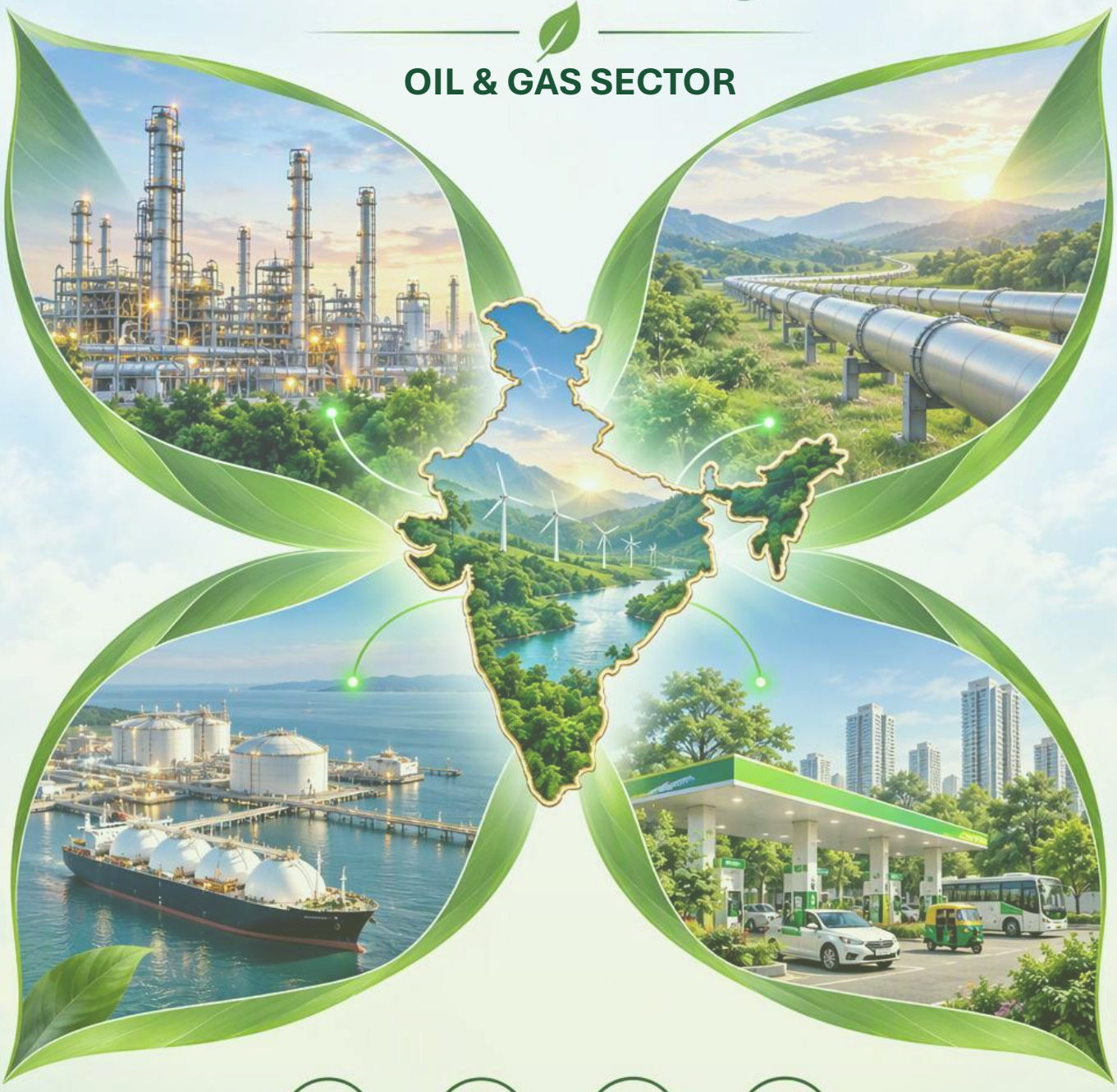
Compendium of Case Studies on Sustainability 2.0

OIL & GAS SECTOR



SUSTAINABILITY CELL

पेट्रोलियम एवं प्राकृतिक गैस विनियामक बोर्ड

Petroleum and Natural Gas Regulatory Board

PREAMBLE

The journey towards sustainable energy practices is not merely an environmental imperative but a strategic transformation that defines the future of the oil and gas industry. As India strides towards becoming a global leader in sustainable development, the petroleum and natural gas sector stands at the forefront of this transformative journey.

This compendium represents a collective testament to the innovative spirit, environmental consciousness, and operational excellence demonstrated by India's Oil and Gas entities. Each case study within these pages narrates a story of commitment—commitment to reduce carbon footprints, optimizing resource utilization, embracing clean technologies, and creating sustainable value for stakeholders and society at large.

The Petroleum and Natural Gas Regulatory Board (PNGRB), as the regulatory authority, recognizes the pivotal role of industry participants in driving sustainable practices across the entire value chain. From midstream to downstream distribution, from pipeline networks to city gas systems, every segment has contributed to this remarkable compilation of best practices.

These case studies are not just documentation of achievements; they are blueprints for replication, catalysts for innovation, and inspiration for continued excellence. They demonstrate that sustainability and profitability are not mutually exclusive but are complementary forces that drive long-term success.

As we celebrate these accomplishments, we also acknowledge the collaborative spirit that has made this compendium possible—the dedication of industry professionals, the vision of corporate leadership, and the unwavering support of all stakeholders committed to a sustainable energy future.

Chairperson's Message



Dr. Anil Kumar Jain
Chairperson, PNGRB

The first edition of PNGRB's Sustainability Compendium began with a simple conviction: good ideas create greater value when they are shared. The response from the sector affirmed that conviction. The inaugural edition evolved beyond a compilation of individual achievements into a common knowledge platform, bringing practical solutions, measurable outcomes and implementation experience into the wider industry conversation. Its value lay not merely in recognizing excellence, but in enabling organizations to learn from one another and consider how proven approaches could be adapted and replicated across the energy value chain.

It is therefore particularly encouraging to see this initiative continue into its second edition. This year, PNGRB received 109 case studies from 21 entities, reflecting sustained confidence in the platform. Even more heartening is the widening character of participation. Contributions have come not only from PNGRB-regulated entities, but also from non-regulated organizations and companies beyond the immediate petroleum and natural gas sector. This broadening of participation is significant. Sustainability challenges rarely remain confined within regulatory or sectoral boundaries, and neither should the exchange of solutions.

As I look across the initiatives represented in this edition, I see an industry increasingly willing to examine its operations differently. Sustainability is finding expression in the recovery of resources once treated as losses, reduction of energy and water intensity, integration of cleaner energy, better management of emissions and waste, protection of natural ecosystems, and application of digital technologies to improve efficiency and reliability. Equally important, many interventions demonstrate that environmental responsibility and operational performance can reinforce each other. Sustainability is progressively becoming part of how businesses solve problems, improve resilience and create long-term value.

For PNGRB, this Compendium has an important role in nurturing that transition. A regulator can provide standards and frameworks, but lasting progress is strengthened when industry participants learn from practical experience, including what worked, what proved difficult, and how implementation challenges were overcome. In that sense, the Compendium is not intended to prescribe a single pathway. It offers a collective repository of experience, allowing each organization to identify ideas relevant to its own operating circumstances.

Chairperson's Message

This is where I believe the greatest value of continuity lies. The first edition established a platform for documenting and disseminating good practices, with the intent of encouraging peer learning and replication across similar operating environments. The initiative was subsequently recognized as a useful mechanism for knowledge sharing, and institutionalizing it as an annual publication was proposed as a means of capturing emerging innovations and the sector's evolving sustainability journey. Each successive edition can therefore become more than a record of another year's achievements. Together, they can provide a growing body of knowledge through which the sector observes its own progress, learns from experience and raises its collective ambition.

I particularly appreciate the organizations participating in this edition for sharing their experience for the benefit of the larger ecosystem. The submission of entities beyond PNGRB's regulated segments reinforces an important message: while institutions may operate under different mandates, the pursuit of efficient resource use, lower environmental impact and responsible growth is a shared undertaking.

My compliments also go to the professionals behind these initiatives. The case studies ultimately represent the work of teams that identified opportunities, questioned established practices, tested alternatives and translated ideas into measurable improvements. The Compendium provides a platform for these experiences to travel beyond the facilities and organizations where they originated.

With this second edition, PNGRB renews its commitment to fostering knowledge sharing, collaboration and continuous learning across the sector. I hope organizations will use this publication not simply to appreciate what has already been accomplished, but to ask a more valuable question*: what can we learn from these experiences and take forward in our own operations?*

If this Compendium continues to prompt that question, encourages one successful intervention to be replicated elsewhere, or inspires the next generation of sustainability initiatives, it will have served its purpose well.

Leadership Corner



Shri Anjani Kumar Tiwari
Member, PNGRB

It is a pleasure to mark the completion of the second edition of PNGRB's Compendium of Case Studies on Sustainability. Having been closely associated with this initiative, I find its continuation particularly meaningful. What began as an effort to bring sustainability experiences together is developing into a sustained platform for dialogue, practical learning and collaboration across the petroleum and natural gas sector.

Behind every case study is a practical journey: an operating challenge recognized, an alternative explored, and an improvement pursued through engineering, coordination and persistence. Documenting that journey matters. It brings attention not only to the outcome, but also to the decisions and lessons that others can use.

This edition reflects the breadth of sustainability in practice. Alongside technological advances, it features interventions rooted in better operating discipline, thoughtful resource management and more effective use of existing infrastructure. These experiences reinforce an important principle: meaningful improvement need not always begin with a major investment. It can begin with examining a familiar process more closely.

I extend my appreciation to the contributing organizations for sharing their experiences and supporting this compilation. I also acknowledge the Sustainability Cell and everyone associated with bringing the publication together. Translating diverse technical submissions into an accessible and coherent resource is an important part of making this initiative useful.

As part of this collective endeavour, I regard its completion with appreciation and a sense of continuing responsibility. The publication is complete; its practical purpose now begins. Its value will grow when the experiences presented here enter technical discussions, inform operational reviews and help teams assess opportunities within their own facilities.

My encouragement to readers is simple: look beyond the headline result. Examine the problem, the choices made and the conditions that enabled improvement. That is where the most useful learning often lies.

I congratulate all those associated with this edition and look forward to this shared effort continuing with the same commitment to substance, clarity and practical relevance

Executive Summary

The second edition of **PNGRB's Sustainability Compendium** brings together practical experiences in making petroleum and natural gas operations cleaner, more efficient and resource-conscious. **Of the 109 case studies received from 21 entities, 36 were shortlisted by the Jury Committee and are featured in this edition.** Participation extended beyond PNGRB-regulated entities to non-regulated organizations and companies from other sectors, bringing a wider range of experiences into the publication.

The Compendium presents sustainability through real operating challenges and the solutions developed to address them. Its coverage extends beyond emissions reduction to include energy efficiency, water conservation, waste recovery, biodiversity, cleaner-energy integration, digital innovation and customer-service improvements. Together, these themes show how sustainability connects environmental responsibility with the everyday management of infrastructure, resources and services.

Sustainability in Practice

The case studies discussed in this publication illustrate several complementary approaches:

- **Reducing emissions and conserving energy:** Recovering gas otherwise flared or vented, improving equipment efficiency, optimizing operating practices and using available process heat more effectively.
- **Managing water responsibly:** Reusing treated municipal wastewater, recovering water from industrial streams and reducing dependence on freshwater sources.
- **Keeping resources in productive use:** Rejuvenating catalysts, repurposing equipment and converting waste materials into useful products.
- **Integrating cleaner energy:** Introducing renewable electricity, alternative fuels and controlled hydrogen-blending applications.
- **Using digital systems effectively:** Applying data analytics, automation and predictive tools to improve monitoring, maintenance, billing and service delivery.
- **Supporting ecosystems:** Undertaking afforestation, mangrove restoration and nature-based treatment initiatives.

What Readers Can Learn

A recurring lesson is that sustainability does not depend on a single technology or investment model. Some initiatives involve new infrastructure and research; others improve the use of existing equipment, revise established operating practices or connect processes that previously functioned separately.

The case studies also demonstrate why implementation experience matters. Technical suitability, safety, resource availability, workforce preparedness and coordination between organizations can influence whether a solution succeeds. Understanding these conditions is as important as understanding the reported benefit.

The publication includes initiatives at different stages of development, from pilots and ongoing projects to completed interventions. **Demonstrated results should therefore be distinguished from projected benefits**, particularly when considering wider adoption. Reported outcomes provide useful evidence, but their applicability depends on the circumstances of each facility.

The central message is straightforward: sustainability advances when practical improvements are identified, tested, documented and carried forward. This edition brings those experiences together as a shared resource for continued progress.

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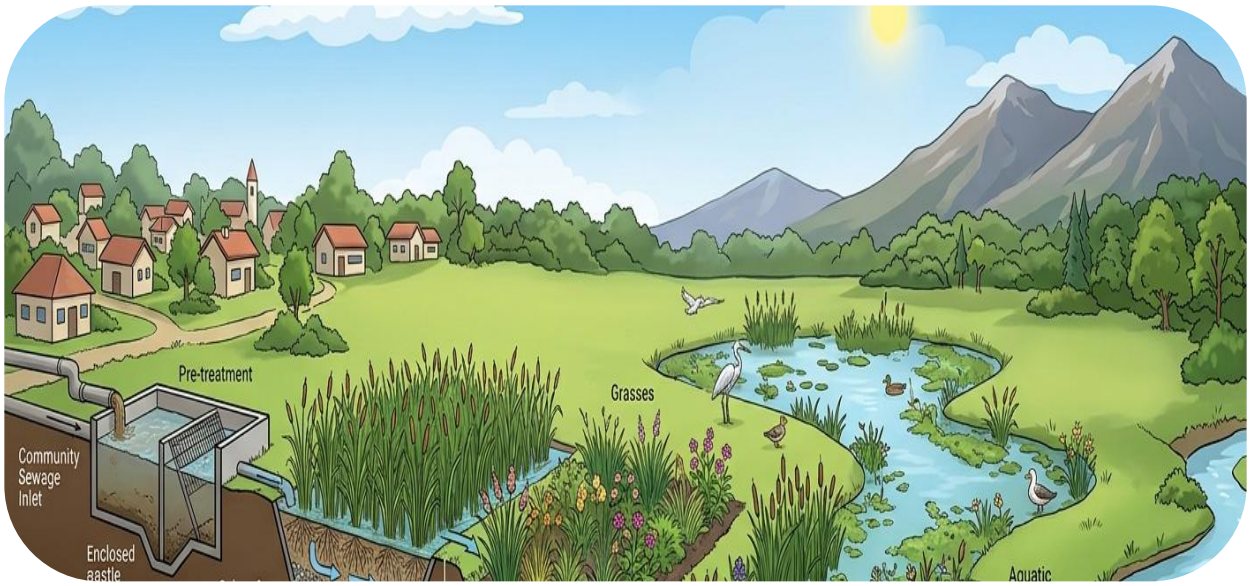
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CIRCULAR ECONOMY



Integrated Wetland Technology: An 85% Lifecycle Cost Reduction through Academic Technology–Startup Collaboration”

Indian Oil Corporation Limited
Haldia Refinery

CIRCULAR ECONOMY

IndianOil Haldia Refinery commissioned a 0.5 MLD Integrated Wetland Technology sewage treatment plant on 31 March 2026 for Township Clusters 10 and 12. Rather than using a conventional engineering route, the refinery licensed technology developed by IIT Bombay and implemented it through Emergy Enviro, a start-up incubated at SINE, IIT Bombay. The plant uses gravity settling, planted-bed treatment with natural root-zone aeration, and polishing to eliminate continuous mechanical aeration. Against a five-year operating cost of ₹6.16 crore for a conventional MBBR, the wetland system is estimated at ₹0.92 crore, an 85% reduction and ₹5.24 crore operating-cost avoidance. Independent April 2026 testing recorded BOD reduction from 91 to 6.1 mg/L, TSS from 248 to below 10 mg/L, fecal coliform from 9,200 to 49 MPN, and fish survival from nil to 100%. The entire 0.5 MLD treated output is reused for township horticulture

Background & Context:

Conventional sewage treatment within a residential township posed operational and financial challenges. MBBR or comparable activated-sludge systems require continuous aeration, skilled attendance and frequent sludge handling, while odour and mosquito concerns can make their proximity to residential areas undesirable. For Clusters 10 and 12, sewage flow was relatively modest and variable, making continuously aerated biological treatment less attractive. Conventional plants would also permanently occupy township land and carry recurring expenditures related to electricity, chemicals, manpower and sludge disposal. The alternative was therefore evaluated on five-year lifecycle cost rather than lowest initial capital cost. The initiative sought a treatment system that could operate close to the sewage source, reduce recurring operating requirements, reuse treated wastewater and retain most of the site for community purposes.

Objectives:

1. Treat sewage from Clusters 10 and 12 close to source and to a standard suitable for reuse.
2. Select technology based on five-year lifecycle cost rather than lowest capital cost.
3. Eliminate odour and mosquito nuisance to enable operation within a residential area.
4. Reduce dependence on continuous electricity, chemicals and skilled attendance.
5. Retain the majority of the treatment-plant plot for community use.
6. Create a direct technology-transfer pathway from an academic institution through its incubated start-up.
7. Independently validate treatment performance before further expansion.
8. Reuse the entirety of treated wastewater within the township

Methodology:

The distinctive aspect of the initiative was both technological and commercial. Integrated Wetland Technology developed by IIT Bombay was implemented through Emergy Enviro, a start-up incubated at SINE. Technology selection was based on five-year lifecycle economics rather than capital expenditure alone. Treatment occurs through three sequential stages. The PSRT stage provides gravity settling and removes 60–70% of total suspended solids without energy input. The SBBR planted-bed stage delivers 80–90% reduction in biochemical oxygen demand using natural oxygen transfer through vegetation root zones instead of mechanical aeration. Final sand and carbon filtration followed by disinfection brings the water to reuse grade. With no mechanical aeration, the conventional requirement for blowers, associated electricity consumption and maintenance is absent. Sludge removal is required approximately once annually rather than continuously. In addition, 90–95% of the treatment plot remains usable as garden and parking.

Stage	Unit	Function	Mechanism
1	PSRT	Gravity settling; 60–70% of TSS removed	Physical separation with no energy input
2	SBBR	Planted beds; 80–90% reduction in BOD	Natural root-zone aeration replacing mechanical aeration
3	Polishing	Sand and carbon filtration followed by disinfection	Brings treated water to reuse grade

Challenges:

One major challenge was contracting with an incubated start-up within a public-sector procurement environment typically structured around turnover, prior capacity and reference-installation criteria. The technology's institutional origin at IIT Bombay and SINE incubation provided supporting assurance, while lifecycle-cost comparison provided the commercial rationale. A second challenge was defending a selection based on operating cost rather than lowest capital cost. The refinery therefore explicitly benchmarked the proposed solution against the ₹6.16 crore five-year operating cost of a conventional MBBR. The technology also had to demonstrate performance within an occupied residential environment. Variable sewage flows and the seasonal nature of living vegetation presented additional considerations. Independent laboratory testing shortly after commissioning was consequently used as an initial validation gate, with performance planned to be assessed over a complete annual cycle before wider deployment

Implementation:

Implementation began with comparison of lifecycle costs for Integrated Wetland Technology and a conventional MBBR serving the same duty. Following selection, the technology developed by IIT Bombay was licensed and Emergy Enviro engaged as the implementation partner. The 0.5 MLD plant was commissioned on 31 March 2026, enabling sewage from Township Clusters 10 and 12 to be treated at source. An independent laboratory assessment followed in April 2026, covering BOD, TSS, faecal coliform and fish survival. Stakeholders included IIT Bombay as technology originator, SINE as incubator, Emergy Enviro as implementation partner, and the refinery's HSE and Township departments as owner/operator. The source does not specify construction dates, so these have been retained as unconfirmed rather than inferred.

Period	Milestone	Outcome
Concept Stage	Lifecycle-cost comparison with conventional MBBR	₹6.16 crore five-year conventional operating-cost benchmark established
Selection	IIT Bombay technology licensed; Emergy Enviro engaged	Technology routed directly from academic institution to refinery
Construction	Not specified in case study	Dates to be confirmed
31 March 2026	0.5 MLD plant commissioned	Clusters 10 & 12 sewage treated on-site
April 2026	Independent laboratory validation	BOD, TSS, faecal coliform and fish-survival results recorded
FY 2026–27	First full operating year	Performance to be tracked over complete annual cycle

Investment:

The case study reports capital expenditure of ₹300 lakh for the 0.5 MLD Integrated Wetland Technology plant. Annual operating expenditure is estimated at ₹18.40 lakh, derived from ₹92 lakh of expenditure over five years. No dedicated manpower, technology-acquisition expenditure or internally incurred R&D cost is reported

Cost Component	Amount (₹ Lakhs)
Capital Expenditure	300
Operational Expenditure	18.40/year
Total Investment	318.4

Outcomes:

The initiative significantly lowered lifecycle operating expenditure compared with conventional MBBR treatment. Five-year operating cost reduced from an estimated ₹616 lakh to ₹92 lakh, representing an 85% reduction and ₹524 lakh of operating-cost avoidance. The treatment process eliminates mechanical aeration through natural oxygen transfer in planted root zones, although the document does not quantify associated electricity or tCO_2e savings. The complete 0.5 MLD treated output is reused for township horticulture, while sludge-removal frequency falls from continuous handling in the conventional alternative to approximately once annually. Independent laboratory testing in April 2026 showed BOD decreasing 93.3%, from 91 to 6.1 mg/L; TSS declining by over 96%, from 248 to below 10 mg/L; and fecal coliform falling 99.5%, from 9,200 to 49 MPN. Fish survival increased from nil in influent water to 100% in treated water

Parameter	Before Implementation	After Implementation	Improvement (%)
GHG Emissions	Not separately quantified	Not separately quantified	Aeration power avoided; tCO_2e not quantified
Energy Consumption	Continuous mechanical aeration required	No mechanical aeration; natural root-zone transfer	Aeration load eliminated
Sewage Treated & Reused	Nil	**0.5 MLD, 100% reused for horticulture**	New capability
Sludge Handling	Continuous removal in conventional plant	Once annually	Frequency reduced
Plot Area Remaining Usable	Conventional footprint not recoverable	**90–95% usable as garden/parking**	Land retained for community use
Five-Year Operating Cost	₹616 lakh	**₹92 lakh**	**85% reduction**
Five-Year Cost Avoidance	-	**₹524 lakh**	Operating cost avoided
BOD	91 mg/L	**6.1 mg/L**	**93.3% reduction**
TSS	248 mg/L	**Below 10 mg/L**	**>96% reduction**
Faecal Coliform	9,200 MPN	**49 MPN**	**99.5% reduction**
Fish Survival	Nil	**100%**	Biological validation

Scalability & Replicability:

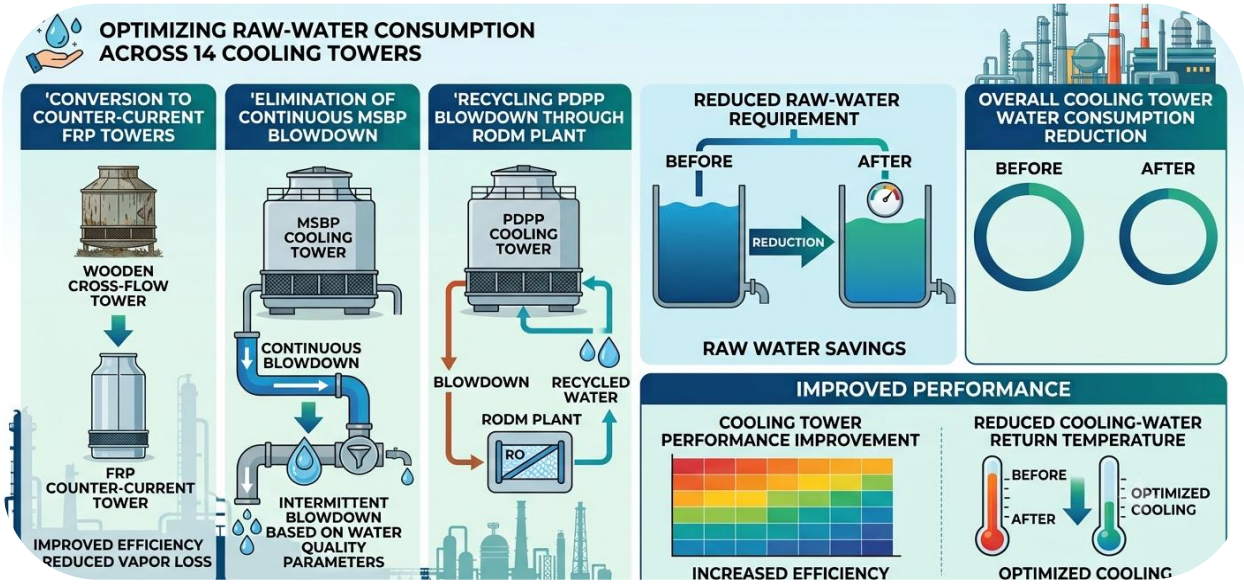
The solution is positioned for sites with modest and variable sewage flows without continuous skilled attendance, including industrial townships, refinery and terminal colonies, pipeline pumping-station complexes, CGD offices and station sites, guest houses and training centres. The document also identifies clear limitations. The system requires adequate land and living vegetation, is not intended for process effluent or high-strength/toxic industrial wastewater, and needs establishment time before reaching full performance. At IndianOil Haldia Refinery, Clusters 10 and 12 represent the first deployment across several township clusters. Expansion to remaining clusters is contemplated subject to successful performance through a full annual operating cycle. The technology-transfer model involving an academic institution and incubated venture is also identified as potentially replicable beyond wastewater treatment.

Key Learnings:

The initiative demonstrates the importance of establishing the conventional lifecycle-cost benchmark before selecting an alternative. Comparing ₹92 lakh of five-year operating expenditure against ₹616 lakh for conventional MBBR transformed the technology proposition into a commercially measurable decision. A second learning is that lifecycle cost requires explicit consideration within approval processes that may otherwise emphasize initial capital expenditure. The case study also demonstrates how institutional provenance can help address vendor-track-record constraints when implementing technology through an incubated start-up. From a technical perspective, removing mechanical aeration entirely generated greater operating-cost reduction than merely optimizing aeration efficiency. The initiative additionally demonstrated the value of using validation measures meaningful to different audiences, combining conventional water-quality parameters with fish-survival testing. Finally, nature-based systems remain season-dependent. Since the planted beds require maturation, the April 2026 results represent early validation rather than full-cycle performance confirmation.

Future Plans:

Performance will be monitored throughout FY 2026–27 to evaluate the system across a complete seasonal cycle, including monsoon and winter conditions. The full-year assessment is intended to precede broader application of the technology. Subject to satisfactory performance, IndianOil Haldia Refinery plans to extend the same technology and delivery approach to the remaining township clusters, enabling sewage to be treated close to source. All treated water is currently reused for township horticulture. As treated volumes increase through future expansion, additional non-potable applications may also be supplied.



Optimization of Raw Water Consumption in Cooling Towers

Bharat Petroleum Corporation Limited
Santosh Kumar Varshney
DGM (Environment)

CIRCULAR ECONOMY

BPCL Kochi Refinery implemented a water-conservation programme to optimize raw-water consumption across its 14 cooling towers, which have a combined circulation rate of approximately 1.3 lakh tonnes/hour. The initiative reduced cooling-tower raw-water requirement from approximately 1,100 TPH to 1,000 TPH through three interventions: conversion of old wooden cross-flow cooling towers to counter-current FRP towers, elimination of continuous MSBP cooling-tower blowdown based on water-quality parameters, and recycling of PDPP cooling-tower blowdown through the RODM plant. Overall cooling-tower water consumption reduced from 24,300 KL/day to 22,000 KL/day, representing approximately 9.5% water savings. The programme also improved cooling-tower performance and reduced cooling-water return temperature.

Background & Context:

Several older cooling towers at Kochi Refinery were based on wooden cross-flow construction and experienced relatively high drift losses due to ageing timber and biofouling. Estimated drift losses were approximately 240 tonnes/day, based on 0.05% of circulating water. In parallel, approximately 10 TPH of continuous blowdown from the MSBP cooling tower was being discharged despite circulating-water turbidity and TSS conditions allowing optimization. This represented another approximately 240 tonnes/day of avoidable water loss. A larger opportunity existed in the PDPP cooling tower, where approximately 80 TPH of blowdown could be recovered by routing it to the RODM plant instead of relying on equivalent fresh raw-water makeup. Collectively, these interventions targeted approximately 2,300 TPD of raw-water savings.

Objectives:

1. Minimize drift losses from cooling towers.
2. Optimize cooling-tower blowdown based on Cycles of Concentration (COC) and cooling-water quality.
3. Recycle cooling-tower blowdown through the RODM plant for production of DM water.
4. Reduce overall raw-water demand across Kochi Refinery cooling towers.
5. Improve the safety, reliability and operating performance of ageing cooling-tower infrastructure

Methodology:

The programme combined cooling-tower modernization, blowdown optimization and water recycling rather than relying on a single intervention. Four old wooden cross-flow towers were targeted for conversion to counter-current Pultruded Fibre Reinforced Plastic (FRP) configuration. Counter-current technology offers lower drift losses and improved contact between air and circulating water. Each cooling-tower cell was planned for sequential rebuilding to minimize impact on refinery production. Continuous blowdown at the MSBP cooling tower was reviewed against actual circulating-water turbidity and TSS. Based on acceptable water quality, continuous blowdown was discontinued. For the PDPP cooling tower, approximately 80 TPH of blowdown was routed to the RODM plant for recycling, thereby reducing equivalent fresh raw-water makeup.

Intervention	Approach	Water-Saving Impact
Cooling Tower Modernization	Cross-flow wooden towers converted to counter-current FRP design	~200 TPD
MSBP Blowdown Optimization	Continuous ~10 TPH blowdown stopped based on water quality	~240 TPD
PDPP Blowdown Recycling	~80 TPH blowdown routed to RODM plant	~1,900–2,000 TPD
Overall Initiative	Combined interventions	~2,300 TPD

Challenges:

The ageing timber cooling towers had experienced significant deterioration, including damage from heavy winds in March 2021. The top decks had become unsafe for maintenance, suitable treated timber for repairs was unavailable, and fan blades could rub against the wooden structure during windy conditions. Conversion from cross-flow to counter-current design presented significant structural and hydraulic challenges. Internal components, including fill media, drift eliminators and water-distribution systems, required redesign because the two cooling-tower configurations operate with fundamentally different air and water-flow arrangements. Space constraints further complicated retrofitting, while the existing basin and piping configuration had to be adapted to a top-distribution system without creating hydraulic imbalance. Maintaining adequate cooling-water availability during construction was also critical to avoiding impacts on refinery process reliability.

Implementation:

The existing cooling towers were initially assessed for structural integrity and available space. Necessary structural reinforcements were incorporated to accommodate the counter-current configuration. Existing splash-fill media was replaced by high-efficiency vertical film-fill packs, while drift eliminators and nozzles were repositioned to support vertical counter-current air and water movement. The water-distribution system was upgraded using pressurized headers and spray nozzles to improve uniformity. Fan and motor assemblies were recalibrated, and basin and support structures were modified to improve drainage and minimize carryover. During commissioning, airflow and water loading were progressively optimized based on observed cooling-tower performance. The cooling-tower conversions were implemented sequentially to minimize disruption to refinery operations, while the MSBP and PDPP water-management interventions were implemented in parallel

Area	Major Intervention
Structural Assessment	Existing tower integrity and space availability evaluated
Tower Configuration	Cross-flow wooden construction converted to counter-current FRP
Fill System	Splash fill replaced with high-efficiency vertical film fill
Drift Control	Drift eliminators repositioned for counter-current operation
Water Distribution	Pressurized headers and spray nozzles introduced
Air System	Fan and motor assemblies recalibrated
MSBP Cooling Tower	Continuous blowdown stopped based on water-quality conditions
PDPP Cooling Tower	Blowdown diverted to RODM plant for recycling
Commissioning	Airflow, water loading and cooling performance optimized

Investment:

The principal capital expenditure related to rebuilding and modernization of the ageing cooling towers. The case study reports a total investment of ₹1,389 lakh, with no separately identified operating, manpower, technology-acquisition or R&D costs

Cost Component	Amount (₹ Lakhs)
Capital Expenditure	1,389
Operational Expenditure	nil
Total Investment	1,389

Outcomes:

The combined interventions reduced cooling-tower water consumption from 24,300 KL/day to 22,000 KL/day, corresponding to an approximately 9.5% reduction. This represents around 2,300 KL/day of raw-water savings across the refinery's cooling-tower system. The largest contribution came from recycling PDPP cooling-tower blowdown through the RODM plant, supplemented by elimination of unnecessary MSBP blowdown and lower drift losses from the upgraded cooling towers. Beyond water savings, the counter-current conversion improved cooling-tower performance and reduced cooling-water return temperature. The project therefore combined water conservation with modernization of ageing cooling infrastructure and improved operational performance.

Parameter	Before Implementation	After Implementation	Improvement (%)
Raw Water Consumption	**24,300 KL/day**	**22,000 KL/day**	**~9.5% reduction**
Overall Water Saving	-	**~2,300 KL/day**	New saving
Cross-Flow Tower Drift Loss	~240 TPD	Reduced through counter-current design	~200 TPD saving stated
MSBP Continuous Blowdown	~10 TPH	Stopped based on water-quality conditions	~240 TPD saving
PDPP Blowdown Reuse	~80 TPH previously requiring equivalent makeup	Routed to RODM plant	~1,900–2,000 TPD raw-water saving
Cooling-Tower Performance	Existing performance	Improved	Qualitative improvement
Cooling-Water Return Temperature	Existing baseline	Reduced	Value not quantified
GHG Emissions	Not reported	Not reported	Not quantified
Cost Savings	Not reported	Not reported	Not quantified

Scalability & Replicability:

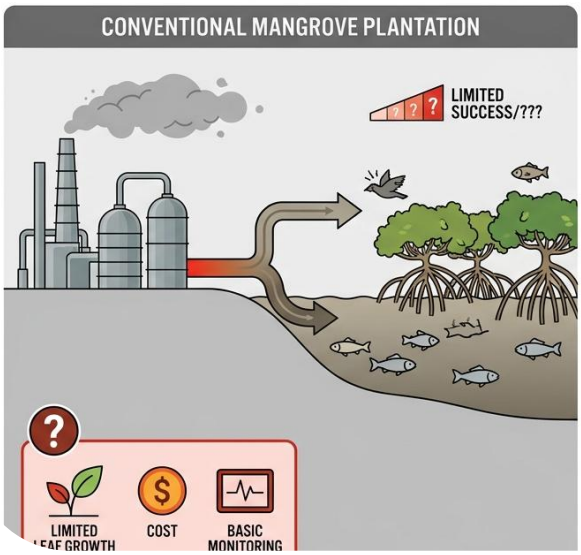
Counter-current cooling-tower technology is standardized and widely deployed, making the modernization approach replicable at facilities operating older cross-flow cooling towers. The broader water-management model is also applicable to refinery and industrial cooling systems where blowdown streams can be optimized according to actual water quality or recycled through suitable treatment facilities. The approach is particularly relevant for sites with ageing wooden cooling towers, high drift losses, continuous blowdown practices or opportunities to integrate cooling-tower wastewater with existing water-treatment and recovery infrastructure

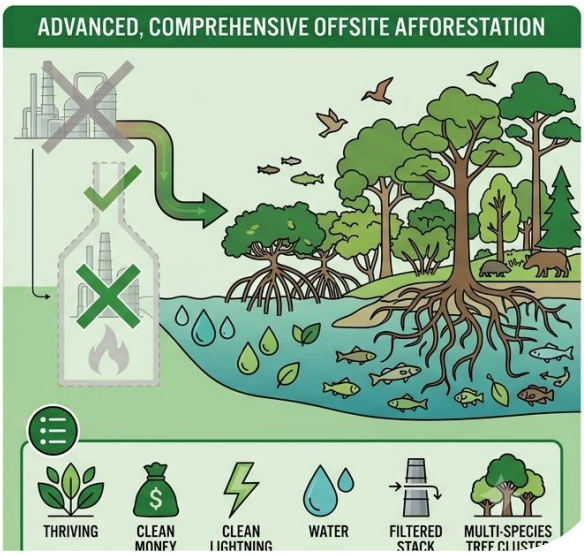
Key Learnings:

The initiative demonstrated that cooling-tower water conservation benefits from addressing the entire water balance, rather than focusing only on fresh-water makeup. Drift losses, blowdown practices and opportunities for recycling each provided material conservation opportunities. Replacement of ageing wooden cross-flow towers required detailed engineering of structural support, fill media, water distribution and hydraulic arrangements. Strong vendor support was therefore important for smooth execution. Another key learning was that continuous cooling-tower blowdown should be evaluated against actual water-quality parameters rather than maintained solely as a fixed operating practice. Similarly, cooling-tower blowdown can become a recoverable water stream where suitable treatment infrastructure is available. The project also confirmed the adequacy of the Kochi Refinery cooling-water circuit following implementation of the optimization measures.

Future Plans:

BPCL Kochi Refinery plans to pursue further reductions in raw-water consumption by stopping two cooling towers, subject to operational requirements. The refinery also plans to convert one additional wooden cooling tower to FRP, extending the modernization and water-conservation approach demonstrated through the present initiative.





Mangrove Plantation 2.0 and the Off-Site Afforestation Program

Indian Oil Corporation Limited
Haldia Refinery

CIRCULAR ECONOMY
Biodiversity Conservation

Haldia Refinery transformed a fundamental land constraint into a large-scale biodiversity programme by developing its greenbelt entirely outside its 610-acre refinery boundary. From a pre-programme baseline of 68,000 trees across 48 acres, cumulative off-site plantation expanded to 32,18,510 trees across 541.37 acres by 31 March 2026, equivalent to 88.75% of the refinery's plant area against a 33% greenbelt threshold. In FY 2025-26, Mangrove Plantation 2.0 added 10,01,841 mangrove saplings across 50 hectares at Beliary Char, under a six-year plantation and maintenance arrangement. The wider programme combines large-scale mangrove restoration, Miyawaki dense forests, conventional forest plantation, institutional plantation and linear plantation, with a total Corporate Environment Responsibility investment of ₹14.91 crore.

Background & Context:

Haldia Refinery was commissioned in 1975 and occupies 610 acres that are already substantially developed with process facilities, tank farms, utilities and roads. Consequently, sufficient land is not available within the refinery boundary to develop the required greenbelt. The refinery therefore adopted an off-site afforestation model. This approach also allowed plantation to be directed toward ecologically valuable locations, particularly cyclone-exposed char lands of the Hooghly estuary. Before the structured programme, cumulative off-site plantation stood at only 68,000 trees across 48 acres. The programme subsequently evolved into a formal multi-site framework supported through agreements with forest authorities, development agencies, railways, local institutions and other land-owning bodies.

Objectives:

1. Meet and exceed the greenbelt requirement through a structured off-site programme.
2. Restore mangrove forests on degraded char lands of the Hooghly estuary.
3. Provide natural protection to cyclone- and storm-surge-exposed char-land communities.
4. Establish closed-canopy native forests on smaller parcels through the Miyawaki approach.
5. Improve plantation survival through multi-year maintenance arrangements.
6. Establish a verifiable register containing location, plot, GPS, area and tree-count information.
7. Generate plantation and maintenance livelihood opportunities for the fringe population.
8. Complete the remaining 100 hectares covered under the 2025 arrangement

Methodology:

The programme operates through three distinct plantation models, selected according to the nature and availability of land. The programme also maintains site-specific records containing mouza, JL number, plot number, GPS coordinates, measured perimeter, area and elevation.

Stream	Approach	Major Deployment
Mangrove on char land	High-density planting of species suited to intertidal saline conditions, coupled with multi-year maintenance	Beliary Char: 100 ha/20 lakh saplings in FY 2021-22 plus 50 ha/10,01,841 saplings in FY 2025-26; another 100 ha sanctioned at Dakshinchara Shankarara
Miyawaki dense forest	Dense native multi-species plantations using prepared and enriched soil to develop closed canopy	56,200 trees across 5.50 acres at Mahishadal Rajbari, Hateberia Railway Station and Haldia Kendriya Vidyalaya area
Forest, institutional & linear plantation	Conventional plantation across forest land, institutional campuses, roadsides, water-treatment sites and township areas	Balughata/Royrayanchak, water-treatment plants, HPL link road, Green Belt Canal, schools, colleges and Durgachak township

Challenges:

The fundamental challenge was the absence of sufficient plantation land within the fully developed refinery. Haldia therefore shifted the greenbelt programme outside the refinery boundary and expanded it through external partnerships. Because plantation occurs on land belonging to multiple external organizations, separate formal arrangements were required with forest authorities, the development authority, railways, Panchayat Samity and educational institutions. Mangrove restoration presented different challenges. Char land is saline, unstable and periodically inundated, making species selection, planting elevation, tidal timing and long-term maintenance critical. The 2025 arrangement therefore incorporates six years of plantation and maintenance rather than focusing only on the number of saplings planted. Another critical requirement was maintaining audit-ready evidence over a programme extending across many years and sites. GPS-based records, Master Registers and satellite-verifiable polygons were used to strengthen traceability.

Implementation:

The programme expanded sharply during FY 2021-22 and FY 2025-26, which together accounted for the majority of cumulative tree planting. During FY 2025-26 alone, 10,01,841 mangrove saplings were planted across 50 hectares at Beliary Cha.

Period	Major Activity	Trees	Area
Pre-2016-17	Legacy off-site plantation	68,000	48.00 acres
2016-17 to 2019-20	General off-site plantation	20,445	20.44 acres
2020-21	Institutional and water-treatment plant sites	31,675	29.16 acres
2021-22	Beliary mangrove, forest and Miyawaki plantation	20,70,149	315.58 acres
2022-23	Hateberia Miyawaki forest	24,000	2.22 acres
2023-24	Durgachak township	661	0.67 acres
2024-25	Durgachak township	1,739	1.75 acres
2025-26	Mangrove Plantation 2.0, Beliary Char	10,01,841	123.55 acres
Total to 31 March 2026	Cumulative off-site plantation	32,18,510	541.37 acres

Investment:

Total Corporate Environment Responsibility investment across nine approved programme items is ₹1,491 lakh, including ₹817 lakh for the FY 2025-26 Mangrove Plantation 2.0 component. Multi-year maintenance is included within the respective arrangements

Cost Component	Amount (₹ Lakhs)
Capital Expenditure / CER Investment	**1,491**
Operational Expenditure	Included above
Human Resources	Nil additional refinery manpower
Technology Acquisition	Nil
R&D & Innovation	Nil

Outcomes:

Between 31 March 2025 and 31 March 2026, cumulative tree plantation increased from 22,16,669 to 32,18,510, representing 45.2% growth, while plantation coverage increased from 417.82 acres to 541.37 acres, a 29.6% increase. Mangrove area increased from 100 to 150 hectares, while cumulative mangrove saplings increased from 20,00,000 to 30,01,841. The programme's plantation area is equivalent to 88.75% of the 610-acre refinery area, substantially exceeding the cited 33% threshold.

Parameter	Before Implementation	After Implementation	Improvement (%)
Annual Mangrove Sequestration	~370–550 tCO_2e	~550–825 tCO_2e	Indicative estimate
Cumulative Trees	22,16,669	**32,18,510**	**45.2% increase**
Area Under Plantation	417.82 acres	**541.37 acres**	**29.6% increase**
Coverage vs. Plant Area	68.5%	**88.75%**	Against 33% threshold
Mangrove Area	100 ha	**150 ha**	**50% increase**
Mangrove Saplings	20,00,000	**30,01,841**	**50.1% increase**

Scalability & Replicability:

The model is particularly relevant to land-constrained refineries, terminals, pipeline facilities and other installations where adequate plantation cannot be accommodated within the operational boundary. It demonstrates how structured partnerships can enable plantation on external land without requiring ownership of that land. The Miyawaki component offers a complementary approach for smaller locations such as offices, stations, depots and campuses where only fragmented land parcels are available. The mangrove model is specifically applicable to coastal environments with suitable degraded intertidal land.

Key Learnings:

The programme demonstrates that limited availability of land need not reduce the ambition of a biodiversity programme. Moving plantation outside the refinery enabled Haldia to achieve substantially greater coverage while directing investment toward ecologically significant areas. The initiative also highlights the importance of funding plantation survival rather than merely plantation numbers. Multi-year maintenance is particularly critical for mangroves exposed to saline, unstable and tidal conditions. A third important learning is the need to create compliance evidence during implementation. GPS-referenced site records, measured polygons, formal agreements and a maintained Master Register improve the long-term verifiability of environmental programmes.

Future Plans:

The remaining 100 hectares at Dakshinchara Shankarara will complete Mangrove Plantation 2.0 and take the total mangrove area to 250 hectares.The six-year maintenance arrangement continues through 2031. Forest Directorate monitoring is planned during the first, third and fifth years to assess survival.A validated carbon-sequestration assessment is also planned to establish the blue-carbon contribution of the restored mangrove area. GPS polygons will progressively support periodic satellite-based canopy verification



Reutilization of 40 MLD VMC Treated Sewage Water for Refinery Operations

Indian Oil Corporation Limited **Gujarat Refinery**	**CIRCULAR ECONOMY** **Water Conservation**

IndianOil Gujarat Refinery partnered with Vadodara Municipal Corporation (VMC) to substitute refinery freshwater consumption with 40 MLD of tertiary-treated municipal sewage water under a long-term Water Purchase Agreement. The programme comprises 21 MLD under Phase 1 and another 19 MLD under Phase 2, with dedicated municipal-side and refinery-side treatment, storage, pumping, pipeline and monitoring infrastructure. During FY 2025-26, average treated sewage-water intake increased to 1,001 m^3/hr, compared with 376 m^3/hr in FY 2023-24, while industrial freshwater draw decreased from 1,565 to 874 m^3/hr, a 44.15% reduction. Total freshwater draw, including other uses, declined by 29.45%. The initiative demonstrates a large-scale municipal-industry circular water model that converts treated municipal wastewater into a dependable industrial resource while strengthening the refinery's long-term water resilience.

Background & Context:

Before implementation, Gujarat Refinery depended extensively on freshwater for refinery operations, while treated sewage generated by VMC was being released into nearby water bodies without full productive utilization.An MoU between the refinery and VMC was signed in 2018, and the Government of Gujarat's High-Power Committee subsequently designated 40 MLD of tertiary-treated sewage for refinery use.The water requirement associated with the Lupech project further increased the importance of securing a reliable long-term alternative water source. The initiative therefore combined municipal wastewater reuse with dedicated transportation, treatment, storage and refinery-integration infrastructure.

Objectives:

1. Substitute freshwater intake with treated wastewater from the VMC Sewage Treatment Plant.
2. Establish long-term and sustainable water security for refinery operations without compromising process-water quality.
3. Promote circular economy through a municipal-industry water-reuse mode

Methodology:

Implementation combined OSBL infrastructure developed by VMC with ISBL infrastructure developed by Gujarat Refinery. A Water Purchase Agreement governs supply of treated wastewater. The OSBL infrastructure comprises a 30 MLD softener plant, two 7,500 m^3 sumps, a 625 m^3/hr pump house and approximately 17.8 km of pipeline connectivity. The refinery developed seven pumps, approximately 7 km of internal pipeline, two MS tanks, seven analysers, DCS and control-room infrastructure to further process and integrate the treated water into refinery systems. The reclaimed water is integrated with the fire-water network, cooling towers, RO plant and service-water networks, supported by continuous water-quality monitoring.

Component	Major Infrastructure
VMC / OSBL	30 MLD softener plant
Storage	Two 7,500 m^3 sumps
Pumping	625 m^3/hr pump house
External Connectivity	~17.3 km pipeline from Rajivnagar STP + 0.5 km to refinery
Refinery / ISBL	7 pumps and ~7 km pipeline
Refinery Storage	2 MS tanks
Monitoring	7 analysers, DCS and control room
End Uses	Cooling towers, RO plant, fire water

Challenges:

Water quality represented an important initial challenge because the treated wastewater contained higher TDS and chloride levels than originally specified. Following technical assessment, permissible limits were revised to 1,375 ppm TDS and 375 ppm chloride, supported by mitigation measures.A commercial challenge arose when VMC initially sought an upfront capital contribution of ₹24.1 crore. Negotiations resulted in a staggered-payment arrangement.The rate structure also required resolution, with VMC ultimately waiving the infrastructure-rate component of ₹16.94/KL specified in the document. Implementation additionally required sustained alignment between municipal, refinery, technical and legal stakeholders. A high-voltage underground cable constraint also limited installation to three of four planned pumps.

Implementation:

Phase 1 covers 21 MLD of treated sewage-water supply and was commissioned during 2022-23. Trial supply was progressively established to refinery cooling towers, the RO plant and the fire-water network.The Water Purchase Agreement was finalized in 2023 for 15 years, with an option for a further 10-year extension.During FY 2025-26, average treated sewage-water intake reached 1,001 m^3/hr, compared with 376 m^3/hr during FY 2023-24. Correspondingly, industrial freshwater draw declined from 1,565 to 874 m^3/hr.Phase 2 covers the remaining 19 MLD and is planned for consumption following commissioning of the Lupech project.

Period	Major Activity
2018	MoU signed between Gujarat Refinery and VMC
2022-23	Phase 1, 21 MLD, commissioned
2023	15-year Water Purchase Agreement finalized
FY 2023-24	Average TWW intake: 376 m^3/hr
FY 2025-26	Average TWW intake increased to 1,001 m^3/hr
Phase 2	Additional 19 MLD planned post-Lupech commissioning

Investment:

Capital expenditure comprised ₹2,234.33 lakh for ISBL facilities and ₹5,954 lakh for OSBL infrastructure, totaling ₹8,188.33 lakh.The source separately reports annual operational expenditure of ₹79,575 lakh, but specifically states that this figure is from the FY 2024-25 submission and requires reverification for FY 2025-26. Consequently, the reported total investment of ₹877.63 crore should also be treated on that basis.

Cost Component	Amount (₹ Lakhs)
Capital Expenditure – ISBL	2,234.33
Capital Expenditure – OSBL	5,954.00
Total Capital Expenditure	**8,188.33**
Operational Expenditure	79,575*
Human Resources	Included in operating expenditure
Technology Acquisition	NA
R&D & Innovation	NA
Reported Total Investment	**87,763.33**

Outcomes:

The initiative significantly reduced dependence on freshwater. Industrial freshwater use declined from 1,565 m^3/hr in FY 2023-24 to 874 m^3/hr in FY 2025-26, representing a 44.15% reduction. Total freshwater draw, including other applications, reduced from 2,000 to 1,411 m^3/hr, representing a 29.45% reduction. Meanwhile, treated sewage-water utilization increased from 376 to 1,001 m^3/hr, an increase of approximately 166%.Based on the source's stated assumptions of ₹40/m^3 for freshwater and ₹11.8/m^3 for STP-treated water, annual savings increased from approximately ₹928.84 lakh to ₹2,472.79 lakh.

Parameter	FY 2023-24	FY 2025-26	Improvement
Industrial Freshwater	1,565 m^3/hr	874 m^3/hr	44.15% reduction
Total Freshwater	2,000 m^3/hr	1,411 m^3/hr	29.45% reduction
STP Treated-Water Intake	376 m^3/hr	1,001 m^3/hr	~166% increase
Estimated Annual Savings	₹928.84 lakh	₹2,472.79 lakh	~166% increase

Scalability & Replicability:

The model is applicable to refineries and other industrial facilities located near municipal sewage-treatment infrastructure. The central concept is to substitute industrial freshwater requirements with appropriately treated municipal wastewater. The study identifies Gujarat Refinery as a pioneer in Vadodara district in utilizing treated municipal sewage for industrial purposes and states that the initiative is among IndianOil's larger refinery applications by volume of municipal wastewater reuse

Key Learnings:

Technical feasibility studies should assess worst-case wastewater quality at an early stage, particularly parameters such as TDS and chloride that can affect refinery-water systems. A second important learning is that uninterrupted availability of treated municipal wastewater cannot be assumed. Appropriate procedures and supply-management arrangements need to be established during the early stages of project development. The initiative also demonstrates the importance of sustained municipal-industry coordination because technical infrastructure, commercial arrangements, water-quality specifications and legal agreements must function together for large-scale wastewater reuse.

Future Plans:

Phase 2 will enable utilization of an additional 19 MLD of treated municipal wastewater following commissioning of the Lupech project, further increasing substitution of freshwater in refinery operations



Desalination Plant – Zero Liquid Discharge for Produced Formation Water

Oil India Limited
Tuhin Kanti Bhattacharjee
DGM (BD)

CIRCULAR ECONOMY
Water Conservation

Oil India Limited successfully demonstrated a 2 m^3/hr pilot Zero Liquid Discharge desalination system for treating highly saline Produced Formation Water at STF-Madhuban. The hybrid process combines pretreatment, Low-Pressure Reverse Osmosis, High-Pressure Reverse Osmosis and thermal concentration/drying to recover reusable water while eliminating liquid discharge. Building on pilot validation, OIL is progressing a commercial 3,000 KLPD modular ZLD plant, which was in final tendering stage as of August 2026. At commercial scale, the initiative is designed to recover and reuse approximately 1,095,000 KL/year of produced water, substitute 182,500 KL/year of freshwater abstraction, and eliminate the need for additional water-disposal wells for the equivalent produced-water volume.

Background & Context:

OIL's mature oilfields in Assam generate substantial Produced Formation Water. At STF-Madhuban, approximately 11,000 KL/day of fluid is processed, generating nearly 3,000 KL/day of highly saline PFW.Increasing produced-water generation exceeded expansion of disposal infrastructure, creating disposal deficits and ullage constraints in ETP clarified-water tanks, with potential to restrict crude processing and cause interruptions.Treated PFW had traditionally been disposed through dedicated water-disposal wells, with some water used for reinjection and workover activities. However, existing wells were insufficient for continuously rising water volumes.PFW typically contained 3,000–4,500 ppm TDS versus the cited CPCB limit of 2,100 ppm, while chloride ranged from 1,500–2,000 ppm versus the cited permissible limit of 600 ppm, preventing direct surface discharge following conventional ETP treatment.

Objectives:

1. Eliminate disposal-related ullage constraints that could affect crude processing and production.
2. Produce high-quality permeate and condensate suitable for utility water, fire water, drilling and other operational requirements.
3. Reduce groundwater abstraction by substituting treated produced water for freshwater.
4. Reduce dependence on water-disposal wells through maximum recovery and reuse.
5. Improve lifecycle economics relative to continued drilling, operation and maintenance of disposal wells.
6. Promote circular water management and environmental stewardship under OIL's Project SANTULAN

Methodology:

The process was tested through a modular 2 m^3/hr pilot plant, demonstrating the technical feasibility of treating high-salinity PFW and producing permeate and condensate meeting the standards cited in the case study

Stage	Process	Function
1	Pretreatment	Coarse and fine filtration removes suspended solids and protects downstream membranes
2	LPRO	Operates at ~40 bar and achieves nearly 90% water recovery
3	HPRO	Operates at ~75 bar and further recovers water while concentrating reject
4	Thermal Concentration	Waste Heat Evaporator recovers remaining water as condensate
5	ATFD	Converts residual concentrate into dry salt-rich solids
6	Water Reuse	Combined permeate and condensate used for industrial applications
7	Solid Management	Residual salt-rich solids collected and treated/disposed according to applicable requirements

Challenges:

PFW contains residual oil, suspended solids, dissolved organics and scale-forming salts that can cause membrane fouling and shorten membrane life. The pilot addressed this through coarse and fine filtration down to one micron, optimized antiscalant dosing and operating-parameter optimization. The process also produces salt-rich solid residues. Potential beneficial applications of recovered salts, including use as oilfield workover brine, were evaluated, but mineral-precipitation issues limited reuse potential. Landfill disposal after treatment was therefore identified as a viable route. Regulatory compliance was another critical issue because untreated PFW salinity prevented direct surface discharge. Pilot testing demonstrated compliance of recovered permeate and condensate with the cited standards, leading to in-principle approval for surface discharge from the Pollution Control Board Assam

Implementation:

The initiative is being implemented through four defined phases progressing from pilot demonstration to commercial-scale ZLD deploymen.

Period	Phase	Major Activity
Apr–May 2024	Pilot Demonstration	2 m^3/hr ZLD pilot installed and operated at STF-Madhuban
Jun 2024–Dec 2025	Regulatory & Commercial Evaluation	Regulatory inspection, in-principle approval and techno-commercial assessment
Jan–Mar 2026	Engineering & Tender Preparation	Technical specifications and project documentation for 3,000 KLPD plant completed
May 2026 onward	Commercial Tendering	Bid invited for 3,000 KLPD modular ZLD facility on EPC basis with two years' O&M support
As of Aug 2026	Commercialisation	3,000 KLPD plant in final tendering stag

Investment:

The commercial project has a reported EPC capital estimate of ₹9,991 lakh, including GST. Annual O&M expenditure is estimated at ₹1,746 lakh, with human resources included under O&M.Total investment for the EPC works and two years of O&M support is reported at ₹13,485 lakh.

Cost Component	Amount (₹ Lakhs)
Capital Expenditure	**9,991**
Operational Expenditure (Annual)	**1,746**
Human Resources	Included under O&M
Technology Acquisition	Modular RO, salt-recovery, ATFD and decanter systems
R&D & Innovation	In-house support
Total Investment, EPC + 2 Years O&M	**13,48**

Outcomes:

At full commercial implementation, the project is designed to replace 182,500 KL/year of groundwater abstraction with treated produced water, corresponding to a 100% reduction in freshwater abstraction for the equivalent demand. Approximately 1,095,000 KL/year of PFW presently requiring disposal through disposal wells is planned to be recovered and reused through the 3,000 KLPD ZLD facility, eliminating liquid disposal for the equivalent quantity. Produced water consequently transitions from a waste stream requiring disposal to a reusable industrial-water resource. The project is also designed to remove the requirement for additional water-disposal wells to handle the 3,000 KLPD stream.GHG and energy improvements have not yet been quantified in the case study and are identified as parameters to be established.

Parameter	Before Implementation	After Full Implementation	Improvement
Freshwater Abstraction	182,500 KL/year	Nil for equivalent demand	100% reduction
PFW Requiring Disposal	1,095,000 KL/year	1,095,000 KL/year recovered/reused	100% elimination of liquid disposal for equivalent volume
Resource Utilization	PFW treated as waste requiring disposal	PFW converted to reusable water	100% beneficial utilization of treated water

Parameter	Before Implementation	After Full Implementation	Improvement
Disposal Infrastructure	Additional disposal-well requirement	No additional wells for 3,000 KLPD PFW	100% elimination of additional well requirement
Operational Efficiency	Disposal deficit and ullage constraints	Disposal constraint intended to be eliminated	Significant improvement stated
GHG Reduction	Disposal-well-related emissions	Reduction expected	To be established
Energy Performance	Disposal-well energy use	ZLD energy use with reduced disposal infrastructure	To be established
Cost Savings	Continued disposal-well CAPEX/O&M	Future disposal-well expenditure avoided	To be realized after project completion

Scalability & Replicability:

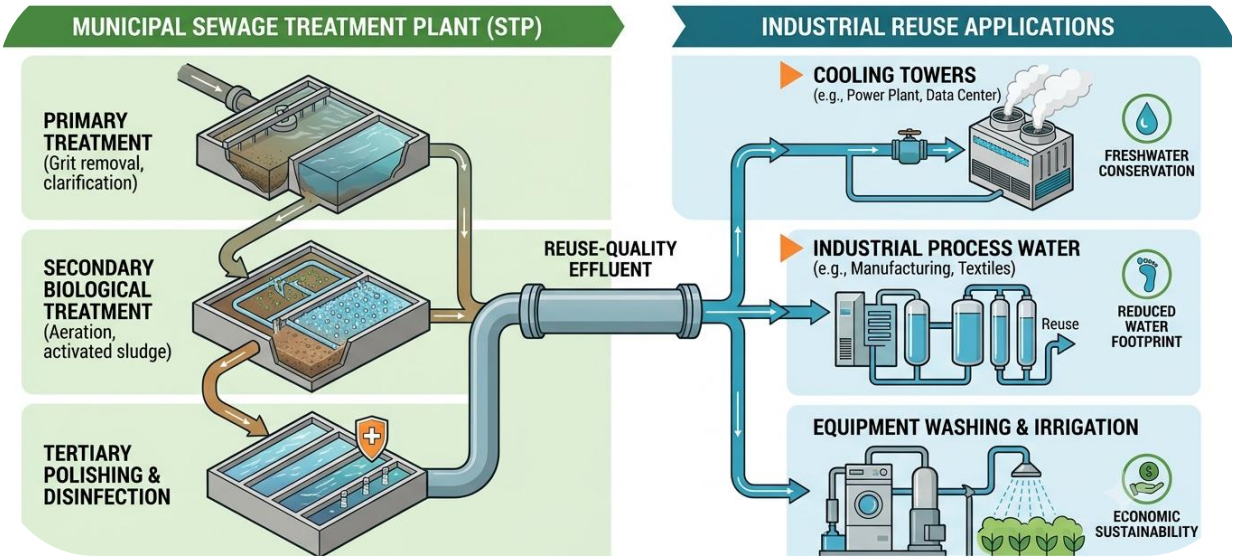
The commercial plant is designed with a modular architecture, providing a basis for future expansion as produced-water volumes increase. OIL identifies its Tengakhat Area as one potential location for further replication. The integrated desalination and ZLD approach is also identified as adaptable to offshore production facilities, with concentrated solids transported onshore for treatment and disposal rather than discharging concentrated brine into sensitive marine ecosystems. The document additionally identifies potential application in refineries, petrochemical complexes, power plants, mining operations and seawater-desalination systems where concentrated brine management represents a significant environmental challenge

Key Learnings:

The pilot demonstrated that Produced Formation Water can be converted from a disposal liability into a reusable industrial-water resource when appropriate treatment technologies are combined. Reverse Osmosis alone was not sufficient to achieve true Zero Liquid Discharge. The successful process required pretreatment, LPRO/HPRO membrane separation, thermal concentration and drying. The study also established that beneficial reuse of recovered salts depends heavily on their mineral composition and therefore must be determined on a site-specific basis. Pilot-scale validation proved particularly valuable by establishing process performance, generating commercial-scale design information and supporting regulatory confidence before committing to the larger 3,000 KLPD facility

Future Plans:

OIL plans to complete tender evaluation, award the EPC contract and commission the 3,000 KLPD commercial ZLD facility at STF-Madhuban, with two years of O&M support. Further replication is proposed at other OIL locations experiencing similar produced-water management challenges, beginning with opportunities already identified in the Tengakhat Area. Future work will also seek to maximize use of recovered permeate and condensate for utilities, firefighting, drilling and other industrial applications, while continuing to evaluate beneficial utilization of recovered salts and process by-products



"Industrial Reuse of Municipal STP Effluent: A Case Study of Indian Oil Mathura Refinery Sustainable Water Management "

Indian Oil Corporation Limited	Circular Economy Water Management

The project originates from the Government of India's "Clean Ganga" mission, launched in 2014, to address pollution in the Ganga and its tributaries, including the Yamuna river. High-level government priority was established on September 2, 2015, during a Ministerial visit to Mathura promoting the reuse of treated wastewater for non-potable purposes. MoU was signed between IOCL, Mathura Refinery and National Mission for Clean Ganga (NMCG) on 17th Aug 2016 to reuse the treated effluent from STP for Non-potable purposes. Tripartite agreement was signed between IOCL-MR, NMCG & Uttar Pradesh Jal Nigam (UPJN) for reuse of 20 MLD of treated sewage water for industrial use at Mathura Refinery on 13th June 2018 at New Delhi. Project was developed by a Special Purpose Vehicle incorporated under Indian Companies Act, 2013 by M/s Triveni Engg., selected by Uttar Pradesh Jal Nigam (UPJN). Currently around 4 MLD of treated sewage water from 8 MLD capacity plant is being supplied to IOCL-MR.

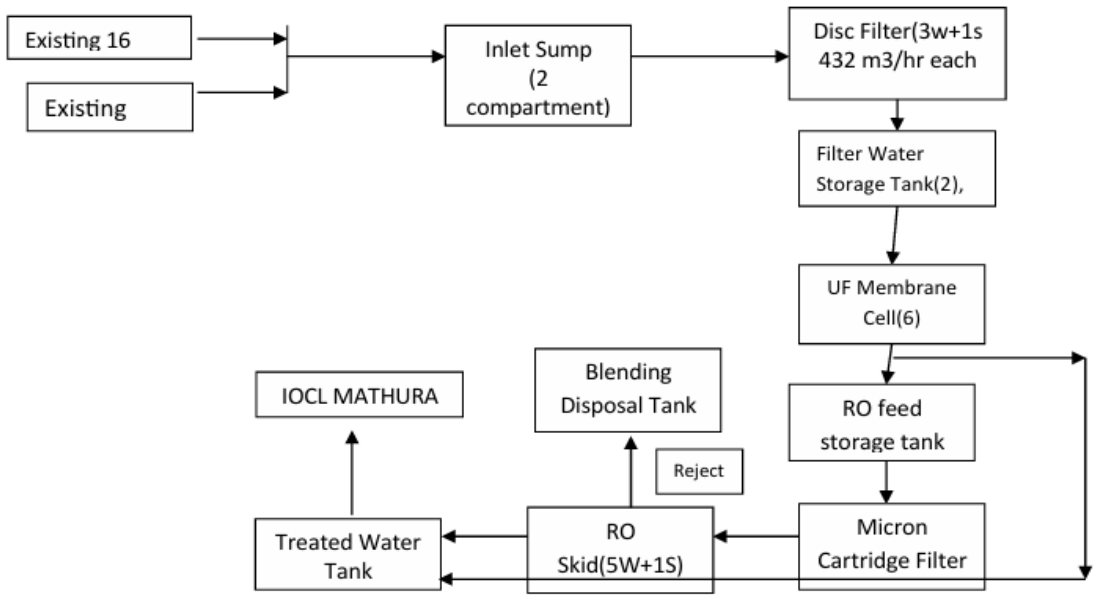
Background & Context:

A tripartite agreement was signed between IOCL-MR, National Mission for Clean Ganga (NMCG) and Uttar Pradesh Jal Nigam (UPJN) for the reuse of maximum 20 MLD of treated sewage water for industrial use at Mathura Refinery on 13th June 2018 at New Delhi. Foundation stone was laid by Shri Nitin Gadkari on 23rd Jan'19. Mechanical completion was achieved in Nov'21, while inception of water discharge to Mathura Refinery took place in Nov'22. The current sewage generation of Mathura City is expected to increase to 61 MLD in 2035. Mathura sewage scheme under Hybrid Annuity based PPP mode (HAM) is first of its kind in the history of wastewater treatment in IndianOil, for integrating the rehabilitation and operation of existing treatment infrastructure along with the development of new Sewage Treatment Plants (STPs). With this significant milestone, IndianOil is not only living up to its vision of environment conservation and preservation but also playing a dynamic role in the mission of Clean Ganga.

Objectives:

1. Reuse of Treated Sewage Water for Non-Potable Purposes at Mathura Refinery to reduce freshwater consumption.
2. Support Environment Conservation and Preservation in line with Indian Oil sustainability goals.
3. Contribute to the National Clean Ganga Mission by effectively managing and utilizing urban sewage.

Methodology:



The Tertiary Treatment Plant (TTP) is designed to upgrade the quality of treated sewage water for reuse in industrial operations, particularly within the refinery. This plant is a part of a sustainable initiative to minimize freshwater consumption and support environmental conservation through the reuse of treated wastewater. The process begins with the inflow of secondary treated sewage water from municipal sources, which is directed to the Inlet Sump and pumped to Disc Filters, capable of handling 432 m^3/hr, to remove larger suspended solids and floating debris. The filtered water is stored in Filtered Water Storage Tanks before undergoing Ultrafiltration (UF), which uses 6 UF membrane cells to remove very fine suspended solids, bacteria, and colloidal matter. The water is then transferred to the RO Feed Storage Tank and passes through Micron Cartridge Filters (6 nos.) to remove remaining fine particles and protect the RO membranes. The Reverse Osmosis (RO) system removes dissolved salts, organic contaminants, and any remaining pathogens, ensuring that the water quality meets the stringent requirements for industrial reuse in the refinery. The RO reject water is directed to a Blending Disposal Tank for proper handling and potential dilution or disposal, minimizing environmental impact. The permeate or treated water is stored in the Treated Water Tank at Laxmi Nagar, Mathura, ready for supply to IOCL Mathura Refinery for various non-potable applications, significantly reducing dependence on freshwater sources. This TTP process represents an advanced and integrated approach to wastewater treatment. It not only ensures compliance with environmental regulations but also aligns with national goals like the Clean Ganga Mission by reducing pollutant load in discharge water and promoting reuse. The plant operates using a combination of physical filtration, membrane technology, and intelligent design to provide a sustainable and reliable source of process water for industrial use.

Challenges:

During the planning and execution of the TTP, several bottlenecks were encountered. One of the primary challenges was coordinating among multiple stakeholders, including IOCL, NMCG, and UP Jal Nigam, each with distinct operational procedures and timelines. integration with existing STPs also posed significant constraints, requiring careful civil planning and design adjustments. To overcome these, a multi-agency coordination cell was formed to streamline communication and approvals. Modular construction and parallel execution strategies were adopted to save time.

Implementation:

The project was implemented with the joint collaboration of the NMCG, UP Jal Nigam, IOCL and third party M/s Triveni's sustained efforts. The treated water from the Laxminagar is sent to Gokul Barrage via pipeline from where it is transferred to Mathura Refinery IOCL through pipeline.

Investment:

Cost Component	Amount (₹ Lakhs)
Capital Expenditure	By NMCG
Operational Expenditure	Rs 7789899.88/- per quarter X 4 months = Rs. 3,11,59,600 /- (per annum)
Human Resources	
Technology Acquisition	-
R&D and Innovation	-
Others	-
Total Investment	

Quantitative Outcomes:

Parameter	Before Implementation	After Implementation	Improvement (%)
GHG Emissions (tCO_2e)	-	-	-
Energy Consumption (units)	-	-	-
Water Consumption (KL)	61,30,740 m3 (2023-24)	55,91,388 m3 (2024-25)	**8.79% reduction**
Waste Generation (tonnes)	-	-	-
Resource Utilization	-	-	-
Operational Efficiency	-	-	-
Cost Savings (₹ in Lakhs)	-	-	-
Others (please specify)	-	-	-

Qualitative Outcomes:

The implementation of the STP at IOCL Mathura has led to several significant qualitative outcomes that go beyond measurable parameters. One of the most impactful benefits is the enhancement of environmental stewardship. By reusing treated sewage water for Refinery operations, IOCL MR has set a strong example in responsible water management and resource conservation, aligning with national sustainability goals and the Clean Ganga Mission.

Innovation & Uniqueness:

This initiative marks the first-of-its-kind integration of rehabilitating existing sewage infrastructure with the development of new STPs under a Public-Private Partnership (PPP) model in IndianOil. The tripartite agreement between IOCL-Mathura Refinery, NMCG, and UP Jal Nigam enables the reuse of maximum 20 MLD treated sewage water for industrial purposes, showcasing a sustainable water Reuse model. The project reflects IndianOil's commitment to environmental conservation while actively contributing to the Clean Ganga Mission.

Key Learnings:

The implementation of STP water reuse at IOCL Mathura Refinery has offered valuable insights into sustainable water management. A major success has been the establishment of a functional model for industrial reuse of municipal wastewater through effective collaboration between IOCL, NMCG, and UPJN. The initiative has reduced dependency on freshwater and aligned with national goals like the Clean Ganga Mission. However, a significant challenge has emerged due to design limitations of the Laxmi Nagar STP, which currently supplies around 2 MLD, well below the intended 8 MLD of 1st phase and 20 MLD for final capacity. This shortfall is primarily due to a mismatch between the actual influent characteristics and the design parameters, affecting treatment efficiency. Key learnings include the importance of accurate assessment of sewage quality during the design phase, the need for flexible and upgradeable treatment technologies, and the benefit of early-stage pilot testing to validate system performance.

Future Plans:

The Focus will be on optimizing and upgrading the existing STP, improving influent quality monitoring, and exploring alternate or supplementary treated water sources to achieve the targeted reduction in freshwater consumption. Future expansion will also emphasize real time monitoring and adaptive treatment solutions for greater reliability and scalability.



Development of Technical textile “Geocell from End-of-Life Plastic Waste”

Bharat Petroleum Corporation Limited
Dr. Mahesh W Kasture
Chief Manager (R&D)

CIRCULAR ECONOMY

The initiative, titled "Development of Technical Textile Geocell from End-of-Life Plastic Waste," has been implemented on Loop No. 1 of the DND-Faridabad-KMP Expressway in New Delhi and has been ongoing since October 2014. It falls primarily under the categories of Emissions Reduction, Waste Management, and Circular Economy. BPCL's Corporate Research & Development Centre (CRDC) developed the technology to convert mixed and end-of-life plastic waste into useful infrastructure products. The initiative resulted in two products: Waste Plastic Modules and Geocells. A key advantage is that the technology can utilize mixed plastic waste without requiring extensive segregation. The solution improves infrastructure quality while reducing waste disposal challenges and dependence on virgin plastic materials

Background & Context:

Plastic waste management remains a major environmental challenge due to the durability and widespread use of plastics. Improper disposal of plastic waste leads to land and water pollution, drainage blockages, flooding risks, and generation of microplastics that enter ecosystems and food chains. Wildlife and marine organisms are particularly vulnerable due to ingestion and entanglement. Open burning of plastic waste releases toxic emissions, creating health hazards and environmental degradation. Significant economic costs arise from cleanup activities, damage to tourism and agriculture, and strain on waste management systems. The initiative emerged from the need to develop sustainable, economically viable alternatives for managing mixed and difficult-to-recycle plastics while supporting circular economy principles and sustainable development goals.

Objectives:

The initiative was launched with three primary objectives:

1. To convert plastic waste into environmentally sustainable and economically viable products while developing a scalable business model.
2. To reduce CO_2 emissions associated with uncontrolled plastic burning and support Net Zero ambitions along with the Swachh Bharat Mission.
3. To create localized industries that process plastic waste near its source, thereby generating employment opportunities and strengthening local economies.

The overall intent was to transform plastic waste from an environmental liability into a valuable infrastructure resource.

Methodology:

BPCL's CRDC conducted feasibility studies to utilize mixed plastic waste in road construction while addressing both plastic pollution and infrastructure durability challenges. The initial technology converted mixed plastic waste into compressed sheets, which were then assembled into hollow structural modules used within pavement layers. The innovation allowed utilization of diverse plastic streams without extensive segregation. Approximately 250 tonnes of plastic waste were consumed across various projects using this technology. In 2025, BPCL partnered with CRRI to develop Geocell technology, a technical textile structure manufactured from mixed and multilayer plastic waste. Field trials conducted with Tata Projects demonstrated both technical and economic feasibility. The technology improves pavement performance, enhances durability, reduces virgin material consumption, and supports circular economy principles.

Challenges:

One of the major challenges was convincing stakeholders that the new technology offered advantages over conventional practices. Collection, segregation, cleaning, and processing of suitable waste plastics posed logistical difficulties. Maintaining consistency in plastic composition and quality was critical for ensuring performance reliability. Temperature control during road construction was another concern because excessive heating could degrade plastics and generate emissions. The project also faced challenges associated with equipment modifications, contractor readiness, and infrastructure requirements. Transportation and processing costs affected economic viability, particularly when waste collection centers were distant from project sites. BPCL addressed these constraints through improved product design, enhanced thermal stability, quality control mechanisms, and demonstration projects validating the technology's performance

Implementation:

The initiative progressed systematically from laboratory research to large-scale infrastructure deployment. Initial demonstrations were conducted at BPCL's Corporate R&D Centre and subsequently expanded to refinery sites, public roads, industrial facilities, and eventually national highway projects. The technology evolved through collaborations with IIT Roorkee, Noida Authority, ITC, BRO, CRRI, NHAI, and Tata Projects. In 2025, BPCL, CRRI, and NHAI jointly conducted India's first highway-scale Geocell field trial on the DND-Faridabad-KMP Expressway. The implementation followed a structured innovation-to-deployment pathway involving technology development, pilot demonstrations, independent validation, and full-scale deployment. This approach ensured technical validation, regulatory acceptance, and performance assessment under real-world conditions

Period	Location / Project	Implementation
July 2016	BPCL Corporate R&D Centre	First demonstration; 1 tonne of plastic over 64 m^2
April 2017	Mumbai Refinery Site-1	2 tonnes over 180 m^2
November 2017	Mumbai Refinery Site-2	2.4 tonnes over 288 m^2
November 2017	Kochi Refinery	4 tonnes over 600 m^2
March 2019	Eastern Region Office, Kolkata	3 tonnes over 400 m^2
November 2020	Noida Sector-129	500 m public-road trial using ~35 tonnes plastic
2021-2023	Multiple locations	175-250 tonnes of plastic utilized
March 2024	BPCL-CRRI Collaboration	Formal collaboration for technology development
July 2025	DND-Faridabad-KMP Expressway	First Geocell field trial

Investment:

The initiative was primarily driven through research and development investments. While specific values for capital and operating expenditure were not reported, BPCL indicated approximately ₹500 lakh was invested in R&D and innovation activities. The implementation was undertaken collaboratively with multiple partner agencies, thereby leveraging external technical expertise and infrastructure support. The technology was developed internally and did not involve technology acquisition costs. The investment reflects BPCL's long-term commitment to sustainable waste management and infrastructure innovation

Cost Component	Amount (₹ Lakhs)
Capital Expenditure	NA
Operational Expenditure	NA
Human Resources	Collaborative implementation
Technology Acquisition	NA
R&D and Innovation	About 500
Others	NA
Total Investment	500

Outcomes:

The initiative demonstrated measurable environmental, resource-efficiency, and economic benefits. The utilization of plastic waste that would otherwise be burned resulted in significant reductions in greenhouse gas emissions. Resource utilization increased remarkably from approximately 2 tonnes/km to 40 tonnes/km of plastic waste incorporation. The technology also demonstrated potential cost savings of approximately ₹5 lakh per kilometer, depending on road conditions and design. These outcomes highlight the effectiveness of the initiative in maximizing plastic waste utilization while supporting sustainable infrastructure development.

The initiative transformed non-recyclable plastic waste into a valuable construction material, significantly advancing circular economy objectives. The technology helps divert plastic waste away from landfills and uncontrolled disposal routes while improving waste management outcomes.

Roads constructed using processed plastic exhibit enhanced resistance to moisture damage, rutting, and surface deterioration, potentially reducing maintenance requirements. The approach also conserves natural resources by partially replacing conventional construction materials. Additionally, the initiative creates opportunities for employment in collection, segregation, processing, and transportation activities. It also raises public awareness regarding responsible waste management and demonstrates how industrial innovation can address environmental challenges while delivering infrastructure benefits.

Parameter	Before Implementation	After Implementation	Improvement (%)
GHG Emissions (tCO_2e)	750	0	90
Energy Consumption	NA	NA	NA
Water Consumption	NA	NA	NA
Waste Generation	NA	NA	NA
Resource Utilization	About 2 tons/km	About 40 tons/km	80
Operational Efficiency	NA	NA	NA
Cost Savings	Conventional	About ₹5 lakhs/km	-

Scalability & Replicability:

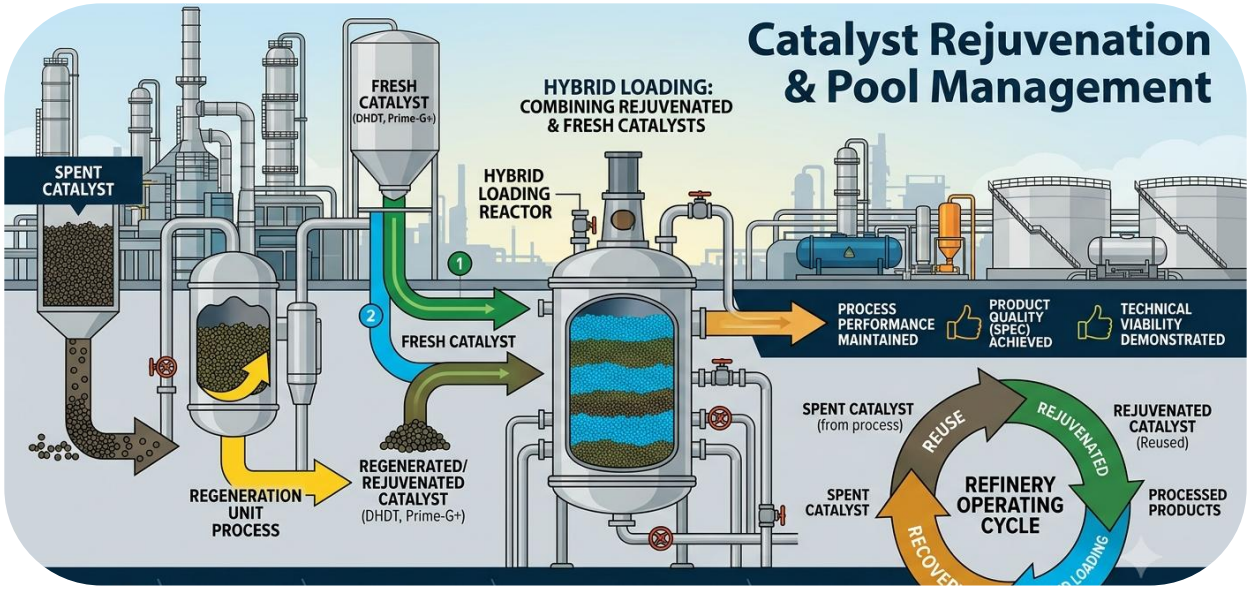
The initiative has strong scalability potential because plastic waste is generated throughout urban and rural India, ensuring a widely available feedstock. There is also substantial demand for geosynthetic reinforcement products in roads, embankments, and civil infrastructure projects. The technology integrates well with existing waste management networks, including municipal collection systems, recovery facilities, and authorized recyclers. India's prior success with waste-plastic road construction provides a supportive institutional environment. By creating engineering products rather than merely disposing waste, the initiative establishes a commercially viable circular economy model that can be replicated nationally.

Key Learnings:

A major learning from the initiative is that waste plastic should be viewed as a resource rather than a disposal problem. By characterizing, engineering, and validating plastic waste-derived products, significant environmental and economic value can be created. Product design and engineering innovation can produce better outcomes than simply mixing waste into conventional materials. The conversion of mixed plastics into modules and Geocells demonstrates that difficult-to-recycle materials can become functional engineering products. The initiative also highlighted the importance of field validation, ecosystem partnerships, standards development, and scalable business models for successful commercialization.

Future Plans:

BPCL intends to scale up the technology for commercial implementation across infrastructure projects. The organization plans to transfer the technology to interested stakeholders to encourage broader deployment. Industry partnerships are proposed for manufacturing modules and Geocells at commercial scale and supplying them based on market demand. BPCL also plans to pursue regulatory approvals and inclusion of Geocells and related products in approved infrastructure material lists. These efforts aim to promote widespread adoption and maximize environmental benefits



Catalyst Rejuvenation & Pool Management

Indian Oil Corporation Limited
N Venkatesh
DGM (PI)

CIRCULAR ECONOMY

The Catalyst Rejuvenation & Pool Management initiative establishes a circular approach to refinery catalyst management by combining rejuvenated/regenerated catalysts with fresh catalysts through hybrid loading. Beginning with regeneration and reuse of spent Prime-G+ catalyst and subsequently expanding to approximately 700 MT of rejuvenated DHDT catalyst, the initiative demonstrated the technical viability of extending catalyst life without compromising process performance or product quality. The framework is now evolving toward a centralized catalyst pool covering assessment, rejuvenation, quality testing, storage, logistics and cross-refinery allocation. The case study reports approximately 40% lower emissions compared with manufacturing equivalent fresh catalyst, 30% reduction in waste generation, and potential cost savings of ₹60 crore/year.

Background & Context:

Traditionally, refinery catalyst requirements were managed at individual-unit level through procurement and use of fresh catalysts. Spent catalysts were generated after completing their effective service life in a particular application, although some retained residual activity that could potentially be utilized in other suitable refinery services. This residual value was not being systematically leveraged. A catalyst reaching end-of-cycle in one unit may retain sufficient activity for a less severe or technically compatible application, provided its condition and performance are adequately validated. The initiative was therefore developed to extend catalyst life, reduce dependence on fresh catalyst, minimize disposal, improve resource efficiency and reduce the associated carbon footprint. Initial Prime-G+ and DHDT rejuvenation projects established technical confidence and formed the basis for a broader catalyst lifecycle and pool-management framework across IndianOil refineries.

Objectives:

1. Promote circularity by maximizing reuse and recycling of spent refinery catalysts.
2. Reduce Scope 3 emissions, with rejuvenation expected to achieve approximately 40% lower emissions than manufacturing equivalent fresh catalyst.
3. Reduce fresh catalyst requirements and associated procurement and spent-catalyst disposal costs.
4. Establish centralized catalyst pool management for improved availability, planning and allocation across refineries.
5. Support domestic catalyst rejuvenation and the “Make in India” objective.
6. Establish single-point responsibility for catalyst assessment, transportation, rejuvenation, storage and inventory management.
7. Enable cascading of catalysts between suitable refinery units and facilitate customized hybrid loading based on technical requirements

Methodology:

The initiative adopts an integrated catalyst lifecycle-management approach covering spent-catalyst assessment, rejuvenation, testing, storage and cross-refinery deployment. A specialized partner has been selected through a long-term rate contract for end-to-end management. Representative catalyst samples are assessed for coke deposition, metal contamination, pore-structure integrity, attrition resistance and expected activity recovery before rejuvenation. Suitable catalyst batches are transported to approved rejuvenation facilities, with the process targeted to recover approximately 90–95% of original catalyst activity. Each rejuvenated batch undergoes activity testing, surface-area measurement, pore-volume analysis and mechanical-strength evaluation, with performance benchmarked against fresh-catalyst specifications. A centralized digital inventory is proposed to capture catalyst source, activity data, quality results, inventory position and utilization history. Rejuvenated catalysts are planned for use through hybrid loading with fresh catalyst, starting at a proposed minimum of 30% rejuvenated catalyst, with potential increase to 40% or higher where technically feasible and supported by performance history

Challenges:

The most important challenge was establishing confidence that rejuvenated catalysts could be deployed without compromising refinery reliability, product quality or catalyst cycle length. Variability in spent-catalyst condition, resulting from differences in feed quality, operating severity, contamination and operating history, required detailed regenerability assessment before reuse. Another challenge was matching suitable catalyst sources with technically compatible destination units. Not all hydro-processing catalysts are equally suitable for rejuvenation, and rejuvenated catalyst cannot be deployed indiscriminately across refinery services. Accordingly, detailed technical screening was incorporated into the framework. Quality assurance, performance accountability, logistics and synchronization of catalyst-replacement schedules across refineries were also significant considerations. These are being addressed through end-to-end partner responsibility, quality certification, hybrid loading, centralized digital inventory and refinery-wide utilization planning

Implementation:

Implementation followed a phased progression from individual catalyst-regeneration projects toward a company-wide lifecycle-management framework. In FY 2023-24, spent Prime-G+ catalyst was regenerated and reused through collaboration between IndianOil, the process licensor and the regeneration service provider. Successful operation and performance-test runs established technical feasibility.

During FY 2025-26, IndianOil developed the broader catalyst pool-management framework. A specialized partner was selected for assessment, rejuvenation, testing, storage, logistics and inventory management, while IndianOil Headquarters is to act as the nodal agency for inventory reconciliation, utilization planning and coordination among refineries. The framework also leverages the Catalyst Manufacturing Unit at Panipat and IndianOil R&D capabilities for catalyst evaluation and validation.

Period	Location / Project	Implementation
FY 2023-24	Prime-G+ catalyst regeneration	Regeneration and reuse demonstrated through tripartite collaboration
FY 2024-25	DHDT catalyst rejuvenation	Spent catalyst from Paradip Refinery rejuvenated through open-tender model
FY 2024-25 onward	Hybrid catalyst deployment	~700 MT rejuvenated catalyst deployed across multiple DHDT units
FY 2025-26	Company-wide pool-management framework	Centralized lifecycle-management model developed
FY 2025-26 onward	Centralized rejuvenation arrangement	Specialized partner selected through long-term rate contract
Ongoing	R&D and CMU integration	Catalyst testing and hybrid-loading optimization supported internally

Investment:

The case study reports nil investment across all listed cost components, including capital expenditure, annual operating expenditure, human resources, technology acquisition and R&D/innovation. The initiative is structured around catalyst lifecycle optimization, rejuvenation partnerships and existing organizational capabilities rather than a separately reported capital investment

Cost Component	Amount (₹ Lakhs)
Capital Expenditure	Nil
Operational Expenditure (Annual)	Nil
Human Resources	Nil
Technology Acquisition	Nil
R&D and Innovation	Nil
Others	Nil

Outcomes:

The initiative is enabling IndianOil to transition from a linear catalyst-consumption model toward circular catalyst lifecycle management, where spent catalyst is evaluated as a potentially recoverable resource instead of solely as a disposal stream. Successful Prime-G+ and DHDT applications have established a structured methodology for catalyst evaluation, rejuvenation, quality assurance and reuse. The case study reports 40% lower emissions compared with manufacturing equivalent fresh catalyst, along with a 30% reduction in waste generation through spent-catalyst reuse. Potential economic savings are reported at approximately ₹60 crore/year. The initiative has also strengthened collaboration between refinery technical teams, R&D, catalyst manufacturers, licensors and rejuvenation partners. Integration with IndianOil's Catalyst Manufacturing Unit and R&D facilities provides additional capability for testing rejuvenated catalysts, optimizing hybrid loading and assessing performance before commercial deployment.

Parameter	Before Implementation	After Implementation	Improvement (%)
GHG Emissions	Not specified	Lower emissions versus equivalent fresh catalyst manufacturing	**40% reduction**
Energy Consumption	-	-	Not quantified
Water Consumption	-	-	Not quantified
Waste Generation	Not specified	Reduced through spent-catalyst reuse	**30% reduction**
Resource Utilization	-	-	Not quantified
Operational Efficiency	-	-	Not quantified
Cost Savings	Not specified	**₹60 crore/year**	Annual economic benefit reported

Scalability & Replicability:

The initiative has been designed for progressive expansion across refinery units, locations and catalyst types. Successful Prime-G+ and DHDT rejuvenation provides an operating basis for expanding catalyst life-extension applications within IndianOil's refining network. The centralized catalyst pool is intended to improve allocation based on refinery requirements, catalyst availability, activity and operating conditions. As additional performance data become available, rejuvenated catalyst proportions in hybrid loading can be optimized where technically feasible. The framework can also be extended to additional hydro-processing catalysts that satisfy technical rejuvenation criteria. Because it relies on established practices such as catalyst characterization, regeneration, quality certification and hybrid loading, the case study identifies the approach as replicable for refining organizations operating multiple refineries with comparable catalyst systems

Key Learnings:

The initiative demonstrated that catalyst management can evolve from a unit-specific procurement activity into an integrated lifecycle-management system. Spent catalysts can retain significant value when systematically assessed, rejuvenated and matched with technically suitable applications. Rigorous catalyst selection and characterization are critical because rejuvenation performance depends on factors including deactivation mechanism, contamination, feed quality and operating history. The phased approach also proved important in reducing implementation risk, as successful pilot applications generated operating experience before broader deployment. Hybrid loading, quality assurance, performance accountability and pilot-scale testing help balance sustainability benefits with operational risk. Centralized planning and inventory visibility are equally important for matching catalyst availability with refinery replacement schedules and maximizing utilization across locations

Future Plans:

IndianOil intends to develop the initiative as an ongoing programme for maximizing catalyst lifecycle value across its refinery network. The near-term focus is establishment of a centralized inventory and planning framework enabling systematic tracking, allocation and utilization of rejuvenated catalyst. As operating experience increases, opportunities will be evaluated to increase the proportion of rejuvenated catalyst in hybrid loading where technical performance supports it. Additional catalyst systems will also be evaluated for rejuvenation, alongside refinement of selection criteria and adoption of improvements in rejuvenation technologies. The longer-term objective is a fully integrated catalyst lifecycle-management system that improves resource efficiency, minimizes waste, reduces environmental impacts and embeds circular-economy principles across IndianOil's refining network





Sustainable Secondary Recovery: Scaling Produced Water Re-Injection to Offset Freshwater Dependency

Oil India Limited	Circular Economy- Water Conservation

The initiative, titled "Sustainable Secondary Recovery: Scaling Produced Water Re-Injection to Offset Freshwater Dependency," focuses on treating produced formation water and reinjecting it into suitable reservoirs for reservoir-pressure maintenance. Initiated in FY 2021-22, the programme has progressively expanded across multiple Water Injection Stations (WIS), achieving annual PWRI volumes of 525,533 KL in FY 2025-26, accounting for 33.13% of total water injection. The initiative reduces freshwater abstraction, minimizes disposal requirements, lowers energy consumption and promotes circular water management. Building on this success, OIL launched Campaign PRISM ("From Reservoir, For Reservoir") in 2026 to accelerate produced-water utilization and advance resource circularity across mature oilfields.

Background & Context:

Water injection is essential for reservoir-pressure maintenance and sustained hydrocarbon recovery. Historically, OIL's secondary recovery operations relied heavily on freshwater and low-salinity groundwater sources for injection purposes. At the same time, mature producing fields generated substantial quantities of produced formation water requiring treatment and disposal. This created a resource imbalance whereby freshwater was being extracted for reservoir support while produced water from the same reservoirs was treated as a waste stream.The disposal of produced water involved additional infrastructure, energy consumption and operational expenditure while increasing environmental exposure. To address this challenge and align with OIL's ESG commitments, including its ambition to become freshwater-positive by 2030, OIL adopted Produced Water Re-Injection (PWRI) as a sustainable solution.

Objectives:

1. To progressively reduce freshwater and groundwater dependency in secondary recovery operations.
2. To utilize produced formation water through treatment and safe reinjection into technically compatible reservoirs.
3. To reduce freshwater abstraction and minimize produced-water disposal requirements.
4. To lower energy consumption and associated emissions linked to groundwater extraction and handling.
5. To reduce operational and environmental exposure associated with produced-water transportation and disposal.
6. To scale up PWRI using a phased and risk-based implementation approach without compromising reservoir performance.
7. To establish a replicable circular water-management framework integrating reservoir engineering, water treatment, asset integrity and HSE considerations.

Methodology:

OIL adopted a closed-loop, site-specific and risk-based approach for converting produced formation water into a valuable resource for secondary recovery operations. Produced water generated during oil production is first collected and routed to Effluent Treatment Plants (ETPs), where it is treated to meet reinjection quality requirements. The treated water is then transferred to designated Water Injection Stations and reinjected through technically suitable injector wells.

The implementation methodology emphasizes multidisciplinary assessment of produced-water availability, water quality, reservoir injection requirements, injector-well suitability, facility connectivity and infrastructure readiness. Existing production, treatment and injection infrastructure are utilized wherever feasible, minimizing the need for major capital investment.

The programme follows a progressive and modular implementation strategy. Operational experience gained from earlier installations is continuously incorporated into new projects, enabling ongoing improvement in design, monitoring and reservoir compatibility assessment. Continuous surveillance of water quality, injection rates and injector performance ensures long-term operational reliability and sustained injectivity

Challenges:

The scale-up of PWRI across multiple operating locations required careful management of site-specific technical and operational challenges. Variations in treated-water quality at different locations necessitated improved surveillance systems and installation of additional strainers and protection mechanisms to safeguard injection infrastructure.

Another challenge involved balancing produced-water availability with reservoir injection demand. Produced-water generation and reservoir requirements are not always aligned geographically; therefore, integrated planning was required to optimize injection capacity and identify suitable injector wells.

Further challenges arose due to differences in reservoir characteristics, treatment requirements, facility connectivity and infrastructure availability across locations. OIL addressed these issues through a phased and flexible implementation strategy, including selective pipelines, tie-ins, booster pumping systems and facility modifications. Continuous operational learning and regular injector-performance monitoring further strengthened implementation effectiveness and reliability.

Implementation Timeline:

Period	Location / Project	Implementation
FY 2021-22	WIS-Dikom	PWRI programme initiated
FY 2021-22	Annual PWRI Volume	20,863 KL
FY 2022-23	PWRI Expansion	192,602 KL
FY 2023-24	PWRI Expansion	435,545 KL
FY 2024-25	PWRI Expansion	509,276 KL
July 2025	WIS-Shalmari	PWRI commissioned
FY 2025-26	Multiple WIS Locations	525,533 KL PWRI achieved (33.13% of total injection)
August 2026	Campaign PRISM	Launched to accelerate freshwater substitution
FY 2026	WIS-Moran	Additional 300 KLPD PWRI capacity established

Investment:

The initiative has primarily leveraged existing production, treatment and injection infrastructure while implementing selective upgrades required for scaling up PWRI. Investment at Shalmari Water Injection Station included PWRI tanks, flowline connectivity and supporting civil works for facility development. The phased implementation strategy helped optimize capital expenditure while maximizing infrastructure utilization

Cost Component	Amount (₹ Lakhs)
PWRI Tanks (3 Nos.)	29,40,000
100 m Flowline	4,60,000
Civil Works	10,50,000
Total Investment	**44,50,000**

Outcomes:

The initiative has delivered substantial environmental, operational and economic benefits. PWRI has eliminated energy consumption previously required for operating deep tube wells used for freshwater abstraction, resulting in a 100% reduction in associated electricity usage. Freshwater dependency has reduced significantly, with produced water now accounting for over one-third of total injection requirements.

The program has also generated considerable savings through reduced formation water disposal and strengthened OIL's capability in water-quality surveillance, injector performance management and integrated water stewardship. Experience gained across multiple operating locations has demonstrated that produced-water reinjection can be successfully integrated into existing field operations without major infrastructure replacement. The initiative has embedded circularity, energy efficiency and sustainable resource management into conventional oilfield operations

Parameter	Before Implementation	After Implementation	Improvement (%)
Energy Consumption	430 MWh	0	100
Water Consumption (KL)	15,86,502	10,60,969	33.13
Resource Utilization (ETP Fresh Water Disposal)	36,76,415 KL	31,50,882 KL	14.30
Cost Savings (₹ Lakhs)	0	252	100
Energy Consumption	430 MWh	0	100

Scalability & Replicability:

The PWRI model has strong potential for replication across mature oil and gas fields because it is built around existing produced-water streams, available reservoir infrastructure and site-specific engineering solutions. Successful deployment across Dikom, GCS06, Shalmari and Moran locations demonstrates its adaptability to diverse operating environments.

The phased and modular implementation strategy enables risk-managed scaling while incorporating operational learning into future projects. Campaign PRISM further provides a common framework for opportunity identification, standardization of practices, knowledge sharing and accelerated replication. The model is particularly relevant for mature producing assets facing increasing produced-water volumes alongside continued reservoir pressure maintenance requirements.

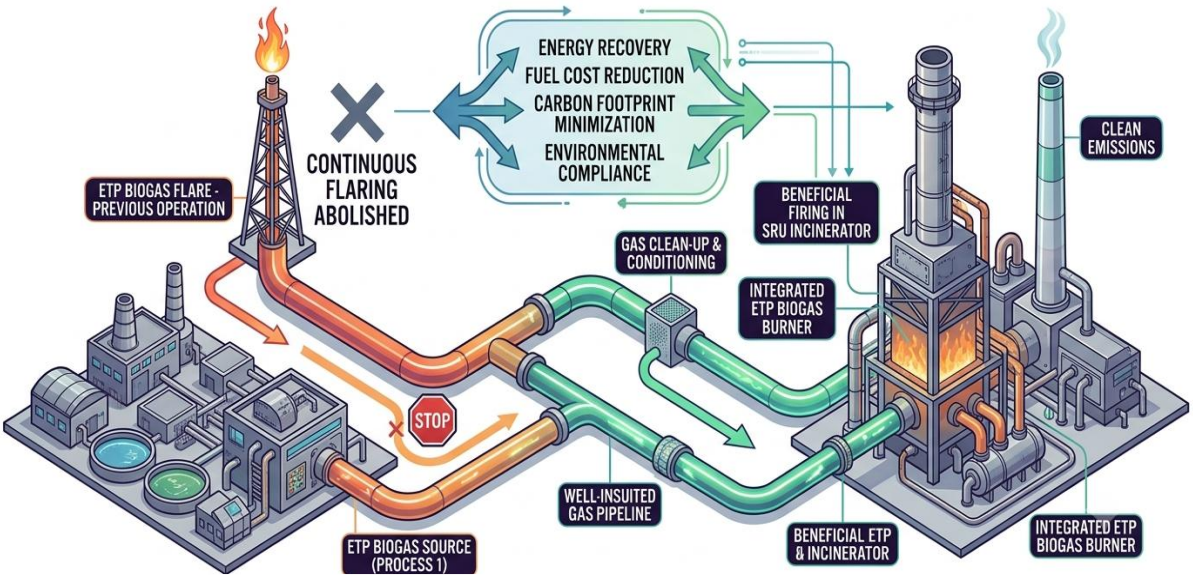
Key Learnings:

A key learning is that water quality and injector performance must be managed as an integrated system through continuous monitoring and timely corrective actions. Successful PWRI implementation depends not only on produced-water availability but also on reservoir capacity to safely accept reinjected water.

The program demonstrated that progressive and site-specific implementation is more practical than adopting a single standardized design. Each installation provided valuable operational insights that improved subsequent projects. Another important learning is that substantial sustainability gains can be achieved through optimization and integration of existing infrastructure rather than relying solely on new capital-intensive developments. These learnings now provide the technical and operational foundation for further expansion under Campaign PRISM.

Future Plans:

OIL plans to accelerate the next phase of PWRI expansion through Campaign PRISM. Near-term plans include establishing additional connectivity between Shalmari OCS-2 and WIS-Shalmari, and between Moran CTF and WIS-Moran by December 2026.Further infrastructure development is planned at WIS-201, HJC, Hapjan and Langkasi by December 2027, including enhanced treated-water storage facilities, additional flowlines and transfer infrastructure. OIL's long-term objective is to reduce LSWI contribution to approximately 26% of terminal injection volume by the end of FY 2027-28, subject to operational feasibility and reservoir requirements



Elimination Of Continuous Flaring Of ETP Biogas Through Beneficial Firing In SRU Incinerator

INDIAN OIL CORPORATION LIMITED
E Panthya
DGM (TS)

CIRCULAR ECONOMY

The initiative addressed continuous flaring of biogas generated from PTA Effluent Treatment Plant (ETP-3), which could not be reliably utilized in the SRU/TGTU incinerator because moisture carryover caused flame instability and operational disturbances. IndianOil resolved the issue by repurposing a redundant LPG Chloride Treater vessel from the PX Unit as a moisture knock-out drum at the SRU end. Following commissioning in November 2025, approximately 350–400 kg/hr of biogas is being beneficially utilized in the incinerator. The project eliminates routine biogas flaring, reduces refinery -gas consumption by approximately 3,072 MT/year and avoids about 7,430 tCO_2e annually as reported in the case-study synopsis. Reuse of an existing vessel also reduced capital requirement and implementation time.

Background & Context:

PTA ETP-3 generates methane-containing biogas through anaerobic treatment, providing a potential supplementary fuel for refinery fired equipment. An earlier arrangement existed for routing this biogas to the SRU/TGTU incinerator; however, the saturated gas experienced condensation while travelling from the ETP to the SRU. Free-water carryover caused burner flame instability and operational disturbances, making sustained biogas firing impractical and leading to routine flaring over several years. Meanwhile, refinery fuel gas continued to be consumed to maintain the required incinerator operating temperature. This resulted in loss of a renewable fuel resource, additional emissions and unnecessary flare-system loading. The initiative therefore focused on addressing the underlying moisture problem and enabling continuous utilization of biogas while minimizing capital expenditure through use of available in-house resources

Objectives:

1. Eliminate continuous flaring of PTA ETP biogas and maximize its utilization in the SRU/TGTU incinerator.
2. Remove free water from the biogas upstream of the incinerator to improve flame stability and temperature control.
3. Reduce refinery fuel-gas consumption through substitution with renewable biogas.
4. Reuse available redundant equipment to minimize project cost and implementation time.
5. Implement the modification through approved Management of Change (MOC) and HAZOP procedures while maintaining process safety and operational reliability

Methodology:

A review of the existing system established moisture carryover as the primary reason for unsuccessful biogas utilization. Since condensation within the long transfer line could not be avoided entirely, the solution focused on separating free moisture immediately before the biogas entered the incinerator. A redundant LPG Chloride Treater vessel from the PX Unit was inspected, modified and relocated to the SRU as a biogas knock-out drum. Modifications included changes to the inlet-nozzle arrangement, installation of a demister pad, level instrumentation, condensate drainage, revised biogas piping and transfer of high-high-level protection to the new vessel. The treated biogas is fired as a supplementary fuel, while the existing refinery fuel-gas system continues to control incinerator temperature. The modification was implemented through IndianOil's MOC framework and underwent formal HAZOP review before commissioning

Challenges:

The principal technical challenge was removing free water from a low-pressure biogas stream without introducing excessive pressure drop. This required appropriate knock-out drum sizing and an effective condensate-drainage arrangement. Biogas flow and composition also vary with ETP operating conditions. To maintain reliable incinerator operation, biogas was therefore integrated as supplementary fuel while refinery fuel gas remained the primary temperature-control fuel. Repurposing the existing vessel required inspection, thickness measurement, cleaning, modification and engineering validation before deployment. Process-safety risks, including backflow, oxygen ingress and start-up safety, were assessed through HAZOP. Finally, because the physical tie-in could only occur during a planned shutdown, fabrication, civil works, inspection and pre-commissioning activities were completed beforehand to minimize shutdown-related execution risk.

Implementation:

Implementation began with a joint site study in May 2025 to understand condensation behaviour in the biogas header. MOC 5380 was initiated on 24 May 2025 and subsequently approved, followed by technical evaluation and issue of revised P&IDs. A formal HAZOP was completed on 16 July 2025.During Q2–Q3 FY 2025–26, vessel inspection, decontamination, relocation, foundation work, piping fabrication, instrumentation, hydrotesting and other pre-commissioning activities were carried out. During the planned November 2025 shutdown, the final incinerator-header tie-in, loop checking, nitrogen purging and commissioning were completed. Post-commissioning monitoring covers biogas flow, condensate drainage, incinerator outlet temperature and refinery fuel-gas consumption. Production, Technical Services/Process Engineering, Projects and Maintenance, Inspection, Fire & Safety and the Environment cell participated in implementation.

Implementation Timeline:

Period	Location / Project	Implementation
20 May 2025	Joint site study	Biogas header and condensation behaviour assessed
24 May 2025	MOC 5380 initiated	Additional KOD scheme formally initiated
26 May 2025	Change request approval	Departmental and Process/Engineering approval obtained
13–14 June 2025	Engineering assessment	Process impacts assessed and marked-up P&IDs issued
16 July 2025	Formal HAZOP	Safety recommendations identified for pre-commissioning closure
Q2–Q3 FY 2025–26	Site execution	Vessel relocation, civil works, piping, instrumentation and hydrotesting
November 2025	Tie-in and commissioning	Biogas firing successfully commissioned
Post-commissioning	Performance monitoring	Biogas utilization, condensate removal, temperature and fuel-gas use monitored

Investment:

The project was implemented predominantly by utilizing existing facilities, manpower, technical expertise and a redundant pressure vessel. Capital expenditure was reported at ₹37.4 lakh, while approximately ₹8 lakh was associated with vessel relocation, insulation and tracing, nitrogen purging and commissioning. The total investment is indicated at approximately ₹50 lakh, with a simple payback of approximately 15 days. The source notes that figures are indicative and expenditure was primarily associated with foundation, relocation, piping, insulation and instrumentation because the vessel itself was an existing redundant asset.

Cost Component	Amount (₹ Lakhs)
Capital Expenditure	37.4
Operational Expenditure (Annual)	Nil, existing facilities used
Human Resources	Nil, existing manpower utilized
Technology Acquisition	Nil, existing in-house asset redeployed
R&D and Innovation	Nil, existing in-house expertise utilized
Others	~8.0
Total Investment	**~50**

Outcomes:

The project converted a routinely flared waste stream into a useful renewable fuel for the SRU/TGTU incinerator. The case study reports a reduction of approximately 3,072 MT/year in refinery fuel-gas consumption and annual cost savings of about ₹1,290 lakh based on a fuel-gas value of ₹42,000/MT. Routine biogas flaring of approximately 200–300 kg/hr was eliminated, while biogas availability to the incinerator increased from approximately zero to above 95%.Approximately 100 KL/year of condensate is now knocked out and returned to the ETP for treatment. Repurposing vessel 202-V-08 eliminated the requirement for fabrication of a new pressure vessel and is reported to have avoided approximately 60% of associated capital expenditure. Operationally, removing moisture carryover has stabilized incinerator firing and temperature control. More broadly, the initiative demonstrates resource circularity by productively utilizing both a waste-derived renewable fuel and a redundant refinery asset.

Parameter	Before Implementation	After Implementation	Improvement (%)
GHG Emissions	3,072 per annum	Nil	100%
Energy Consumption	3,072 MT/year refinery fuel gas	Reduced by 3,072 MT/year	100%
Water / Condensate Recovery	Nil recovered	~100 KL/year returned to ETP	New recovery stream
Biogas Utilization	~3,072 MT/year destroyed in flare without energy recovery	100% of available biogas beneficially utilized	100%
Resource Utilization	Redundant vessel idle; new KOD required	Existing vessel redeployed as KOD	1 vessel reused; ~60% CAPEX avoidance
Operational Efficiency	~0% biogas availability; burner disturbance	>95% availability; stable firing and temperature control	>95 percentage-point improvement
Cost Savings	Nil	~₹1,290 lakh/year	New annual saving
Continuous Flare Load	200–300 kg/hr	Nil	100%

Scalability & Replicability:

The approach can be replicated in refineries and petrochemical facilities where wastewater-treatment biogas is being flared because of moisture-related operating constraints. The solution uses conventional gas-liquid separation rather than complex or specialized technology. Facilities with a suitable fired heater, thermal oxidizer, boiler or incinerator may potentially use recovered biogas as supplementary fuel, subject to site-specific engineering and safety assessment. The project also demonstrates the value of screening redundant equipment before procuring new assets for energy-conservation and resource-recovery projects. The case study states that the engineering methodology, MOC process and implementation approach can be adapted at other IndianOil installations with minimal modification.

Key Learnings:

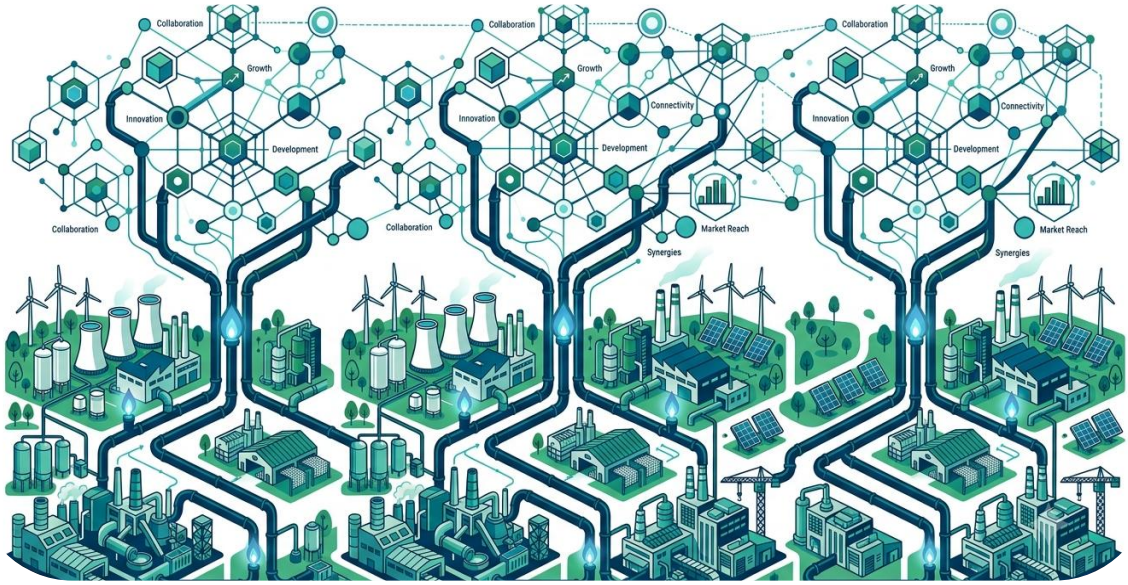
The initiative demonstrated that long-standing operational issues can sometimes be resolved through targeted root-cause engineering rather than major capital investment. In this case, moisture carryover, rather than biogas quality itself, was identified as the principal constraint preventing beneficial utilization. The project also highlighted the importance of hydraulic design in low-pressure gas systems, where relatively small pressure losses can materially affect performance. Waste-derived fuels can be integrated effectively as supplementary energy sources while the primary fuel continues to safeguard the core process requirement. Finally, the initiative demonstrated the value of systematic asset reuse. Engineering validation, inspection and safety review enabled an idle pressure vessel to be repurposed for a resource-recovery application while reducing capital requirement and avoiding new vessel fabrication.

Future Plans:

The immediate priority is to strengthen performance monitoring through periodic verification of biogas flow and composition, refinery fuel-gas displacement and associated emission reductions. Seasonal performance of the knock-out drum and condensate-management system will also be monitored to sustain reliability throughout the year. IndianOil also intends to explore opportunities to increase ETP biogas recovery and maximize utilization within the existing system. The asset-reuse approach demonstrated through this initiative is proposed to be promoted as a standard practice for screening idle equipment before procurement of new assets for similar applications



EFFECIENCY IMPROVEMENT



From Pipeline to Partnership: Customer-Centric Business Innovation for Sustainable PNG

Indraprastha Gas Limited (IGL)
Sushant Kumar Chaudhary
GENERAL MANAGER

EFFICIENCY IMPROVEMENT

The Hapur initiative demonstrates how customer-centric business innovation can create a sustainable PNG market without requiring significant new technology or infrastructure investments. Starting from virtually zero Industrial & Commercial (I&C) PNG consumption in 2023, the initiative transformed Hapur into a growing PNG market with average consumption of approximately 20,000 SCMD and peak consumption of around 25,000 SCMD by January 2026. The approach focused on customer confidence, anchor-customer development, technical-commercial advisory, one-stop facilitation, digital customer acquisition and proactive stakeholder engagement. The initiative successfully onboarded 125 I&C consumers across six industrial clusters and generated cumulative revenue of approximately ₹37.85 crore during FY 2025-26, while creating a replicable model for market development in emerging CGD geographies.

Background & Context:

District Hapur was a greenfield Industrial & Commercial PNG market with negligible gas penetration and virtually zero PNG offtake despite its growing industrial base. Most industrial establishments were familiar with LPG and other conventional fuels but had limited awareness regarding PNG applications and benefits. The challenge was twofold. Industries were reluctant to commit without visible pipeline infrastructure, while infrastructure development required confidence regarding future demand. Additionally, the conversion process involving registration, agreements, internal piping, metering and commissioning appeared complex and fragmented.

Fuel-price volatility created another challenge, as PNG could not always be positioned as the lowest-cost fuel. Consequently, market development required a broader strategy centered on customer confidence, simplified conversion journeys, total energy economics, anchor consumers, industrial associations and transparent communication, rather than price alone

Objectives:

1. Create a sustainable Industrial & Commercial PNG market in Hapur.
2. Build customer awareness and confidence regarding PNG's operational, economic, environmental and safety benefits.
3. Leverage industrial associations and anchor customers to accelerate adoption.
4. Shift customer discussions from fuel pricing to total energy economics.
5. Simplify the customer journey from registration to commissioning.
6. Improve responsiveness and transparency through continuous communication.
7. Digitize customer acquisition and tracking processes.
8. Develop sector-specific anchor consumers to encourage peer adoption.
9. Support customers through fuel-conversion, energy-efficiency and operational guidance.
10. Create a customer-centric service ecosystem that sustains growth beyond individual leadership.

Methodology:

The initiative was implemented through a structured market-development framework comprising customer segmentation, technical-commercial advisory, digital process standardization and stakeholder collaboration. Industrial and commercial clusters were mapped to identify prospective consumers based on fuel usage, demand potential and conversion readiness. Regular field visits, industrial-association meetings and customer outreach programmes were conducted to understand customer requirements and address concerns. Prospective consumers were provided energy-equivalent calculations, efficiency assessments and operating-cost analyses to help them evaluate PNG based on total energy economics. Prominent businesses across dairy, steel, textiles, food processing and manufacturing sectors were identified as anchor customers to build market confidence. A single-point coordination model was established whereby one representative coordinated with Projects, O&M, Finance, Fire & Safety and other departments, simplifying customer interactions. Google Forms and digital tracking mechanisms were introduced for lead generation, customer acquisition and status monitoring. Continuous engagement with industrial associations, district administration, road-owning authorities and service providers supported infrastructure execution and market development

Challenges:

The primary challenge was breaking the demand-infrastructure deadlock. Customers wanted visible pipeline infrastructure before committing to PNG, while infrastructure investment required reliable demand visibility. This was addressed through cluster-level demand aggregation, customer engagement and transparent communication. Low awareness regarding PNG and resistance to fuel conversion also posed challenges. Concerns related to equipment modifications, internal piping, operational reliability and conversion costs were overcome through consultative energy advisory and personalized fuel-equivalent analyses.PNG was not always the most economical fuel option on a unit-price basis. Therefore, customer discussions focused on lifecycle value, uninterrupted supply, reduced storage requirements, safer operations and overall convenience rather than fuel price alone. Other challenges included fragmented customer journeys, limited acceptance of digital platforms, infrastructure-execution delays and lack of local market references. These were addressed through one-stop facilitation, assisted digital adoption, proactive communication and development of trusted anchor consumer.

Implementation:

Implementation commenced in FY 2025-26 with the objective of creating an entirely new PNG market in Hapur. The first phase focused on industrial outreach, association engagement and conversion of influential early adopters. One of the earliest PNG consumers was an Industrial Association President whose successful conversion significantly increased confidence among neighboring industries. The initiative subsequently evolved into a one-stop facilitation model that integrated service providers responsible for internal piping, burner modifications, equipment conversion and technical services. Parallel efforts were undertaken to coordinate infrastructure development, regulatory permissions and customer onboarding. Through systematic deployment across six industrial clusters and continuous customer engagement, Hapur developed into a sustainable PNG market with growing industrial consumption and customer participation. The initiative demonstrated that making gas available creates opportunity, but simplifying conversion creates customers.

Milestone	Achievement
Baseline	Virtually zero I&C PNG offtake
Industrial Coverage	Six major industrial areas covered
Digital Adoption	Customer acquisition progressively shifted to 100% online
Field Outreach	Approximately 250 field visits conducted
Anchor Customer Development	Dairy, steel, textiles, food processing and manufacturing sectors
GSA and Commissioning	Approximately 95 GSA signings and 54 commissionings
Consumer Base	125 I&C consumers onboarded
Consumption	~20,000 SCMD average; ~25,000 SCMD peak
Service Performance	Ageing reduced to approximately 1.25 day

Investment:

The development of the Industrial & Commercial PNG segment in Hapur involved cumulative capital expenditure of approximately ₹25 crore up to FY 2025-26. The investment supported network creation, market development activities and customer onboarding processes. Unlike conventional infrastructure-led growth models, the initiative relied heavily on organizational coordination, customer engagement and service innovation rather than large incremental technology investments

Outcomes:

The initiative successfully transformed Hapur from a virtually non-existent PNG market into a functioning industrial and commercial gas ecosystem. PNG consumption reached approximately 20,000 SCMD on average and peaked at approximately 25,000 SCMD by January 2026. The consumer base expanded to 125 Industrial & Commercial users across six major industrial clusters.

The project generated cumulative revenue of approximately ₹37.85 crore during FY 2025-26. Beyond quantitative metrics, the initiative built customer confidence in PNG, improved customer experience, established a coordinated service-provider ecosystem and reduced dependence on fuel-price competitiveness as the sole adoption driver.

Industries increasingly recognized the benefits of uninterrupted supply, operational convenience, reduced fuel handling and improved safety. Perhaps most significantly, market growth continued even after the initiative lead was transferred, indicating that customer confidence had become institutionalized rather than dependent on individual relationships

Parameter	Before Implementation	After Implementation	Improvement (%)
Resource Utilization	Existing resources and service ecosystem not fully leveraged	Integrated ecosystem supporting 125 I&C consumers and ~20,000 SCMD consumption	Significant improvement
Operational Efficiency	Zero I&C consumers and negligible PNG sales	125 I&C consumers; ~20,000 SCMD average consumption and ~25,000 SCMD peak	Growth from zero base
Revenue Generation	Zero (2023)	~₹37.85 Crore in FY 2025-26	New value creation
Industrial Coverage	Limited market presence	Six industrial clusters covered	Market-wide expansion

Scalability & Replicability:

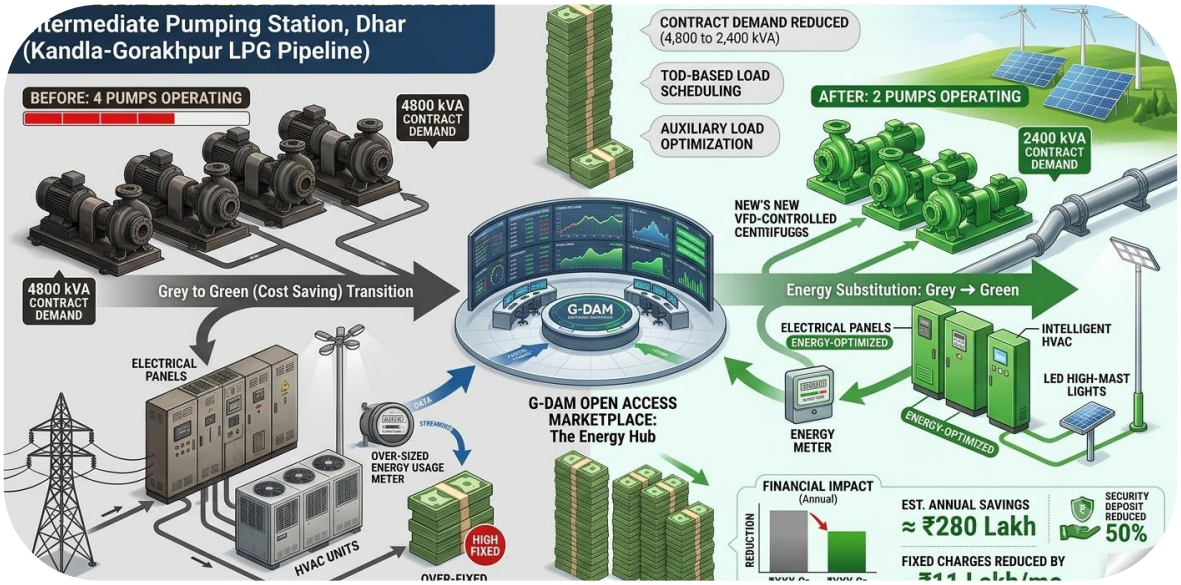
The Hapur model demonstrates that customer-centricity can be scaled alongside infrastructure. The initiative relies primarily on ownership, coordination, responsiveness and customer engagement rather than expensive technology investments. The model is adaptable to local conditions while retaining core principles such as anchor-customer development, single-point ownership, technical-commercial advisory, one-stop facilitation and digital tracking. These elements can be replicated across emerging industrial clusters and new CGD geographies. The approach is particularly relevant in low-penetration markets where customer confidence, awareness and conversion support are as important as physical infrastructure. By focusing on market creation and customer experience, the model provides a practical pathway for accelerating PNG adoption and sustainable demand growth across the CGD sector.

Key Learnings:

The Hapur experience demonstrated that infrastructure development alone does not automatically create a market. Customers adopt PNG when they understand the product, trust the supplier and perceive long-term value beyond price. Anchor customers proved especially effective in reducing hesitation among prospective consumers and accelerating peer-driven adoption. The initiative also highlighted that uninterrupted supply, convenience, safety, energy efficiency and responsive service often influence customer decisions as much as fuel pricing. Coordinating technical-service providers through a one-stop facilitation model simplified the conversion process and reduced delays between connection availability and actual consumption. Another important lesson was that transparent and timely communication can effectively manage customer expectations even when execution timelines are affected by external dependencies. Most importantly, sustainable business growth is achieved when customer confidence becomes embedded within organizational processes rather than remaining dependent on individual relationships

Future Plans:

The next phase focuses on institutionalizing the Hapur experience as a measurable and replicable market-development framework. The immediate objective is to deepen PNG penetration among industrial consumers and increase Hapur's I&C PNG consumption to approximately 50,000 SCMD by 2030, subject to network expansion and market conditions. Future initiatives include maintaining cluster-wise customer pipelines, strengthening the fully digital acquisition process, developing performance dashboards, formalizing one-stop facilitation through defined service-provider networks and continuing anchor-customer development across industrial clusters. The model is also planned for piloting in other low-penetration industrial areas using KPIs such as lead-to-GSA conversion, commissioning time, active consumption, customer retention and complaint-resolution performance



Energy Conservation at Intermediate Pumping Station by Optimizing Contract Demand

IHB Limited
Dhiraj M Karwale
CHIEF MANAGER

EFFICIENCY IMPROVEMENT

IHB Limited implemented a zero-CAPEX energy optimization initiative at the Intermediate Pumping Station, Dhar, on the Kandla-Gorakhpur LPG Pipeline. The project rationalized operation of mainline centrifugal pumps, VFDs, 33 kV/6.6 kV electrical systems, HVAC, high-mast lighting and auxiliary loads based on actual operational requirements. A key intervention was reducing Contract Demand from 4,800 kVA to 2,400 kVA, supported by reducing peak pump operation from four to two pumps and adopting Time-of-Day (TOD) based load scheduling. Fixed charges consequently reduced from ₹22.58 lakh/month to ₹11.36 lakh/month, while the security deposit reduced by 50%. The case study estimates annual savings of approximately ₹280 lakh, while maintaining pipeline reliability, safety and throughput commitments.

Background & Context:

The Intermediate Pumping Station, Dhar was designed to support varying throughput requirements of the Kandla-Gorakhpur LPG Pipeline. Historically, mainline pumps, HT switchgear auxiliaries, HVAC systems and lighting remained energized for extended periods irrespective of actual operational requirements. Energy-trend analysis showed that some equipment was operating under low-load or standby conditions longer than necessary. A significant proportion of pumping and auxiliary load also coincided with peak TOD tariff periods notified by MPKVVCL, resulting in higher electricity charges. The initiative therefore examined both equipment utilization and the station's temporal load profile. Energy-intensive operations were shifted, where operationally feasible, toward off-peak/rebate periods. The project sought to improve energy and cost efficiency through operational intelligence rather than capital-intensive infrastructure changes, without compromising safety, reliability or statutory compliance.

Objectives:

1. Reduce electrical energy consumption and fixed charges at the pumping station.
2. Optimize mainline centrifugal pump operation according to actual throughput requirements.
3. Maximize VFD utilization and reduce throttling losses.
4. Minimize auxiliary consumption from HVAC, lighting and HT electrical systems.
5. Shift energy-intensive operations from peak TOD windows to off-peak/rebate periods where operationally feasible.
6. Reduce the station's contribution to grid peak demand and support better load management.
7. Reduce indirect GHG emissions associated with electricity consumption.
8. Improve operational efficiency and reduce electricity expenditure.
9. Establish a replicable energy-management and TOD load-shifting framework for other pipeline stations.

Methodology:

A multidisciplinary team comprising Operations, Maintenance and Electrical functions evaluated existing power-demand patterns and their alignment with MPKVVCL TOD tariff blocks. Pump operation was optimized through the existing VFD system, under which pump sequence and RPM are integrated with pipeline-pressure requirements and auto start/stop functionality. This reduced peak pump operation from four pumps to two, enabling corresponding optimization of Contract Demand. VFDs were used to operate pumps at optimum speeds and improve matching between electrical load and operational demand. Energization of 33 kV and 6.6 kV panels, feeders and transformers was rationalized according to equipment requirements. HVAC operations were aligned with occupancy and equipment heat loads, while high-mast lighting was restricted during daylight and low-activity periods subject to safety requirements. MPKVVCL's peak, normal and off-peak/rebate TOD windows were mapped against pumping schedules. Where hydraulic and commercial conditions permitted, energy-intensive activities were shifted toward off-peak periods. Maximum Demand, load factor and electricity consumption were continuously monitored through SCADA and utility-metering data. Based on the resulting operating envelope, Contract Demand was formally revised from 4,800 kVA to 2,400 kVA.

Challenges:

Implementation required maintaining pump availability during sudden throughput variations, including situations coinciding with peak tariff periods. TOD considerations also had to be incorporated into routine decision-making across operating shifts, requiring operator awareness and behavioral change. Lighting and HVAC optimization had to remain fully aligned with station safety requirements. Another challenge involved separating and monitoring savings arising from multiple interacting parameters, including equipment runtime, TOD blocks, energy charges and demand charges. The Contract Demand revision also required coordination with the distribution licensee while ensuring continued compliance with grid-code and connectivity requirements. These issues were addressed through SOPs, SCADA visibility, cross-functional ownership, phased implementation, management review and engagement with MPKVVC.

Implementation:

Standard operating procedures were developed covering equipment optimization and TOD-aware scheduling. SCADA-based monitoring enabled daily review of pump utilization and TOD-block-wise energy consumption, while personnel were trained on the revised operating practices and rationale for load shifting. The measures were implemented without affecting pipeline reliability, safety or throughput commitments. Following operational optimization, IHB formally revised its Contract Demand with the electricity utility from 4,800 kVA to 2,400 kVA. Post-implementation Maximum Demand remained within the revised Contract Demand, demonstrating adequate operational headroom. TOD-based scheduling additionally allowed the station to utilize rebate-period electricity rates while reducing its contribution to peak grid demand

Intervention	Implementation
Mainline Pumps	Peak operation reduced from 4 pumps to 2 using pressure-linked VFD sequencing
VFD Optimization	Pump speed aligned with actual operating requirements
HT Systems	33 kV/6.6 kV panels, feeders and transformers rationalized
HVAC	Operation aligned with occupancy and equipment heat-load requirements
Lighting	Daylight and low-activity operation restricted subject to safety requirements
TOD Management	Flexible loads shifted toward off-peak/rebate periods where feasible
Monitoring	Maximum Demand, load factor and consumption monitored through SCADA/metering
Contract Demand	Revised from 4,800 kVA to 2,400 kV

Investment:

The initiative required no capital expenditure and was implemented through operational and contractual optimization of existing infrastructure. Operational and human-resource requirements were described as minimal and managed internally, with no expenditure reported for technology acquisition or R&D.

Outcomes:

The initiative produced substantial financial benefits by aligning contracted electricity capacity with the station's demonstrated operational requirements. Contract Demand fell 50%, from 4,800 kVA to 2,400 kVA, while Billing Demand reduced from 4,320 kVA to 2,160 kVA. Monthly fixed charges decreased by 49.7%, from ₹22.58 lakh to ₹11.36 lakh. The security deposit held by the utility reduced from ₹141.95 lakh to ₹70.97 lakh, while the illustrative net bill payable reduced from ₹60.52 lakh to ₹31.31 lakh. Estimated annual cost savings are approximately ₹280 lakh/year for the period stated as July 2025 to March 2026 in the case study. Qualitatively, the initiative strengthened data-driven energy management and demonstrated the value of reviewing utility contracts alongside physical equipment performance. The document also notes indirect GHG benefits associated with reduced electricity demand, but does not quantify the actual electricity or tCO_2e reduction

Parameter	Before Implementation	After Implementation	Improvement (%)
Contract Demand	4,800 kVA	2,400 kVA	**50% reduction**
Billing Demand	4,320 kVA	2,160 kVA	**50% reduction**
Fixed Charges	₹22.58 lakh/month	₹11.36 lakh/month	**49.7% reduction**
Security Deposit Held	₹141.95 lakh	₹70.97 lakh	**50% reduction**
Net Bill Payable (Illustrative)	₹60.52 lakh	₹31.31 lakh	**~50% reduction**
Estimated Annual Cost Savings	-	~₹280 lakh/year	Significant

Scalability & Replicability:

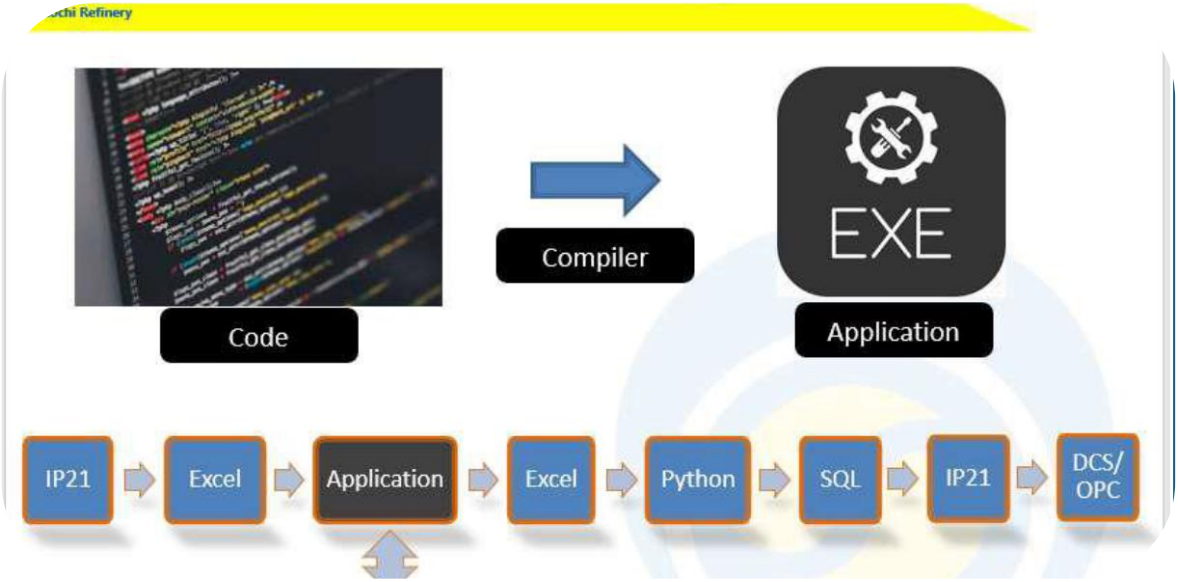
The approach has strong replication potential across pumping stations, terminals and pipeline installations where Contract Demand was established on projected requirements but actual operating demand has subsequently evolved. Facilities operating under TOD tariff structures may similarly identify opportunities for commercial optimization and load shifting. The methodology is relatively simple and data-driven, involving periodic demand assessment, equipment-utilization review, TOD-block mapping and utility-contract optimization. As it relies primarily on operational changes rather than new equipment, the approach can potentially be extended across IHB Limited's asset network.

Key Learnings:

The case study demonstrates that periodic review of electricity contracts can reveal significant cost-saving opportunities, particularly where installed or contracted capacity was determined using original design assumptions rather than actual operating conditions. Actual operating data should therefore inform Contract Demand and equipment-scheduling decisions. The initiative also demonstrates that material efficiency improvements can be achieved without significant capital investment when existing pumps, VFDs, electrical systems and auxiliary equipment are optimized collectively. Cross-functional collaboration between Operations, Maintenance and Electrical teams was central to implementation. Another key learning is that TOD-based load shifting can combine commercial benefits with demand-side grid support when operational flexibility permits energy-intensive activities to be shifted away from peak periods.

Future Plans:

IHB Limited plans to undertake similar Contract Demand and load assessments at other pumping stations and operating facilities. TOD-aware scheduling is proposed to be institutionalized as a standard operating practice, subject to throughput and safety requirements. Future actions include regular monitoring of electrical performance indicators and TOD-wise consumption, adoption of digital energy analytics for continuous demand visibility, and implementation of additional energy-conservation measures to improve operational efficiency and cost competitiveness.



Machine Learning Model for Real-Time Propylene Purity Prediction and Closed-Loop APC Control

Bharat Petroleum Corporation Limited
Roshan Sihab PM
GEENRAL MANAGER (HSE)

EFFICIENCY IMPROVEMENT

BPCL Kochi Refinery developed an in-house Machine Learning model for real-time prediction and control of propylene purity in the Propylene Recovery Unit. Previously, quality monitoring depended substantially on laboratory analysis conducted once or twice daily, while the existing APC inferential generated a broad purity range of 96%–105% against a required minimum specification of 99.6%. Off-spec conditions could require 12–16 hours for recovery. BPCL developed a Gaussian Process Regression model using 17 critical plant tags and integrated its prediction into the DCS and Advanced Process Control system through a custom architecture involving MATLAB, IP21, Python and SQL. The initiative shifted quality management toward predictive, closed-loop control and is reported to offer ₹2 crore/year of additional revenue potential by reducing quality giveaway.

Background & Context:

BPCL Kochi Refinery produces propylene from the Petrochemical Fluidized Catalytic Cracking Unit through the Propylene Recovery Unit. Part of the propylene feeds the PDPP complex, while the balance is sold as finished product. The minimum required propylene purity is 99.6%.The existing APC inferential provided purity estimates ranging approximately from 96% to 105%, limiting its usefulness for precise quality control. Consequently, manufacturing and process teams relied substantially on laboratory analysis. Laboratory testing was generally conducted only once or twice daily and involved delays associated with sampling, transportation and analysis. When propylene became off-spec, corrective intervention was required in the PRU column and restoration could take approximately 12–16 hours, resulting in production losses. The initiative therefore focused on developing accurate, real-time propylene purity prediction capable of being incorporated directly into process control

Objectives:

1. Predict propylene purity in real time using Machine Learning.
2. Deploy ML predictions in real time and make results available on the plant DCS.
3. Integrate predicted purity as a controlled variable within APC.
4. Automate and optimize PRU process control.
5. Minimize quality giveaway.
6. Reduce off-spec propylene production

Methodology:

BPCL utilized historical process information stored in the Aspen InfoPlus-21 historian, which maintains minute-wise refinery data. A detailed study of the PFCCU and PRU identified 17 critical plant tags capable of influencing propylene purity. Historical datasets were cleaned and prepared by addressing missing values, removing outliers, aligning timestamps and converting raw sensor information into usable ML features. Multiple algorithms were assessed over more than two months using R^2 and RMSE as performance metrics. Gaussian Process Regression provided the best fit and was selected for deployment. A custom architecture was subsequently developed to transfer predictive outputs from MATLAB through supporting digital systems and ultimately into IP21 and the DCS/APC environment.

Layer	Role
Aspen IP21	Historical and real-time process data
ML Model	Gaussian Process Regression for propylene purity prediction
MATLAB	Model-development environment
MATLAB Compiler Runtime	Standalone execution of model
Python	Automated transfer of prediction output
SQL Server	Intermediate data-transfer layer
IP21	Receives model prediction
DCS / APC	Displays and uses predicted purity for process control

Challenges:

One of the first challenges was identifying the process variables most relevant to propylene purity and aligning them with appropriate historian tags. Close collaboration with Operations was required to obtain process knowledge and prepare the training dataset. Considerable work was required to clean missing values, filter outliers, align timestamps and engineer suitable model features. Selecting the appropriate ML algorithm also required evaluation of alternative models using R^2 and RMSE. Deployment represented a more significant technical challenge. Direct transfer of MATLAB prediction output into Aspen IP21 could not initially be achieved despite discussions with relevant technology providers. The model was temporarily deployed through cloud access while the team developed an in-house integration architecture. User confidence was another consideration, particularly in enabling operations and APC teams to rely on ML predictions for process control.

Implementation:

The initiative was implemented during January–December 2022. A MATLAB Compiler Runtime was installed on a standalone machine to overcome MATLAB licensing constraints and enable model execution. Python automation was then developed to transfer MATLAB-generated predictions to an SQL Server. In collaboration with the Information Systems team, the SQL Server was connected to Aspen IP21, allowing prediction outputs to become accessible at DCS level. ML prediction was subsequently incorporated into the process-control environment so that real-time predicted propylene purity could support Advanced Process Control. The integration was undertaken in-house using existing and available technologies rather than procuring a new dedicated commercial solution.

Stage	Major Activity	Result
Process Study	PFCCU and PRU analysed	17 critical tags identified
Data Preparation	Cleaning, outlier removal and timestamp alignment	ML-ready dataset established
Model Evaluation	Multiple algorithms evaluated using R^2 and RMSE	Gaussian Process Regression selected
Initial Deployment	Model output made available digitally	User validation initiated
Integration Architecture	MATLAB/MCR, Python, SQL and IP21 connected	Prediction transferred to plant systems
DCS Integration	ML output brought to DCS	Real-time operational visibility
APC Integration	Predicted purity used within process-control framework	Closed-loop ML-APC approach established

Investment:

The project required a limited capital investment of ₹4 lakh, primarily for a high-end machine hosting the MATLAB-licensed server. Existing software tools and in-house capabilities were used, with no separately reported annual operating, human-resource or technology-acquisition expenditure.

Outcomes:

The ML model improved real-time propylene purity prediction and enabled a shift from delayed laboratory-based intervention toward predictive process control. Integration with APC enables the model's output to contribute directly to process-control decisions, helping minimize purity deviations, quality giveaway and associated off-spec production. The case study reports potential additional revenue of approximately ₹2 crore/year through reduced quality giveaway and off-spec generation. The initiative also strengthened collaboration between Digital, Information Systems, APC and Manufacturing teams and developed internal ML model-development, validation and control-system integration capability. The source does not quantify GHG, energy, water or waste reductions, so these parameters should not be assigned sustainability savings beyond those explicitly reported

Parameter	Before Implementation	After Implementation	Improvement
Propylene Specification	Minimum 99.6% required	Minimum 99.6% required	Specification unchanged
Existing APC Purity Estimate	Broad range of ~96%–105%	ML-based real-time prediction	Improved prediction capability
Laboratory Monitoring	Generally 1–2 tests/day	Real-time predictive monitoring added	Continuous prediction capability
Off-Spec Recovery	~12–16 hours stated	ML-driven process control introduced	Exact reduction not quantified
Quality Giveaway	Purity deviations caused production losses	Substantially reduced through ML-driven control	Exact percentage not quantified
Revenue Potential	Existing baseline	~₹2 crore/year additional potential	New value potential
GHG / Energy / Water / Waste	Not quantified	Not quantified	Not quantified

Scalability & Replicability:

The initiative has already provided the basis for additional ML-based quality prediction applications at BPCL. The case study identifies subsequent models for CDU-3 AGO, CDU-2 HGO, DCU LCGO, CDU-3 VDO, DCU HCGO and VGOHDT Diesel D95 prediction, together with the MSBP FGH IBP prediction model and PFCCU Depropaniser bottom-product quality prediction. The architecture is therefore replicable where sufficient historical process data, reliable instrumentation and appropriate digital control infrastructure exist. Future replication can leverage the same ML infrastructure and in-house expertise rather than developing an entirely new deployment architecture for every application

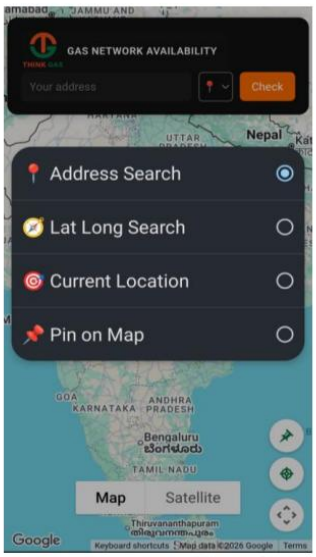
Key Learnings:

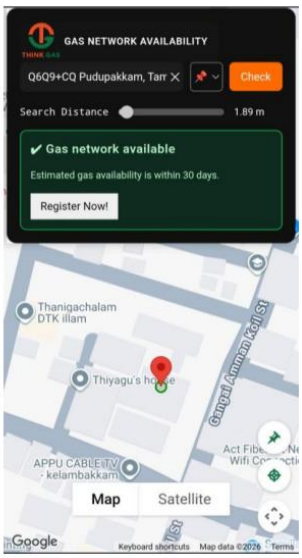
Reliable ML development requires close integration of process knowledge and data science. Identifying the correct plant parameters and historian tags was as important as model selection. Data preparation emerged as a major requirement, particularly management of missing data, outliers and timestamp alignment. Algorithm selection also required systematic evaluation rather than assuming a particular ML technique would perform best. The most significant implementation lesson was that developing an accurate model is only part of the challenge. Integration of the prediction into plant operating systems is critical if analytics are to influence real-time operations. BPCL's custom MATLAB, Python, SQL, IP21 and DCS architecture demonstrated how existing technologies can be combined when direct commercial integration is unavailable

Future Plans:

BPCL plans to extend the ML-APC framework to other quality-critical parameters, particularly IBP, D95 and other product-quality predictions.Existing models will continue to be retrained with updated operational data to maintain and improve accuracy. BPCL also plans to explore development of self-learning models.Internal training on ML tools and techniques will continue to strengthen in-house capability and facilitate broader adoption across refinery operations







GIS-Based Online PNG Registration

Think Gas Barun Singh DGM (Strategy)	EFFICIENCY IMPROVEMENT

The GIS-Based Online PNG Registration platform was developed as a digital self-service solution enabling citizens to apply for Piped Natural Gas (PNG) connections online through a simple "Pin Your Location and Get a PNG Connection" model. Using GIS-based geo-tagging and automated feasibility checks, the platform instantly determines whether a location is serviceable based on proximity to the existing gasified network. The initiative eliminated dependence on customer-care-led registration and manual field verification as the primary entry point. By integrating GIS, Google Maps and automated workflows into a unified platform, THINK Gas significantly improved customer experience, reduced registration timelines, optimized field resource deployment, and generated valuable demand-intelligence data for future network expansion planning

Background & Context:

Before implementation, obtaining a new PNG connection relied heavily on customer care interactions and subsequent field verification visits by DMA officials. High call volumes often led to customer drop-offs, delayed responses, and incomplete application journeys. Manual site verification was time-intensive and difficult to schedule, resulting in extended turnaround times between registration and approval. Furthermore, DMA agencies lacked upfront visibility regarding network serviceability and infrastructure availability. Applications were frequently initiated in locations where pipeline connectivity was not readily available, resulting in delays, resource inefficiencies, and customer dissatisfaction. These operational challenges highlighted the need for a technology-enabled registration and feasibility-checking mechanism that could simplify the customer journey while enabling intelligent, location-based decision-making

Objectives:

1. Enable online self-registration for new PNG connections, reducing dependency on physical visits and customer care interactions.
2. Automate serviceability assessment through GIS-based verification against existing gasified networks.
3. Create a centralized demand-intelligence system for identifying future PNG demand clusters.
4. Improve customer experience through transparent and faster registration processes.
5. Support data-driven network planning and infrastructure expansion decisions.
6. Reduce manual verification efforts and optimize deployment of field resources.

Methodology:

The initiative leveraged existing GIS infrastructure rather than creating a new standalone platform. The solution integrated customer registration, GIS mapping, feasibility validation, and workflow routing into a single digital ecosystem. The core GIS layer utilized GE Smallworld technology to overlay applicant locations onto existing gasified networks and determine serviceability within a defined 100-metre radius. Applicants register through a web portal, pin their location on an interactive map, and upload supporting documents digitally. The system automatically performs serviceability checks and routes applications accordingly. Applications requiring physical verification are forwarded to surveyors with pre-filled location information, while serviceable applications proceed directly to approval. Application status can be tracked throughout the process, while centralized geo-tagged data enables planners to identify future demand clusters and prioritize network expansion opportunities.

Challenges:

Data quality represented an initial challenge because historical operating datasets contained missing The first major challenge involved developing and deploying the platform within a relatively short implementation timeline while ensuring accurate serviceability assessment against actual field infrastructure. Any discrepancy between GIS mapping data and ground realities could adversely affect customer experience and system reliability. The second challenge was the secure integration of a public-facing customer portal with sensitive internal GIS infrastructure. To address cybersecurity and data protection concerns, a dual-layer security architecture was implemented. The customer portal transmits only location information, while the internal GIS system independently validates serviceability and returns a limited response without exposing critical infrastructure data. This ensured both operational efficiency and information security.

Implementation:

The GIS-Based Online PNG Registration platform was implemented through a rapid cross-functional deployment involving GIS experts, software developers, IT specialists, database administrators, and utility domain experts. The rollout was completed over approximately eight days through a structured, phased approach. The process began with requirement gathering and workflow design, followed by portal development, GIS integration, and pilot deployment within a selected GA. Real-world testing validated location accuracy and serviceability logic. Feedback-driven refinements improved user experience, workflow efficiency, and API performance before the solution was progressively deployed across operational geographies. The implementation created a standardized and scalable digital registration model linking customer onboarding with infrastructure intelligence and planning

Implementation Timeline:

Phase	Activity	Outcome
Phase 1	Assessment & Design	Registration workflow and feasibility logic finalized
Phase 2	Development & Integration	Web portal integrated with GIS layers and network data
Phase 3	Pilot Rollout	Proof of concept tested in selected GA
Phase 4	Refinement	User feedback incorporated and performance optimized
Phase 5	CGD-wide Rollout	Entity-wide deployment of digital registration platform

Investment:

The initiative was implemented through a relatively low-cost digital transformation approach by leveraging existing GIS infrastructure and standard mapping services. Minimal capital investment was required for platform development, integration, and supporting operational resources. By maximizing utilization of existing technology assets, THINK Gas delivered a scalable customer-centric solution without significant infrastructure expenditure. The total investment of approximately ₹13 lakh demonstrates how targeted digital interventions can generate substantial operational improvements with limited financial outlay

Cost Component	Amount (₹ Lakhs)
Capital Expenditure	5
Operational Expenditure (Annual)	6
Human Resources	2
Technology Acquisition	-
R&D & Innovation	-
Others	-
Total Investment	13

Outcomes:

The initiative significantly improved operational efficiency by converting a registration process that previously required 7-14 days into an almost instantaneous digital workflow. Customers can now independently determine serviceability and submit applications without waiting for customer-care interactions or preliminary field visits. The platform has improved customer confidence through greater transparency regarding PNG availability. It has reduced the need for repeated customer follow-ups while enabling approximately 10% of new applications to be received through the digital channel. The GIS-based filtering mechanism optimizes deployment of DMA resources by prioritizing genuinely serviceable applications. In addition, geo-tagged registration data now provides valuable insights into customer demand patterns, helping planners identify future growth corridors and prioritize network expansion activities.

Parameter	Before Implementation	After Implementation	Improvement (%)
GHG Emissions	NA	NA	NA
Energy Consumption	NA	NA	NA
Water Consumption	NA	NA	NA
Waste Generation	NA	NA	NA
Resource Utilization	NA	NA	NA
Operational Efficiency	Registration required 7–14 days	Registration completed immediately	100
Cost Savings	NA	NA	NA

Scalability & Replicability:

The solution has strong scalability potential because it is built upon existing GE Smallworld GIS infrastructure and widely available mapping APIs. Expansion into new Geographical Areas requires only updates to the underlying network layer rather than redevelopment of the platform. As CGD infrastructure expands, the automated 100-metre feasibility engine automatically reflects updated network availability. This allows the platform to scale naturally alongside network growth. The concept has broader industry relevance and is referenced as contributing to the design thinking behind the Unified PNG Portal developed by MoPNG and PNGRB, demonstrating strong replicability across the CGD sector

Key Learnings:

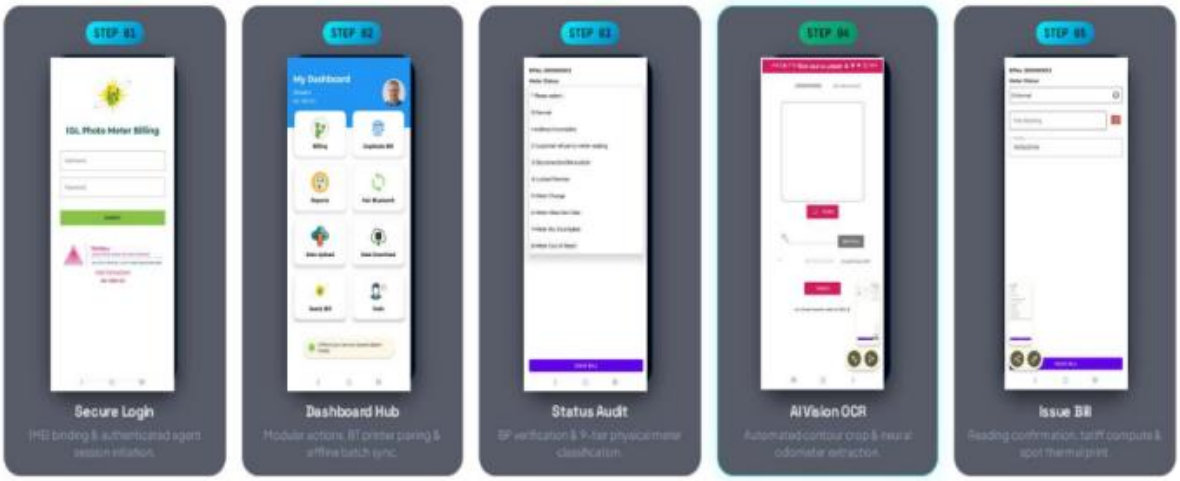
A key lesson from the initiative is that meaningful digital transformation does not always require large budgets, extensive timelines, or complex technology ecosystems. By focusing on the most time-consuming and customer-sensitive stage of the registration journey, a relatively simple intervention generated substantial efficiency gains.

The project also demonstrated the importance of leveraging existing digital infrastructure and GIS capabilities to create customer-centric services. Equally important was the need to address data security and system integration challenges proactively during design rather than treating them as post-implementation concerns. These learnings provide a valuable model for future utility-sector digitalization initiatives

Future Plans:

Future enhancements are focused on expanding the platform's intelligence and customer engagement capabilities. The company plans to extend GIS-based feasibility beyond the current 100-metre serviceability logic by incorporating planned and under-construction network assets. This will allow customers in future service areas to register proactively.

Additionally, automated customer communication through SMS and WhatsApp notifications is planned to provide stage-wise updates throughout the application lifecycle. These enhancements are expected to further reduce customer-care interactions, strengthen transparency, and create a more seamless digital customer experience



SPOT Billing of Domestic PNG Customers

Indraprastha Gas Limited (IGL)
Sushant K. Chaudhary
General Manager, CNG O&M

EFFICIENCY IMPROVEMENT
DIGITALIZATION

IGL introduced SPOT Billing to transform domestic PNG billing from a fragmented multi-stage process into a single field-level transaction. The solution combines photo-based meter reading, validation, SAP-integrated bill generation, Bluetooth printing, delivery and digital Proof of Delivery during one customer interaction. The conventional billing cycle of around 15 days is targeted to be completed on the spot, with QR-based payment capability. During FY 2025-26, SPOT Billing was completed for 27,274 customers, while the broader operating model was working for approximately 1.5 lakh domestic PNG customers across multiple GAs. Reading/billing collection efficiency improved from 40–50% to 80–90%, and per-unit billing cost reduced from ₹22.85 to ₹15. The case study estimates potential annual savings of approximately ₹9 crore.

Background & Context:

IGL's expanding PNG customer base required a billing mechanism capable of providing accurate and timely bills across geographically dispersed areas. Under the conventional approach, meter reading, data processing, SAP upload, bill generation, printing and delivery were performed sequentially through multiple resources and interfaces. The multiple hand-offs increased the possibility of delays, errors, manual intervention and customer complaints, particularly in GAs outside Delhi/NCR where customers can be geographically dispersed. Timely readings also directly affect billing accuracy, revenue realization and outstanding management. SPOT Billing was therefore conceived as an end-to-end redesign of the billing value chain, integrating reading, billing, printing and customer delivery into a single field interaction instead of merely digitizing meter reading.

Objectives:

1. Reduce the conventional approximately 15-day process into an on-the-spot billing transaction.
2. Integrate meter reading, bill generation, printing and delivery within a single customer visit.
3. Improve transparency through photographs, GPS coordinates, timestamps and digital Proof of Delivery.
4. Enable real-time integration between field operations and SAP.
5. Improve customer experience through immediate bill generation and QR-based payment capability.
6. Optimize meter-reader productivity through route sequencing and performance monitoring.
7. Establish a scalable platform capable of accommodating future PNG customer growth.

Methodology:

The model integrates mobile field technology, SAP integration, billing, printing, geospatial verification and analytics into a single workflow. The meter reader retrieves customer information on a handheld/mobile device, records the meter reading, captures a meter photograph and completes system-based validation. The field information is transmitted to IGL's SAP environment, where the invoice is generated. The bill can then be printed through a Bluetooth thermal printer and handed to the customer. Proof of Delivery is captured digitally through signature, coordinates or receiver information. The application supports both online and offline operation. GPS coordinates, photographs and timestamps provide evidence of the field visit, while the SPOT portal retains historical billing information, meter photographs and POD records.

Stage	Activity
Customer Identification	Consumer data retrieved on mobile device
Meter Reading	Reading recorded with photograph
Validation	System checks applied to reading
SAP Integration	Field data transferred to SAP
Bill Generation	Invoice generated
Printing	Bill printed through Bluetooth thermal printer
Delivery	Bill handed to customer
Proof of Delivery	Signature, GPS or receiver details recorded
Analytics	MIS, exceptions and field productivity monitored

Challenges:

The principal challenge was consolidating meter reading, billing, printing and delivery, which were traditionally separate processes, into a single transaction. Real-time integration with SAP also had to preserve billing accuracy and data integrity. Variable mobile-network availability required both online and offline functionality. Customer premises visits also needed to be verifiable, leading to incorporation of photographs, GPS coordinates, timestamps and digital POD. Reading accuracy was another important concern. Backend monitoring, physical audits and random quality checks were incorporated, with the vendor required to randomly check at least 5% of readings. House-lock and customer-refusal cases require repeat contacts or visits within the billing cycle.

Implementation:

The programme progressed from process redesign and application development to SAP integration, field deployment, quality-control mechanisms, analytics and wider geographical scale-up. Meter readers are equipped with dedicated mobile devices and Bluetooth thermal printers, with an average deployment assumption of approximately one reader per 1,500 customers in each GA. The solution is structured for 15 GAs across Haryana, Uttar Pradesh and Rajasthan. Projected customer volumes rise from approximately 1.22 lakh in Year 1 to 3.02 lakh in Year 3, while the document states that the operating model currently serves approximately 1.5 lakh customers

Implementation Timeline:

Phase	Major Activity
I	Existing billing workflow redesigned
II	Mobile SPOT Billing application developed
III	Application integrated with SAP
IV	Mobile devices and Bluetooth printers deployed
V	Quality checks, GPS, POD and reconciliation implemented
VI	Reporting, exception analytics and route optimization introduced
VII	Model scaled across multiple GA

Investment:

The initiative operates primarily through a service-contract model. Capital equipment and human resources are included within the service cost, while application development/integration forms part of the service order. IGL manages the billing engine and SAP development internally.

Cost Component	Amount (₹ Lakhs)
Capital Expenditure	Included in service cost
Operational Expenditure	**200**
Human Resources	Included in service cost
Technology Acquisition	App development/integration included in service order
R&D & Innovation	N

Outcomes:

SPOT Billing was completed for 27,274 customers during FY 2025-26. Operational efficiency for reading collection/billing improved from 40–50% to 80–90%.The reported per-unit cost reduced from ₹22.85 to ₹15, while the quantitative table reports a 34% cost improvement. The case study separately estimates potential annual savings of approximately ₹9 crore. The initiative additionally improves billing traceability through meter photographs, GPS coordinates, timestamps and POD, while real-time SAP integration reduces manual intervention.

Parameter	Before	After	Improvement
Reading/Billing Efficiency	40–50%	80–90%	Material improvement
Customers Spot-Billed in FY 2025-26	-	27,274	New digital capability
Per-Unit Cost	₹22.85	₹15.00	~34% reduction
Annual Savings	-	~₹9 crore expected	New saving potential
GHG / Energy / Water / Waste	NA	NA	Not quantified

Scalability & Replicability:

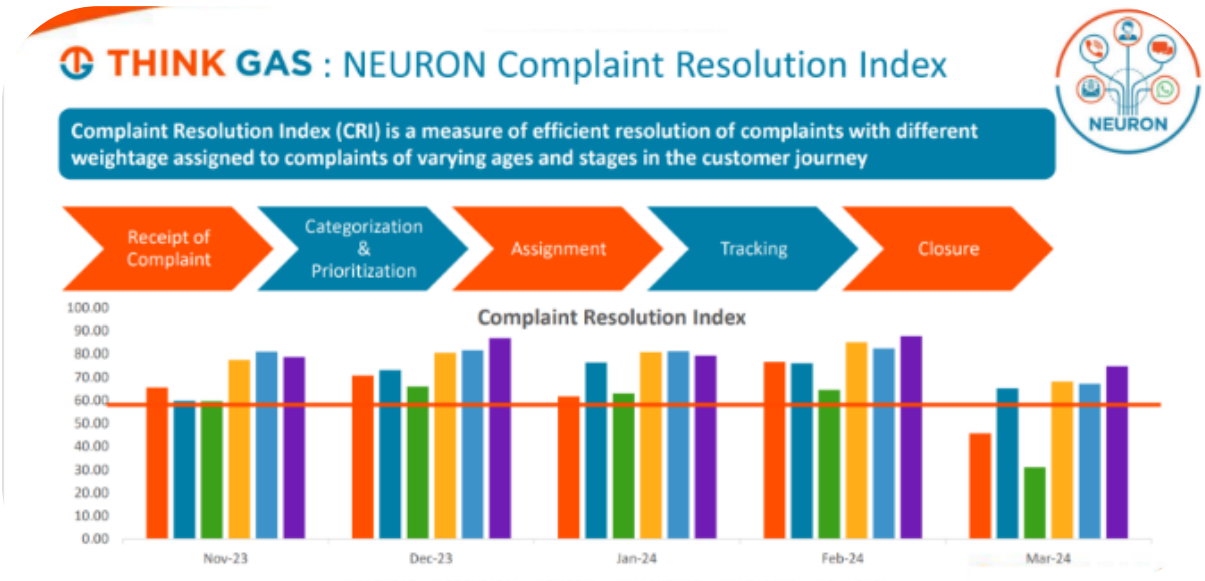
Scalability was embedded into the application architecture, allowing year-on-year addition of customers without fundamental redevelopment. The initial implementation covers 15 GAs, with projected customer volumes exceeding 3 lakh by Year 3.The same architecture is expected to be extended to Delhi NCR, where the case study cites a dense customer base of approximately 22 lakh

Key Learnings:

The initiative demonstrates that digital transformation generates greater value when technology is accompanied by end-to-end process redesign. Digitizing meter reading alone would not have addressed inefficiencies across billing, printing and delivery. Real-time ERP integration, offline capability and geo-verification emerged as important design requirements. Data generated through the process can also be used beyond billing to monitor consumption variation, non-read cases and field productivity

Future Plans:

IGL expects to extend SPOT Billing to Delhi NCR. The case study also proposes embedding real-time payment collection and payment intimation, including incentive/discount schemes for on-the-spot payment realization.



Neuron – A Centre of Excellence for Best-in-Class Customer Experience

Think Gas **Barun Singh** **AGM (Strategy)**	**EFFICIENCY IMPROVEMENT** **Optimization**

THINK Gas developed Neuron, an in-house omnichannel customer-care platform integrating cloud telephony, CRM/SAP-based ticket management, 24×7 multilingual call-centre support, SLA monitoring, auto-escalation and real-time analytics. Before Neuron, customer calls were handled through outsourced teams without a connected system for tracking complaints and field resolution. Neuron established a central digital platform linking customer interactions, ticket management and field teams. Following implementation, First Call Resolution increased from approximately 30% to 70%, Complaint Resolution Index improved from around 40% to 85–95% across GAs, average complaint closure time reduced from more than 72 hours to less than 24 hours, and customer disconnections reduced by 60%.

Background & Context:

Before Neuron, THINK Gas lacked an integrated system for managing customer complaints and service requests. Calls were handled by outsourced teams, resulting in delayed follow-ups, incomplete records and limited visibility of complaint status. Customer issues included meter recharge problems, site-related concerns and emergency calls. The fragmented system could result in extended resolution times and, in some cases, service disconnection. Neuron was therefore conceived as an in-house omnichannel system integrating the call centre, complaint tracking and field teams. Customer queries can be followed through channels including SMS, calls, email and app, while agents coordinate resolution through the common system.

Objectives:

1. Establish a unified platform for registering, tracking and resolving customer complaints.
2. Increase First Call Resolution.
3. Establish a 24×7 in-house call centre supported by cloud telephony.
4. Reduce service disconnections by resolving issues before service stoppage.
5. Improve customer communication and complaint-resolution transparency.

Methodology:

Implementation began with analysis of historic customer complaints to identify recurring causes of delay and dissatisfaction. A SaaS-based CRM integrated with cloud telephony was initially developed to enable real-time tracking of calls and tickets, and the system was subsequently integrated with SAP. Neuron incorporates ticket segmentation by priority, SLA-based auto-escalation and analytics dashboards. Rollout was undertaken across GAs progressively rather than through a single enterprise-wide cutover. A multilingual 24×7 in-house call-centre team was established to manage emergency and non-emergency interactions. Customer-engagement measures included instructional videos, calls and visits, including support relating to recharge processes

Challenges:

The first challenge involved migrating customer-care operations from outsourced teams to an internal operating model without interrupting customer service. Standardizing SLA compliance across GAs with different operating practices was another challenge. Field teams also required training to adopt the new digital tools. Migration of historical complaint information into the new environment required careful handling to prevent loss of legacy customer-service records.

Implementation:

The programme began with data audit and technology-partner selection in April 2022. CRM deployment across GAs occurred from July 2022 through December 2023, followed by deployment to southern GAs during September-December 2024.By early 2024, the system included 24×7 toll-free lines, multilingual agents, verified Truecaller identification and live analytics dashboards. Special helplines for urgent and routine issues were also operational across major GAs identified in the study.

Period	Activity
April 2022	Data audit and technology-partner selection
Jul 2022–Dec 2023	GA-wise CRM rollout
By Early 2024	24×7 call centre and live dashboards established
Sep–Dec 2024	Deployment extended to southern GAs
Ongoing	System enhancement and wider capability development

Investment:

Cost Component	Amount (₹ Lakhs)
Capital Expenditure	16.00
Operational Expenditure	42.65
Human Resources	26.40
Technology Acquisition	10.47
R&D & Innovation	0.31
Total Investment	**69.73**

Outcomes:

Neuron substantially improved customer-service performance across the metrics reported in the case study. First Call Resolution increased from approximately 30% to 70%, while the Complaint Resolution Index increased from approximately 40% to 85–95% across GAs. Average complaint closure time decreased from more than 72 hours to less than 24 hours, customer disconnections reduced by 60%, and service downtime after implementation is reported at below 0.5%

Parameter	Before Neuron	After Neuron	Reported Improvement
First Call Resolution	~30%	**70%**	+133%
Complaint Resolution Index	~40%	**85–95%**	>100%
Customer Disconnection Rate	High	**Reduced by 60%**	Significant
Complaint Closure Time	72+ hours	**<24 hours**	66% faster
Service Downtime	Frequent	**<0.5%**	Highly stable

Scalability & Replicability:

Neuron is already deployed across THINK Gas's GAs. Its cloud-based and modular architecture is intended to support additional locations and users without heavy incremental investment. The same processes, training framework and tools can be reused in new locations and support both domestic and industrial/commercial customer segments.

Key Learnings:

The initiative showed that centralized digital platforms depend heavily on effective on-ground adoption. Training field teams and creating departmental ownership were important to successful technology adoption. The case study also identifies increased accountability through in-house customer-care operations and productivity improvement through clearly defined escalation paths and automated CRM functionality

Future Plans:

THINK Gas plans to add WhatsApp support, launch a customer mobile application for real-time request tracking, and use AI to predict issues and suggest potential solutions.



Revamp of DHDS Charge Heater to Improve Efficiency

Bharat Petroleum Corporation Limited **Santosh Kumar Varshney** **DGM (Environment))**	**EFFICIENCY IMPROVEMENT**

BPCL Kochi Refinery revamped the Diesel Hydrodesulphurization (DHDS) charge heater DDH-01 to improve thermal efficiency, reduce emissions and remove a constraint on unit capacity. The original combination-fired forced-draft heater, designed for 85% efficiency and 8.82 MMkcal/hr absorbed duty, was converted into a fully gas-fired balanced-draft heater with a design absorbed duty of 10.58 MMkcal/hr. Post-revamp performance testing demonstrated 91.5% efficiency at the design duty. The project reduced annual GHG emissions from 19,000 to 12,000 tCO_2e, fuel consumption from 5,700 to 4,960 MT/year, and steam consumption from 9,680 MT/year to zero. The revamp also enabled 100% gaseous-fuel firing in process furnaces at the refinery and increased the heater's capacity to support higher diesel processing toward catalyst end-of-run conditions.

Background & Context:

The DHDS plant at BPCL Kochi Refinery was commissioned in 2000 with a design capacity of 250 TPH and revamped to 317 TPH in 2005. Subsequent catalyst changeovers required higher heater duty to meet BS-VI fuel specifications, while the existing charge heater had not been revamped since commissioning. The original DDH-01 heater used both fuel oil and fuel gas, had a design efficiency of 85%, and provided an absorbed duty of 8.82 MMkcal/hr. Its available duty became a capacity constraint toward catalyst end-of-run conditions. A previous DHDT charge-heater revamp in 2022 had increased efficiency from 81% to 91%, providing the basis for a similar intervention in the DHDS unit. The DHDS project combined energy-efficiency improvement with fuel substitution and heater debottlenecking to improve the overall economic case.

Objectives:

1. Increase charge-heater thermal efficiency from 85% to at least 90%.Reduce GHG emissions by converting the heater to 100% fuel-gas firing.
2. Increase absorbed heater duty and improve DHDS capacity utilization.
3. Address high convection skin-temperature and arch-temperature limitations.
4. Reduce surface heat losses by replacing refractory brick with ceramic-fibre insulation in the radiant section.
5. Eliminate steam used for fuel-oil atomization, heating and tracing, air preheating and associated operations

Methodology:

The project began with a preliminary feasibility assessment to identify suitable revamp configurations, followed by detailed engineering of the selected option. The revamp substantially modified the heater's combustion, heat-recovery, convection and refractory systems. The existing convection section and in-board air preheater were dismantled and replaced with a new eight-pass modular convection section and plate-type air preheater. A new ID fan was installed to enable balanced-draft operation. The four existing combination-fired burners were replaced with six 100% gas-fired burners, requiring furnace-floor modifications. Additional changes included new radiant-tube supports, combustion-air and flue-gas duct modifications, stack-damper modifications, shut-off blinds and radiant-section refractory replacement

Challenges:

The revamp required specialist engineering because BPCL did not have in-house capability to redesign the heater. Engineers India Limited (EIL) was therefore engaged for feasibility assessment, detailed engineering and project-management consultancy. Energy-efficiency improvement alone was not considered sufficient to economically justify the project for the relatively small heater. The business case therefore incorporated the benefits of additional diesel production toward catalyst end-of-run conditions and reduced raw-material costs alongside energy savings. Long-lead equipment had to be engineered and delivered within approximately one year before the scheduled turnaround. Several foundations, structural supports, APH modules, the ID fan and ducting also had to be installed while the unit remained operational. Execution required multiple simultaneous work fronts during the turnaround, extensive hot work, lifting and radiography testing, management of dimensional differences between old drawings and actual field conditions, and refractory work within constrained spaces. A multidisciplinary Pre-Commissioning Safety Audit also had to be closed before commissioning.

Implementation:

A preliminary feasibility study was awarded to EIL in February 2023. Three revamp alternatives were identified and the preferred option was selected by BPCL. Detailed engineering commenced in June 2023, with the complete revamp package released by September 2023.Long-lead items including the air preheater, ID fan, burners and convection module were procured following fund approval. EIL acted as PMC, while the APH, ID fan and burners were supplied by Kamal Encon Industries Limited, TLT Engineering India Pvt. Ltd. and Zeeco India, respectively. The heater-modification package, including the modular convection section, was executed by Esteem Projects Pvt. Ltd. The principal modification was completed during the September-October 2024 DHDS turnaround. Pre-commissioning safety review, commissioning and Performance Guarantee Test Run (PGTR) were completed by November 2024. PGTR demonstrated 91.5% efficiency at 10.58 MMkcal/hr absorbed duty

Implementation Timeline:

Period	Milestone	Outcome
February 2023	Preliminary feasibility study	Three revamp options evaluated by EIL
June 2023	Detailed engineering awarded	Engineering of selected configuration initiated
September 2023	Revamp package released	Procurement and execution planning initiated
Pre-turnaround period	Long-lead procurement and preparatory works	APH, ID fan, burners, convection module and supporting works progressed
Sep-Oct 2024	DHDS turnaround	Major heater modifications completed
November 2024	Commissioning and PGTR	**91.5% efficiency at 10.58 MMkcal/hr duty demonstrated**

Investment:

The project involved reported capital expenditure of ₹2,701 lakh and annual operating expenditure of ₹27 lakh. No separate expenditure was reported for human resources, technology acquisition or R&D and innovation.

Outcomes:

The revamp delivered material improvements in energy efficiency and emissions. GHG emissions reduced from 19,000 to 12,000 tCO_2e, representing a 36.8% reduction, while annual fuel consumption fell from 5,700 MT to 4,960 MT, a 12.2% reduction. Steam consumption associated with the heater reduced from 9,680 MT/year to zero, reflecting elimination of requirements linked to fuel-oil heating, tracing and atomization as well as air preheating and soot blowing. The reported operational-efficiency indicator increased from 78.4 to 91.5.The case study reports ₹192 lakh as a negative cost-saving figure, while the value of additional diesel production toward catalyst end-of-run conditions is reported at ₹962 lakh. The source explains that efficiency improvement alone was economically unattractive and the project's business case depended on combining energy benefits with additional process capacity and reduced raw-material costs. Completion of the project also enabled BPCL Kochi Refinery to achieve 100% gaseous-fuel firing in process furnaces, removing the requirement for the fuel-oil network in the area.

Parameter	Before Implementation	After Implementation	Improvement
GHG Emissions	19,000 tCO_2e	**12,000 tCO_2e**	**36.8% reduction**
Fuel Consumption	5,700 MT/year	**4,960 MT/year**	**12.2% reduction**
Water/Steam Consumption	9,680 MT/year	**0**	**100% reduction**
Operational Efficiency	78.4	**91.5**	**13.1% reported improvement**
Design Absorbed Duty	8.82 MMkcal/hr	**10.58 MMkcal/hr**	Higher heater duty
Reported Cost Savings	-	**-₹192 lakh**	As reported

Parameter	Before Implementation	After Implementation	Improvement (%)
Additional Diesel Production Value toward EOR	-	**₹962 lakh**	Additional value
Fuel Configuration	Fuel oil + fuel gas	**100% fuel gas**	Complete fuel substitution

Scalability & Replicability:

The heater-revamp approach can be replicated across refineries where high-duty process furnaces operate at relatively low efficiency or constrain unit throughput. The combination of efficiency enhancement and debottlenecking can strengthen the investment case where energy savings alone are insufficient. The case study also identifies substitution of heavy fuel oil with cleaner gaseous fuel as an approach with both environmental and economic benefits for refinery applications. Site-specific engineering would remain necessary depending on furnace configuration, space availability, turnaround schedules and existing combustion systems.

Key Learnings:

The project demonstrated that energy-efficiency investments should be evaluated alongside their wider process benefits. In this case, capacity-utilization improvement and fuel substitution were necessary to strengthen the economic justification beyond energy savings alone. Conversion from fuel oil to gaseous fuel created benefits beyond combustion efficiency, including elimination of fuel-oil handling and associated heating, tracing and atomizing steam requirements. The initiative also highlighted the importance of long-term turnaround planning. Major furnace revamps require timely detailed engineering, procurement of long-lead equipment, extensive pre-turnaround works, coordination of multiple execution fronts and rigorous safety management within a constrained shutdown window.

Future Plans:

Having achieved 100% gaseous-fuel firing in process furnaces, BPCL Kochi Refinery intends to extend fuel-oil elimination to its boilers. A retrofit project has already been initiated for one boiler, while feasibility studies are underway for three additional boilers.



Driving Digital Innovation in City Gas Distribution – SCADAvantage Implementation

Think Gas **Barun Singh** **AGM (Strategy)**	**EFFICIENCY IMPROVEMENT** **Optimization**

THINK Gas partnered with ABB India to digitalize its multi-state CGD network using the cloud-based ABB Ability™ SCADAvantage platform. The system centralizes monitoring and control through a control room in Chennai and integrates a network covering 500+ CNG stations, more than 5.5 lakh domestic PNG connections and around 17,000 inch-km of steel pipelines across 19 GAs in 10 states. Field equipment including RTUs, sensors and pressure/flow meters feeds operational information into the centralized platform, supporting pressure/flow monitoring, gas reconciliation, planning, price management and automated alerts. The case study reports improvement in system uptime from 70% to 95%, reduction in alarm-response time from 20–30 minutes to under one minute, approximately 75% reduction in unplanned downtime, and a reported 60% improvement in resource utilization.

Background & Context:

THINK Gas operates a geographically dispersed CGD network spanning 19 licensed GAs across 10 states. The network described in the submission includes more than 500 CNG stations, over 5.5 lakh domestic PNG connections and approximately 17,000 inch-km of steel pipelines supplying domestic, industrial and commercial consumers. Managing such a distributed network created the need for scalable digital infrastructure capable of centralizing visibility, reducing manual intervention and increasing operational responsiveness. The company therefore partnered with ABB India to deploy ABB Ability™ SCADAvantage, a cloud-based SCADA environment intended to integrate multi-state operations within a centralized monitoring and control framework.

Objectives:

1. Establish centralized real-time visibility and control from Chennai.
2. Optimize manpower requirements and reduce manual intervention.
3. Reduce gas-distribution costs and improve process efficiency.
4. Strengthen safety and reliability through improved pressure and flow monitoring.
5. Improve gas reconciliation, price management and planning through real-time information.
6. Establish a scalable digital infrastructure capable of supporting future expansion.

Methodology:

Implementation began with assessment of existing pipelines, CNG stations and PNG infrastructure and identification of scalability, cybersecurity and future-integration requirements.ABB India designed a cloud-based SCADA architecture integrating pipelines, meters, compressors and CNG stations. Field assets were connected using sensors, RTUs and communications networks, while the centralized control room in Chennai provides real-time operational visibility.The platform also supports integration with price management, billing, gas reconciliation and pressure/flow monitoring. Automated alerts and dashboards provide operational information for faster response

Challenges:

The scale and heterogeneity of the network made integration a significant challenge. Assets across 10 states, including hundreds of CNG stations and extensive PNG and pipeline infrastructure, had to be brought into a single centralized environment. Because the solution is cloud-based, secure transmission and storage of operational data was identified as important. Workforce adaptation also required training because the operating model moved from manual/semi-automated practices toward centralized digital operations. Other challenges included ensuring scalability for future expansion, maintaining continuity of gas supply during system deployment, and integrating/migrating information from legacy systems while maintaining data consistency

Implementation:

ABB India deployed and customized the SCADAvantage platform for THINK Gas's assets, while a centralized control room was established in Chennai. RTUs, IoT-enabled sensors and pressure/flow meters were connected to the centralized system. The platform was then integrated with core functions including price management, billing, gas reconciliation, pressure/flow monitoring, automated abnormal-parameter alerts and manpower allocation. Operators and field personnel received training, while initial deployment was piloted in selected GAs before broader rollout and post-deployment optimization.

Stage	Major Activity
Assessment	Existing network, scalability and integration requirements evaluated
System Design	Cloud-based SCADA architecture designed
Field Integration	RTUs, sensors, meters and stations interconnected
Centralization	Chennai control room established
Business Integration	Reconciliation, planning, price and billing functions linked
Automation	Dashboards and automated alerts introduced
Training	Operators and field teams trained
Rollout	Pilot validation followed by broader deployment

Outcomes:

SCADAvantage expanded operational visibility from compressor stations to all critical stations, while providing a centralized archive of historical data that was previously unavailable. System uptime increased from a stated 70% to 95%, while alarm-response time decreased from 20–30 minutes under manual monitoring to less than one minute with real-time monitoring. The case study also reports 60% improvement in resource utilization, approximately 35% higher operational efficiency, and about 75% reduction in unplanned downtime. No quantified GHG, energy, water or monetary-cost savings are provided in the quantitative-outcomes table%.

Parameter	Before implementation	After implementation	Reported Improvement
Resource Utilization	Workforce/assets underutilized	Balanced load distribution and asset optimization	**60%**
System Uptime	70%	**95%**	~35% higher efficiency reported
SCADA Visibility	Compressor stations only	**All critical stations integrated**	100%
Alarm Response	20–30 minutes	**<1 minute**	>95%
Historical Data	Not available	**Central SCADA archive**	100%
Unplanned Downtime	Higher	Reduced	**~75%**

Scalability & Replicability:

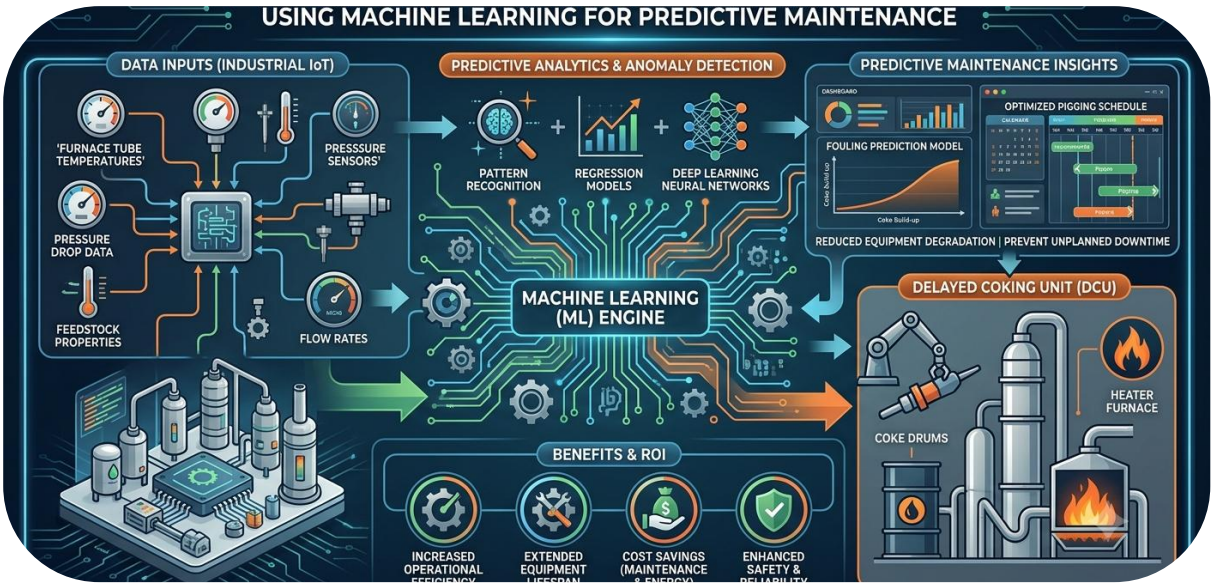
The initiative uses a modular architecture designed to support network expansion without major redesign. The framework can be adapted to different operating environments while maintaining the core centralized monitoring structure. The cloud-based model, documented practices, SOPs and knowledge repositories are identified in the case study as enablers for broader replication

Key Learnings:

The implementation demonstrated that digital integration can improve operational visibility and responsiveness, but successful deployment depends on stakeholder collaboration, workforce adoption and training. The case study emphasizes technology as an enabler of efficiency and scalability, while adaptability of processes is necessary when deploying across different locations and operating conditions. Capacity building and continuous stakeholder engagement are also identified as important to sustaining adoption.

Future Plans:

THINK Gas plans to further strengthen digital integration through additional data analytics and automation. The future programme also envisages expansion of the model, continuous introduction of new digital practices and pilot initiatives, and ongoing training and capability-building activities.



Optimizing Pigging Frequency in Delayed Coking Units Using Machine Learning for Predictive Maintenance

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EFFICIENCY IMPROVEMENT

BPCL Kochi Refinery developed an in-house Machine Learning-based predictive maintenance solution to optimize pigging frequency of Delayed Coking Unit (DCU) heaters. Previously, the DCU followed fixed schedules of spalling every three months and pigging every six months, irrespective of actual heater condition. Using historical operating data and heater skin-temperature behaviour, ML models were developed with 92–96% prediction accuracy and integrated with the Distributed Control System (DCS), supported by a web-based scenario-analysis tool. The initiative enabled pigging intervals to be extended from six to nine months, delivered 860 additional production hours over three years, and achieved a stated 50% increase in operational uptime based on capacity utilization. The case study also reports 375 tonnes/year of steam savings, reduced fuel-gas flaring, and total savings of approximately ₹22.62 crore/year for the tested cycle, with nil external investment

Background & Context:

A Delayed Coking Unit converts heavy residual oil into lighter products and petroleum coke. During operation, coke and fouling accumulate inside heater tubes, restricting flow, reducing heat-transfer efficiency and causing uneven or elevated tube skin temperatures. Periodic pigging is therefore required to restore heater performance. Before the initiative, BPCL Kochi Refinery followed calendar-based maintenance, with spalling every three months and pigging every six months. This rigid approach did not consider the actual condition of individual heaters, potentially resulting in unnecessary shutdowns and maintenance activities. Analysis of the first five pigging cycles showed skin-temperature differences across heater passes ranging from 22.7°C to 32.1°C, indicating uneven operating conditions. This provided the basis for moving from calendar-based maintenance toward condition-based predictive maintenance using operational data and ML.

Objectives:

1. Optimize pigging frequency based on actual heater skin-temperature conditions instead of fixed schedules.
2. Increase DCU operational uptime by extending run length between pigging cycles.
3. Reduce maintenance expenditure, personnel workload and spalling requirements.
4. Reduce unnecessary heater wear and extend equipment operating life.
5. Improve energy and resource efficiency through lower steam consumption and fuel-gas flaring.
6. Develop a web-based scenario-analysis tool for forecasting heater skin temperatures under different operating conditions.
7. Transition DCU maintenance from a reactive/fixed-schedule approach to predictive, condition-based maintenance.

Methodology:

Historical data from five pigging cycles were collected, including heater skin temperatures, pass-flow rates, coil inlet/outlet temperatures, steam consumption and other operating parameters. Data cleaning involved interpolation of missing values and removal of outliers and anomalies, followed by exploratory analysis and feature engineering. Predictive features included the rate of change in heater skin temperature and cumulative operating hours. ML models were trained using historical data and subsequently validated using later pigging cycles, achieving 92–96% prediction accuracy. The concept was also experimentally validated by redistributing charge between Heater-A and Heater-B. A 12 TPH difference was established, stabilizing maximum skin temperatures at approximately 590°C and 600°C respectively. The skin-temperature difference fell from 20°C to 10°C, while Heater-B recorded an average maximum skin-temperature reduction of 8–12°C.The validated model was integrated with the refinery DCS. A web-based scenario tool was additionally developed to allow operators to vary process parameters and forecast their effect on skin temperatures and pigging requirements

Challenges:

Data quality represented an initial challenge because historical operating datasets contained missing values, noise and inconsistencies. Rigorous preprocessing and validation were therefore necessary before the data could reliably support model development. Feature engineering also required close collaboration between data scientists and process engineers because predictive variables needed to reflect actual DCU operating and fouling behaviour. Relevant indicators included temperature trends, rate of change and cumulative operating hours. Another significant challenge involved embedding the ML model into the existing DCS without disrupting refinery operations. This required collaboration with the Information Systems team to establish a data-flow architecture linking Python outputs → SQL Server → IP21 historian → DCS. Finally, usability of the web-based scenario tool required iterative refinement based on operator feedback to balance analytical capability with practical operational requirements.

Implementation:

The initiative was implemented between April 2021 and May 2023 through a phased process covering data collection, ML model development and validation, system integration and operational deployment. Following validation, Python-based ML outputs were transferred to a SQL Server using automation scripts. The Information Systems team subsequently established connectivity between SQL Server, the IP21 historian and the DCS, making predictive outputs available for real-time operational monitoring. A heater-optimization system was also implemented to distribute heater pass flows so that skin temperatures remained more uniform. Predictive models continue to be refined with new operational information from subsequent pigging cycles.

Implementation Timeline:

Stage	Major Activities	Outcome
Data Collection	Historical operating data from five pigging cycles collected	Dataset established for predictive modelling
Data Preparation	Missing values, noise and anomalies addressed; EDA conducted	Model-ready dataset developed
Experimental Validation	Charge redistributed between Heater-A and Heater-B	Temperature difference reduced from 20°C to 10°C
Model Development	ML models developed for heater skin-temperature prediction	**92–96% prediction accuracy** achieved
System Integration	Python → SQL Server → IP21 → DCS architecture established	Real-time predictions made available operationally
Scenario Analysis	Web-based decision-support application deployed	Operators able to assess alternative operating scenarios
Continuous Improvement	Models refined using latest operational-cycle data	Adaptability to changing process conditions maintained

Investment:

The solution was developed entirely in-house using existing data-science, process-engineering, automation and Information Systems capabilities. No capital expenditure, annual operating expenditure, external technology acquisition or separately identified R&D expenditure was reported.

Outcomes:

The initiative enabled the refinery to extend the pigging interval from six months to nine months, supporting a stated 50% increase in operational uptime based on capacity utilization. The case study further reports 860 additional production hours over three years. Energy and resource benefits include approximately 375 tonnes of annual steam savings and reduced fuel-gas flaring. Predictive model accuracy of 92–96% allowed maintenance decisions to be increasingly based on actual heater condition rather than predetermined schedules. The source reports total savings of ₹22.62 crore/year for the tested cycle. However, the principal quantitative-outcomes table does not separately quantify GHG reductions, overall energy consumption, water savings or waste reduction. These parameters should therefore not be assigned values beyond what the case study explicitly reports.

Parameter	Before Implementation	After Implementation	Improvement
Pigging Interval	Every 6 months	Every 9 months	50% extension
ML Prediction Accuracy	No predictive model	92–96%	Predictive capability established
Operational Uptime	Fixed-schedule maintenance baseline	Increased through extended pigging interval	50% increase based on capacity utilization
Additional Production Time	-	860 hours over 3 years	Additional uptime created
Steam Consumption	Existing baseline	375 tonnes/year saved	Annual resource saving
Fuel-Gas Flaring	Existing baseline	Reduced	Reduction not quantified

Parameter	Before Implementation	After Implementation	Improvement (%)
Cost Savings	Fixed-schedule baseline	**₹22.62 crore/year for tested cycle**	Significant saving
Heater-B Maximum Skin Temperature	Pre-adjustment condition	**8–12°C average reduction**	Improved temperature management
Heater Temperature Difference	20°C	**10°C**	**50% reduction**

Scalability & Replicability:

The predictive-maintenance framework has potential for replication because the ML models use operational parameters such as flow rates and coil temperatures that are commonly monitored in DCUs. Models would require adaptation to the operating characteristics and historical datasets of individual units. The underlying approach is also potentially transferable beyond DCU pigging to refinery and other heavy-industrial equipment where fouling, temperature trends and condition-dependent maintenance influence shutdown planning. The combination of predictive modelling, DCS integration and scenario analysis provides a modular implementation framework that can be adapted where comparable operational data and digital infrastructure are available.

Key Learnings:

The initiative demonstrated that maintenance frequency can be optimized using actual equipment-condition data rather than fixed calendar intervals. Prediction accuracy of 92–96% provided sufficient confidence to support extension of the DCU pigging interval from six to nine months. Experimental validation proved valuable in establishing operational confidence. Redistributing charge between the two heaters reduced their skin-temperature differential from 20°C to 10°C and lowered Heater-B's maximum skin temperature by approximately 8–12°C.Data quality emerged as a fundamental requirement for predictive maintenance, with missing values and outliers requiring substantial preprocessing. Equally important was integration of ML output into existing refinery systems so that predictive information became accessible within normal operating workflows rather than remaining a standalone analytics exercise. The case study consequently highlights the importance of combining data science, process engineering, automation expertise and operator engagement when deploying AI/ML in complex refinery operations.

Future Plans:

BPCL Kochi Refinery plans to extend AI/ML-based predictive maintenance beyond DCU pigging to other critical refinery equipment. The broader objective is to improve forecasting of equipment condition and optimize maintenance scheduling using data-driven approaches. The expansion is intended to support improved asset utilization, energy efficiency, equipment reliability and early identification of potential equipment risks, building on the operational framework demonstrated through the DCU initiative



Implementation of AI/ML-Based Pipeline Intrusion Detection System Using Optical Fiber Sensors

GSPL Transmission Ltd.
Vinay Kaul
Senior Manager

EFFICIENCY IMPROVEMENT

GSPL Transmission Limited implemented an AI/ML-enabled Pipeline Intrusion Detection System (PIDS) using Distributed Acoustic Sensing (DAS) over existing optical fiber infrastructure to strengthen surveillance of natural gas pipeline Right-of-Use corridors. The system provides continuous 24×7 monitoring and detects acoustic signatures associated with manual digging, mechanical excavation, vehicle movement and physical interference. AI/ML-based classification filters environmental noise, while GIS-enabled monitoring helps locate potential threats and supports targeted field response. The project replaced reliance on periodic manual surveillance with a proactive, real-time monitoring model. The investment section covers approximately 350 km of pipeline at a capital cost of ₹420 lakh, while the supporting infographic states 330+ km of pipeline is protected.

Background & Context:

Prior to implementation, pipeline surveillance largely depended on manual patrols and periodic inspections, creating limitations in remote and difficult-to-access areas. Third-party construction, agricultural activity and excavation along the ROU could damage pipeline infrastructure or anti-corrosion coatings without immediate detection. Accidental optical-fiber cuts could disrupt remote communication, while delayed discovery through manual surveillance increased operational risk and potential exposure to gas-leak incidents. The initiative was therefore driven by the need to transition from reactive monitoring to continuous detection and proactive threat interception. DAS and AI/ML were deployed to transform existing optical fiber into a continuous sensing network, allowing field teams to identify potentially hazardous third-party activity earlier and focus intervention on specific locations.

Objectives:

1. Establish 24×7 real-time surveillance of pipeline ROU sections for unauthorized activities, excavation and tampering.
2. Transition from reactive repairs to proactive threat interception before physical or coating damage occurs.
3. Reduce incident-response time through GIS-enabled alerts and control-room/mobile notifications.
4. Integrate AI/ML with Distributed Acoustic Sensing to differentiate credible threats from environmental noise.
5. Optimize field resources by reducing dependence on routine manual patrols.
6. Strengthen public and environmental safety by minimizing risks associated with pipeline damage, leakage and fiber cuts.
7. Improve reliability and protection of critical natural gas transportation infrastructure

Methodology:

The initiative followed a phased, risk-based approach using three principal technology layers: Distributed Acoustic Sensing, AI/ML analytics and GIS-enabled monitoring. Existing optical fiber along pipeline ROU corridors was used as a high-sensitivity acoustic sensor capable of detecting micro-vibrations associated with activities such as manual digging, machinery operation, vehicle movement and tampering.AI/ML algorithms process these acoustic signatures and distinguish potential intrusion events from environmental noise generated by sources such as rainfall, trains or animal movement. Sensor outputs are linked with a centralized GUI and GIS environment to indicate the geographic location of potential threats and generate automated alerts. High-risk sections were prioritized using historical incidents, land-use information and proximity to third-party development. Field calibration was undertaken under varying ground and weather conditions, while continuous operational feedback was used to refine the machine-learning models and improve detection accuracy. SOPs and surveillance-crew training supported field response supported dashboard rationalization, storage optimization and continuous improvement.

Challenges:

The first challenge involved accurately identifying and prioritizing high-risk pipeline sections. GSPL addressed this using historical incident information, geographic assessment and proximity to third-party activities. High initial investment requirements were managed through phased deployment beginning with priority zones.

Environmental conditions affected calibration of the sensitive fiber-optic sensors, resulting in customized installation methodologies and scheduling of calibration activities during suitable conditions. Another significant challenge was the initial generation of nuisance alarms from benign environmental noise. Continuous feedback and refinement of AI models, supported by multi-sensor validation, were used to improve accuracy.

Limited internal experience with specialized AI and fiber-optic systems was addressed through training and knowledge transfer with technology partners. The case study also notes that optical-fiber losses must remain within acceptable limits, while fiber cuts can isolate individual monitoring zones

Implementation:

Implementation was undertaken through four phases over approximately 18 months. Initial activities included route mapping, risk assessment, feasibility studies, budget planning and vendor selection. This was followed by pilot deployment on a critical pipeline segment, GUI integration and real-time alert testing. The subsequent rollout expanded PIDS across prioritized pipeline sections while training field personnel and control-room operators and establishing monitoring centres and emergency-response protocols. The final phase focused on system audits, performance reviews, feedback-based improvements, maintenance and software updates. Pipeline ROU coordinators managed implementation, while technology vendors supported hardware, software and project execution

Phase	Major Activities	Period
Planning & Risk Assessment	Route mapping, high-risk zone identification, feasibility assessment, budgeting and vendor selection	Months 1–3
Pilot Deployment	PIDS installation, GUI integration, alert testing and AI fine-tuning	Months 4–7
Full-Scale Rollout	Deployment across prioritized sections, staff training and response protocols	Months 8–15
Optimization & Maintenance	Performance review, audits, system improvements and maintenance planning	Months 16–1

Investment:

The initiative involved capital expenditure of ₹420 lakh for approximately 350 km of pipeline coverage. Annual operational expenditure is reported at approximately ₹20 lakh. Human-resource expenditure was reported as nil, while technology acquisition was outsourced internationally. R&D and innovation activities were undertaken jointly by the in-house team and OEM.

Cost Component	Amount (₹ Lakhs)
Capital Expenditure	420 (~350 km pipeline stretch)
Operational Expenditure (Annual)	20/year
Human Resources	Nil
Technology Acquisition	Outsourced (International)
R&D and Innovation	In-house team jointly with OEM

Outcomes:

The system transformed pipeline surveillance from routine vehicle patrolling toward location-specific, targeted intervention. Field teams can receive information on high-activity ROU locations and focus field response on identified threat areas rather than relying solely on continuous patrols across the complete pipeline route. The case study reports a 100% improvement under resource utilization. Operationally, manual identification has been supplemented by real-time automated threat pinpointing, faster decision-making and proactive early-warning alerts. Qualitative benefits include improved situational awareness, reduced reliance on manual monitoring and an organizational shift from reactive troubleshooting toward proactive risk prevention. The document identifies potential exposure of approximately ₹200 lakh per rupture/pinhole incident, along with possible gas-venting and reputational impacts. However, it does not quantify actual monetary savings, number of incidents prevented, GHG savings or energy savings achieved by PIDS

Parameter	Before Implementation	After Implementation	Improvement (%)
Resource Utilization	Continuous routine vehicle patrols across pipeline route	Targeted dispatch to identified high-activity locations	100% improvement reported
Operational Efficiency	Manual threat identification with risk of downtime and service disruption	Real-time automated threat pinpointing and faster intervention	Substantially accelerated
Prevention Model	Periodic manual patrols and reactive intervention	Continuous monitoring, predictive analytics and automated early-warning alerts	Complete proactive shift
Potential Incident Exposure	~₹200 lakh per rupture/pinhole incident cited	Potential failures mitigated through real-time alerts and timely intervention	Major risk mitigation

Scalability & Replicability:

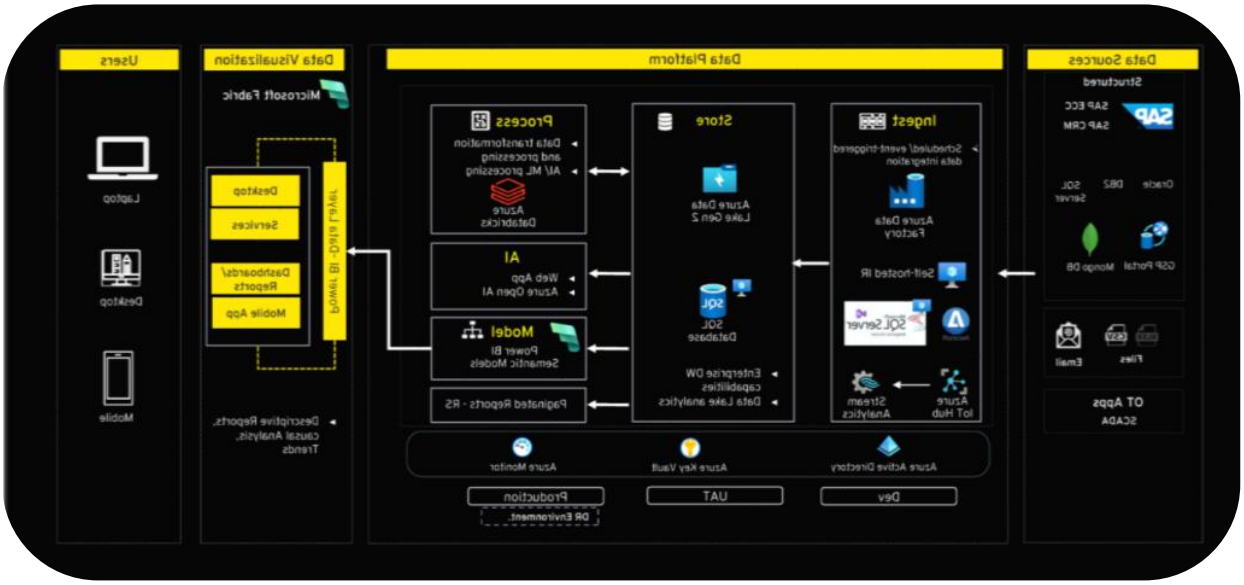
The modular design allows PIDS to be expanded across longer pipeline routes and new geographical areas without disrupting existing operations. The AI models can also be customized for different threat environments and operating conditions. The case study identifies potential cross-sector applications across oil pipelines, water lines, power grids and industrial perimeters. Existing internal knowledge, SOPs and vendor partnerships are expected to support subsequent rollout. The approach therefore provides a scalable digital surveillance model for pipeline infrastructure, particularly for remote or high-risk sections where continuous manual observation is challenging.

Key Learnings:

The project demonstrated that AI/ML and fiber-optic acoustic sensing can strengthen pipeline surveillance by enabling real-time identification of potential third-party intrusion. Continuous refinement of AI models was particularly important because initial environmental noise generated relatively high false-alarm rates. Phased implementation helped address high upfront investment, while training and technology-partner engagement helped overcome limited availability of specialized internal skills. The case study also highlights the importance of maintaining acceptable optical-fiber losses because fiber cuts can isolate monitoring zones. The broader learning is that effective technology-led pipeline surveillance depends on the combination of sensing technology, adaptive algorithms, field feedback, skilled personnel and stakeholder engagement rather than technology deployment alone.

Future Plans:

GSPL Transmission Limited plans to extend PIDS coverage to remaining pipeline sections, particularly remote and high-risk areas. Predictive analytics is proposed to use historical activity and behavioral patterns for anticipating potential threats. Future enhancements also include drone-assisted surveillance for difficult-to-access locations and mobile applications enabling field teams to receive alerts and live information. The AI algorithms will continue to be trained with field data to improve detection accuracy and further reduce false positives



General Service Platform (GSP) : From Fragmented Data to an AI-Enabled Decision Intelligence Ecosystem

Indraprastha Gas Limited (IGL)
Pankaj Sikka
GM (ERP & IT)

EFFICIENCY IMPROVEMENT

The General Service Platform is an enterprise-wide cloud-based data and decision-intelligence ecosystem that integrates fragmented IT, OT and manually governed data into standardized KPIs, dashboards, alerts and AI/ML-enabled insights. Initiated in FY 2019-20, the platform has evolved from descriptive reporting to predictive analytics and conversational AI. A 2025 functional assessment estimated annual savings of 62,816 employee-hours, equivalent to approximately 30 working-years, and productivity-equivalent benefits of ₹6.84 crore annually. During FY 2025-26, IGL further optimized cloud consumption, modernized its data architecture, rationalized low-value content and introduced Generative AI capabilities.

Background & Context:

Before implementation, business information across IGL was distributed across SAP ECC/CRM, SCADA, GIS, databases, spreadsheets, emails and departmental applications. Managers depended extensively on manual data extraction, reconciliation and follow-ups to prepare MIS reports, while existing transactional systems did not provide integrated trends, exceptions or root-cause analysis. Reports relating to customer acquisition, outstanding payments and other cross-functional areas could require several hours to consolidate. Operational exceptions such as nil sales, repeated complaints, abnormal gas loss, inventory ageing and delayed customer-lifecycle stages also required manual identification. The General Service Platform was therefore conceived to establish a trusted enterprise data foundation that could standardize business logic, improve data quality and deliver actionable insights. By FY 2025-26, the focus expanded to optimizing cloud utilization, modernizing data ingestion and enabling secure, natural-language access to governed enterprise data

Objectives:

1. Create a trusted enterprise-wide data foundation integrating heterogeneous IT, OT and manually governed information.
2. Replace repetitive extraction and reconciliation with automated dashboards, reports, alerts and exception-based monitoring.
3. Improve customer service, safety, revenue assurance, operational efficiency and resource planning through actionable analytics.
4. Progress from descriptive reporting to predictive AI/ML and conversational decision intelligence while maintaining security and governance.
5. Establish standardized KPIs and clearly defined departmental ownership of information.
6. Build a sustainable analytics culture through adoption monitoring, training and continuous value assessment

Methodology:

The platform was developed through an “analytics-as-a-service” model combining business-led KPI design with cloud-based data architecture and continuous value governance. Departmental workshops and designated GSP champions translated business processes into KPIs, exception conditions, decision questions and visualization requirements. Business logic was validated by process owners before production deployment. Structured, semi-structured and unstructured data from SAP ECC/CRM, SCADA and historian systems, databases, files, emails and other applications were integrated into a Microsoft Azure-based data lake and warehouse environment through batch and near-real-time pipelines. Common dimensions, business rules, authorization controls and audit mechanisms established a governed analytical layer and common version of truth. Power BI dashboards, drill-downs, geo-analytics, mobile views, scheduled reports and automated email alerts were used to deliver actionable information. Machine-learning applications covered customer-default prediction, sales forecasting and planning, while Conversational BI allowed natural-language interaction with governed sales and PNG acquisition data. Usage analytics, departmental reviews and periodic assessments supported dashboard rationalization, storage optimization and continuous improvement.

Challenges:

The principal challenge was establishing a trusted analytical layer across diverse processes, information systems, business rules, data owners and levels of user capability. Differences in data structures, completeness and refresh frequencies were addressed through common data models, departmental validation, audit trails and feedback mechanisms for correcting information at source.

User adoption was another important challenge. IGL used departmental workshops, GSP champions, repeated training, single sign-on, mobile access, automated email distribution and usage monitoring to embed dashboards within operating processes. The 2025 assessment also obtained departmental decisions on whether individual dashboards should continue or be phased out.

As the platform expanded, cloud-storage and computational efficiency became material considerations. Historical data and low-use dashboards were archived or retired, refresh processes were optimized, and incremental refresh was implemented. AI-related challenges concerning accuracy, security and usability were addressed through model retraining, governed access and iterative user demonstrations. The customer-default model improved from approximately 68% to around 84% accuracy in February 2026, with March 2026 results reported in the mid-80% range

Implementation:

Implementation began in FY 2019-20 with business-process assessment, KPI workshops, visualization design and establishment of the Azure data-lake architecture. EY supported implementation and managed services. Between FY 2020-21 and FY 2021-22, source-system integration and enterprise dashboard deployment expanded, accompanied by exception analytics, geo-analytics and automated alerts. From FY 2022-23 to FY 2024-25, the platform was integrated with IGL's digital workplace and Active Directory. Power BI and mobile capabilities were strengthened, users were trained, and GenAI applications such as Chat with Data and Chat with PDF were explored. Historical project records indicate that the platform reached more than 500 dashboards and reports and over 400 KPIs at its peak.

During FY 2025-26, IGL undertook a formal functional and usage assessment. Between July and November 2025, 224 active users generated 27,925 logins, averaging 5,585 logins per month. Modernization activities included dashboard optimization, data archiving, incremental refresh, automated pipeline alerts, SAP integration proofs of concept using ADF/Fabric, Databricks/Fabric evaluation and Conversational BI for sales and PNG acquisition.

Period	Implementation Stage	Major Activities
FY 2019-20	Foundation	Process assessment, KPI workshops, GSP champions, wireframes and Azure data-lake architecture
FY 2020-22	Enterprise Rollout	Dashboards, reports, source integration, exception analytics, geo-analytics and automated alerts
FY 2022-25	Industrialization	Digital workplace integration, Active Directory, training, mobile capabilities and GenAI discovery
July-November 2025	Usage Assessment	224 active users and 27,925 logins recorded
FY 2025-26	Value-led Modernization	Content rationalization, cloud optimization, incremental refresh and architecture modernization
FY 2025-26	Advanced Intelligence	Default-model retraining and Conversational BI for sales and PNG acquisition

Investment:

The total project investment amounted to approximately ₹20.68 lakh. Capital expenditure accounted for ₹20.30 lakh, including GST, while annual operational expenditure was estimated at ₹0.38 lakh with an escalation factor of 6% annually.

The investment included canopy strengthening, Solar PV modules, inverters, balance-of-system components, electrical integration and compliance-related activities. The project serves as a low-footprint renewable energy solution that leverages existing infrastructure without requiring additional land acquisition

Cost Component	Amount (₹ Lakhs)
Capital Expenditure	20.30
Operational Expenditure (Annual)	0.38
Human Resources	NA
Technology Acquisition	NA
R&D and Innovation	NA
Others	NA

Outcomes:

The General Service Platform changed the operating model from manually collecting and reconciling information to receiving governed insights and exceptions for action. The 2025 assessment estimated annual savings of 62,816 employee-hours, equivalent to approximately 30 working-years, and productivity-equivalent benefits of ₹684 lakh annually. Selected reports that previously required two to four hours can now be accessed in seconds or through a single click, representing cycle-time compression exceeding 99% for the cited reports. Procurement-planning accuracy improved from approximately 85% to 92%, while the customer-default model improved from approximately 68% to around 84% accuracy in February 2026, with a cited outcome of around 85.08%.The platform also improved transparency, auditability and consistency across functions. Automated monitoring supports gas-loss management, incident tracking, complaint turnaround time, customer acquisition, outstanding payments, inventory and performance analysis. Earlier assessments also recorded correction of more than two lakh PNG records after the platform identified incorrect or missing information.

Parameter	Before Implementation	After Implementation	Improvement (%)
Resource Utilization	Manual, person-dependent extraction and reconciliation	62,816 employee-hours/year released; approximately 30 working-years	Material improvement; percentage baseline not specified
Operational Efficiency	Selected reports required approximately 2-4 hours	Selected reports available in seconds or through a single click	More than 99% cycle-time compression for cited reports
Platform Adoption	Not specified	224 active users and 27,925 logins during July-November 2025	Not specified
Productivity-Equivalent Benefit	No GSP productivity benefit	₹684 lakh/year	₹684 lakh/year estimated benefit
Procurement Planning	Approximately 85%	Approximately 92%	7 percentage-point improvement
Default-Model Accuracy	Approximately 68%	Approximately 84% in February 2026; approximately 85.08% cited outcome	Approximately 16 percentage-point improvement

Scalability & Replicability:

The platform is scalable because its data foundation, business logic and analytical-consumption layers are separated. Additional departments, Geographical Areas, data sources, KPIs and AI applications can therefore be incorporated without rebuilding the complete enterprise architecture. Its batch, near-real-time and manually governed ingestion capabilities also support diverse information environments.

Within IGL, scalability is demonstrated through deployment across multiple departments and Geographical Areas, hundreds of KPIs and dashboards, mobile access, automated distribution and more than 200 active users. Planned ADF/Fabric ingestion, Databricks/Fabric data patterns, optimized refresh and Conversational BI are intended to increase technical scalability while controlling cloud costs.

The model can be replicated across the CGD sector because operating domains such as PNG acquisition, billing, collections, CNG sales, gas loss, complaints, safety, station performance, inventory and regulatory reporting are common across entities. Replication would involve establishing a governed data foundation, developing KPIs with process owners, automating exception identification, measuring adoption and value, and subsequently introducing predictive and conversational AI.

Key Learnings:

Business ownership must precede technology deployment. KPI workshops, departmental validation and process-owner approval were essential for ensuring that the analytical outputs remained credible and relevant to operational decisions. A single version of truth requires continuous governance rather than one-time data integration. The platform must expose data-quality issues and support their correction at source. Adoption must similarly be measured through usage analytics and departmental decisions, rather than assuming that dashboard availability automatically creates value. The FY 2025-26 rationalization established that increasing the number of dashboards does not necessarily improve outcomes. Sustainable digitalization requires archiving unused data, retiring low-value content and optimizing storage, refresh and computing cycles.AI applications should be built upon governed enterprise data, with accuracy, access control, explainability and business relevance developed together. The broader learning is that digital transformation is a continuous cycle of integration, governance, adoption, measurement, optimization and innovation.

Future Plans:

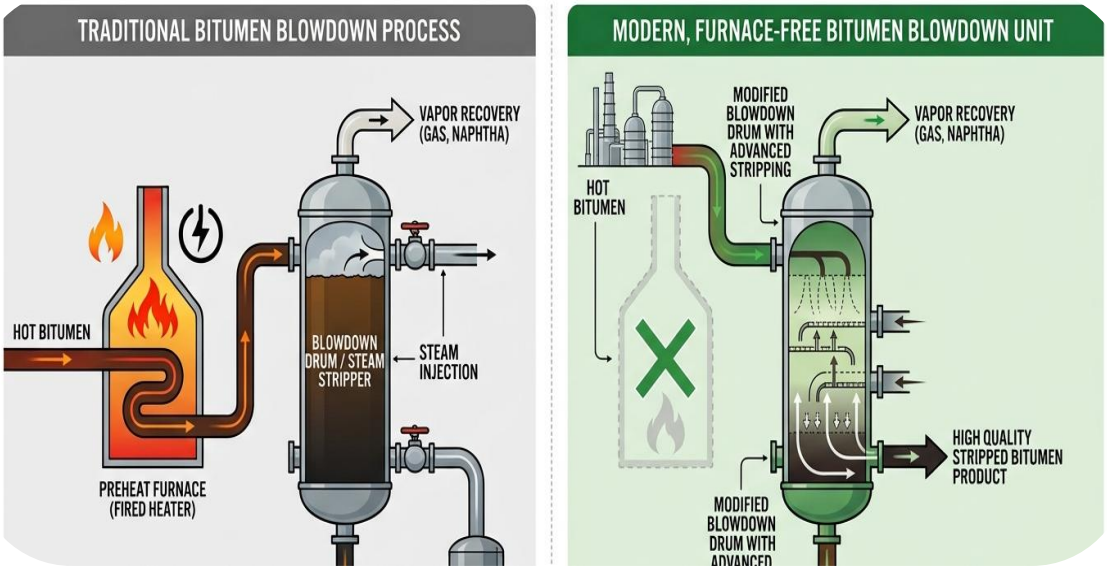
IGL plans to evolve the General Service Platform from an enterprise analytics system into an AI-enabled decision-intelligence layer. Priorities include completing data-ingestion and platform modernization using ADF, Fabric and Databricks patterns, together with further cloud-storage and compute optimization through archiving, incremental refresh and job optimization.

The Conversational BI and GenAI layer will be strengthened for Chat with Data and other knowledge applications. Planned improvements include greater response accuracy, enhanced user experience and extension of predictive analytics to customer sentiment and predictive maintenance.

Future applications and new source systems will be integrated through the common data foundation. Adoption will continue to be governed through training, departmental ownership, usage analytics and periodic impact assessment to ensure that platform expansion remains linked to measurable operational or strategic value



DECARBONIZATION



Stopping of Bitumen Blowing Unit Furnace by Routing 100% Hot Feed to the Unit

Indian Oil Corporation Limited
Atul Kumar
Chief Manager (TS)

Emission Reduction

Gujarat Refinery implemented a heat-integration initiative that enabled complete shutdown of the Bitumen Blowing Unit furnace by routing 100% hot Vacuum Residue directly from upstream VDU and FPU-1 units to the BBU. Previously, Vacuum Residue was cooled to storage temperature of up to 120°C, transferred to tanks and subsequently reheated from approximately 120°C to 240°C in the BBU furnace using around 200 kg/hr of fuel gas. Under the revised configuration, VR reaches the reactor directly at approximately 235–240°C, eliminating the reheating requirement. The project achieved annual energy savings of 16,800 GCal, avoided 4,492 tCO_2e/year, saved 1,680 MTOE, and generated reported savings of ₹684.34 lakh, against a total investment of only ₹33.54 lakh

Background & Context:

The BBU at Gujarat Refinery has a design capacity of 0.5 MMTPA and receives Vacuum Residue generated from upstream VDU and FPU-1 units. Traditionally, this hot VR was cooled to storage temperature through cooling-water heat exchangers, transferred to feed tanks and then pumped to the BBU. Within the BBU, a natural-draft furnace equipped with four fuel-gas burners reheated the cold feed from approximately 120°C to 240°C before processing in the reactor. The furnace consumed around 200 kg/hr of fuel gas. The refinery identified an opportunity to eliminate this inefficient cool-store-reheat cycle by directly routing hot VR from upstream units to the BBU. This recovered sensible heat already contained in the feed and simultaneously reduced cooling requirements upstream.

Objectives:

1. Improve process heat integration and overall energy efficiency.
2. Completely stop BBU furnace operation and eliminate approximately 200 kg/hr of fuel-gas firing.
3. Reduce heat rejection to cooling water and associated cooling-tower load

Methodology:

The initiative focused on hot-feed maximization between upstream and downstream process units. A direct routing scheme was developed to transfer hot VR from VDU and FPU-1 directly to the BBU rather than cooling, storing and subsequently reheating the stream. The modification principally involved piping and control valves. Suitability of downstream equipment was checked for the higher-temperature feed before implementation. Existing control valves and instrumentation were reused where possible from revamped units. Hot tapping was undertaken to enable execution without requiring a shutdown of the operating units.

Challenges:

A major challenge arose from keeping the BBU furnace and associated piping idle. Vacuum Residue remaining inside the furnace coils or piping could congeal during prolonged inactivity. The coils and associated piping therefore required proper flushing with flushing material to preserve them for safe future use. A second challenge was confirming that all downstream equipment could safely handle hot feed. This required extensive checking of metallurgy and the design schedules of piping, valves and equipment. A multidisciplinary HAZOP was also carried out to evaluate the process modification before implementation.

Implementation:

The project was developed through a multidisciplinary engineering effort. Detailed isometric drawings were prepared against actual site conditions and available space after the scheme had been technically assessed. Most materials, including the temperature-control valve and other instruments, were arranged internally from revamped units, while some piping material was procured specifically for the scheme. Hot tapping allowed physical modifications to proceed without shutting down the relevant operating units. The overall scheme was completed in approximately eight months.

Stage	Major Activity
Engineering Assessment	Heat integration and hot-feed opportunity evaluated
Equipment Verification	Metallurgy and design suitability of downstream system reviewed
Detailed Engineering	Actual-site isometric drawings prepared
Materials Strategy	Control valve/instruments reused; balance piping procured
Risk Assessment	Multidisciplinary HAZOP conducted
Execution	Hot tapping used to minimize operational interruption
Commissioning	100% hot VR progressively routed to BBU
Final Operating State	BBU furnace stopped

Investment:

The project required relatively modest investment. Capital expenditure amounted to ₹15.81 lakh, while other execution costs were ₹17.73 lakh, giving a total investment of ₹33.54 lakh. No annual operating, manpower, technology-acquisition or R&D expenditure was separately reported.

Cost Component	Amount (₹ Lakhs)
Capital Expenditure	**15.81**
Operational Expenditure	0
Human Resources	0
Technology Acquisition	0
R&D & Innovation	0
Other Execution Cost	**17.73**
Total Investment	**33.54**

Outcomes:

The most important outcome was complete elimination of BBU furnace firing, removing approximately 200 kg/hr of fuel-gas consumption. The case study reports annual energy reduction of 16,800 GCal and 1,680 MTOE, with the reported baseline values falling to zero following furnace shutdown. Associated emissions of 4,492 tCO_2e/year were eliminated, while reported cost savings amounted to ₹684.34 lakh. The initiative also reduced upstream cooling requirements because hot VR no longer needs to be cooled solely for storage before being reheated.

Parameter	Before Implementation	After Implementation	Improvement (%)
GHG Emissions	4,492 tCO_2e/year	0	100% reduction
Energy Consumption	16,800 GCal/year	0	100% reduction
Fuel Gas Consumption	~200 kg/hr	0	100% reduction
Energy Equivalent	1,680 MTOE	0	100% reduction
Cost Savings	0	₹684.34 lakh	New annual saving reported
BBU Feed	Cooled, stored and reheated	100% hot direct feed	Cool-reheat cycle eliminate

Scalability & Replicability:

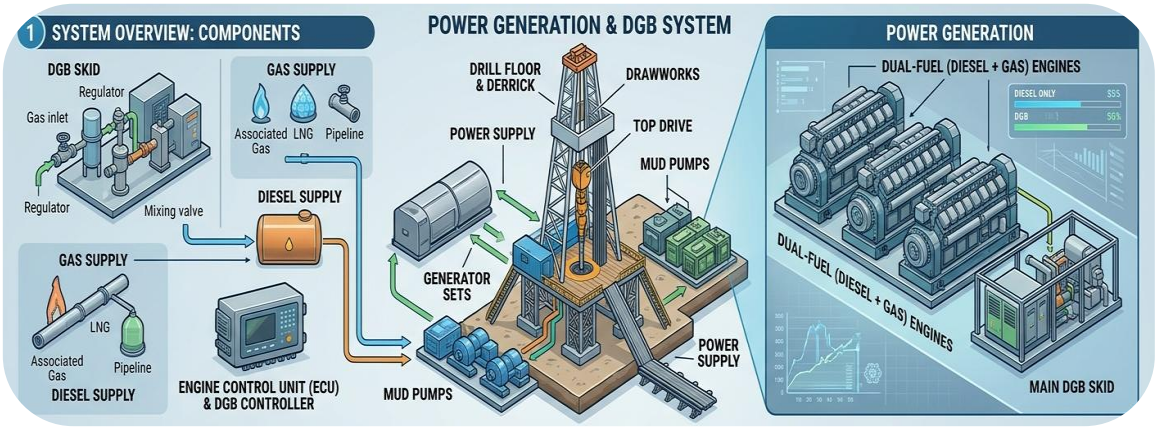
The study identifies the concept as scalable to other refineries with comparable BBU configurations where hot feed is available from upstream units. The core principle is straightforward: preserve and directly utilize sensible heat already available in process streams rather than cooling and subsequently reheating them. Gujarat Refinery itself plans to adopt a similar configuration in another BBU associated with a forthcoming greenfield project. Hot-feed opportunities in other downstream units are also planned for evaluation

Key Learnings:

The project demonstrates that process heat integration can generate substantial energy and emissions benefits with comparatively modest capital expenditure. The central opportunity came not from installing new energy-efficient equipment, but from eliminating an unnecessary cool-store-reheat cycle. Reuse of control valves and instrumentation from revamped facilities helped control project cost, while hot tapping enabled implementation without interrupting normal unit operation. The initiative also highlights that apparently simple process-integration changes still require detailed checks of metallurgy, piping design conditions, equipment capability and process safety before execution.

Future Plans:

Gujarat Refinery plans to replicate the furnace-elimination concept in another BBU associated with an upcoming greenfield project. Additional opportunities for hot feeding of downstream units are also planned to further capture process heat and improve refinery-wide energy integration.



Dynamic Gas Blending System for Decarbonization and Fuel Efficiency in Drilling Rigs

Oil India Limited | **Emission Reduction**

Oil India Limited implemented Caterpillar Dynamic Gas Blending (DGB) technology on drilling-rig engines to substitute a portion of conventional diesel consumption with natural gas while retaining diesel-engine power output and operational reliability. The system was deployed on CAT 3512B engines, initially on Rig S#7 and subsequently shifted to Rig S#5 across multiple drilling locations in Assam. Between January 2024 and June 2026, the initiative reportedly displaced approximately 1.68 million litres of diesel, avoided 4,481.89 tCO_2e emissions, and generated savings exceeding ₹15 crore. The initiative demonstrates the feasibility of operating drilling-rig engines in dual-fuel mode while maintaining drilling performance, providing a practical pathway for reducing diesel dependency and emissions across upstream drilling operations.

Background & Context:

OIL has set an ambition to achieve Net Zero emissions by 2040 and has been exploring opportunities to reduce carbon emissions from energy-intensive upstream operations. Drilling rigs represent an important intervention area because drilling operations rely substantially on diesel-powered generator engines to meet varying power requirements. Diesel has traditionally been preferred because of its favorable torque characteristics, transient response and reliability under fluctuating rig loads. At the same time, rising fuel costs, increasing focus on emissions reduction and availability of natural gas resources created an opportunity to reduce exclusive dependence on diesel. Gas engines already existed for power-generation applications, but adoption in drilling operations was constrained by concerns around fuel quality, gas availability and performance under dynamically changing loads. OIL therefore adopted Caterpillar Dynamic Gas Blending technology, enabling existing CAT 3512B diesel engines to operate using a combination of diesel and natural gas while maintaining required power output and operational reliability

Objectives:

1. Reduce diesel consumption in drilling-rig power-generation engines.
2. Substitute part of the diesel requirement with natural gas.
3. Reduce GHG emissions associated with rig power generation.
4. Improve fuel efficiency and lower drilling operating costs.
5. Demonstrate reliable dual-fuel operation under variable drilling loads.
6. Utilize available natural gas as a lower-carbon substitute for diesel.
7. Establish a model capable of replication across suitable OIL drilling rigs

Methodology:

Caterpillar Dynamic Gas Blending technology was integrated with existing CAT 3512B diesel engines used to supply drilling-rig power. Rather than completely replacing the diesel engine, the DGB configuration enables natural gas to substitute part of the diesel fuel while diesel continues to support ignition and engine response. The operating concept allows the engine to dynamically manage the fuel mix according to operating conditions while maintaining the power and reliability needed for drilling activities. The technology was first deployed on Rig S#7 and subsequently shifted to Rig S#5, allowing operational experience to be generated across different drilling locations in Assam

Conventional Configuration	DGB Configuration
Diesel-only engine operation	Diesel + natural gas dual-fuel operation
Entire energy requirement from diesel	Part of diesel substituted by gas
Higher diesel consumption	Lower diesel requirement
Diesel-related emissions baseline	Reduced overall emissions through fuel substitution
Conventional drilling power supply	Existing CAT engine retained with DGB integratio

Challenges:

A major challenge was ensuring that dual-fuel operation could meet the highly variable power requirements associated with drilling operations without compromising engine responsiveness or drilling performance. Natural gas availability and quality can vary between drilling locations, making reliable fuel supply an important consideration for sustained DGB operation. The system also needed to maintain operating stability while dynamically changing the ratio of diesel and natural gas according to engine load. Unlike stationary industrial power-generation applications, drilling rigs periodically relocate between wells. The DGB deployment therefore had to remain compatible with the mobile nature of rig operations. Most importantly, the project had to demonstrate that fuel substitution and emissions reduction could be achieved without compromising drilling performance or operational reliability

Implementation:

The initiative was undertaken from January 2024 to June 2026 and remained categorized as ongoing in the submitted case study. DGB technology was initially installed on Rig S#7 and was subsequently shifted to Rig S#5, enabling the dual-fuel system to operate at multiple drilling locations. The deployment covered locations identified in the submission as MGS, MGR, MGL, MGK, DJR, DJP, DJU, HABM and HABF. Operational deployment demonstrated that natural gas could substitute significant quantities of diesel while the existing rig engines continued to provide the power required for drilling activities.

Implementation Framework:

Stage	Major Activity
Opportunity Identification	Drilling-rig diesel consumption identified as a decarbonization opportunity
Technology Selection	Caterpillar Dynamic Gas Blending selected
Engine Integration	DGB deployed on CAT 3512B diesel engines
Initial Deployment	System implemented on Rig S#7
Operational Validation	Dual-fuel operation assessed during drilling activity
Subsequent Deployment	System shifted to Rig S#5
Multi-Location Operation	DGB operated across various drilling locations in Assam
Performance Monitoring	Diesel displacement, emissions reduction and savings evaluated

Outcomes:

The key outcome was significant displacement of diesel through substitution with natural gas while retaining dual-fuel drilling-rig operation. The project reports a cumulative reduction of approximately 1.68 million litres of diesel consumption. Associated GHG emissions reduction is reported at 4,481.89 tCO_2e, while financial savings are stated to exceed ₹15 crore. Importantly, the case study reports that these benefits were achieved through successful dual-fuel operation without compromising drilling performance, demonstrating the practical applicability of DGB technology in upstream drilling.

Parameter	Before Implementation	After Implementation / Impact	Improvement
Engine Fuel Configuration	Diesel-only operation	Diesel + natural gas DGB operation	Dual-fuel capability established
Diesel Consumption	Conventional diesel requirement	1.68 million litres displaced	Significant reduction
GHG Emissions	Diesel-operation baseline	4,481.89 tCO_2e avoided	Emissions reduction
Financial Impact	Diesel-only fuel expenditure	>₹15 crore savings	Economic benefit
Drilling Performance	Conventional diesel operation	Maintained under DGB deployment	No reported compromise
Operational Deployment	Conventional engine configuration	Rig S#7 and Rig S#5 across multiple locations	Demonstrated field applicability

Scalability & Replicability:

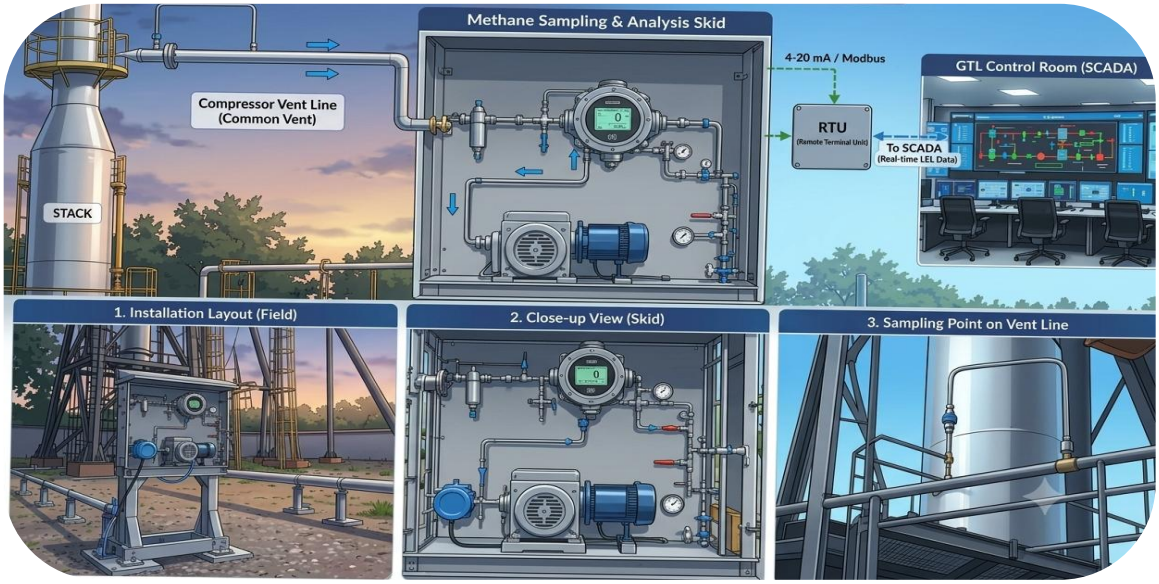
The initiative demonstrates potential for replication across additional drilling rigs equipped with technically compatible engines and having access to suitable natural gas supplies. The approach is particularly relevant in producing regions where natural gas is available close to drilling locations, enabling locally available gas to substitute imported or transported liquid fuel. Because the DGB solution retains the underlying diesel engine and introduces natural gas as a supplementary fuel, replication can potentially leverage existing rig-engine infrastructure rather than requiring complete replacement of the power-generation system. Actual deployment would remain dependent on engine compatibility, gas availability, gas quality and drilling power requirement

Key Learnings:

The initiative demonstrates that drilling-rig decarbonization does not necessarily require complete replacement of conventional diesel-engine infrastructure. Dual-fuel operation provides an intermediate pathway for reducing diesel dependency while retaining the operational characteristics of existing engines. Natural gas availability and quality are fundamental to sustained DGB operation, making site-level fuel assessment important when rigs shift between drilling locations. Dynamic fuel management is particularly relevant for drilling because engine loads vary considerably during operations. The technology must therefore balance natural-gas substitution with power response and engine reliability. Most importantly, the field deployment demonstrates that substantial diesel displacement can be achieved while maintaining drilling performance, providing a practical basis for assessing wider replication

Future Plans:

The submitted DGB content available here does not clearly specify a standalone future-plan section for this initiative. Accordingly, I would not attribute the future compressor-investment plans appearing later in the PDF to DGB, as those belong to the separate gas-flaring reduction case study. The demonstrated deployment across Rig S#7 and Rig S#5 nevertheless establishes an operating basis for evaluating the technology at other technically compatible drilling rigs where adequate natural gas is available.



Implementation of an Active Suction-Based Sampling System for Methane Leak Detection

GSPL Transmission Ltd.
Vinay Kaul
Senior Manager

Emission Reduction

GSPL Transmission Limited implemented an active suction-based methane sampling system to continuously detect unintended natural gas leakage into the common compressor vent line. Previously, minor leakage through passing or partially closed valves could remain unnoticed until periodic manual inspection, resulting in methane emissions and increased Lost and Unaccounted for Gas (LUAG). The new system continuously draws gas from the vent line to a high-sensitivity Infrared (IR) detector and transmits real-time Lower Explosive Limit (LEL) readings to the central SCADA system through an RTU. Implemented between April 2022 and January 2023, the system replaced periodic manual measurements with continuous 24×7 monitoring, enabling early identification and rectification of abnormal venting while strengthening operational safety, emission monitoring and gas-loss control.

Background & Context:

The Gas Compressor Station operates two single-stage centrifugal compressors in a 1+1 configuration, each rated for 14.15 MMSCMD. Gas released during maintenance, compressor changeovers or emergency depressurization is safely routed through a common vent system to an approximately 50-metre-high vent located about 60 metres from the compressor area. Multiple manual valves and automated Blow Down Valves connect to this common vent. Minor passing through valves or incomplete isolation could result in continuous, unnoticed methane release into the vent system Earlier monitoring depended on portable LEL detectors used at weekly or monthly intervals. These inspections were time-consuming, operator-dependent and provided only point-in-time observations without continuous historical data. The initiative was consequently developed to establish an automated, traceable and continuous methane-monitoring system

Objectives:

1. Minimize methane losses and LUAG by rapidly identifying unintended venting from passing or improperly isolated valves.
2. Reduce greenhouse gas emissions associated with continuous and unnoticed methane release.
3. Replace periodic manual measurements with continuous 24×7 automated monitoring.
4. Establish a continuous and traceable digital record of vent-line activity through SCADA integration.
5. Enable timely field intervention whenever abnormal methane concentrations are detected.
6. Implement an automation-based and cost-effective monitoring solution with minimal manual intervention

Methodology:

The solution uses the station's permanent cold-flare/common vent system as the monitoring point. A strategically positioned probe extracts a representative sample from the elevated vent line, while a continuous-duty sampling pump actively draws the gas through dedicated tubing to an Infrared point gas detector installed at an accessible ground-level location. The IR detector continuously measures gas concentration as percentage of LEL. Its signal is sent to a local Remote Terminal Unit (RTU), integrated with the station's SCADA system. Live readings are therefore visible continuously in the main control room and retained as a traceable digital record. Preset thresholds generate visual and audible SCADA alarms when readings exceed defined levels. Operators verify whether elevated readings correspond to planned venting activities. Persistent abnormal readings trigger notification and field inspection to identify passing valves or incomplete isolation. Following rectification, readings are restored to the normal baseline of 0% LEL.

Challenges:

Selecting a safe yet representative sampling point on the approximately 50-metre-high vent presented an installation challenge. The selected sampling arrangement had to provide representative measurements while minimizing risks associated with high-elevation work. Sample transport time was another technical consideration because excessive lag between sampling and detection could compromise the objective of real-time monitoring. The system therefore utilized a short sampling line with minimal bends, supported by an appropriately engineered flange and pumping arrangement. Equipment interfacing with hazardous areas also had to meet applicable PESO certification requirements. Integration presented an additional challenge because the detector's analog output had to be digitized through an RTU for transmission, historical logging, SCADA visualization and alarm generation

Implementation:

Implementation used an existing 2-inch, 300-class Mild Steel flange on the vent line near an access platform as the sampling connection. This avoided major structural modification and hot work on the elevated vent stack. A stainless-steel sampling probe was mounted on the existing flange and connected through corrosion-resistant tubing to the analysis unit. A suction pump continuously draws vent-line samples to the IR detector. The detector and supporting electronics were installed at an accessible, non-hazardous ground-level location. The detector was integrated with the local RTU and central SCADA system, while reliable electrical supply was maintained using UPS power. Final commissioning included calibration of the detector, SCADA alarm configuration and end-to-end testing of the sampling, detection, signal-transmission and alarm sequence.

Stage	Major Activity
Site Preparation	Existing 2-inch, 300-class flange identified and utilized for sampling
Sampling System	Stainless-steel probe, tubing and suction pump installed
Detection System	High-sensitivity IR detector installed at accessible ground level

Investment:

The system required relatively limited capital expenditure because existing vent-line infrastructure was utilized and the solution was developed in-house in collaboration with the OEM. The reported capital investment is ₹6.29 lakh per compressor location, with no annual operational expenditure, additional human-resource expenditure or technology-acquisition cost reported.

Cost Component	Amount (₹ Lakhs)
Capital Expenditure	₹6.29 lakh per compressor location
Operational Expenditure (Annual)	Nil
Human Resources	Nil
Technology Acquisition	Nil
R&D and Innovation	In-house
Others	Nil
Total Investment	**₹6.29 lakh per compressor location**

Outcomes:

The principal improvement was the transition from periodic manual methane checks to continuous, automated surveillance of the compressor vent. Prior to implementation, manual monitoring recorded LEL values exceeding 5% in certain instances; following implementation, the system provides 24×7 monitoring intended to ensure that LEL returns to zero before and after venting activities. Continuous monitoring enables detection of minor passing-valve leakage before it develops into prolonged gas loss. SCADA integration provides a traceable record of vent-line conditions and enables operations teams to respond immediately when abnormal readings occur. The system also reduces reliance on frequent manual inspection at the elevated vent outlet and supports proactive maintenance and improved process integrity. The case study does not quantify actual methane saved, LUAG reduction, tCO_2e avoided or financial savings, so these benefits should remain qualitative unless subsequently validated through operating data.

Parameter	Before Implementation	After Implementation	Improvement (%)
GHG Emissions	Periodic manual monitoring; LEL reported above 5%	Continuous 24×7 monitoring with LEL targeted at zero before and after venting	Continuous methane surveillance
Energy Consumption	Not quantified	Not quantified	-
Water Consumption	Not quantified	Not quantified	-

Parameter	Before Implementation	After Implementation	Improvement (%)
Waste Generation	Not quantified	Not quantified	-
Resource Utilization	Manual periodic inspection	Automated continuous sampling	Improved monitoring utilization
Operational Efficiency	Weekly/monthly manual checks	Real-time SCADA monitoring and alarm generation	Shift to 24×7 monitoring
LUAG Reduction	Not quantified	Improved ability to identify unintended gas loss	Not quantified
Cost Savings	Not quantified	Not quantified	-

Scalability & Replicability:

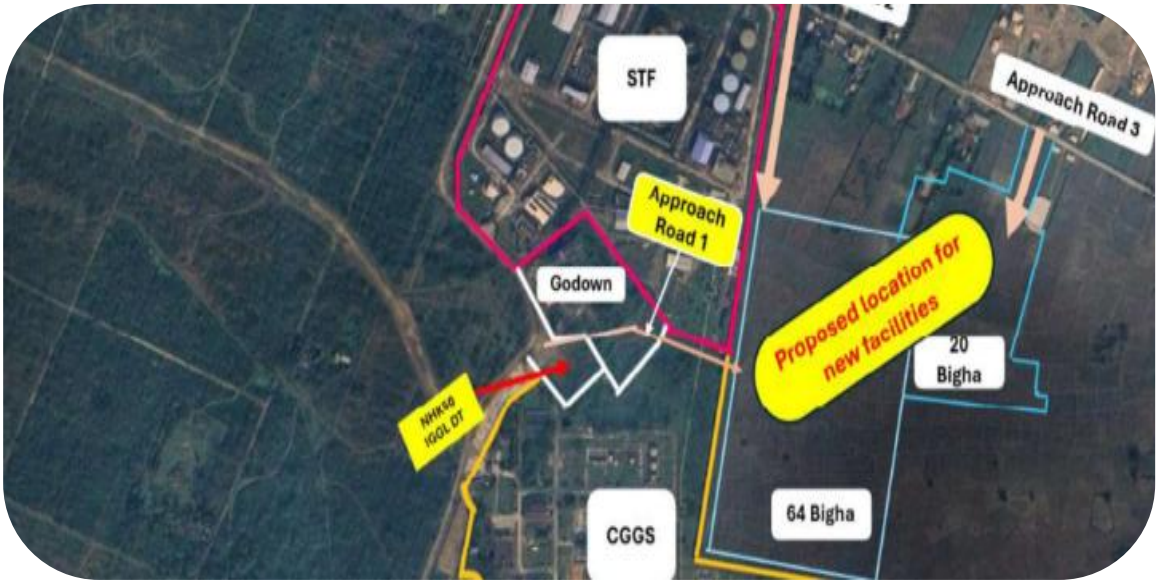
The system is scalable by installing additional point detectors and sampling systems at other potential leak locations. Different detector technologies, including infrared, electrochemical and catalytic-bead sensors, may be selected according to the gas and operating environment. Replication requires standardization of detector models, sampling assemblies and installation procedures. The case study also notes that differences in temperature, humidity and atmospheric conditions may require site-specific sensor selection, enclosure ratings and calibration practices. The relatively simple architecture comprising a sampling probe, suction system, detector, RTU and SCADA interface provides a practical framework for replication at additional compressor vent locations where similar unattended methane leakage risks exist.

Key Learnings:

The initiative demonstrated that detector positioning must consider the physical behaviour of the target gas and the characteristics of the monitored system. Detector technology should similarly be selected according to gas composition and operating conditions. Sensitivity, accuracy and calibration are critical for reliable detection and for minimizing false alarms. The project also demonstrated the importance of minimizing sample-transport lag when an analyzer is located away from the actual vent-line sampling point. A broader learning is that relatively simple automation can transform intermittent manual inspection into continuous condition monitoring, improving traceability and enabling earlier intervention without requiring major modification to existing compressor-station infrastructure.

Future Plans:

Future improvements are expected to focus on higher detector accuracy and reliability through advances such as dual IR sources and receivers, continuous self-checking and improved resistance to sensor drift.The broader objective remains earlier identification of methane leakage before it develops into a significant operational or safety issue. The case study also identifies lower maintenance requirements, reduced sensor drift and prevention of unexpected operational downtime as areas that could reduce the total cost of ownership of future gas-detection systems.



Reduction in Gas Flaring, GHG Emissions and Monetization of Gas at Nine Locations

Oil India Limited | **Emission Reduction**

Oil India Limited implemented a large-scale flare-reduction programme to recover and monetize low-pressure associated gas that was previously being flared because of inadequate evacuation infrastructure. Eleven low-pressure gas booster compressors with a combined capacity of 320,000 SCMD were installed across nine locations in Upper Assam. The initiative reduced annual gas flaring from 82.22 MMSCM in FY 2024-25 to 56.28 MMSCM in FY 2025-26, representing a 32% reduction. Correspondingly, reported GHG emissions decreased from 217,069 to 148,585 tCO_2e annually. Beyond emissions reduction, the initiative converts previously flared gas into a commercially usable energy resource, improves gas-handling capacity and supports OIL's objective of reducing flaring below 0.5% by FY 2028-29.

Background & Context:

More than 90% of OIL's hydrocarbon production is concentrated in its Main Producing Areas in Assam and Arunachal Pradesh. Mature oilfields within these areas generate significant quantities of low-pressure associated natural gas. A substantial portion of this gas could not previously be evacuated because adequate compression and transportation infrastructure was unavailable. Consequently, recoverable gas had to be flared, resulting in both greenhouse gas emissions and loss of potentially marketable energy. OIL therefore identified major low-pressure flaring locations and initiated installation of dedicated booster compressors to raise gas pressure sufficiently for routing through the company's gas-gathering and transmission network.

Objectives:

1. Reduce routine flaring of low-pressure associated gas across OIL's producing areas.
2. Recover and monetize gas that would otherwise be flared.
3. Reduce GHG emissions associated with gas flaring.
4. Strengthen gas-handling and evacuation infrastructure.
5. Improve utilization of produced gas as a valuable energy resource.
6. Support OIL's roadmap to reduce flaring below 0.5% by FY 2028-29

Methodology:

The project began with identification of major low-pressure gas-flaring locations across OIL's producing areas in Upper Assam. Each location underwent engineering assessment, compressor sizing and evaluation of the associated infrastructure required to evacuate recovered gas.Based on these assessments, 11 low-pressure gas booster compressors were installed across nine locations: Baghjan, Barekuri, Bhekuli, Bhogpara, Balimara, Hapjan, Hebeda, HJC-QPS (Chabua) and Hatiali.The compressors increase the pressure of low-pressure associated gas from mature fields to levels suitable for routing through OIL's gas-gathering and transmission infrastructure.The installed compressor facilities have a combined handling capacity of 320,000 SCMD. Engineering design, procurement, installation, commissioning, operational requirements and safety management were integrated within the implementation programme.

Challenges:

OIL's producing fields are spread across remote and geographically dispersed areas, which increases infrastructure-development and logistics complexity. Several locations contain ageing installations where equipment integration requires additional attention to plant configuration and safety compliance. Land availability and statutory approvals were also significant constraints, particularly where suitable land was not already owned by OIL and coordination with district administration, statutory authorities and local communities was required. Production of low-pressure associated gas is dynamic, requiring infrastructure capable of accommodating changing supply conditions over time. Gas booster compressors are also long-lead equipment, with the case study indicating that the overall planning-to-execution cycle can require approximately 18 months

Implementation:

The project was implemented in a phased manner. Procurement started in FY 2023-24, equipment was delivered during FY 2024-25, and compressor facilities were installed and commissioned during FY 2025-26.Eleven compressor installations were completed across nine operating locations in Upper Assam. Supporting infrastructure was developed to connect the compressed gas with OIL's existing gas-gathering and transportation network. Cross-functional coordination across engineering, operations, projects, HSE and external stakeholders was critical because the installations were geographically dispersed and required site-specific infrastructure and approvals.

Implementation Framework:

Stage	Major Activity
Flare Mapping	Major low-pressure gas-flaring locations identified
Technical Assessment	Gas availability and compression requirements evaluated
Engineering	Compressor sizing and site-specific infrastructure planned
Procurement	11 low-pressure booster compressors procured
Infrastructure Development	Site and gas-evacuation connections established
Installation	Compressors installed across nine locations
Commissioning	Compressor facilities integrated with gas-gathering system
Gas Monetization	Recovered gas routed for productive utilization

Investment:

The initiative required substantial infrastructure investment because dedicated compressor and associated gas-evacuation systems had to be established across multiple production locations.

Cost Component	Amount
Capital Expenditure	₹84.54 crore
Operational Expenditure (Annual)	₹7 crore
Total	₹84.54 crore CAPEX + ₹7 crore annual OPE

Outcomes:

The initiative substantially reduced flaring by converting low-pressure associated gas from a waste stream into a recoverable energy resource. Annual gas flaring reduced from 82.22 MMSCM in FY 2024-25 to 56.28 MMSCM in FY 2025-26, representing a 32% reduction. Reported GHG emissions correspondingly declined from 217,069 tCO_2e/year to 148,585 tCO_2e/year, also representing approximately 32% reduction. The project additionally strengthened OIL's capacity to recover, evacuate and monetize associated gas that would previously have been lost through flaring.

Parameter	Before Implementation	After Implementation	Improvement
Annual Gas Flaring	82.22 MMSCM	56.28 MMSCM	32% reduction
GHG Emissions	217,069 tCO_2e/year	148,585 tCO_2e/year	32% reduction
Low-Pressure Gas Compression	Inadequate evacuation capacity	320,000 SCMD installed capacity	New recovery capacity
Booster Compressors	-	11 units	New infrastructure
Locations Covered	-	9 locations	Expanded flare-recovery network

Scalability & Replicability:

The initiative has strong potential for replication across OIL's producing assets and other upstream oil and gas operations facing similar low-pressure associated-gas flaring constraints. The installed compressor packages establish an operating model for identifying stranded low-pressure gas, appropriately sizing compression infrastructure and connecting recovered gas with suitable evacuation networks. OIL is already planning additional booster-compressor installations and replacement of ageing compressor systems, demonstrating the scalability of the approach.

Key Learnings:

Timely recovery and monetization of associated gas can simultaneously create environmental and economic value, converting a recurring emissions source into a marketable energy resource. The initiative also demonstrates that substantial emissions reductions can be achieved through targeted investment in gas evacuation and compression infrastructure, rather than through changes to the hydrocarbon-production process itself. Cross-functional coordination between exploration, engineering, operations, projects and HSE functions is critical when implementing projects across geographically dispersed operating sites. Early planning is particularly important because gas-compression equipment has long procurement and delivery cycles.

Future Plans:

OIL intends to reduce its overall flare percentage to below 0.5% by FY 2028-29.The next phase includes procurement and installation of 13 additional low-pressure gas booster compressors, with an estimated investment of approximately ₹88.66 crore. OIL also plans to establish a CNG plant at Mechaki, Assam, on a BOO basis with an investment of approximately ₹41.22 crore, and replace six existing ageing gas compressors with an estimated capital expenditure of ₹85.28 crore. A significantly larger intervention involves development of a 5.0 MMSCMD Gas Compression Facility at Madhuban, Assam, with estimated investment of approximately ₹1,867.24 crore. The proposed facility includes feed-gas compressor packages, Glycol Dehydration Unit, Dew Point Depression Unit, Custody Transfer Metering and interconnection systems, with the objective of enabling evacuation of additional gas and further reducing intermittent flaring.



"Change in operation philosophy from 4 GT+1 STG+1 UB+ Grid to 4 GT+0 STG+1 UB+ Grid by stoppage of STG and maximization of Grid"

Indian Oil Corporation Limited
Satyander Singh Saini
Deputy General Manager (DGM-TS)

Emission Reduction

The CPP plant of Panipat Naphtha Cracker Complex (PNC) is designed to meet the steam and power demand of the complex through 5 GTGs, 5 HRSGs, 3 STGs and 2 UBs. With commissioning of Grid in Dec'23 for PNC, 1 STG was stopped in FY2024-25, and PNC was running with 4 GTG + 4 HRSG + 1 STG + 1 UB + Grid. With further identification of 15 MW of power-load that can be shifted to Grid, STG was stopped in Jun'26.

Background & Context:

The Captive Power Plant (CPP) of Panipat Naphtha Cracker Complex (PNC) meets the steam and power demand of the complex through 5 GTGs, 5 HRSGs, 3 STGs and 2 UBs, along with PRDS units to cater to low-pressure steam demand. With commissioning of 220 KV Grid in Dec'23, 1 STG was stopped in FY2024-25, and PNC was running with 4 GTG + 4 HRSG + 1 STG + 1 UB + Grid. With identification of additional ~13–15 MW of power load that can be shifted to Grid, STG was stopped in Jun'26, with HP steam demand catered through increased load of SHP-HP PRDS. STG stoppage reduced the condensing steam load by 40 TPH, HP steam requirement of SHP Boiler Feed Water pump by 2.5 TPH and Main oil Pump steam by 0.5 TPH, collectively reducing the steam load of the complex by ~43 TPH and imported fuel (RLNG) consumption by 3 TPH.

Objectives:

1. Maximization of cost-effective Grid Power
2. Reduction in Steam Load of complex by 43 TPH by stoppage of STG (condensing steam load)
3. Energy Savings
4. CO2 Emission Reduction

Methodology:

The methodology involved reviewing the CPP operating philosophy following STG stoppage and identifying avoidable steam and fuel consumption. A comprehensive review of the power consumers was done and, accordingly, consumer's mapping was done as per criticality to sustain essential unit operation even during grid failure. The total grid import was increased and STG was stopped. The Electronically controlled System (ECS) based Power Load Shedding scheme, along with revised frequency based automatic Power Load Shedding Scheme, was implemented to avoid tripping of essential process units due to lower frequency. With identification of additional 15 MW of power load that can be shifted to Grid, STG was stopped in Jun'26, and HP steam demand was catered through increased load of SHP-HP PRDS. The MOP was kept out of service and lubrication was maintained through the electrically driven AOP, while the BFW Pump operating arrangement was optimized to reduce unnecessary HP steam consumption

Challenges:

- Formalization and Implementation of Automatic Power Load Shedding Scheme as no spinning reserve was available in case of Grid failure post STG stoppage.
- Onboarding of all stakeholders for Nil STG operation.

Implementation:

- STG stoppage done on 6th Jun'26.
- Effective operation days in FY 2025-26= 279 days (intermittently operated during Grid Maintenance)

Investment:

Cost Component	Amount (₹ Lakhs)
Capital Expenditure	Nil
Operational Expenditure	-
Human Resources	-
Technology Acquisition	-
R&D and Innovation	-
Others	-
Total Investment	Nil

Outcomes:

Energy Savings Calculation:
Energy Saving due to 40 TPH STG Condensing Load reduction and 2.5 TPH of HP steam reduction in SHP BFW Pumps:

S. No.	Parameters	UoM	Value
1.	Reduction in Condensing SHP Steam Load post STG stoppage	TPH	40
2.	SHP equivalent of HP steam reduced in SHP BFP pump (2.5 TPH of HP steam)	TPH	2.35
3.	Steam to Fuel ratio in UB	MT of Steam/SRFT of fuel	13
4.	Energy Savings per hr	SRFT per hour	42.35/13
5.	Annual Energy Savings for 8760 hrs	SRFT	28,537
6.	Equivalent CO2 emission Reduction	Tons of CO2 emission	68,489
7.	No of hrs STG Operation in FY 2025-26	Hrs	2184
8	SRFT saving achieved in FY 2025-26 (8760 hrs – 2184 hrs = 6576 hrs)	SRFT	21,422
9.	Equivalent CO2 emission Reduction in FY 2025-26	Tons of CO2 emission	51,413

Energy Saving due to 0.5 TPH of HP Steam reduction due to MOP Stoppage:

S. No.	Parameters	UoM	Value
1.	HP Steam Required for MOP (TPH)	TPH	0.50
2.	SHP equivalent of HP steam	TPH	0.45
3.	Steam to Fuel ratio in UB	MT of Steam/SRFT of fuel	13
4.	Energy Savings per hr	SRFT per hour	0.45/13
5.	Power consumption due to AOP (KW)	KW	50
6.	Additional SRFT consumption due to AOP	SRFT	0.012
7.	Net Energy Savings due to operation of AOP instead of MOP	SRFT	0.023
8.	Annual Fuel Saving (8760 hrs)	SRFT	200
8	Operation of AOP instead of MOP in FY2025-26	Hrs	6408
10.	SRFT Savings in FY 2025-26	SRFT	146
11.	Equivalent CO2 emission Reduction in FY 2025-26	Tons of CO2 emission	350

Parameter	Before Implementation	After Implementation	Improvement (%)
GHG Emissions (tCO_2e)	23,00,000	22,78,237	**2.25%**
Energy Consumption (units)	9,58,333	9,36,765	**2.25%**
Water Consumption (KL)			
Waste Generation (tonnes)			
Resource Utilization			
Operational Efficiency			
Cost Savings (₹ in Lakhs)	₹ 40,41.6 Lakh		
Others (please specify)			

Qualitative Outcomes:

- SRFT savings of 21,772 achieved in FY2025-26.
- Annual Benefit of ₹40 Cr.
- RLNG consumption reduction by 3 TPH
- CO2 emission reduction by 52,253 Tons

INNOVATION & UNIQUENESS :

- Integrated optimization of steam, fuel and auxiliary power consumption following STG stoppage.
- Use of AOP in place of MOP to eliminate avoidable steam consumption while maintaining lubrication reliability.
- Optimized BFW Pump operation to minimize HP steam requirement without affecting boiler performance.
- Energy savings through operational modification with minimal capital investment and no major process changes.

Scalability & Replicability:

Horizontal deployment of this initiative can be done at other locations based on available margin in Grid.

Key Learnings:

Explore the feasibility of conversion of condensing turbines to Motor in the complex to reduce steam load.

Future Plans:

Conversion of HP steam operated Quench Oil pump from turbine to Motor. Maximization of Grid power in upcoming projects.



Vent-to-Value: Recovery of Vented Natural Gas at GAIL Chhainsa Compressor Station

GAIL (INDIA) LIMITED
Dikshant Singh
SENIOR MANAGER

DECARBONIZATION

The Vent-to-Value: Recovery of Vented Natural Gas initiative was implemented at the GAIL Chhainsa Compressor Station to recover natural gas that was previously vented to the atmosphere during compressor shutdown and depressurization activities. Prior to implementation, approximately 18,000 SCM of natural gas was released during every Gas Turbine Compressor (GTC) stoppage, resulting in annual financial losses of nearly ₹2.5 crore and greenhouse gas emissions of about 10,668 tCO_2e/year. A Vent Recovery System (VRS) comprising dedicated piping, a filtration skid, pressure reduction system, and interconnection with the nearby CGD network was commissioned on 24 March 2025. The project reduced venting by approximately 72%, avoided nearly 7,800 tCO_2e annually, and generated annual financial recovery of about ₹1.9 crore

Background & Context:

The Chhainsa Compressor Station operates two gas compressor units, each with a capacity of 54 MMSCMD, to boost gas pressure in the Vijaipur-Dadri Pipeline (VDPL) from 75 kg/cm^2 to 99.9 kg/cm^2 for downstream customers. During compressor shutdowns, depressurization activities require natural gas contained within the compressor system to be vented to the atmosphere.

The original station design did not include any mechanism for recovering or utilizing this gas. Consequently, approximately 18,000 SCM of natural gas was lost during each GTC stoppage, representing both a significant resource loss and a source of avoidable methane and CO_2-equivalent emissions. The annual financial impact was estimated at approximately ₹2.5 crore, while associated greenhouse gas emissions amounted to nearly 10,668 tCO_2e per year. The Vent Recovery System was conceptualized to convert this operational loss into a resource-recovery opportunity by capturing and productively utilizing the vented gas through the nearby CGD network.

Objectives:

1. Reduce natural gas venting during GTC shutdown and depressurization activities.
2. Reduce greenhouse gas emissions associated with atmospheric release of natural gas.
3. Recover and productively utilize gas that would otherwise be lost.
4. Minimize financial losses associated with vented natural gas.
5. Improve HSE performance through controlled gas handling and routing.
6. Develop a low-CAPEX solution that can be replicated across other compressor stations and gas facilities

Methodology:

The project was designed around retaining the existing compressor shutdown sequence while introducing a dedicated gas recovery pathway. During compressor stoppage, gas that would normally be vented to the atmosphere is diverted through a dedicated vent-recovery system.The recovered gas first passes through a filtration skid that removes particulate contaminants. It is then routed through an Active/Monitor Pressure Reduction System (PRS) that safely regulates pressure before transferring the gas to the nearby CGD network operated by ATGL. Isolation valves, interlocks, and safety systems ensure controlled and safe operation without affecting existing shutdown logic.The methodology transformed the conventional venting arrangement into a structured gas recovery and utilization pathway, enabling productive use of gas previously treated as operational loss.

Challenges:

A key challenge was integrating the recovery system into a live compressor station without compromising existing shutdown and safety philosophies. The project required identification of suitable gas take-off points, integration of pressure reduction systems, filtration requirements, and safe interconnection with the receiving network.Additional challenges included incorporating isolation systems and safety interlocks while minimizing operational disruption during installation. The strategy adopted was to preserve the established compressor shutdown sequence while creating a dedicated and controlled recovery route for previously vented gas. This ensured both operational continuity and safety compliance.

Implementation:

The Vent Recovery System was implemented through installation of dedicated vent-recovery piping, filtration equipment, pressure reduction skid and downstream interconnection with the ATGL CGD network. The pressure reduction system ensures controlled gas transfer while the filtration arrangement protects the receiving network from contaminants.

Necessary safeguards, monitoring systems, and operational controls were incorporated to institutionalize the recovery process. Following testing and commissioning activities, the system became operational on 24 March 2025 and was integrated into regular compressor station operations. The project demonstrates how relatively simple process modifications can create substantial environmental and financial benefits.

Implementation Timeline:

Period	Location / Project	Implementation
July 2024	Project initiation	Detailed engineering and planning commenced
FY 2024-25	Installation of dedicated vent recovery system	Piping, filtration and pressure reduction systems installed
FY 2024-25	Integration with ATGL network	Productive utilization pathway established
24 March 2025	Commissioning	Vent Recovery System commissioned and operational

Investment:

The project was executed as a highly cost-effective sustainability initiative with an overall capital investment of only ₹35 lakh. No additional operational expenditure, technology acquisition costs, or manpower expenses were required beyond existing station resources.

Despite the low investment requirement, the initiative delivers approximately ₹1.9 crore in annual financial recovery, resulting in a payback period of less than one year. The project demonstrates the economic attractiveness of low-CAPEX decarbonization and resource recovery projects in natural gas infrastructure.

Cost Component	Amount (₹ Lakhs)
Capital Expenditure	35
Operational Expenditure (Annual)	Nil
Human Resources	Nil (Existing Manpower)
Technology Acquisition	Nil
R&D & Innovation	Nil
Others	Nil
Total Investment	**35**

Outcomes:

The initiative successfully transformed a recurring operational loss into a revenue-generating sustainability intervention. Natural gas venting was reduced substantially, leading to major reductions in greenhouse gas emissions and recovery of valuable natural gas for productive use through the CGD network.

The project generated annual financial recovery of approximately ₹1.9 crore while avoiding nearly 7,800 tCO_2e emissions each year. In addition to financial and environmental benefits, the project strengthened operational control over depressurization activities and enhanced HSE performance through controlled gas handling. The initiative clearly demonstrates how process optimization can simultaneously advance decarbonization, resource conservation, operational efficiency, and economic performance.

Parameter	Before Implementation	After Implementation	Improvement (%)
Natural Gas Venting	~18,000 SCM/event	<5,000 SCM/event	~72% Reduction
GHG Emissions	~10,668 tCO_2e/year	Reduced Significantly	~7,800 tCO_2e/year Avoided
Financial Impact	~₹2.5 Cr/year Loss	~₹1.9 Cr/year Recovery	~₹1.9 Cr/year Benefit
Project Investment	₹35 Lakh	Low-CAPEX Solution	High Return
Payback Period	-	Within 1 Year	Highly Attractive

Scalability & Replicability:

The initiative is inherently scalable across compressor stations and natural gas facilities where significant quantities of gas are vented during shutdowns or depressurization activities. Replication can be assessed based on vent quantities, gas quality, pressure profiles, shutdown frequencies, receiving-network availability, and HSE requirements.

Because the solution relies on established technologies such as piping, filtration, pressure reduction, and control systems, implementation complexity remains relatively low. The Chhainsa installation serves as a practical proof-of-concept for broader deployment across GAIL's gas transmission infrastructure and potentially throughout the natural gas sector.

Key Learnings:

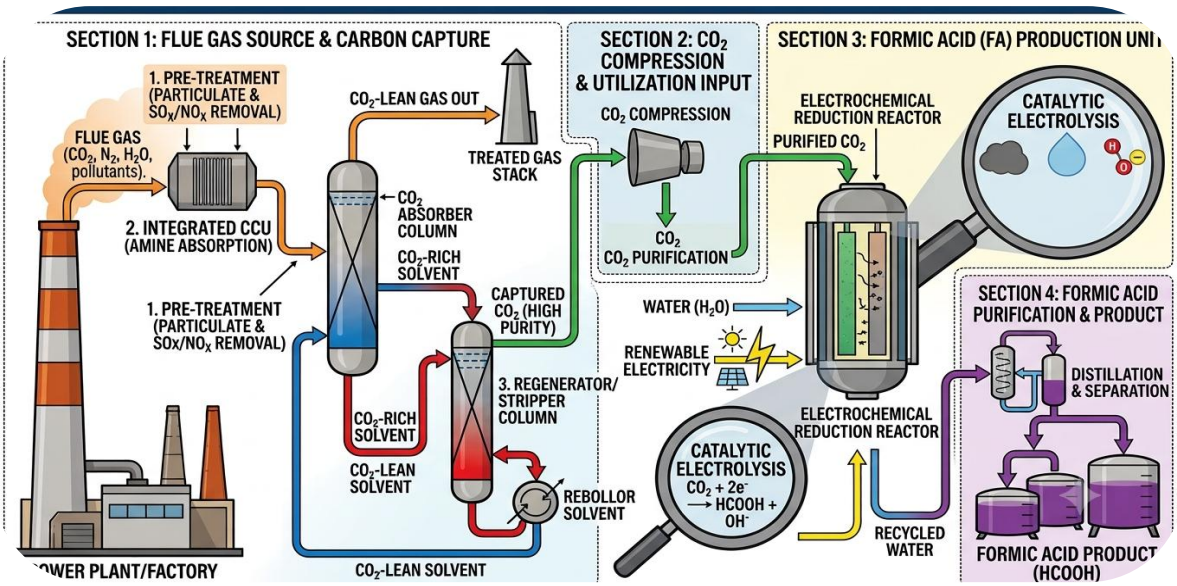
The project demonstrated that routine operational venting can represent a significant opportunity for both decarbonization and resource recovery. Considerable environmental and financial benefits can be achieved through simple process integration without requiring large-scale technological interventions.

The experience also emphasized the importance of preserving existing safety and shutdown philosophies when implementing recovery systems. Pressure reduction and gas filtration emerged as critical interfaces for safe transfer into downstream networks. Most importantly, the initiative proved that low-CAPEX sustainability projects can achieve extremely short payback periods while maintaining strong scalability and replicability potential.

Future Plans:

GAIL plans to identify and implement similar vent-recovery opportunities across other suitable compressor stations and gas installations. Future efforts will focus on station-wise identification of vent sources, quantification of recoverable gas, technical and economic feasibility studies, and standardization of engineering approaches.

The company also intends to establish systematic monitoring mechanisms for recovered gas volumes, financial benefits, and avoided greenhouse gas emissions to support wider deployment across its network.



Integrated Carbon Capture and Utilization – CO_2 Capture and Conversion to Formic Acid

Bharat Petroleum Corporation Limited
Dr. Chanchal Samanta
DGM(R&D)

DECARBONIZATION

BPCL R&D is developing an integrated carbon capture and utilization (ICCU) process that combines CO_2 capture and direct conversion to formic acid in a single system. The process uses heat-stable aqueous amine solvents to capture CO_2 and novel air-stable, water-soluble iridium catalysts to hydrogenate the captured CO_2 directly to formic acid. Operating under relatively mild conditions of around 50°C and up to 40 bar hydrogen pressure, the catalyst has demonstrated turnover numbers exceeding 20,000 and formic-acid selectivity above 97%. The approach eliminates separate solvent regeneration, CO_2 desorption, purification, compression and storage steps required in conventional routes. The initiative therefore offers a potentially simpler and lower-carbon pathway for converting captured CO_2 into a commercially useful chemical.

Background & Context:

Conventional formic-acid production is largely based on the two-stage BASF route involving carbonylation of methanol with high-purity carbon monoxide followed by hydrolysis of methyl formate. This requires handling, storage and compression of toxic CO and remains linked to fossil-derived feedstocks. Direct conversion of CO_2 to formic acid offers an alternative, but the inherent thermodynamic and kinetic stability of CO_2 makes hydrogenation technically challenging. Earlier homogeneous and heterogeneous catalysts also faced constraints related to stability, selectivity, recycling and sensitivity to air and moisture. Conventional carbon capture and utilization additionally requires separate CO_2 absorption, solvent regeneration, desorption, compression and downstream conversion stages. BPCL therefore sought to integrate capture and conversion within one process, reducing complexity, energy demand and carbon footprint.

Objectives:

1. Develop an integrated CO_2 capture and conversion process.
2. Design and synthesize novel iridium-based catalysts.
3. Achieve high catalytic activity and selectivity for formic acid.
4. Optimize operating and reaction parameters.
5. Develop a sustainable alternative to conventional CO-based formic-acid production.
6. Demonstrate practical feasibility and potential scalability

Methodology:

The technology combines CO_2 capture in heat-stable aqueous amine solvents with direct catalytic hydrogenation of the captured CO_2. The amine system was optimized to reduce equipment corrosion compared with conventional MEA-based CO_2 capture. BPCL developed air- and moisture-stable, water-soluble iridium catalysts containing proton-responsive ligands. These enable hydrogenation under relatively mild conditions of around 50°C and hydrogen pressures up to 40 bar, while demonstrating turnover numbers above 20,000.A Continuous Stirred Tank Reactor (CSTR) is used to combine CO_2 capture and catalytic conversion within the same system. This avoids intermediate solvent regeneration, CO_2 purification and compression, thereby simplifying the process configuration.

Conventional Approach	**Integrated BPCL Approach**
CO_2 capture	CO_2 capture in heat-stable amine
Solvent regeneration	Eliminated as an intermediate step
CO_2 desorption	Eliminated
CO_2 purification/compression	Eliminated
Separate downstream conversion	Integrated hydrogenation
Multiple process stages	Capture and conversion combined

Challenges:

The principal technical challenge was overcoming the thermodynamic and kinetic stability of CO_2. BPCL addressed this through iridium catalysts containing proton-responsive ligands that improve catalytic activity and enable hydrogenation under moderate conditions. Catalyst stability and selectivity represented another major challenge because conventional catalysts can suffer from poor air/moisture stability, degradation and recycling difficulties. The newly developed catalysts demonstrated air and moisture stability and formic-acid selectivity above 97%.Process integration was also challenging because conventional CCU systems separate capture, solvent regeneration, compression and conversion. BPCL's CSTR-based approach combines absorption and hydrogenation within a single system. Further scale-up challenges remain, particularly around long-duration continuous operation, catalyst recycling and solvent management

Implementation:

The initiative progressed from concept and catalyst design to process integration and validation over approximately 30 months from early 2023 to mid-2025.Activities included catalyst design, synthesis, performance testing, optimization of operating conditions and integration of CO_2 capture with catalytic hydrogenation. BPCL R&D led the development with multidisciplinary support. The work has generated peer-reviewed scientific publications and intellectual property, including patent applications related to efficient carbon capture solvent composition, integrated CO_2 hydrogenation to formic acid and direct hydrogenation using iridium catalysts

Stage	Key Activity
Concept Development	Integrated capture-conversion pathway conceptualized
Solvent Development	Heat-stable aqueous amine system developed
Catalyst Development	Air-stable, water-soluble iridium catalysts synthesized
Performance Optimization	Reaction conditions and catalyst performance optimized
Process Integration	CO_2 absorption and hydrogenation integrated using CSTR
Validation	High turnover and selectivity demonstrated
IP Development	Patent applications and scientific publications generated

Investment:

Cost Component	Amount (₹ Lakhs)
Capital Expenditure	45
Operational Expenditure (Annual)	25
Human Resources	30
Technology Acquisition	NA
R&D and Innovation	NA
Others	NA
Total Investment	100

Outcomes:

The initiative has demonstrated the feasibility of directly converting captured CO_2 into formic acid without first releasing and compressing a purified CO_2 stream. The developed catalyst systems have achieved turnover numbers above 20,000 with formic-acid selectivity exceeding 97%.The integrated route simplifies the conventional process by eliminating separate solvent regeneration, CO_2 desorption, compression and storage steps. It also avoids dependence on high-purity toxic carbon monoxide used in conventional formic-acid manufacturing. However, the case study does not provide quantified GHG, energy, water, waste or monetary savings, so these benefits should presently be treated as potential rather than demonstrated quantitative outcomes

Parameter	Reported Outcome
Catalyst Turnover Number	>20,000
Formic Acid Selectivity	>97%
Operating Temperature	~50°C
Hydrogen Pressure	Up to 40 bar
Product Concentration	>0.5 M reported in key learnings
GHG Reduction	Not quantified
Energy Reduction	Not quantified
Cost Savings	Not quantified

Scalability & Replicability:

The technology uses commercially viable heat-stable amine solvents at industrially relevant concentrations of approximately 1–2 M, supporting potential integration with existing gas-treatment infrastructure. The air-stable iridium catalysts operate under comparatively moderate temperature and pressure conditions, potentially simplifying catalyst handling at larger scale. Eliminating solvent regeneration, CO_2 desorption and compression could also reduce process complexity. The technology could potentially be integrated with different CO_2-emitting processes, including flue-gas applications. However, industrial scale-up still requires validation of continuous stability, catalyst recycling, solvent management and economic performance

Key Learnings:

The project demonstrated that highly active, stable iridium catalysts can facilitate integrated CO_2 capture and conversion under comparatively mild conditions. Combining CO_2 absorption and catalytic hydrogenation within a single reactor can eliminate several energy- and cost-intensive intermediate operations associated with conventional carbon capture and utilization. The technology achieved >97% formic-acid selectivity and product concentrations exceeding 0.5 M, supporting potential downstream application. The biggest remaining scale-up considerations are long-term continuous operation, catalyst recycling and solvent management

Future Plans:

BPCL plans to further optimize the CSTR system for long-term continuous operation, catalyst recycling and solvent regeneration. The integrated process is also proposed to be coupled with green hydrogen generation to improve the sustainability and carbon profile of formic-acid production. Future development will additionally include techno-economic analysis and Life Cycle Assessment to assess commercial viability, identify environmental hotspots and guide industrial-scale deployment.



Development of Active and Selective Catalyst for CO_2 Conversion to Syngas via Reverse Water Gas Shift Reaction

Bharat Petroleum Corporation Limited
Dr. Arundhathi Racha
Chief Manager (R&D)

DECARBONIZATION

The initiative focused on developing an active and highly selective Pt/ZnO-Al_2O_3 catalyst for converting captured CO_2 and hydrogen into carbon monoxide through the Reverse Water Gas Shift reaction. The optimized catalyst achieved 34.8% CO_2 conversion and 99.4% CO selectivity at 400°C and 20 bar using a stoichiometric H_2:CO_2 ratio of 1:1. Stable performance was demonstrated over 100 hours with minimal activity loss. A cradle-to-gate Life Cycle Assessment was also conducted for production of 10 tonnes per day of CO, integrating catalyst performance with environmental assessment. The technology provides a potential carbon-utilization pathway for producing syngas intermediates used in methanol, Fischer-Tropsch fuels and sustainable aviation fuel

Background & Context:

BPCL is pursuing Net Zero Scope 1 and Scope 2 emissions by 2040, with carbon capture, utilization and storage identified as an important decarbonization lever. Renewable syngas produced from captured CO_2 and hydrogen can serve as an intermediate for low-carbon chemicals and synthetic fuels. The Reverse Water Gas Shift reaction converts CO_2 and hydrogen into carbon monoxide, which can subsequently support methanol, Fischer-Tropsch fuel and sustainable aviation fuel production. However, conventional RWGS catalysts generally require temperatures above 550°C and excess hydrogen to achieve high CO selectivity, resulting in higher energy requirements and reactor costs. The initiative therefore targeted a low-temperature catalyst capable of achieving high CO selectivity under a stoichiometric H_2:CO_2 ratio of 1:1. The intended outcome was to improve carbon utilization, reduce hydrogen requirements and minimize competing methane formation.

Objectives:

1. Develop a highly selective RWGS catalyst for captured CO_2 utilization.
2. Achieve high CO selectivity at temperatures below 450°C.
3. Reduce hydrogen consumption by operating at an H_2:CO_2 ratio of 1:1.
4. Improve catalyst stability for extended-duration operation.
5. Convert captured CO_2 into valuable syngas intermediates.
6. Evaluate the environmental sustainability of the process through Life Cycle Assessment.
7. Enable future integration with methanol and Fischer-Tropsch synthesis processes.

Methodology:

A ZnO-Al_2O_3 catalyst support was synthesized through co-precipitation using a Zn:Al molar ratio of 3:1. Platinum was subsequently deposited through wet impregnation at loadings ranging from 0.6 to 1.2 wt%, producing four catalyst formulations designated PZA-1 to PZA-4.The catalysts were characterized using BET surface-area analysis, XRD, NH_3-TPD, H_2-TPR, XPS, SEM-EDS and TEM. Catalytic testing was conducted in a fixed-bed reactor using 8 g of catalyst, temperatures of 350-450°C, pressures of 10-40 bar, a CO_2:H_2 feed ratio of 1:1, and gas hourly space velocities ranging from 3,111 to 7,920 h^{-1}.Environmental performance was assessed in OpenLCA 2.3.1 using the ReCiPe 2016 Midpoint methodology and ISO 14040/44 standards. The cradle-to-gate boundary included catalyst production, CO_2 capture, hydrogen production through steam methane reforming, electricity consumption and RWGS operation for producing 10 tonnes per day of CO

Challenges:

The principal technical challenge was achieving high CO selectivity at lower temperatures, where competing methane and methanol formation may occur. Catalyst stability under elevated-temperature operation and the prevention of platinum agglomeration were also important considerations, as both directly affect available active surface area and long-term catalyst effectiveness.

The project also sought to limit platinum loading while maintaining suitable conversion and selectivity. In parallel, the process had to reduce hydrogen consumption relative to systems requiring excess hydrogen and address environmental impacts associated with electricity and hydrogen production.

These challenges were addressed by optimizing platinum loading at 1 wt%, using ZnO-Al_2O_3 to improve CO_2 adsorption and catalyst stability, and undertaking detailed characterization to establish the complementary roles of metallic Pt^0 and partially oxidized $Pt\delta^+$ species

Implementation:

The project was executed at the BPCL Corporate Research & Development Centre between December 2023 and April 2026. Implementation progressed through support preparation, platinum impregnation, catalyst characterization, RWGS reaction testing, operating-condition optimization, stability assessment, mass and energy balance preparation, and cradle-to-gate Life Cycle Assessment.

The optimized formulation comprised 1 wt% Pt on ZnO-Al_2O_3. The best reported operating conditions were 400°C, 20 bar, a GHSV of 3,111 h^{-1} and an H_2:CO_2 ratio of 1:1. Under these conditions, the catalyst achieved 34.8% CO_2 conversion and 99.4% CO selectivity. A 100-hour stability study demonstrated sustained performance with minimal loss of catalytic activity. This implementation framework combined material development, reactor testing and environmental assessment within a single research programme

Period	Location / Project	Implementation
December 2023	Project commencement	Catalyst-development programme initiated
Catalyst preparation	$ZnO-Al_2O_3$ support prepared through co-precipitation	Base catalyst support developed
Catalyst formulation	0.6-1.2 wt% Pt deposited through wet impregnation	PZA-1 to PZA-4 formulations prepared
Characterization	BET, XRD, NH_3-TPD, H_2-TPR, XPS, SEM-EDS and TEM conducted	Structural and catalytic properties assessed
Reaction testing	Fixed-bed RWGS evaluation under varied conditions	Optimal formulation and operating conditions identified
Stability assessment	100-hour continuous testing	Stable performance with minimal activity loss
Sustainability assessment	Mass and energy balance and cradle-to-gate LCA	Environmental performance evaluated
April 2026	Project completion	Laboratory-scale development completed

Investment:

The initiative involved a total reported investment of ₹540 lakh. Capital expenditure of ₹400 lakh represented the largest cost component, followed by annual operational expenditure of ₹100 lakh and human-resource expenditure of ₹40 lakh. No separate costs were reported for technology acquisition, R&D and innovation, or other expenditure categories. The investment supported catalyst synthesis, advanced material characterization, high-temperature and high-pressure reactor testing, analytical evaluation, process assessment and Life Cycle Assessment

Cost Component	Amount (₹ Lakhs)
Capital Expenditure	400
Operational Expenditure (Annual)	100
Human Resources	40
Technology Acquisition	NA
R&D and Innovation	NA
Others	NA
Total Investment	**540**

Outcomes:

The optimized $Pt/ZnO-Al_2O_3$ catalyst improved CO_2 conversion from 10.5% to 34.8% and CO selectivity from 93.0% to 99.4%. The catalyst also sustained stable operation for 100 hours, compared with less than 50 hours before implementation. The study reports reductions in greenhouse gas emissions, energy consumption, water consumption and waste generation, together with annual value creation of ₹225 lakh. Qualitatively, the project demonstrated the conversion of captured CO_2 into a useful chemical intermediate while maintaining high CO selectivity and resistance to catalyst deactivation. By combining catalyst development with Life Cycle Assessment, the study established an integrated framework for evaluating both technical performance and environmental implications. The resulting syngas intermediate may support downstream methanol, Fischer-Tropsch fuel and sustainable aviation fuel pathways. The study also identified electricity supply, CO_2-capture technology and hydrogen production as important determinants of overall environmental performance

Parameter	Before Implementation	After Implementation	Improvement (%)
GHG Emissions (tCO_2e)	40.0	30.9	22.8% reduction
Energy Consumption	50,000 kWh/day	40,000 kWh/day	20.0% reduction
Water Consumption	18 KL/day	15 KL/day	16.7% reduction
Waste Generation	1.5 tonnes/year	1.0 tonne/year	33.3% reduction
Resource Utilization	10.5% CO_2 conversion	34.8% CO_2 conversion	231.4% improvement
Operational Efficiency	93.0% CO selectivity	99.4% CO selectivity	6.9% improvement
Cost Savings / Value Creation	Nil	₹225 lakh/year	New value creation
Stable Operation	Less than 50 hours	100 hours	100% improvement

Scalability & Replicability:

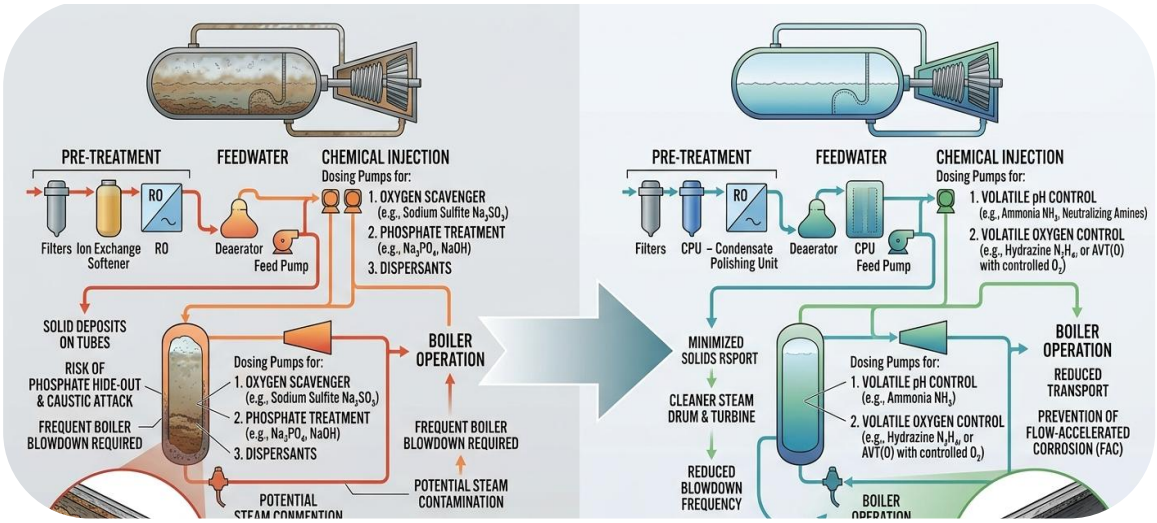
The technology is positioned for scale-up because the RWGS reaction can be implemented using conventional fixed-bed reactor systems. The catalyst may be integrated with CO_2-capture systems and downstream methanol, Fischer-Tropsch or sustainable aviation fuel synthesis facilities. Its use of conventional reactor hardware may support engineering and deployment through established fabrication and EPC capabilities. The technology can also be configured as a modular process linked with existing carbon-capture and downstream synthesis units, enabling phased capacity development.
Potential replication settings identified in the case study include refineries, petrochemical complexes and CCUS hubs already handling CO_2, hydrogen or syngas. Environmental performance can be further improved through renewable electricity and green hydrogen integration, while standardized process flow diagrams, heat and mass balances, and safety documentation could support replication with site-specific adjustments

Key Learnings:

The study identified 1 wt% platinum loading as the optimum balance between metal dispersion, catalytic activity and use of the precious metal. Higher platinum loading did not necessarily improve performance because agglomeration could reduce the available active surface area. The coexistence of metallic Pt^0 and partially oxidized $Pt\delta^+$ species supported improved catalytic performance and high CO selectivity. Lower gas hourly space velocity increased reactant residence time and consequently improved CO_2 conversion.
Temperature was found to exert a substantially stronger influence on catalytic performance than pressure under the tested conditions. The Life Cycle Assessment further showed that electricity supply, CO_2-capture technology and hydrogen production are major environmental hotspots. Consequently, the sustainability advantage of the process depends significantly on access to renewable electricity and low-carbon hydrogen

Future Plans:

Future development will focus on progressing the technology from laboratory-scale validation towards integrated, renewable-powered pilot and demonstration systems. Proposed technical activities include electrolyzer-reactor integration studies, operation under variable renewable-energy conditions, extended catalyst-aging tests and process intensification to improve CO_2 conversion.
The development roadmap also proposes defined capacity and throughput targets for pilot and demonstration units, reliability and availability indicators, and assessment of product-specification compliance for methanol and sustainable aviation fuel intermediates. Further sustainability and commercialization work will include updated cradle-to-grave Life Cycle Assessment, development of carbon-intensity metrics, assessment of policy eligibility and offtake positioning, and translation of catalyst durability and process-efficiency improvements into lower levelized production cost.



“Reduction in Blowdown Post AVT Implementation in TPS/CRU”

Indian Oil Corporation Limited
Shri Rakesh Roshsan
STSM

Emission Reduction

Hydrazine and Trisodium Phosphate (TSP) chemical programs for boiler water previously led to severe sludge buildup, elevated Total Dissolved Solids (TDS), and continuous high blowdown operations, causing significant thermal energy losses, high DM water consumption, and localized corrosion and deposition challenges. To address these issues, the refinery transitioned to an advanced polyamine-based All Volatile Treatment (AVT) regime, utilizing the plant's existing chemical dosing pumps and piping without requiring major hardware overhauls. This transition yielded annual financial savings of approximately ₹3.12 crore, conserved boiler feedwater at a rate of 3.1 tonnes per hour (TPH), improved overall water chemistry parameters, and extended critical equipment operating life.

Background & Context:

Before the execution of this sustainability project, the boiler units operating in the Thermal Power Station (TPS) and Catalytic Reforming Unit (CRU) relied on conventional chemical treatment programs based on Hydrazine and Trisodium Phosphate (TSP). This traditional chemistry caused sludge accumulation, elevated Total Dissolved Solids (TDS), excessive blowdown losses, thermal energy losses, and high demineralized water consumption. Phosphate hideout and hydrazine decomposition also caused localized pH fluctuations, exacerbating corrosion risks and equipment damage. Driven by national decarbonization mandates, resource conservation targets, and the imperative to protect capital-intensive assets, Mathura Refinery identified the transition to an advanced, polyamine-based All Volatile Treatment (AVT) as a high-impact solution.

Objectives:

1. Minimize Continuous Boiler Blowdown: Significantly reduce continuous blowdown flow rates across TPS and CRU boilers to drastically curb demineralized water and thermal energy losses.
2. Eliminate Sludge and Scale Deposition: Completely remove Trisodium Phosphate (TSP) from the treatment loop, eliminating phosphate sludge accumulation, lowering drum TDS, and preventing tube fouling.
3. Protect Boiler Metallurgy & Assets: Achieve superior corrosion inhibition by establishing a volatile, protective passivating film across all steam and condensate contact surfaces, preventing corrosion in CRU Steam Drum 15-V-16.
4. 4mprove Water Chemistry Precision: Standardize control over critical water parameters, including drum pH, electrical conductivity, silica levels, and dissolved iron concentrations.
5. Achieve Sustainable CAPEX-Free Savings: Realize recurring annual operational expenditure (OPEX) savings and water conservation metrics with zero capital expenditure by using existing dosing infrastructure.

Methodology:

The transition from conventional inorganic water chemistry to advanced polyamine-based All-Volatile Treatment (AVT) was planned and executed using a structured engineering methodology. Process and utility specialists conducted detailed technical evaluations of existing boiler metallurgy, drum operating pressures, thermal loading profiles, and feed-water purity levels to determine the optimum polyamine chemical formulations. Existing chemical dosing tanks, positive displacement pumps, and injection quills were evaluated, confirming that polyamine-based AVT formulations could be safely and accurately metered through existing hardware, eliminating the need for new capital equipment. Dosing of legacy Hydrazine and TSP was systematically phased out while polyamine AVT chemicals were introduced. System flushing was conducted to clear residual phosphate deposits without disturbing boiler baseline stability. Following AVT introduction, analytical testing was performed to monitor pH, iron concentration, silica levels, and conductivity. As boiler water TDS dropped, continuous blowdown valves were incrementally closed to lock in water and energy savings.

Challenges:

During project planning, conversion, and stabilization, the engineering team addressed several technical and operational challenges:

- System Chemistry Stabilization During Conversion: Transitioning away from phosphate chemistry presented a temporary risk of shifting pH balances and releasing legacy iron oxides from piping surfaces. This required close analytical chemistry tracking during the initial dosing phase.
- Passivation Management in Critical Vessels: Ensuring complete protective film formation inside high-stress areas—such as CRU Steam Drum 15-V-16—demanded precise control over chemical dosing rates to prevent under-deposit corrosion.
- Preserving Existing Hardware Infrastructure: Avoiding capital expenditure required adapting the properties of the polyamine AW formulations to suit the flow rates, seals, and pressure ratings of existing chemical injection systems.
- Mitigation Strategy Adopted: The team established strict sampling protocols and utilized existing chemical dosing skids. By closely adjusting stroke lengths and monitoring water quality, the conversion was completed safely without process interruptions.

Implementation:

The project followed a multi-stage timeline involving Process, Utilities, Laboratory and Inspection divisions. Baseline water quality, blowdown rates, and thermal losses were established, followed by inspection, cleaning, and calibration of dosing skids in TPS and CiU for polyamine handling. Polyamine AW chemical injection was launched directly into the TPS/CRU feedwater circuits, and continuous blowdown valves were systematically adjusted down as drum TDS levels stabilized at low levels. Utility Operations managed real-time dosing and blowdown valve adjustments, while the Refinery Quality Control Laboratory conducted round-the-clock testing of drum pH, conductivity, silica, and dissolved iron. Inspection and Maintenance Teams conducted internal inspections of CRU Steam Drum 15-V-16 during scheduled maintenance, verifying the elimination of vessel bottom corrosion.

Investment:

Cost Component	Amount (₹ Lakhs)
Capital Expenditure	NA
Operational Expenditure	NA
Human Resources	NA
Technology Acquisition	NA
R&D and Innovation	NA
Others	NA
Total Investment	No Additional Cost

Quantitative Outcomes:

Parameter	Before Implementation	After Implementation	Improvement (%)
GHG Emissions (tCO_2e)	Baseline Boiler Emissions	Reduced due to lower thermal energy demand	1386 MT C02e reduction per year
Energy Consumption (units)	High thermal loss via blowdown	522 SRFT Reduction ler year	622 SRFT Reduction der year
Water Consumption (KL)	Baseline ontinuous blowdown	Reduced continuous blowdown by 3.1TPH	3.1 m3/hr water ;aving which is squivalent to 24800 Kl/year
Waste Generation (tonnes)	No	No	No
Resource Utilization	No	Existing chemical Cosing skid nfrastructure utilization	Existing chemical Josing skid Infrastructure utilization

Operational Efficiency	High blowdown trequency	Reduced blowdown frequency	lmproved Operational efficiency with reduced' blowdown
Cost Savings (₹ in Lakhs)	Baseline operating-.xpense	Saved -t319 !akhs/year	319 Lakhs/year
Others (please specify)	No	No	No

Qualitative Outcomes:

- Transitioning to polyamine-based AVT delivered significant operational, metallurgical, and environmental improvements:
- Complete Elimination of Phosphate Sludge: Discontinuing TSP eliminated phosphate sludge ' precipitation, maintaining clean internal heat-transfer surfaces and maximizing boiler heat transfer efficiency.
- Metallurgical Protection & Extended Equipment Life: Polyamine chemicals form a uniform, monomolecular protective layer across all steam and condensate piping. Inspections of CRU Steam Drum 1.5-V-16 confirmed the complete elimination of historical vessel-bottom corrosion.
- Superior Water Chemistry Stability: Boiler operations achieved tighter control over drum pH, low conductivity, minimized dissolved iron carryover, and reduced silica contamination.
- Reduced Environmental & Water Footprint: Lowering continuous blowdown rates by 3.1 TPH conserved demineralized water and reduced thermal effluent discharge, supporting sustainable water management goals.

INNOVATION & UNIQUENESS :

Zero-CAPEX Sustainability Upgrade: The initiative achieved significant operational savings and water conservation without requiring capital investment or hardware overhauls, utilizing existing dosing equipment. Volatile Polyamine Metal Passivation: Unlike non-volatile inorganic treatment schemes, polyamine AW volatilizes along with steam, protecting the entire steam circuit, condensate lines, and return loops. Process-Integrated Eco-Efficiency: The project links chemical process optimization directly to decarbonization, demonstrating that chemical adjustments can yield thermal efficiency and resource conservation gains.

Scalability & Replicability:

High Replicability Across Refining & Petrochemical Assets: This polyamine AW application offers a clear template for implementation in other industrial boilers, captive power plants, and process units utilizing steam drums. Cross-Industry Scalability: The methodology can be scaled across fertilizer plants, power utilities, chemical manufacturing facilities, and paper mills operating medium-to-high pressure steam generation units. Low-Barrier Sustainability Template: Because implementation requires zero capital outlay and uses existing dosing skids, facility operators can replicate this project with minimal lead time.

Key Learnings:

Chemical Optimization Delivers High ROI: Substantial financial savings and energy performance gains can be unlocked by optimizing chemical treatment programs without major capital projects. Addressing Root Causes Eliminates Secondary Waste: Eliminating TSP solved the root cause of elevated boiler TDS, which in turn eliminated high blowdown losses and sludge generation. Asset Protection Enhances Operational Reliability: Advanced chemical passivation protects high value assets like CRU Steam Drum 15-V-16, extending equipment run-lengths and preventing unscheduled outages. Analytical Vigilance is Crucial During Conversions: Frequent laboratory testing during chemical transitions ensures smooth passivation and prevents operating disturbances

Future Plans:

Expanded Rollout Across Remaining Boilers: The refinery plans to evaluate extending polyamine AW chemistry to all remaining utility and steam generating units across the facility. Knowledge Sharing & Standardization: Technical teams intend to compile operational guidelines and share best-practice case studies across Indian Oil Corporation Limited (IOCL) refineries to standardize AW adoption.



Integration of Fuel Gas Networks for Fuel-Oil Substitution and Minimization of Flaring

Bharat Petroleum Corporation Limited
Santosh Kumar Varshney
DGM (Environment)

Emission Reduction

BPCL integrated fuel-gas networks across its refinery blocks to address situations where surplus gas was flared in one block while another consumed supplementary fuels. The project connected surplus-generating areas with fuel-deficit areas and added amine-treatment capacity for recovering stripper off-gas. Redundant pipelines and an available amine absorber were repurposed, with engineering and execution undertaken in-house. Completed between May 2022 and August 2024, the initiative supported gaseous-fuel operation of process furnaces and reduced steam requirements associated with fuel-oil burner purging. The case study reports ₹480 lakh investment, ₹760 lakh cost savings and elimination of a reported 2,100 tCO_2e emissions baseline for the assessed intervention.

Background & Context:

The refinery's Old Refinery, CEMP, IREP and MSBP blocks were originally designed with largely independent fuel-gas generation, treatment and consumption systems. This created imbalances: excess gas could be flared in one area while another required LPG, RLNG or fuel oil. The IREP block frequently generated surplus fuel gas, while the Old Refinery block generally faced a deficit. Separately, MSBP NHT stripper off-gas could be flared when a CEMP amine absorber was unavailable. Integration offered an opportunity to recover these streams and reduce supplementary-fuel requirements

Objectives:

1. Reduce fuel-gas flaring.
2. Substitute fuel oil with gaseous fuel in process furnaces.
3. Improve furnace efficiency through cleaner-fuel availability.
4. Reduce steam consumption associated with fuel-oil use in CDU2

Methodology:

The refinery assessed gas generation and consumption across blocks under different operating conditions. Schemes were developed to transfer surplus IREP fuel gas to CEMP and the Old Refinery area. Compatible redundant pipelines were identified instead of installing entirely new interconnections. An available amine absorber was also assessed and repurposed to treat MSBP NHT stripper off-gas before routing it into the fuel-gas network. Engineering incorporated pressure-drop assessment, overpressure protection and safeguards for the interconnections.

Challenges:

Inter-block distances required approximately 2–4 km of connectivity, making new piping costly and execution-intensive. Existing fuel-gas headers required hot tapping, with particular attention to gas velocity and hydrogen content. Procuring a new amine absorber would have increased cost and delivery time. Operations also needed confidence that gaseous-fuel availability would remain adequate during major gas-generating-unit shutdowns before discontinuing liquid-fuel backup practices. These constraints were addressed through asset reuse, detailed engineering and operating validation

Implementation:

A redundant hot HCGO pipeline was converted for fuel-gas transfer between IREP and CEMP, followed by reuse of kerosene and propylene lines for low-pressure fuel-gas connectivity to the Old Refinery area. An absorber removed during an earlier retrofit was installed for MSBP off-gas treatment. Following operating experience, CDU2 discontinued fuel-oil gun steam purging, saving approximately 2 TPH of steam.

Period	Intervention	Outcome
June 2023	IREP–CEMP fuel-gas connection commissioned	Surplus gas transferred through a repurposed HCGO line
March 2024	IREP–Old Refinery connection commissioned	Low-pressure gas availability improved
August 2024	Repurposed amine absorber commissioned	MSBP stripper off-gas treated and recovered
Following operating validation	CDU2 fuel-oil gun purging discontinued	Approximately 2 TPH steam saved

Investment:

The project relied on in-house engineering and reuse of available infrastructure. Total reported capital investment was ₹480 lakh, with no additional expenditure reported under the other listed categories.

Cost Component	Amount (₹ Lakhs)
Capital Expenditure	480
Operational Expenditure—Annual	Nil
Human Resources	Nil
Technology Acquisition	Nil
R&D and Innovation	Nil
Others	Nil
Total Investment	**480**

Outcomes:

Integration improved the ability to use surplus gas within the refinery rather than flare it while purchasing supplementary fuels elsewhere. Additional amine treatment and fuel-oil substitution also reduced SOx emissions. The case study reports complete gaseous-fuel operation of process furnaces, approximately 2 TPH of purging-steam savings, and ₹760 lakh cost savings. The quantitative table does not specify the reporting period for the emissions, energy or financial figures; these are therefore retained without annualization

Parameter	Before Implementation	After Implementation	Improvement (%)
GHG Emissions	2,100 tCO_2e	0	**100% reported**
Energy Consumption	900 MT	0	**100% reported**
Water/Steam Consumption	16,000 MT/annum	Not specified	**Approximately 2 TPH steam saving described separately**
Waste Generation	Not reported	Not reported	**Not quantified**
Resource Utilization	Not reported	Not reported	**Not quantified**
Operational Efficiency	Not reported	Not reported	**Not quantified**
Cost Savings	Not specified	₹760 lakh	**Reporting period not specified**
Others	Not reported	Not reported	**Not quantified**

Scalability & Replicability:

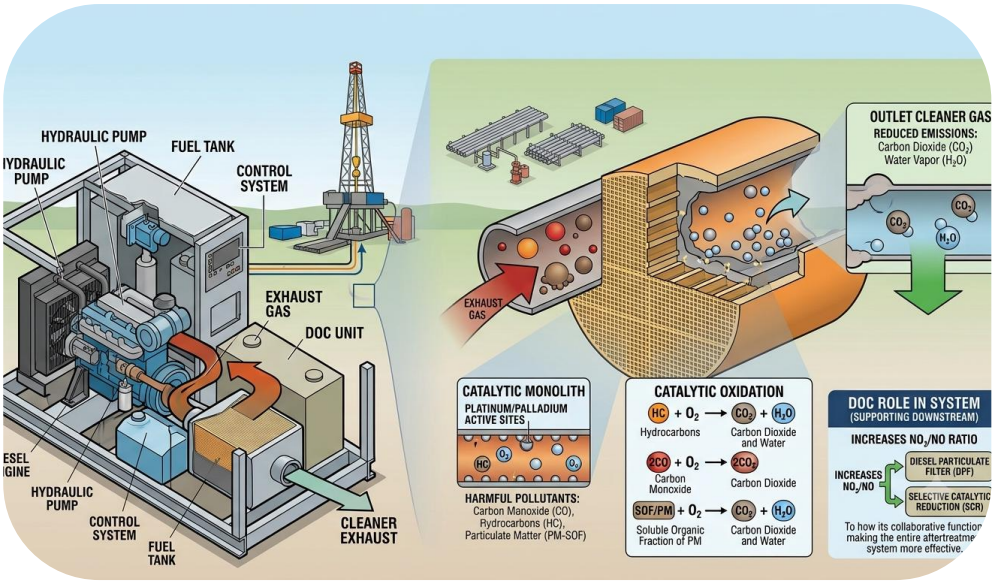
The approach is relevant to refineries experiencing fuel-gas imbalances between independently developed blocks. Replication requires adequate interconnection capacity, compatible pressure conditions and safeguards for emergency and turnaround scenarios. The project also demonstrates how redundant pipelines and equipment can support integration without entirely new infrastructure.

Key Learnings:

Peak-flow pressure-drop calculations and appropriate line sizing are essential for reliable inter-block transfers. Differences in system design pressures require overpressure safeguards. Backup fuels should only be discontinued after assessing shutdown and turnaround conditions. The experience also demonstrates the value of evaluating available assets before procuring new equipment

Future Plans:

The refinery plans to debottleneck the CDU2 LPG supply arrangement through a new inlet control valve, supporting operation without fuel oil during IREP turnaround. A chloride guard has also been approved to enable surplus fuel-gas use in gas turbines while protecting Heat Recovery Steam Generators from potential chloride-related corrosion.



Conversion of Steam Tracing to Electrical Tracing

Indian Oil Corporation Limited
Rakesh Roshan Gupta
Senior Manager (TS)

Emission Reduction

IndianOil replaced steam tracing with Electric Heat Tracing on offsite VGO, VR, vacuum-slop, industrial-fuel-oil and bitumen lines. The project installed thermostatically controlled heating cables and 23 Local Distribution Panels, powered through spare capacity in existing electrical infrastructure rather than new substations. Execution was undertaken on operating lines above 100°C in congested pipe racks. The case study reports 8 TPH steam savings, approximately 10,356 tonnes/year CO_2 reduction, 72,000 KL/year water savings and ₹20.9 crore annual financial savings. The project combines electrification with infrastructure optimization, although the reported investment total requires reconciliation with its listed components

Background & Context:

Heavy hydrocarbon transfer lines require heat to maintain fluidity and prevent solidification. Conventional steam tracing at the refinery involved thermal losses, steam-trap maintenance, condensate losses and localized corrosion associated with leaks. Steam generation also required boiler fuel consumption. Electrical tracing was selected to improve temperature control and reduce utility demand. The principal constraints were live-line installation, high temperatures, congested elevated work areas and availability of electrical distribution capacity.

Objectives:

1. Eliminate approximately 8 TPH of tracing-steam demand.
2. Reduce operating expenditure and boiler-related emissions.
3. Supply 23 distribution panels through existing spare electrical capacity.
4. Improve temperature control on heavy-hydrocarbon lines.
5. Reduce steam-trap failures, leakage and thermal-distribution losses

Methodology:

The refinery surveyed relevant lines and calculated heat losses using operating temperature, insulation, pipe diameter and ambient conditions. Self-regulating and series-resistance heating cables were selected and installed along operating pipelines, followed by insulation and protective cladding. Electrical assessments identified spare transformer, switchgear and feeder capacity to supply the 23 panels. Temperature sensors and digital controllers provided automatic heating when temperatures fell below set thresholds.

Challenges:

Work on live lines above 100°C required specialized protection, handling tools and job-safety assessments. Congested pipe racks and elevated locations restricted access. Summer conditions increased heat-stress exposure, addressed through staggered schedules and hydration arrangements. Supplying geographically dispersed panels without new substations required load-flow studies and reassignment of spare electrical capacity

Implementation:

Implementation progressed through line mapping, electrical audits, panel installation, cable laying, insulation and commissioning. Specialized contractors installed heating cables while process lines remained operational. Following loop testing and thermostat calibration, electrical tracing was energized and steam tracing isolated progressively. Electrical Maintenance, Technical Services, Inspection, Safety and Process Operations functions coordinated execution. The submission records completion but does not provide a dated implementation schedule..

Stage	Major Activity
Engineering	Lines surveyed and heat-loss requirements assessed
Electrical Assessment	Spare transformer, switchgear and feeder capacities identified
Distribution Setup	23 Local Distribution Panels installed
Field Installation	Heating cables laid on operating pipelines
Insulation	Thermal insulation and weather protection installed
Controls	Sensors and digital thermostats integrated
Commissioning	Loops tested and electrical tracing energized
Steam Isolation	Existing steam tracing progressively decommissioned

Investment:

The source reports ₹1,500 lakh capital expenditure, ₹490 lakh annual operating expenditure and ₹2,090 lakh total investment. The reported total does not reconcile with the listed components. All figures are retained below without adjustment; clarification is required before publication.

Cost Component	Amount (₹ Lakhs)
Capital Expenditure	1,500
Operational Expenditure—Annual	490
Human Resources	NA
Technology Acquisition	NA
R&D and Innovation	NA
Others	NA
Total Investment—as reported	**2,090**

Outcomes:

The conversion eliminated 8 TPH of continuous steam demand and introduced automated temperature control. Reported annual benefits include approximately 10,356 tonnes of CO_2 reduction, 4,395 SRFT energy reduction, 72,000 KL water savings and ₹2,090 lakh financial savings. Operational benefits include reduced dependence on steam traps and condensate systems and more precise line heating. The submission does not provide a separate calculation showing electricity-related emissions within the reported carbon benefit.

Parameter	Before Implementation	After Implementation	Improvement (%)
GHG Emissions	Baseline emissions	Approximately 10,356 tonnes/year reduction	**Absolute reduction reported**
Energy Consumption	Steam-tracing baseline	4,395 SRFT/year reduction	**As reported**
Steam Demand	Existing tracing demand	8 TPH eliminated	**Reduced utility requirement**
Water Consumption	Baseline consumption	9 m^3/hr; 72,000 KL/year saved	**As reported**
Waste Generation	No	No	**No change reported**
Resource Utilization	Existing infrastructure	Existing electrical capacity used	**New substation avoided**
Operational Efficiency	Steam-trap-based system	Automated thermostatic control	**Improved thermal control**
Cost Savings	Baseline operating cost	₹2,090 lakh/year	**₹20.9 crore/year reported**
Others	No	No	**No change reported**

Scalability & Replicability:

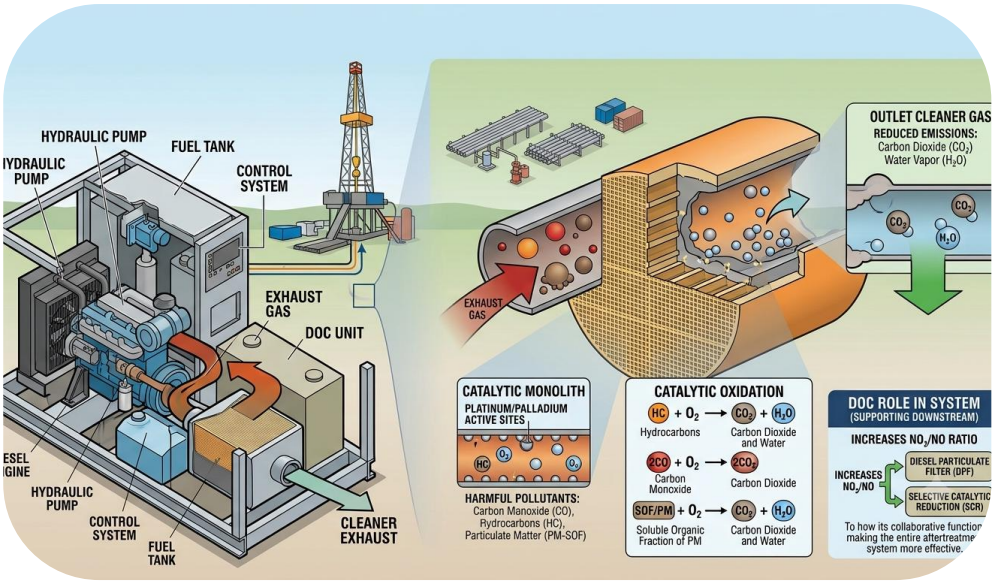
The approach is relevant to facilities using steam tracing, including refineries, petrochemical, fertilizer and chemical plants. Local distribution panels supplied from available electrical capacity offer a potential model for brownfield sites with space or capital constraints. Replication requires site-specific heat-loss assessment, electrical-capacity verification and safe installation planning.

Key Learnings:

Detailed electrical audits can identify spare capacity and avoid new substation construction. Temperature-controlled heating allows energy delivery to follow actual line requirements. The project also demonstrates the importance of multidisciplinary planning for live-line retrofits in congested environments. Its reported financial and environmental benefits should be supported by reconciled investment figures and clearly documented calculation boundaries

Future Plans:

The refinery plans to survey remaining steam-traced lines for further conversion. It also proposes exploring integration of panel-health and temperature information with central DCS/SCADA systems to support monitoring and predictive maintenance.



Installation of Diesel Oxidation Catalysts in Drilling-Rig Power Packs

Oil India Limited | **Emission Reduction**

OIL installed Diesel Oxidation Catalysts in drilling-rig engine exhaust systems to reduce harmful exhaust pollutants without replacing existing engines. The programme began with four units on Rig S#7, followed by 27 additional installations across other rigs. Comparative monitoring of four engines reported average concentration reductions of 21.98% for carbon monoxide, 23.51% for sulphur dioxide, 20.29% for nitrogen oxide and 25.75% for particulate matter. The submission also records lower measured CO_2 concentration, but does not establish an absolute greenhouse-gas reduction. The initiative demonstrates a phased, monitoring-led approach to improving the environmental performance of existing drilling equipment

Background & Context:

Drilling-rig power generation depends on high-capacity diesel engines that emit carbon monoxide, hydrocarbons, nitrogen oxides, sulphur dioxide and particulate matter. OIL sought a retrofit solution that could improve exhaust quality while retaining existing engine assets and operational reliability. Diesel Oxidation Catalysts were initially tested on Rig S#7. Following performance evaluation, deployment expanded across Rigs S#1, S#2, S#3, S#5, S#6, S#8, DM-5 and Dihing-1

Objectives:

1. Reduce harmful exhaust emissions from drilling-rig power packs.
2. Improve the environmental performance of existing diesel engines.
3. Assess changes in major exhaust-pollutant concentrations.
4. Support sustainability objectives through practical retrofit technology.
5. Expand deployment following field-performance validation

Methodology:

The DOC comprises a flow-through honeycomb substrate coated with precious-metal catalysts. Installed in the exhaust system, it facilitates oxidation of carbon monoxide and hydrocarbons and reduces the soluble organic fraction of particulate matter. OIL's R&D department measured exhaust parameters with and without DOC installation on four engines. The comparison covered CO, CO_2, SO_2, nitrogen oxide and particulate matter, providing the evidence used to support wider deployment.

Challenges:

Installation required integration with existing exhaust systems while maintaining drilling continuity. Reliable before-and-after measurements were needed to validate performance under field conditions. Expansion across multiple rigs also required consistent installation quality. Operations, maintenance and R&D functions collaborated to address integration requirements and substantiate the reported outcomes.

Implementation:

The pilot involved four DOC units on Rig S#7, with baseline and post-installation monitoring. Following positive results, 27 additional units were installed across eight other rigs. The submission identifies five further units for the upcoming Dihing-2 rig. The programme remains ongoing; specific installation dates are not provided..

Phase	Activity	Status
Pilot	Four DOC units installed on Rig S#7	Completed
Validation	Four-engine exhaust comparison undertaken	Completed
Expansion	27 additional units installed across other rigs	Completed as reported
Further Deployment	Five units for Dihing-2	Planned

Outcomes:

Monitoring recorded lower concentrations across the five reported exhaust parameters. The largest average reduction was in particulate matter, followed by sulphur dioxide, carbon monoxide and nitrogen oxide. These are measured concentration changes, not quantified annual pollutant-mass reductions. Similarly, the recorded CO_2 concentration decrease does not establish annual tCO_2e savings. The programme nevertheless provided field evidence supporting wider use of the retrofit across the drilling fleet

Parameter	Engine 1: ED300120	Engine 2: ED300121	Engine 3: ED300124	Engine 4: ED300115	Average Reduction
CO, mg/Nm^3	25.1 → 18.2; 27.49%	25.7 → 19.1; 25.68%	25.1 → 20.6; 17.93%	23.8 → 19.8; 16.81%	21.98%
CO_2, % v/v	5.8 → 5.0; 13.79%	5.6 → 5.2; 7.14%	5.2 → 5.0; 3.85%	6.2 → 5.4; 12.90%	9.42%
SO_2, mg/Nm^3	26.5 → 18.4; 30.57%	27.1 → 19.8; 26.94%	28.3 → 21.4; 24.38%	24.7 → 21.7; 12.15%	23.51%
Nitrogen Oxide, ppmv	83.7 → 63.7; 23.89%	85.6 → 67.1; 21.61%	87.6 → 70.5; 19.52%	81.3 → 68.2; 16.11%	20.29%
Particulate Matter, mg/Nm^3	40.5 → 26.4; 34.81%	41.7 → 32.4; 22.30%	42.5 → 31.9; 24.94%	38.7 → 30.6; 20.93%	25.75

Scalability & Replicability:

The submission identifies potential replication across diesel-powered rigs, generators and industrial equipment. Installation modifies the exhaust system rather than requiring major engine redesign. The phased rollout provides a model for validating performance before wider adoption, with installation consistency and reliable monitoring remaining important.

Key Learnings:

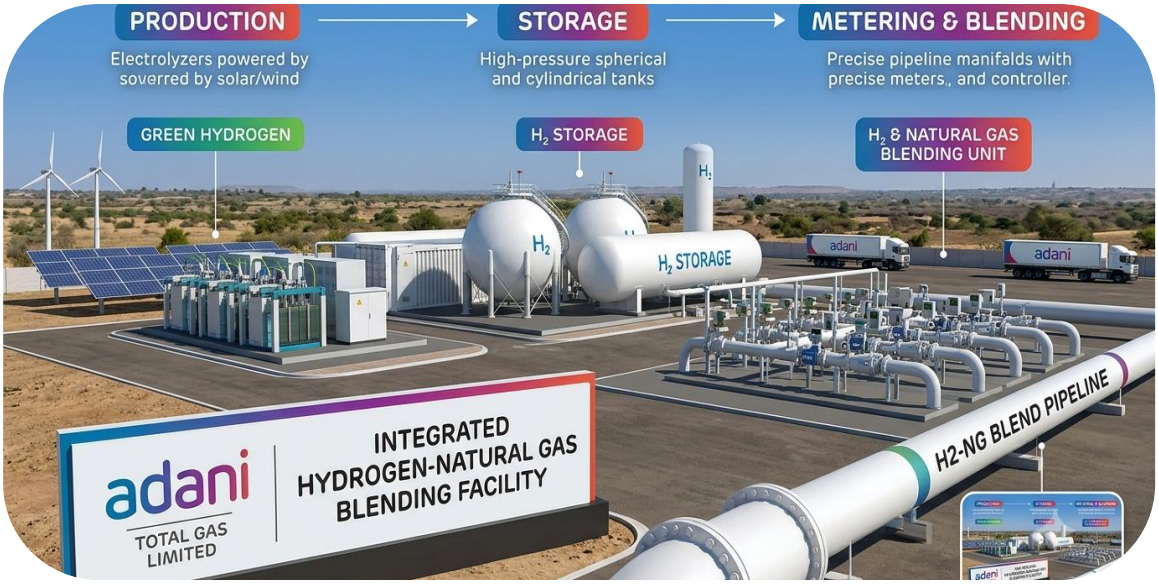
Existing assets can achieve environmental improvements through targeted retrofits. Pilot deployment and performance validation help reduce implementation uncertainty. Reliable monitoring is essential to substantiate outcomes, while collaboration between operating and R&D teams supports adoption. Reported concentration reductions should remain distinct from absolute emissions or carbon-footprint claim

Future Plans:

The identified next deployment is installation of five DOC units on Dihing-2. The submission does not provide a separate dated roadmap or quantified future-investment plan.



CLEAN ENERGY INTEGRATION



Hydrogen Production, Storage, Metering and Blending with Natural Gas

Adani Total Gas Limited	CLEAN ENERGY INTEGRATION

ATGL implemented a pilot for hydrogen production, storage, metering and controlled blending with natural gas in the existing PNG network at Shantigram, Ahmedabad, serving approximately 4,000 domestic and commercial customers. The pilot commenced at around 2% hydrogen blending and subsequently progressed toward the approved 5% level, with peak-hour data during the higher-blend phase averaging approximately 4.6% H_2. The system integrates a PEM electrolyzer, hydrogen storage, metering, automated injection, gas analysers, PLC-based controls and layered safety systems with the existing CGD infrastructure. Independent assessment by Bureau Veritas found stable operation, satisfactory safety systems and no adverse material effects over the evaluated exposure periods. The pilot provides field-level evidence for controlled low-percentage hydrogen blending as a potential CGD decarbonization pathway.

Background & Context:

ATGL initiated the pilot to determine whether hydrogen could be safely integrated into an existing city gas distribution network and generate practical operating experience for future deployment. The initiative was driven by India's transition toward cleaner fuels and the need to develop field evidence on hydrogen use within CGD infrastructure. Approval was available for blending hydrogen with natural gas up to 5%, and the pilot was implemented in a live PNG network serving approximately 4,000 customers. The assessment covered gas quality, network pressure and flow, pipelines and fittings, customer appliances, safeguards, leak detection and emergency response. After approximately one year of operation, Bureau Veritas independently assessed blending performance, material compatibility, safety compliance, documentation, stakeholder readiness and scale-up potential

Objectives:

1. Demonstrate safe and stable blending of hydrogen up to 5% into the existing PNG network.
2. Verify gas quality, pressure and flow stability and material and appliance compatibility.
3. Validate leak detection, control interlocks and emergency safeguards under operating conditions.
4. Assess customer acceptance and stakeholder preparedness through surveys and hydrogen-safety training.
5. Generate independently verified operational evidence and regulatory learnings for future scale-up of hydrogen blending

Methodology:

The pilot integrates hydrogen generation, compressed storage, metering and controlled injection into the existing PNG network. The system operates with hydrogen generation pressure of 30 bar, maximum generation rate of 10 Nm^3/h (approximately 0.8 kg/h), electrolyzer capacity of 257 SCMD (approximately 19 kg/day), hydrogen storage capacity of 6 kg, and blending pressure of 4 bar. The system includes hydrogen analysers, flow-control valves, pressure and temperature instrumentation, PLC controls, gas detectors, pressure-relief valves, slam-shut/emergency shut-off valves and automatic shutdown logic. Independent assessment by Bureau Veritas covered operating logs, composition tests, material compatibility, leak detection, customer perception, training, QRA, HAZOP, hazardous-area classification, SOPs, calibration records, interlock/alarm testing and emergency-response documentation. Testing also included PE/GI network components, burner parts, elastomers and fittings

Challenges:

The principal operational challenge was maintaining the higher hydrogen-blend concentration within the regulatory ceiling while PNG demand varied, particularly during peak periods. At a nominal 5% setpoint, changing gas demand occasionally resulted in concentration exceeding the allowable limit. The operating setpoint was therefore optimized to approximately 4.5% to retain a compliance margin. Hydrogen service also required confidence in existing PNG pipelines, fittings, elastomers and customer appliances. Accordingly, gas-composition analysis, periodic material testing, leak-detection verification, safety-system checks and customer surveys were undertaken. The pilot further demonstrated the need to assess technical feasibility as an integrated system involving gas quality, network behaviour, material compatibility, customer appliances, safeguards and emergency-response preparedness rather than blending performance alone.

Implementation:

The project commenced in October 2024 under approval for hydrogen blending with natural gas up to 5%. During the initial phase through June 2025, hydrogen-analyser readings during active blending were typically around 2.0–2.5%, with no critical alarms reported in the assessment. Phase 2 commenced in July 2025 and progressed toward the 5% blend level. Peak-hour observations from July to November 2025 recorded average hydrogen concentration of approximately 4.6%, HNG flow of 58.42 SCM/h, NG flow of 58.15 SCM/h, and NG pressure of 3.95 bar. When demand variation resulted in occasional excursions above the allowable concentration at a 5% setpoint, the operating setpoint was optimized to 4.5%. Independent assessment found no adverse material effects over evaluated exposure periods of approximately eight months at 2% and five months at 5%, while safety interlocks and control loops were assessed as satisfactory

Implementation Timeline:

Period	Implementation	Outcome
October 2024	Pilot commenced	Hydrogen blending initiated in existing PNG network [
Oct 2024 – Jun 2025	Initial phase	Typical active-blending readings of ~2.0–2.5% H_2; no critical alarms reported
July 2025	Phase 2 commenced	Progression toward 5% hydrogen blend
Jul – Nov 2025	Higher-blend monitoring	Peak-hour H_2 averaged ~4.6%; HNG flow 58.42 SCM/h, NG flow 58.15 SCM/h, pressure 3.95 bar
Higher-blend operation	Setpoint optimization	5% setpoint optimized to 4.5% to maintain margin below regulatory ceiling
Assessment phase	Independent evaluation	Materials, safety systems, controls, customer feedback and documentation reviewed

Investment:

The pilot required approximately ₹3 crore in capital expenditure, while annual operating expenditure was approximately ₹45 lakh. Human resources comprised ATGL head-office personnel and site operators and were included in the overall cost. The initiative uses a PEM electrolyzer supplied by Plug Power USA, with technology-acquisition expenditure included within overall project cost. Total investment is reported at approximately ₹3.5 crore

Cost Component	Amount (₹ Lakhs)
Capital Expenditure	~₹3 crore
Operational Expenditure (Annual)	~₹45 lakh
Human Resources	ATGL HO team and site operators; included in overall cost
Technology Acquisition	PEM electrolyzer from Plug Power USA; included in overall cost
Total Investment	**~₹3.5 crore**

Outcomes:

The pilot demonstrated controlled low-percentage hydrogen blending within an operating PNG network serving approximately 4,000 domestic and commercial customers. During the higher-blend phase, peak-hour hydrogen concentration averaged approximately 4.6%, with stable reported flow and pressure parameters. Independent testing found no adverse material effects over the evaluated exposure periods and verified satisfactory safety interlocks, leak detection and control loops. Surveyed customers reported no significant deterioration in appliance performance or safety experience. The quantitative table separately reports approximately 5.12 tCO_2e, 44,000 units of energy consumption and 170 KL water consumption after implementation. However, the source itself states that absolute tCO_2e reduction, cost savings, water-use benefits and waste benefits were not quantified in the compliance assessment. These figures should therefore not be interpreted as verified improvement or savings metrics without supporting ATGL record.

Parameter	Before Implementation	After Implementation	Improvement (%)
GHG Emissions	-	~5.12 tCO_2e reported in quantitative table	Improvement not established
Energy Consumption	-	44,000 units	Improvement not established
Water Consumption	-	170 KL	Improvement not established
Waste Generation	Not reported	Not reported	N/A
Resource Utilization	Conventional PNG, 0% H_2	Stable 2%; higher-blend peak-hour average ~4.6% H_2	Hydrogen integrated into existing PNG network
Operational Efficiency	Conventional PNG distribution	Stable blending; HNG 58.42 SCM/h, NG 58.15 SCM/h, pressure 3.95 bar; no critical failures	Qualitative improvement
Cost Savings	Not reported	Not reported	Not determinable
Customer / Safety Evidence	-	~4,000 customers served; no safety-critical events reported in assessment	Safe pilot operation demonstrated

Scalability & Replicability:

The pilot provides a potential replication framework for other CGD networks where asset condition, gas composition, metering, materials and end-use compatibility are appropriately validated. The approach begins with a low hydrogen blend, verifies pressure, flow and customer performance, tests representative materials and confirms risk studies and emergency systems before concentration is increased following evidence-based review and regulatory approval. The Shantigram experience demonstrates technical feasibility of low-percentage hydrogen blending in existing PNG infrastructure over the evaluated exposure periods. Wider deployment would require stronger SCADA/historian data capture, more frequent material and corrosion monitoring, periodic independent audits, customer surveys, and appropriate training and permit controls. Any increase beyond the presently approved 5% would require further technical testing and explicit regulatory approval.

Key Learnings:

Phased blending was found to be an effective approach for managing technical and safety uncertainty. The 2% hydrogen-blending phase operated stably under the assessed conditions, providing a base for progression toward higher blends. Network-demand variation can affect hydrogen concentration at higher setpoints. The pilot demonstrated the practical value of retaining an operating margin below the regulatory ceiling, with the nominal higher-blend setpoint ultimately optimized to 4.5%.Analysers, flow controls, alarms, interlocks and emergency shutdown arrangements were identified as essential safeguards. Material compatibility requires periodic verification rather than reliance only on short-duration exposure, while appliance and customer performance should be monitored alongside pipeline infrastructure. Overall, scale-up requires sustained monitoring, independent assurance, stakeholder preparedness and continued regulatory alignment in addition to demonstrating technical feasibility.



Operational Excellence through Renewable Energy Integration at CNG Stations: A Pilot Initiative

Indraprastha Gas Limited (IGL)
Sushant K. Chaudhary
GENERAL MANAGER, CNG O&M

CLEAN ENERGY INTEGRATION

The initiative involved installation of a 31.86 kWp grid-connected rooftop Solar PV power plant over the canopy structures of the IFC-5 COCO CNG Station in Delhi. Implemented as a pilot project between December 2023 and September 2025, the system was commissioned under the Net Metering Scheme of the Delhi Electricity Regulatory Commission (DERC). The project demonstrated the feasibility of integrating renewable energy generation within an operational CNG station without requiring additional land. The initiative reduced dependence on conventional grid electricity, lowered Scope 2 greenhouse gas emissions, generated annual electricity cost savings, and provided a scalable model for deployment across IGL's CNG station network.

Background & Context:

As part of its ongoing Net Zero strategy, IGL has been assessing Scope 1 and Scope 2 greenhouse gas emissions and identifying decarbonization pathways across its operations. Renewable energy integration was identified as a key opportunity for reducing emissions associated with purchased electricity.

The company had already undertaken renewable energy initiatives including a 500 kWp grid-connected rooftop solar project under DERC's Group Net Metering Scheme and had engaged with regulatory authorities to facilitate renewable energy access through Green Energy Open Access mechanisms.

Recognizing the significant canopy infrastructure available at CNG stations, IGL explored the possibility of utilizing these structures for solar power generation. The IFC-5 COCO CNG Station in Delhi was selected as a pilot site to evaluate technical feasibility, operational suitability, safety considerations and replicability of a canopy-mounted rooftop solar installation.

Objectives:

1. Integrate renewable energy generation into CNG station operations using existing canopy infrastructure.
2. Optimize utilization of available station space without requiring additional land.
3. Generate clean electricity to offset grid power consumption.
4. Reduce Scope 2 greenhouse gas emissions associated with purchased electricity.
5. Demonstrate technical feasibility of solar PV integration under the DERC Net Metering Scheme.
6. Establish a scalable and replicable model for similar installations across other IGL CNG stations.
7. Support IGL's broader renewable energy and energy-transition objectives

Methodology:

The project followed a structured approach encompassing site assessment, safety evaluation, engineering design, regulatory compliance, construction and commissioning. Available canopy space was assessed for structural and operational suitability, followed by a Quantitative Risk Assessment (QRA) to evaluate potential risks within an operational CNG station environment. A detailed structural assessment identified the need for strengthening the existing canopy structure using ISMC 75 channels to support the additional loading from solar panels. Design and engineering activities covered selection of PV modules, inverters, mounting structures, protection systems, cabling and grid integration requirements.

The project also required extensive statutory compliance. Station drawings and licenses were amended to incorporate Solar PV facilities, PESO approvals were obtained, and Delhi Fire Service was informed before commissioning. Following installation, the solar plant was synchronized with the station's electrical system under DERC's Net Metering Scheme.

Challenges:

The primary challenge involved obtaining regulatory approvals for installation of a Solar PV facility within an operational CNG station. Since the project was the first of its kind at IGL, comprehensive risk assessment and engagement with PESO were required. Following submission of the QRA study and supporting documentation, in-principle PESO approval was obtained in February 2024.A second major challenge involved canopy strengthening, which required temporary shutdowns of the operational CNG station. Scheduling these shutdowns was difficult because nearby stations were simultaneously undergoing remodeling activities and operational continuity during the festive season had to be maintained. To address these constraints, project execution was carried out through carefully planned phased shutdowns, enabling uninterrupted customer service while ensuring structural strengthening and safety compliance.

Implementation:

The pilot project progressed through five structured phases covering assessment, approvals, procurement, structural preparation, installation and commissioning. Multiple stakeholders participated in implementation, including internal engineering teams, structural consultants, Solar PV vendors, PESO, Delhi Fire Service and station operations personnel. The project was implemented as a proof-of-concept to validate the feasibility of canopy-mounted solar installations at operational CNG stations. The learnings from technical assessment, regulatory approvals, structural modifications and operational integration have created a framework for future deployments across the network. Following successful installation and completion of statutory requirements, final PESO approval was received on 16 September 2025 and the plant was commissioned on 25 September 2025.

Implementation Timeline:

Phase	Major Activities	Period
Technical Assessment & Approvals	QRA finalization, structural consultant engagement, PESO approval and DFS intimation	Dec 2023 – Apr 2024
Administrative Approval & Procurement	Administrative approvals and work-order placement	Sept 2024 – Nov 2024
Structural Preparation	Canopy strengthening and roof-sheet modification	Mar 2025 – Jun 2025
Solar PV Installation	Installation of Solar PV plant and associated systems	Aug 2025
Final PESO Approval	Regulatory approval obtained	16 Sept 2025
Commissioning	Grid-connected Solar PV plant commissioned	25 Sept 202

Investment:

The total project investment amounted to approximately ₹20.68 lakh. Capital expenditure accounted for ₹20.30 lakh, including GST, while annual operational expenditure was estimated at ₹0.38 lakh with an escalation factor of 6% annually. The investment included canopy strengthening, Solar PV modules, inverters, balance-of-system components, electrical integration and compliance-related activities. The project serves as a low-footprint renewable energy solution that leverages existing infrastructure without requiring additional land acquisition

Cost Component	Amount (₹ Lakhs)
Capital Expenditure	20.30
Operational Expenditure (Annual)	0.38
Human Resources	NA
Technology Acquisition	NA
R&D and Innovation	NA
Others	NA

Outcomes:

The initiative delivered measurable environmental and financial benefits through reduced dependence on conventional grid electricity. Annual electricity consumption was reduced by approximately 40,701 units, resulting in a reduction of about 29 tCO_2e in annual greenhouse gas emissions. The project also generated annual electricity cost savings of approximately ₹3.80 lakh.

Beyond quantified benefits, the pilot validated the technical and operational feasibility of integrating renewable energy infrastructure within active CNG stations. It generated valuable organizational learning relating to structural assessment, canopy design, safety integration, electrical connectivity and execution planning. The project demonstrated that existing station infrastructure can be effectively utilized for renewable energy generation, thereby supporting decarbonization without requiring additional land resources.

Parameter	Before Implementation	After Implementation	Improvement (%)
GHG Emissions (tCO_2e)	369	340	8%
Energy Consumption (Units)	5,19,502	4,78,801	7.8%
Water Consumption (KL)	-	-	-
Waste Generation (Tonnes)	-	-	-
Resource Utilization	-	-	-
Operational Efficiency	-	-	-
Electricity Cost (₹ Lakhs)	60.57	56.77	6.3%
Annual Electricity Savings	-	40,701 units saved	-
Annual GHG Reduction	-	29 tCO_2e avoided	-
Annual Cost Saving	-	₹3.80 lakh	-

Grid Emission Factor: 0.710 tCO_2/MWh as per CEA FY 2024-25

Scalability & Replicability:

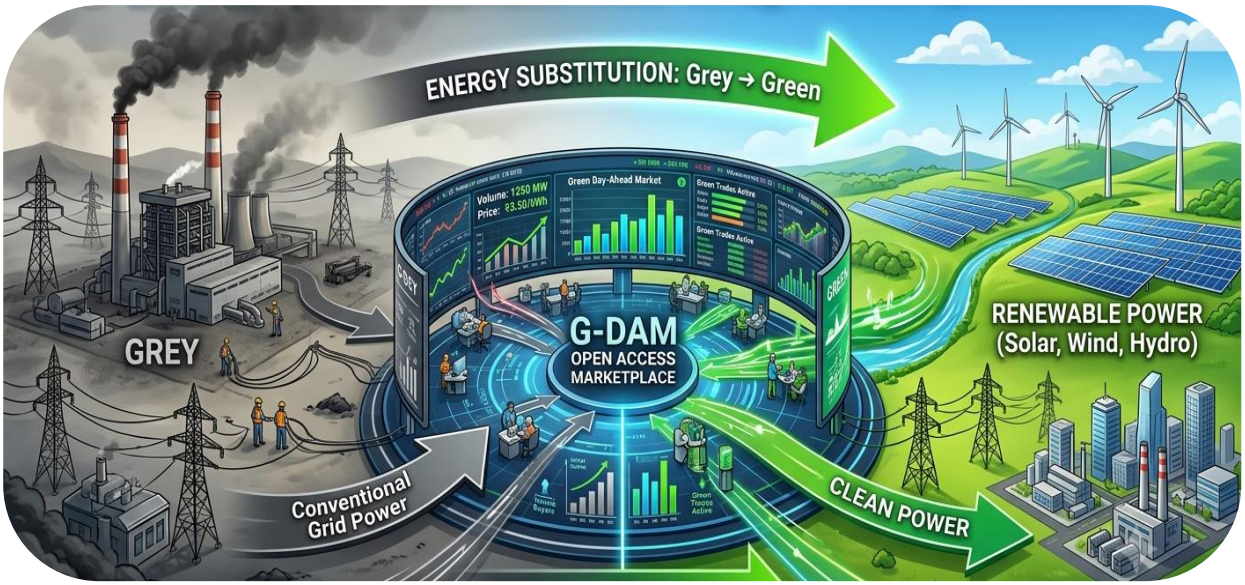
The pilot demonstrated that canopy-mounted Solar PV installations can be integrated into operational CNG stations while maintaining safety and regulatory compliance. Because the approach utilizes existing station infrastructure, additional land acquisition is not required, significantly improving scalability. The implementation framework developed through structural assessments, QRA studies, safety reviews, regulatory approvals and phased execution can readily be adapted for deployment at other suitable stations. Replication would require site-specific assessment of canopy strength, available installation area, electrical integration requirements and regulatory approvals. The initiative provides a practical roadmap for increasing renewable-energy penetration across IGL's station network and advancing company-wide decarbonization objectives

Key Learnings:

The pilot established the technical feasibility of installing rooftop Solar PV systems over operational CNG station canopies while maintaining safety and operational continuity. Structural assessments and canopy strengthening were identified as critical prerequisites for successful implementation. One important lesson was that Solar PV integration should ideally be incorporated during the design stage of new CNG stations. Designing canopies with future solar installations in mind can minimize structural modifications, reduce implementation costs and accelerate deployment schedules. The project also demonstrated the importance of phased shutdown planning and coordination when implementing renewable-energy infrastructure at active operational sites. The experience has provided a practical methodology for future deployments across the network

Future Plans:

IGL plans to expand renewable energy integration across its CNG infrastructure by installing rooftop Solar PV systems at 12 additional CNG stations over the next three financial years. The planned installations are expected to provide an aggregate capacity of approximately 450 kWp and build upon the lessons learned from the IFC-5 pilot project



Grey to Green: Substitution of Conventional Grid Power with Exchange-Traded Renewable Power

Indian Oil Corporation Limited
E Panthya
DGM (TS)

CLEAN ENERGY INTEGRATION

The Grey to Green initiative enables IndianOil refineries to substitute conventional grid electricity with physically delivered renewable power procured through the Green Day-Ahead Market (G-DAM) on the Indian Energy Exchange (IEX) under Open Access. Procurement commenced in January 2026 at Gujarat and Panipat Refineries. During FY 2025-26, the two refineries procured 23,073 MWh of green power, increasing to 62,076 MWh in Q1 FY 2026-27. The initiative achieved renewable-energy integration without creating new generation assets or entering long-term PPAs. The case study reports 61,903 tCO_2e of avoided emissions since January 2026, ₹20.39 crore of realized savings, and a 28.8% reduction in per-unit power cost for the substituted electricity

Background & Context:

Historically, IndianOil refineries sourced only about 10% of their power requirement from the state grid, with no green-power procurement, while the remaining requirement was met from gas turbines operating within refinery captive power plants. This resulted in a relatively higher carbon footprint because of dependence on captive fossil-fuel-based generation. Conventional renewable-power options such as captive generation and long-term PPAs required significant investment, land and long-term commitments. Renewable Energy Certificates could support compliance but did not reduce actual fossil-based electricity consumption. G-DAM provided an alternative by enabling physical procurement of renewable electricity through the power exchange under Open Access. Haryana's tariff provisions, including waiver of Additional Surcharge and nil wheeling charges at 220 kV, also supported commercial attractiveness. The initiative was therefore designed to reduce Scope 2 emissions, support Renewable Consumption Obligation (RCO) compliance and lower refinery power costs

Objectives:

1. Substitute part of conventional DISCOM grid electricity with physically delivered renewable electricity procured through G-DAM on the Indian Energy Exchange.
2. Optimize renewable-power procurement based on daily market prices.
3. Improve sustainability performance and reduce carbon emissions.
4. Make a significant contribution towards meeting Renewable Consumption Obligation targets.

Methodology:

The initiative follows a structured daily energy-procurement process beginning with assessment of the refinery's next-day power requirement. A slot-wise Time-of-Day breakeven price is calculated after incorporating exchange charges, transmission losses, transmission charges, scheduling fees, trading margins and cross-subsidy charges. Based on this economic assessment, G-DAM bids are submitted through NTPC Vidyut Vyapar Nigam Limited (NVVN) and forwarded to the power exchange. Power is allocated based on the Market Clearing Price and available renewable-power supply. The subsequent process covers obligation reporting, exchange payment settlement, weekly billing, invoicing, Renewable Energy Certificate issuance, monthly energy reconciliation and adjustment in DISCOM billing. The methodology ensures that renewable electricity is procured only for economically viable time blocks rather than irrespective of prevailing market conditions. Regular market monitoring, invoice verification and energy reconciliation support both commercial and regulatory control.

Challenges:

Implementation involved both planning and execution challenges. Renewable generation variability makes 24-hour-ahead forecasting of residual electricity requirements difficult and can increase deviation risk. Short-Term Open Access also requires regulatory approvals and compliance with applicable state-level requirements. Commercial viability is affected by cross-subsidy surcharges, wheeling charges, transmission losses, regulatory levies and fluctuations in G-DAM market prices. Transmission congestion can further restrict the quantum of renewable electricity available for scheduling. Execution constraints included grid congestion, technical minimum-load limitations of conventional thermal units and equipment supply-chain issues involving transformers, protection systems and automation equipment. Coordination was also required with multiple agencies, including NVVN, IEX, SLDC, NLDC, transmission utilities and local DISCOMs. IndianOil addressed these constraints through standardized procedures, slot-wise breakeven pricing, market monitoring, weekly invoice verification and monthly reconciliation

Implementation:

The green-power Open Access initiative commenced in January 2026 after establishment of an operational framework for G-DAM procurement through the Indian Energy Exchange (IEX), with NVVN acting as trading partner and exchange member. The programme was implemented at Gujarat Refinery and Panipat Refinery & Petrochemical Complex. Internal stakeholders included Process & Utilities, the Energy Management Cell, Finance, Electrical Department and Operations teams responsible for demand forecasting and monitoring. External stakeholders included NVVN, IEX, SLDC, NLDC, transmission utilities and the local DISCOM. The operating process integrates demand assessment, breakeven-price determination, bid submission, market clearing, power allocation, settlement, certification and reconciliation. A standardized operating procedure was established to institutionalize this process and ensure consistent market participation while maintaining commercial viability.

Implementation Timeline:

Stage	Implementation
Power Requirement Assessment	Next-day refinery electricity requirement assessed
TOD Breakeven Price Calculation	Slot-wise landed-cost threshold determined
G-DAM Bid Submission	Renewable-power bids submitted through NVVN
Power Exchange	Bids forwarded for market clearing
MCP Discovery & Allocation	Power allocated based on clearing price and availability
Settlement	Exchange payments and weekly invoices processed
REC Issuance	Renewable Energy Certificates issued
Energy Reconciliation	Monthly reconciliation undertaken through SLDC
DISCOM Adjustment	Green-power procurement adjusted in DISCOM billing

Investment:

The initiative required no capital expenditure because no new generation asset was created. IndianOil utilized existing 220 kV grid connectivity, metering and DCS infrastructure for participation in green-power procurement. Annual operating expenditure is approximately ₹50 lakh and includes exchange transaction fees, NVVN trading margin, NLDC/SLDC scheduling and operating charges, annual exchange fees and monthly Short-Term Open Access NOC charges. The initiative is executed by the existing team, with no separately reported technology-acquisition or R&D expenditure

Cost Component	Amount (₹ Lakhs)
Capital Expenditure	Nil
Operational Expenditure (Annual)	~50
Human Resources	Existing team
Technology Acquisition	Nil
R&D and Innovation	Nil
Total Investment	**~50/year**

Outcomes:

The initiative achieved simultaneous environmental and economic benefits by replacing conventional grid electricity with physically delivered renewable power. During FY 2025-26, IndianOil procured 23,073 MWh of renewable electricity, comprising 16,429 MWh at Gujarat Refinery and 6,644 MWh at Panipat Refinery & Petrochemical Complex. During Q1 FY 2026-27, procurement increased to 62,076 MWh, comprising 37,495 MWh at Gujarat Refinery and 24,581 MWh at Panipat. The case study reports cumulative avoided emissions of 61,903 tCO_2e since January 2026, comprising 16,774 tCO_2e during FY 2025-26 and 45,129 tCO_2e during Q1 FY 2026-27. It also reports ₹20.39 crore in savings, comprising ₹5.12 crore in FY 2025-26 and ₹15.27 crore in Q1 FY 2026-27, together with a 28.8% reduction in per-unit power cost. Beyond the financial gains, the initiative increased renewable-energy integration in refinery operations and supported Renewable Consumption Obligation compliance..

Parameter	Before Implementation	After Implementation	Improvement (%)
GHG Emissions	61,903 tCO_2e/annum equivalent for substituted conventional power	Nil for substituted block through 100% renewable G-DAM power	100% improvement for substituted block
GHG Emissions Avoided	Nil	61,903 tCO_2e since Jan 2026	61,903 tCO_2e avoided
Renewable Power, FY 2025-26	No G-DAM procurement	23,073 MWh	New renewable procurement
Renewable Power, Q1 FY 2026-27	-	62,076 MWh	Increased procurement
Cost Savings	Nil against DISCOM variable cost baseline	₹20.39 crore realized	28.8% reduction in per-unit power cost
FY 2025-26 Savings	Nil	₹5.12 crore	New value creation
Q1 FY 2026-27 Savings	-	₹15.27 crore	New value creation

Grid Emission Factor: 0.727 tCO_2/MWh.

Scalability & Replicability:

The initiative has significant scope for expansion within IndianOil refineries and for replication by other energy-intensive industrial facilities. Renewable-power procurement can be increased depending on power demand and prevailing market conditions, with additional cleared G-DAM blocks directly increasing renewable-energy consumption without requiring additional generation infrastructure. The model is replicable because it depends primarily on commercial and regulatory mechanisms rather than site-specific generation technology. Refineries, petrochemical complexes, pipeline installations, LNG terminals and other large grid-connected industrial consumers can potentially adopt a similar approach, subject to applicable Open Access eligibility, power tariff structures, state charges and operating procedures.

Key Learnings:

The initiative demonstrates that renewable-power integration can simultaneously reduce power-procurement costs and emissions when market participation is guided by robust commercial assessment. G-DAM enables actual renewable electricity consumption rather than relying solely on certificate-based compliance. A central learning is the importance of detailed landed-cost and breakeven analysis. Exchange prices alone do not determine economic viability because transmission losses, scheduling costs, trading margins and applicable surcharges materially influence the final delivered cost. The initiative also demonstrates the importance of formal operating procedures, defined responsibilities, accurate load forecasting, coordination with market and grid agencies, and regular reconciliation. The case study reports benefits spanning reduced electricity procurement costs, lower CO_2 emissions, refinery GRM improvement, decarbonization and RCO compliance

Future Plans:

IndianOil plans to further increase renewable-power procurement through G-DAM by extending the mechanism to other locations and improving load forecasting and bidding strategies, thereby increasing the number of economically viable time blocks cleared each day. Further digitalization is planned through automated load forecasting, market analysis and performance monitoring to support improved decision-making and operational efficiency

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