is recommended for industrial-scale implementation to ensure high-purity liquid ammonium sulphate production.

Operational Advantages

- Eliminates ammonia load on SRU
- Reduces:
  - MCC temperature (from ~1300°C to ~850°C)
  - Catalyst poisoning
  - Corrosion issues
- Prevents exchanger choking
- Improves plant load by 12-16%

Conclusion

The project demonstrates a highly profitable, technically feasible, and environmentally beneficial solution for ammonia recovery from sour gas. Every one mole ammonia recovery can be reduced four moles of carbon di oxide emission. Global level implementation led to considerable activity towards NetZero concept.

Condensed from the author's abstract for this one-page compendium.

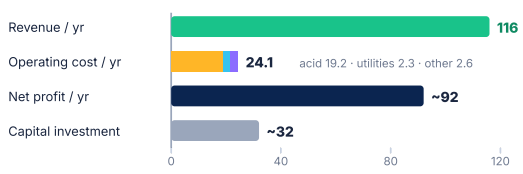
₹116 Cr/yr
potential annual revenue at Gujarat Refinery

₹92 Cr/yr
net profit, on ~₹32 Cr capital investment

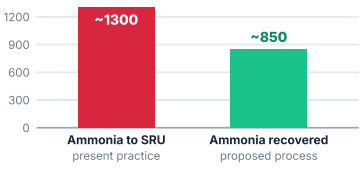
~4 months
payback period (~0.35 years)

12-16 %
improvement in plant load

Economics · ₹ crore, Gujarat Refinery



MCC temperature · °C, SRU



KEYWORDS Sour gas | Ammonium sulphate | Sulphur Recovery Unit | Ammonia recovery | Refinery waste vaporization | Sustainable refinery operation

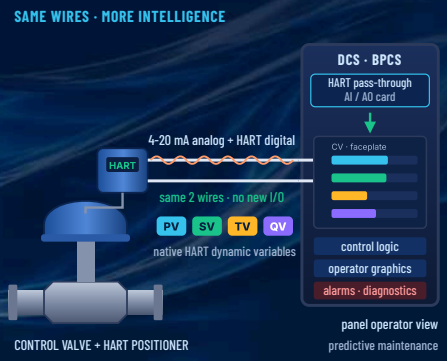
SMART INSTRUMENTATION · HART

PREDICTIVE MAINTENANCE · BROWNFIELD DCS

Same Wires, More intelligence: Harnessing HART Dynamic Variables in DCS control logic for Diagnostics and Predictive Maintenance by panel operators

Mr. Nirmalya Nandi, Mr. Anup Kumar Nayak, Mr. Praveer Kumar Singh, Mr. Abhay Singh

BPCL, Bina Refinery (Instrumentation Maintenance)



ABSTRACT

Executive Summary

HART-enabled field instruments installed across refineries generate multiple digital process and diagnostic variables in addition to the conventional 4-20 mA signal. In most installations, these variables are not used in process control and are accessible only through handheld communicators or asset management systems (AMS). This innovation directly integrates native HART dynamic variables, Primary Variable (PV), Secondary Variable (SV), Tertiary Variable (TV) and Quaternary Variable (QV), into the Basic Process Control System (BPCS) using the existing HART pass-through capabilities of Emerson DeltaV, Yokogawa CENTUM VP and other DCS platforms. Where installed-system compatibility is confirmed, the solution requires **no additional field hardware, I/O channels, software licences or wiring**.

Industry Challenge

This conventional approach has the following limitations:

- Limited real-time operational visibility of actual field-device condition.
- Fault detection depends on the frequency of maintenance intervention.
- No online mechanism for detecting incipient device failure.

3.2 Advanced usage of HART dynamic variables in DCS control logic.

The proposed methodology utilizes the existing HART pass-through capability available in modern DCS Analog Input/Output cards. Instead of restricting HART communication to maintenance applications, the native dynamic variables (PV, SV, TV and QV) are mapped directly into DCS control modules and become available for operator graphics, alarms, advanced control logic and predictive maintenance.

- Verify that the field instrument and DCS I/O module support HART pass-through communication.
- Configure the Analog Input/Output channel as a HART-enabled channel.
- Map the Primary, Secondary, Tertiary and Quaternary HART variables within the DCS engineering database.

Benefits of the Innovation

Instead of using only the primary analog measurement, each HART device becomes a multi-variable information source. Examples include valve position, actuator air pressure, electronics temperature, device health, Coriolis density, radar signal strength and differential pressure diagnostics.

By adopting this approach, Bina Refinery has integrated HART variables from more than 100 critical field instruments across multiple process units into DCS control logic, thereby **avoiding approximately ₹2 crore in capital expenditure**. Furthermore, enhanced diagnostics enable early detection of degradation in critical field instruments and control valves, helping prevent failures, process-unit upsets and unplanned shutdowns. Avoiding even one such event could prevent an estimated opportunity loss of approximately ₹5 crore.

Benefits in Plant Reliability

- Continuous online equipment health monitoring by Panel Operators.
- Early detection of valve degradation, air leakage and sensor drift.
- Predictive maintenance replacing reactive maintenance.
- Reduced unplanned shutdowns and faster troubleshooting.
- Improved asset availability and maintenance planning.

Conclusion

This first-of-its-kind implementation demonstrates a practical engineering methodology for utilizing native HART dynamic variables within refinery DCS control logic using existing HART pass-through infrastructure. The approach improves plant reliability, enhances process safety, reduces instrumentation footprint, maximizes value from installed smart instrumentation and lowers lifecycle cost without additional hardware investment. It offers a scalable solution for brownfield modernization and provides a foundation for future digital transformation projects.

Condensed from the author's abstract for this one-page compendium.

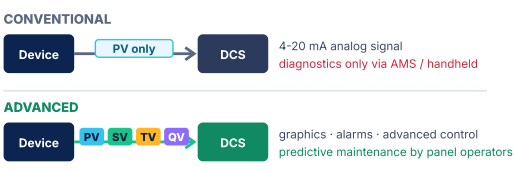
>100
critical field instruments integrated at Bina Refinery

≈₹2 cr
capital expenditure avoided

≈₹5 cr
opportunity loss avoided per prevented upset

No new I/O
no additional field hardware, I/O channels, licences or wiring

What the DCS receives · same wires, before and after

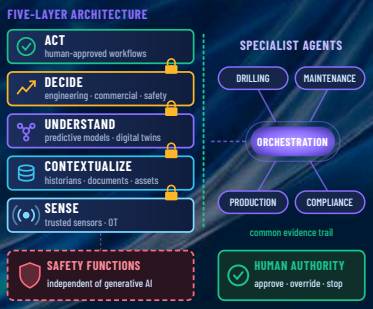


Value reported at Bina Refinery · ₹ crore

AGENTIC AI · INDUSTRIAL AUTONOMY | OIL AND GAS VALUE CHAIN

AI Beyond Chatbots: From Research to Autonomous Industry

S. Mahesh Kumar, GM(Inst.), EIL



ABSTRACT

Artificial intelligence is entering a new phase in which its value is measured not by how convincingly a chatbot answers questions, but by how reliably an industrial system can understand conditions, recommend decisions, and execute bounded actions. For the oil and gas sector, this transition is especially consequential. Exploration uncertainty, complex reservoirs, capital-intensive assets, volatile operating conditions, stringent safety requirements, and pressure to reduce emissions demand intelligence that connects engineering knowledge with real-time operations.

This paper examines the progression from AI research and conversational assistants to agentic, increasingly autonomous industrial systems, and proposes a practical pathway for applying this progression across the upstream, midstream, and downstream value chain.

Traditional industrial automation follows predefined logic, while predictive analytics identifies patterns in historical and streaming data. Generative AI adds the ability to interpret documents, engineering narratives, images, and natural-language instructions. The next step, agentic AI, combines reasoning models with authorized tools, live data, memory, and workflow orchestration so that systems can plan multistep tasks, check results, coordinate specialist models, and escalate exceptions. Autonomy extends this capability into the physical world, where decisions may influence equipment or process set points. Crucially, credible industrial AI is not a single large language model connected directly to a valve. It is a layered system in which verified data, domain-specific models, engineering rules, simulators, and independent protection systems each perform defined functions.

During drilling, intelligent systems can monitor mechanical specific energy, vibration, torque, hydraulics, and downhole measurements to recommend safer operating windows, adjust drilling parameters within approved limits, and improve well placement. These applications create a progression from faster analysis to decision support and, where justified, supervised or conditional autonomy, while retaining engineering judgment for low-confidence or novel situations. Models can combine vibration, temperature, corrosion, pressure, and inspection histories to prioritize maintenance before equipment fails. Methane monitoring, using ground sensors, aircraft, and satellite observations, can help prioritize leak investigation and repair, connecting operational excellence with measurable environmental performance.

This paper proposes a **five-layer operating architecture**: **sense**, through trusted industrial sensors and operational technology; **contextualize**, by connecting historians, maintenance systems, documents, and asset relationships; **understand**, through predictive models, digital twins, and grounded AI reasoning; **decide**, using optimization against engineering, commercial, and safety constraints; and **act**, through human-approved workflows or narrowly authorized control interfaces. An orchestration layer can direct specialist agents for drilling, maintenance, production, and compliance, while a common evidence trail records data provenance, confidence levels, decisions, and outcomes. At each boundary, access permissions and validation gates prevent a plausible AI response from being mistaken for a safe operating instruction.

Safety and reliability determine whether such systems are deployable. Accordingly, AI should be introduced through risk classification, offline testing, simulation, shadow-mode trials, controlled pilots, and continuous monitoring. Safety instrumented functions and existing process-protection layers **must remain independent of generative AI**. Human operators require clear authority to approve, override, or stop actions, with automatic fallback when data become unreliable or operating conditions leave the validated envelope.

A business case for industrial autonomy should move beyond demonstrations and chatbot adoption counts. The strongest implementation strategy begins with high-value, low-consequence decisions; uses domain experts to validate recommendations; and increases automation only after repeatable evidence of safety, reliability, and economic benefit.

Ultimately, the shift from AI research to autonomous industry is a transformation of work, accountability, and engineering practice rather than a replacement of professionals by chatbots. For oil and gas organizations, the strategic question is no longer whether AI can generate an answer, but where it can be trusted to improve a decision, when it may execute an action, and how that action can be verified. The paper concludes that the most realistic near-term future is **human-governed, evidence-based, progressively autonomous operations**, trustworthy data, operational discipline, and measurable field value.

Condensed from the author's abstract for this one-page compendium.

5
layer architecture: sense, contextualize, understand, decide, act

Human governed
evidence-based, progressively autonomous operations

Shadow mode
trials after offline testing and simulation, before controlled pilots

Independent
safety instrumented functions stay separate from generative AI

From automation to autonomy · responsibility, validation and risk grow at each step

Automation	Predictive analytics	Generative AI	Agentic AI	Autonomy
predefined logic	patterns in data	documents · images · language	plan · check · escalate	equipment · set points

KEYWORDS Agentic AI | Industrial Autonomy | Oil and Gas | Digital Twins | Predictive Maintenance | Operational Safety | AI Governance

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