



सत्यमेव जयते



पी एन जी आर बी  
PNGRB

# COMPENDIUM OF CASE STUDIES ON SUSTAINABILITY

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OIL AND GAS SECTOR

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**PETROLEUM AND NATURAL GAS REGULATORY BOARD**

*Sustainability is not about doing less harm.  
It's about doing more good.*

**- Jochen Zeitz**

*The greatest threat to our planet is the  
belief that someone else will save it.*

**- Robert Swan, Polar Explorer**

*Sustainability is about meeting the needs of  
the present without compromising the ability  
of future generations to meet their own needs.*

**- Gro Harlem Brundtland**



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## 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



Globally, the new mandate entrusted to Energy Regulators is to advance sustainability in energy business. India has decided to adopt clean energy at its own pace with an Indian flavour. PNGRB is fully cognizant of the above and has begun its efforts to drive sustainability in downstream oil and gas sector operations. The creation of a Sustainability Cell is the first step in this direction. We believe that our T4S Regulations are not only a tool to lay down standards for safety and efficiency but also to drive sustainability. We

intend to reduce environmental impact in process and delivery of energy to consumers. The substitution of road transport of liquid and gaseous fuels by pipelines, efficiency in sourcing of petroleum products so that they use the shortest route, transition of gas turbines by electric motors, reducing gas loss in CGD networks are some of the initiatives that are underway. Making natural gas pipelines compatible with hydrogen and connecting CBG plants with gas pipeline networks are high on our focus.

I am delighted to present this compendium of case studies that range from reducing greenhouse gas emissions to implementing cutting-edge technologies for energy efficiency, from zero-waste-to-landfill initiatives to community-centric renewable energy projects— each initiative represents a step toward a sustainable future. They reflect the wider definition of ‘Sustainability’ which is not merely reduction in emissions and adoption of renewable energy but of water use, effluent discharge, lesser imprints on land and resource efficiency in general.

This publication marks a significant milestone in our collective journey toward environmental stewardship and operational excellence. What strikes me most about these initiatives is that they go far beyond regulatory compliance. They demonstrate proactive leadership, where companies have identified opportunities to create value while minimizing environmental impact. This

approach aligns perfectly with India's broader sustainability goals and positions our sector as a responsible contributor to the nation's development agenda.

When PNGRB initiated this comprehensive documentation exercise, our vision was clear: to create a knowledge repository that would serve as both a celebration of achievements and a roadmap for future endeavours. We sought case studies from oil and gas entities, and were overwhelmed by the response. As I review the 118 case studies submitted by 25 entities, almost 40 exceptional case studies across the petroleum and natural gas value chain, I am deeply impressed by the innovation, commitment, and results demonstrated by our industry participants.

This compendium serves as more than just documentation. It is a catalyst for peer learning, a source of inspiration for emerging best practices, and a foundation for industry-wide scaling of successful models. The transparency shown by participating entities in sharing their experiences, including challenges faced and solutions developed, exemplifies the collaborative spirit essential for sectoral transformation.

Today's release function is not just a publication launch—it is a celebration of excellence and a recognition of the dedicated professionals who have made these initiatives successful. Their efforts deserve acknowledgment, and their achievements should inspire others to pursue similar paths of innovation and sustainability. PNGRB is happy to highlight these initiatives of our companies and will continue to encourage them by acknowledging, rewarding and knowledge sharing.

I commend all participating entities for their contributions and encourage continued innovation in sustainability practices. Together, we are not just managing today's energy needs—we are building tomorrow's sustainable energy ecosystem. My grateful thanks to Maneesh David Singh, Director, PNGRB for leading this initiative and making this publication a reality.

**"Dr. Anil Kumar Jain"**

## MEMBER'S MESSAGE



### **Contributing to a Sustainable Energy Future**

It is my privilege to present the PNGRB's first edition of the Sustainability Compendium, which brings together transformative case studies from across India's oil and gas sector. This compilation reflects a sector in motion—one that is embracing change, reimagining its responsibilities, and actively shaping a more sustainable energy future.

Each case study featured here is a testament to what's possible when innovation meets intent. From decarbonization strategies and

circular economy models to digital interventions and community-driven clean energy projects, these initiatives underscore the sector's capacity to lead by example.

What stands out is not just the scale of ambition—but the clarity of purpose. These efforts signal a clear shift: from reactive compliance to proactive climate leadership.

As the world navigates the energy transition, India's oil and gas industry is demonstrating how legacy systems can evolve into future-ready, responsible frameworks.

This compendium is more than a publication—it is a catalyst for collaboration. By showcasing replicable solutions, sharing learnings, and celebrating progress, it encourages every stakeholder to step forward and contribute to this shared mission.

I applaud all contributors for their vision and perseverance. Let this be the beginning of a larger conversation—one that accelerates our journey toward sustainability, resilience, and energy equity for all.

**"Anjani Kumar Tiwari"**

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# EXECUTIVE SUMMARY

## Introduction

The Petroleum and Natural Gas Regulatory Board (PNGRB) has prepared this compendium to showcase pioneering sustainability initiatives undertaken across the oil and gas sector. It reflects the industry's growing commitment to embedding sustainability into its core operations, thereby aligning with national climate goals and global best practices.

## Purpose

- To provide a **knowledge platform** for sharing innovative practices and lessons learned.
- To **encourage replication** of successful sustainability initiatives across the sector.
- To serve as a **benchmark repository** guiding organizations toward low-carbon future.

## Highlights

The compendium highlights initiatives across multiple dimensions of sustainability:

- **Emissions Reduction & Efficiency** – lowering carbon footprint through optimized energy use and cleaner processes.
- **Operational Efficiency**– optimizing resource use, reducing losses, and improving reliability, leveraging AI/ML, digital twins, and automation for energy efficiency.
- **Circular Economy** – converting waste into renewable energy and useful byproducts.
- **Clean Energy**- expanding adoption of clean energy solutions to support the transition toward a low-carbon future.

This compendium is more than a record of initiatives—it is a statement of intent. It underscores that **industrial growth, and environmental responsibility can progress together**, provided innovation, collaboration, and regulatory foresight guide the way. Through this initiative, PNGRB reaffirms its role as an enabler of **sustainability-driven growth** in India's energy landscape.



# **Circular Economy**



## Translocation of Corals at Vadinar

Indian Oil Corporation Limited  
Shri Sanjeev K Jaiswal  
DGM (O)

Circular Economy- Bio-Conservation

IOCL, while replacing its ageing offshore SPM facilities in the Gulf of Kutch, discovered that the proposed pipeline route passed through protected live corals. To safeguard the Marine National Park ecosystem, it successfully translocated about 15,000 coral colonies—the largest such initiative in India—demonstrating its strong commitment to environmental sustainability.

### BACKGROUND & CONTEXT

Indian Oil Corporation Limited (IOCL) operates two Single Point Mooring (SPM) systems in the ecologically sensitive Gulf of Kachchh (GoK) at Vadinar for unloading crude oil to supply its major refineries—Koyali (JR), Mathura (MR), and Panipat (PR). These SPMs, commissioned in 1978 and 1997 respectively, have aged significantly, prompting the need for their replacement.

To ensure uninterrupted operations and minimize ecological impact, IOCL proposed laying new offshore pipelines adjacent to the existing ones, followed by their

decommissioning post-commissioning of the new SPMs. However, initial marine surveys revealed that the proposed route intersects live coral habitats within the Marine National Park.

Corals, protected under Schedule-I of the Wildlife Protection Act, are crucial to marine biodiversity, coastal protection, and ecological balance—on par with species like tigers and leopards in conservation significance. As direct disturbance or destruction of coral reefs was not permissible, IOCL undertook the initiative to translocate ~15,000 live coral colonies to a safe and ecologically suitable location.

## OBJECTIVES

The key objectives of the coral translocation initiative were:

- Corals provide an important ecosystem for underwater life-teem with diverse marine life.
- Protect coastal areas from waves.
- Crucial source of income for local people.
- Promising sources of novel pharmaceutical compounds for treatment of various diseases.
- Fascinating appearance attracts a lot of tourism.

## METHODOLOGY

Coral translocation, also known as coral relocation or coral gardening, is a technique used to move corals from degraded or threatened areas to locations where they are more likely to survive and thrive. The process involves collecting healthy coral fragments from donor sites and transplanting them to recipient sites with suitable environmental conditions.

The translocation of corals requires full-fledged scientific, fieldwork and laboratory exercises and carried out in following stages:

- Initial survey of the proposed pipeline route to identify the diversity, quantum and type of coral species to be translocated: - More than 15000 coral colonies were translocated successfully.
- To identify suitable locations in the intertidal and subtidal areas for fixing translocated corals. Each highly potential site will be subjected to water quality assessment (i.e., Salinity, pH, Hardness, Dissolved Oxygen, Temperature, Total Suspended Solids, Turbidity, average water column height and water currents), sediment quality

assessment (sediment size and sedimentation rate), bottom profile of the site and current velocity. This is required to understand the micro level physical conditions of the selected site and to identify locations (recipient sites) for coral transplantation in the area.

- To tag and translocate all the excavated corals from the demarcated pipeline area to suitable areas using suitable scientific techniques such as cementing or attaching coral fragments to artificial structures or existing reef substrates are used to secure them in the recipient site.
- To attach the translocated corals in the selected recipient sites with similar conditions to that of the excavated site, using scientific procedures.
- To carryout intensive monitoring, post-translocation for about 5 years until the translocated corals are well settled.
- Translocation of Coral has been carried out in intertidal zone as well as subtidal zone and following procedure was adopted.
- Demarcation of pipeline route was carried out with the help of DGPS.
- Preparation of grids for translocation.
- Manual removal of each coral to prevent any damage.
- Measurement of removed corals.
- Removal of diseased portion from the corals.
- Securing of each coral on cement frame with marking.
- Shifting of coral from donor site to recipient site.
- Placement of coral frames in water at recipient site.



- Translocation of corals in subtidal zone (having a sea water depth of varying from 1-2 m to 5-6 m in low tide) involves underwater diving and can be carried out only during good visibility season which normally prevails from November to March in the Nararabet region.

Monitoring of transplanted corals is necessary to ensure their survival and growth. Monitoring can include regular visual surveys, measuring coral growth and reproduction rates, and tracking water quality and environmental conditions.

## CHALLENGES

During the coral translocation process, several operational and environmental challenges were encountered. These challenges, however, were systematically addressed through meticulous planning, adaptive strategies, and close coordination with all stakeholders. The key challenges and corresponding mitigation approaches are outlined below:

- The intertidal zone where coral translocation was carried out extended over 2.5 km, with depth variations ranging from 4 to 6 meters, making access and operations difficult.
- Vadinar being a high tidal range location, the working window was limited due to significant tide variation every six hours, resulting in shifting shorelines up to 2.5 km. No vehicular movement was permitted in the intertidal area due to ecological sensitivity. All materials, tools, and equipment had to be manually transported, increasing time and effort.
- Translocation in the intertidal zone commenced in July 2021, coinciding with the monsoon season. Operations were frequently hampered by poor visibility,

intermittent rainfall, and fluctuating weather.

- Coral translocation in the intertidal zone could only be performed during low tide, which allowed for a limited working window of approximately 3–4 hours per day.
- A daily shift of approximately 40 minutes in the tide cycle demanded precise planning and continuous adjustment of work schedules.
- For 7–8 days each month, low tides occurred during nighttime, rendering those days unsuitable for safe working conditions.
- Translocation in the subtidal zone required daily boat travel of approximately 1 hour and 15 minutes each way between DPA jetty and the work site. This further reduced the net effective working hours.
- The subtidal operations during winter were affected by frequent spells of bad weather, high turbidity, and reduced underwater visibility.
- High underwater currents during spring tides significantly restricted diver movement and coral handling, limiting safe working conditions.
- Owing to all the above factors, diving operations in the subtidal zone were extremely challenging, requiring highly skilled divers and strict safety protocols.

Despite these challenges, the entire coral translocation initiative was successfully executed through detailed planning, phased execution, environmental forecasting, and adherence to safety and ecological guidelines.

## IMPLEMENTATION

The coral translocation activity was carried out in two distinct ecological zones: Intertidal





**Demarcation of pipeline route**



**Preparation of grids for translocation**



**Removal of corals**



**Removal of diseased portion**



**Measurement**



**Placement of corals in temporary tray filled with sea water**

and Subtidal. Corals located within the intertidal zone were successfully translocated between July 2021 and October 2021, while those in the subtidal zone were translocated during the period from November 2021 to February 2022. Translocated corals were then put back to their original sites by March 2025.

The intertidal zone included four environmentally sensitive categories:

- Forest Area under section-20
- Marine Sanctuary
- Marine National Park
- Eco sensitive zone

Given the highly sensitive and scientifically intensive nature of the task, IndianOil engaged M/s Zoological Survey of India (ZSI), a premier government agency under the Ministry of Environment, Forest and Climate Change (MoEF&CC) specializing in coral reef studies, restoration, and rehabilitation.

The translocation work was carried out under the supervision of the local Forest Department, covering a stretch of approximately 900 meters along the proposed offshore pipeline route.

## INVESTMENTS

Cost Component	Amount (₹ in Lakhs)
Capital Expenditure	₹474 Lakh
Operational Expenditure (annual)	₹85 Lakh
Total Investment	₹559.00 Lakh

## QUANTITATIVE OUTCOMES

Parameter	Before Implementation	After Implementation	Improvement (%)
Others (please specify)	Subject work was undertaken to protect coral ecosystems, promote environmental conservation, and support sustainable development.		

## QUALITATIVE OUTCOMES

This monumental achievement reflects not just technical excellence, but a deep-rooted respect for nature — a value consistently

upheld by our director throughout his distinguished tenure. The successful integration of complex engineering with environmental sensitivity stands as a legacy of his leadership.

As we reflect on this journey, we take pride in the harmony achieved between industrial growth and environmental conservation — a feat made possible through visionary direction, meticulous planning, and unwavering commitment to sustainable development.

## INNOVATION & UNIQUENESS

[The coral translocation initiative undertaken by IndianOil is a first-of-its-kind effort at this scale in India's oil and gas sector. The uniqueness of the initiative lies in its integration of large-scale industrial infrastructure development with marine biodiversity preservation. Key innovations include:

- Custom-engineered cement frames for securing translocated corals in recipient sites, allowing for higher survival rates.
- Meticulous manual removal and tagging of each coral colony to prevent any physical damage during the process.
- Use of scientific techniques like environmental parameter-based site selection (salinity, current, turbidity, substrate suitability), developed in coordination with specialized institutions like the Zoological Survey of India.
- Two-zone execution approach—distinct strategies were adopted for the intertidal and subtidal zones based on tidal conditions, coral species, and accessibility.
- Largest coral translocation ever attempted in India with more than 15,000 colonies moved successfully, reinforcing IOCL's leadership in sustainable industrial practice.



## SCALABILITY & REPLICABILITY

This initiative provides a scalable and replicable model for future offshore and coastal development projects across India and globally.

- The data-driven selection of recipient sites based on micro-environmental parameters can serve as a template for other coastal pipeline projects, ports, or undersea cable installations.
- The initiative establishes a standard operating framework combining infrastructure execution with conservation science, which can be mandated in future Environmental Impact Assessments (EIAs).

## KEY LEARNINGS

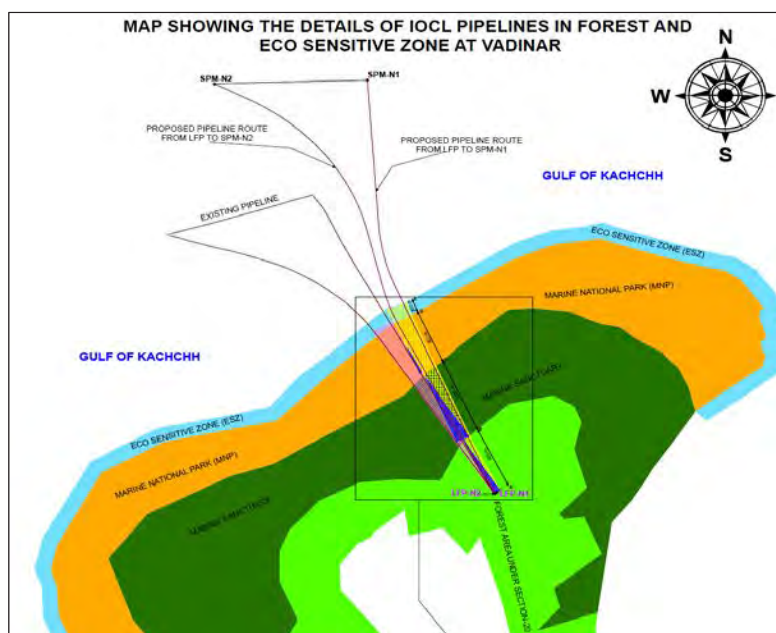
- **Strategic Planning is Critical:** A well-thought-out timeline accommodating environmental windows (tides, weather) was key to the project's success.
- **Coordination with Regulators and Experts:** Early and sustained engagement with scientific institutions and regulatory bodies facilitated timely clearances and technically sound execution.
- **Manual over Mechanical:** In sensitive ecological zones, manual handling of marine organisms proved more effective than mechanized methods in preserving biodiversity.
- **Monitoring and Documentation:** Continuous post-translocation monitoring has reinforced the importance of data collection for demonstrating success

and guiding future projects.

- **Adaptability:** The team exhibited exceptional flexibility in responding to tidal shifts, poor visibility, monsoon disruptions, and underwater current challenges.
- **Public-Private-Scientific Collaboration:** The success highlights the power of multi-stakeholder collaboration where public enterprises work hand-in-hand with research bodies for conservation-oriented industrial development.

## FUTURE PLANS

1. Continue long-term monitoring of coral health and settlement for 5 years as per the ecological restoration plan.
2. Document and publish the learnings in national/international environmental journals to promote replicability.
3. Leverage the success of this initiative to establish standard coral handling protocols for future IOCL coastal projects, thereby institutionalizing marine biodiversity conservation in core project planning.





# Reprocessing of Waste Oils and Spent Charcoal in Kochi Refinery

Bharat Petroleum Corporation Limited  
Shri Roshan Sihab PM  
General Manager (HSE)

Circular Economy

Kochi Refinery feeds used transformer and cooking oils, oily sludge, and spent activated charcoal into its Delayed Coking Unit, blending the charcoal with petroleum coke. This waste-to-energy strategy lowers emissions, eases the effluent treatment plant's load, and converts waste into valuable fuel.

## BACKGROUND & CONTEXT

Earlier, the management of oily sludge was posing significant environmental and operational challenges. Large volumes of sludge were generated from ETPs, Crude tank bottom, and maintenance activities. The sludge, being hazardous in nature, used to be stored in designated pits or lagoons, leading to potential risks of soil and groundwater contamination due to seepage or overflow, especially during monsoons. The conventional disposal methods were landfilling through authorized Treatment, Storage and Disposal Facility (TSDF),

incineration, etc., which were incurring high transportation and disposal costs, while posing long-term environmental liabilities. Storage of untreated oily sludge was occupying large valuable space within the refinery premises, increasing the operational complexity.

Used transformer oil (UTO) is generated during the electrical equipment maintenance in refineries. It contains degraded hydrocarbons, oxidation products etc. UTO is classified as hazardous waste under Schedule I of the Hazardous Waste Rules. Earlier, the disposal of UTO was similar to



that of oily sludge.

Used Cooking Oil (UCO) contains harmful compounds like aldehydes and free radicals, which contribute to inflammation and other health problems. Earlier, UCO was being treated in STP / ETP which was increasing the load as well as the affecting inlet feed characteristics.

In refineries, spent charcoal is generated from Effluent Treatment Plant (ETP), Amine Treatment Unit, VOC Adsorbers, etc. This is also classified as hazardous waste due to its adsorbed hydrocarbons and contaminants. Earlier, the disposal of spent charcoal was done similar to that of oily sludge.

Kochi Refinery has always been at the forefront to protect the environment. Being a socially responsible corporate, to demonstrate proactive waste minimization and implement sustainable waste management practices, idea was explored to reprocess oily sludge, UTO and UCO in Delayed Coking Unit (DCU) which was set up for vacuum residue upgradation. Another idea was to mix spent charcoal in a controlled manner with petroleum coke which is the byproduct of DCU.

## OBJECTIVES

- To protect the environment by minimizing waste
- To recover valuable hydrocarbons for its reuse in refining processes / fuel blending.
- To promote sustainability in refining operations.
- To create energy and wealth from waste

## METHODOLOGY

The DCU is a thermal cracking unit designed to convert heavy residue streams such as vacuum residue into lighter hydrocarbon fractions and petroleum coke. It operates at temperatures of 480 - 520°C and pressure of 1–2 bar. The following methodology has

been adopted to implement the ideas:

- Water content is reduced to less than 50% from the oily sludge followed by its homogenization to maintain uniform consistency.
- UTO is tested to ensure the absence of PCBs (Poly Chlorinated Bi phenyls), heavy metals, halogens, etc.
- Oily sludge along with controlled quantity of UTO and UCO (less than 10%) are injected into the bottom section of the coke drum of DCU.
- Upon injection, the hydrocarbons in the sludge undergo thermal cracking, get vaporized into lighter fractions which exit the drum and are routed to fractionator.
- The non-volatile, solid portion of the sludge remains in the drum and contributes to pet coke formation.
- Further, spent charcoal is mixed with pet coke in controlled rate. The mixture is thoroughly blended to achieve the uniform composition and calorific value of pet coke.

## CHALLENGES

Oily sludge has inconsistent composition in terms of water, solids, oil, heavy metals, etc., which makes it difficult to predict the processing strategy. Inorganic solids like rust, sand, spent catalyst, etc. increase the pet coke yield, however, reduces its quality and causes fouling in the downstream section of coke drum. Acidic compounds like sulfur, chlorides, etc. present in the oily sludge causes corrosion in the associated equipment.

## IMPLEMENTATION

Delayed Coking Unit was installed for the upgradation of low value heavier hydrocarbons. Opportunity was identified to use DCU for the reprocessing of waste material and the same was implemented



after the commissioning of DCU.

## INVESTMENTS

Cost Component	Amount (₹ in Lakhs)
Capital Expenditure	Existing facilities have been utilized
Operational Expenditure (annual)	No additional operational expenditure
<b>Total Investment</b>	Accommodated with existing investment

## QUANTITATIVE OUTCOMES

Parameter	Before Implementation	After Implementation	Improvement (%)
Waste Generation (tonnes)	6000	500	92

Normally, 10,000 MT of oily sludge is generated in a year, which has around 60% of hydrocarbon corresponding to 6000 MT. In this process around 3000 MT light hydrocarbons (gases, naphtha and gas oil) and 2500 MT of coke is recovered. Therefore, around 92% of hydrocarbon is recovered through this initiative.

## QUALITATIVE OUTCOMES

The initiative has helped in protecting the environment through waste minimization. Valuable hydrocarbons are being recovered. This has promoted sustainability in refining operations. The initiative has turned the waste material into a source of energy as well as wealth. After implementing this initiative, the quantity of waste material being disposed through TSDF, has significantly reduced which in turn has improved the surrounding environment.

## INNOVATION & UNIQUENESS

The resemblance of the waste material with vacuum residue which is the typical feedstock for DCU, was identified by Kochi Refinery. It was their unique innovation to use DCU for the reprocessing of oily sludge, UTO, UCO and spent charcoal. It is a perfect example of circular economy.

## SCALABILITY & REPLICABILITY

The idea is replicable in nature and can be implemented across the refineries where DCU is available. This can be also thought of implementing where Vis Breaker Units (VBU) are available. The UCO and UTO are widely available across the industries. The idea can be implemented in all the thermal cracking units.

## KEY LEARNINGS

The existing facility could be utilized for different applications like waste processing. Earlier, the money was spent on the disposal of waste which turned out to be wealth and energy creator.

## FUTURE PLANS

Study is being carried out to maximize sludge processing and the target is zero sludge generation from the refinery. As sludge processing impacts the metallurgy, study shall be done for its protection.





# Development of Low-Carbon Methanol Production from CO<sub>2</sub> as a Renewable Chemical and Sustainable Fuel

Bharat Petroleum Corporation Ltd  
Dr. Chanchal Samanta  
Dy. General Manager-R&D

Circular Economy

Existing methanol production is based on fossil fuels and emit CO<sub>2</sub> during the process. Production of methanol from CO<sub>2</sub> can promote circular economy. By integrating renewable energy driven hydrogen production along with capturing CO<sub>2</sub> from process flue gases, low-carbon methanol can support decarbonization goal. Under this background, development of catalyst and process for CO<sub>2</sub> hydrogenation to methanol has been undertaken. A novel copper-based bimetallic catalyst has been developed and performance of the catalyst system for selective hydrogenation of CO<sub>2</sub> to methanol under mild conditions has been validated. The catalyst enhances CO<sub>2</sub> conversion and methanol selectivity while reducing greenhouse gas emissions, contributing to sustainable methanol production integrated with potential renewable hydrogen usage.

## BACKGROUND & CONTEXT

Describe the situation before the initiative, including challenges faced and drivers for change (max 300 words)

The transition to a sustainable and low-carbon economy requires innovative solutions for reducing greenhouse gas emissions and transforming waste carbon

into valuable products. Methanol—a vital platform chemical and alternative fuel—has traditionally been produced from fossil-derived feedstocks through energy-intensive processes, contributing significantly to carbon emissions. Increasing regulatory, market, and environmental pressures are driving the search for cleaner, circular approaches to methanol synthesis.



Selective hydrogenation of CO<sub>2</sub> to methanol offers an attractive pathway for carbon recycling, enabling direct conversion of captured CO<sub>2</sub> into a renewable fuel and chemical. However, existing catalytic technologies encounter fundamental constraints: low CO<sub>2</sub> conversion rates, rapid catalyst deactivation, and insufficient selectivity. Competing side reactions, notably the reverse water-gas shift (RWGS: CO<sub>2</sub> + H<sub>2</sub> → CO + H<sub>2</sub>O) and methanation (CO<sub>2</sub> + 4H<sub>2</sub> → CH<sub>4</sub> + 2H<sub>2</sub>O), result in undesired byproducts and inefficient hydrogen utilization, further hindering industrial adoption. Achieving high methanol yields under mild reaction conditions (180–250°C, 20–50 bar) is particularly challenging, as conventional catalysts struggle to activate CO<sub>2</sub> efficiently without promoting these side reactions—especially at reduced temperatures and pressures desirable for operational safety and energy savings.

This initiative was set in motion to overcome these technical hurdles and societal imperatives. The motivation arose from the dual necessity to transform CO<sub>2</sub> emissions into a high-value chemical feedstock and to provide a scalable route to sustainable liquid fuels. By focusing on the development and deployment of a highly selective, nanostructured bimetallic hydrogenation catalyst, this project aims to maximize methanol selectivity while suppressing undesired reactions. The novel catalyst platform is engineered to operate reliably under milder, energy-efficient conditions, enabling continuous methanol production with minimized environmental impact.

Ultimately, this initiative responds directly to the pressing need for circular carbon solutions that support India's and global net-zero commitments. It establishes a framework for industrial adoption of methanol as a renewable, low-carbon fuel and chemical, reducing reliance on fossil resources and propelling the transition to a sustainable energy future.

## OBJECTIVES

### List the specific objectives of the initiative

- Develop a catalyst with enhanced selectivity for methanol production from CO<sub>2</sub>.
- Improve catalyst stability and operational life under reaction conditions.
- Enable methanol synthesis at lower temperature and pressure to reduce energy consumption.
- Demonstrate pilot-scale deployment and scalability and integration with renewable hydrogen sources.

## METHODOLOGY

This initiative developed a highly selective catalyst for CO<sub>2</sub> hydrogenation to methanol under mild conditions by integrating advanced catalyst synthesis, multi-scale characterization, pilot reactor testing, and process optimization. The catalyst was prepared via controlled co-precipitation of copper and promoters (e.g., Indium, noble metals) on oxide supports (ZnO, ZrO<sub>2</sub>), with precise control over synthesis parameters to produce nanostructured particles optimized for activity and stability. Comprehensive characterization methods—including XRD, TEM, BET, TPR, TPD, XPS, and FTIR—guided iterative improvements. Performance testing was conducted in a fixed-bed twin reactor under mild conditions (180–250°C, 20–50 bar, H<sub>2</sub>/CO<sub>2</sub> ~3:1), with continuous gas chromatography monitoring to optimize conversion, selectivity, and stability over extended runs (>100 hours). Produced methanol was rigorously analyzed for purity and fuel quality via GC, NMR, and standard fuel tests, ensuring compliance with ASTM standards. Scale-up synthesis was successfully transferred to a commercial partner, and continuous methanol production was demonstrated at a pilot plant (10 kg/day) at CRDC-BPCL, enabling sustainable, scalable low-carbon methanol



production integrated with renewable hydrogen.

## CHALLENGES

Describe the bottlenecks faced while planning, executing and the strategy adopted to overcome (max 500 words)

Developing and scaling a novel catalyst for selective CO<sub>2</sub> hydrogenation to methanol under mild conditions involved several critical challenges. Initially, achieving high methanol selectivity was hindered by competing side reactions and catalyst deactivation, which were addressed through iterative catalyst design, doping with promoters like Indium and Nickel, and fine-tuning process parameters based on thorough characterization. Catalyst stability was compromised by sintering and poisoning during prolonged use, mitigated by enhancing metal-support interactions, stability testing, and regeneration techniques. Scaling synthesis posed difficulties in maintaining batch consistency and quality, overcome by partnering with catalyst manufacturers to standardize protocols and validate pilot-scale production. Reactor design faced heat and mass transfer limitations impacting selectivity and catalyst integrity, resolved by optimizing reactor geometry, flow dynamics, and control systems while integrating renewable hydrogen for sustainability. Ensuring methanol purity to meet stringent standards required robust analytical methods and ongoing process refinement. Finally, effective coordination across R&D, manufacturing, operations, and regulatory teams was essential to prevent delays and maintain compliance, achieved through structured communication, standardized procedures, shared platforms, and targeted training.

## IMPLEMENTATION

Provide details of how the initiative was implemented, including timeline, stakeholders involved, and any challenges

encountered during implementation (max 500 words)

The initiative was implemented through a phased approach starting with catalyst development and lab-scale testing at CRDC, Greater Noida, between November 2023 and March 2024, achieving proof-of-concept with 17% CO<sub>2</sub> conversion and 65% methanol selectivity under mild conditions. Subsequent quarters focused on iterative catalyst optimization and nano structuring (April–June 2024), followed by scaling up synthesis with a commercial manufacturer to ensure batch consistency (July–September 2024). From October 2024 onwards, a pilot plant was commissioned for continuous methanol production, integrating renewable hydrogen supply to align with circular carbon economy goals. Key stakeholders included the CRDC CCUS team (leading catalyst design, testing, reactor operations, and safety), the commercial manufacturer (managing large-scale synthesis and quality control), and CRDC analytical teams (ensuring methanol quality compliance). Implementation involved controlled catalyst synthesis, rigorous characterization, real-time reactor management, and systematic data analysis for ongoing optimization. Challenges such as ensuring catalyst uniformity at scale, stable reactor operation under mild conditions, reliable renewable hydrogen supply, and stringent product purity were addressed through close collaboration, advanced process control, and continuous quality monitoring. Effective multi-team communication and scheduling maintained smooth execution and project momentum throughout.



## INVESTMENTS

Cost Component	Amount (₹ in Lakhs)
Capital Expenditure	417 (31,930,000.00 lakhs for fixed bed twin reactor setup and 70,00,000 lakhs for online gas analyzer and 2,778,725.00 liquid gas analyzer)
Total Investment	417

## QUALITATIVE OUTCOMES

The development and deployment of the selective catalyst for low-carbon methanol synthesis from CO<sub>2</sub> have driven significant qualitative benefits beyond technical metrics. This initiative advances sustainable chemical manufacturing by converting captured CO<sub>2</sub> into valuable methanol using renewable hydrogen, setting a new standard for circular carbon chemistry aligned with climate goals. Mild operating conditions enhance process safety and reliability, enabling longer continuous runs with fewer disruptions. Strong interdisciplinary collaboration has strengthened team expertise and organizational capacity for future sustainable innovations. Environmentally, the project reduces emissions and fossil fuel dependence, boosting stakeholder trust and reinforcing India's carbon neutrality commitments. Pilot-scale experiences offer vital scalability insights, supporting replication across industries. Overall, the project exemplifies circular economy principles by efficiently valorizing CO<sub>2</sub> feedstock, fostering a sustainable shift towards regenerative, low-carbon chemical production.

## INNOVATION & UNIQUENESS

### Highlight innovative aspects and unique features of the initiative (max 300 words)

This initiative pioneers sustainable methanol production by enabling direct hydrogenation of CO<sub>2</sub> into high-purity methanol under exceptionally mild conditions (180–250°C,

20–50 bar), significantly lowering energy use and enhancing safety compared to conventional processes. Central to its uniqueness is the innovative nanostructured bimetallic catalyst, precisely engineered through controlled promoter doping (e.g., Indium) to optimize metal-support interactions and electronic properties, achieving high methanol selectivity while suppressing side reactions like reverse water-gas shift and methanation. The project's integration of advanced multi-scale characterization techniques with real-time pilot reactor analytics accelerated catalyst optimization and ensured reproducible, scalable performance. Aligning production with circular carbon economy principles, it utilizes renewable hydrogen and captured industrial CO<sub>2</sub>, marking a strategic shift from fossil-based to carbon-neutral chemical manufacturing. The successful scale-up—including a ₹4 Crores fixed-bed twin reactor pilot and collaboration with commercial manufacturers—demonstrates a robust pathway for industrial adoption. Rigorous compliance with ASTM fuel standards ensures commercial viability. Together, these innovations in catalyst design, process intensification, scaling strategy, and circular carbon integration establish the initiative as a transformative model for global sustainable methanol production.

## SCALABILITY & REPLICABILITY

### Discuss potential for scaling up and replicating the initiative in other locations/ contexts (max 300 words)

The highly selective nanostructured catalyst technology for converting CO<sub>2</sub> into methanol presents significant potential for scaling and replication across multiple industrial sectors, especially in refineries producing transportation fuels and chemical manufacturing.

### Targeted Industries and Applications:

Traditional petroleum refineries producing gasoline, diesel, and aviation turbine fuel (ATF)



face increasing pressure to reduce carbon emissions and transition to sustainable fuels. Methanol synthesized from CO<sub>2</sub> hydrogenation using renewable hydrogen can serve as a low-carbon alternative or blendstock for these transportation fuels. For example:

- **Gasoline Blending:** Methanol is used as a methyl tert-butyl ether (MTBE) precursor or as a direct fuel component in gasoline blends to improve octane rating while reducing harmful emissions.
- **Diesel and ATF Replacement:** Methanol can be converted into dimethyl ether (DME), which is a clean-burning diesel substitute, or further processed into hydrocarbon fuels compatible with ATF specifications, supporting low-emission transportation sectors.

Beyond fuels, methanol is a versatile feedstock for the chemical and petrochemical industries:

- **Formaldehyde Production:** Methanol can be oxidized to formaldehyde, foundational to producing resins, adhesives, and plastics.
- **Olefin Synthesis:** Through Methanol-to-Olefins (MTO) processes, methanol provides ethylene and propylene, key building blocks for polyethylene and polypropylene polymers.
- **Acetic Acid and Other Derivatives:** Methanol serves as a reactant to produce acetic acid, methyl methacrylate, and other value-added chemicals, expanding its industrial relevance.

### Scalability and Industrial Integration:

The catalyst synthesis and methanol production process have been demonstrated at pilot scale (10 kg/day), with synthesis protocols successfully transferred to

commercial manufacturers. The modular nature of the fixed-bed reactor system and the mild operating conditions enable straightforward scale-up to industrial production volumes compatible with refinery integration or standalone chemical plants.

Methanol facilities can be co-located with existing emission sources (power plants, cement factories, refineries) to utilize captured CO<sub>2</sub> streams onsite, reducing transportation logistics and costs. This synergy facilitates circular carbon economy practices at scale across industrial hubs.

### Replicability Across Geographies and Feedstocks:

Access to carbon dioxide emissions and renewable hydrogen is critical; regions with dense industrial activity and expanding renewable energy capacity—such as power generation hubs, petrochemical clusters, or emerging clean energy zones—are prime candidates for adopting this technology. The catalyst's robustness toward variable feedstock gas compositions enhances applicability across locations with differing emission profiles.

### Economic and Environmental Viability:

Techno-economic and life cycle analyses indicate favorable cost structures and significant greenhouse gas emission reductions relative to fossil-based methanol or hydrocarbon fuels, supporting investment attractiveness for refineries and petrochemical producers seeking decarbonization pathways.

### Knowledge Transfer and Collaboration Models:

The initiative's collaborative framework involving R&D institutions, catalyst manufacturers, and plant operators serves as a replicable model to accelerate technology adoption. Standardized operating procedures, training regimes, and data management protocols enable smooth technology transfer and operational scaling across multiple industrial setups.



## KEY LEARNINGS

**Summarize the key learnings, including successes and challenges (max 300 words)**

The initiative to develop and deploy a highly selective catalyst for low-carbon methanol production from CO<sub>2</sub> provided valuable insights across technical development, scale-up, and operational integration stages.

### Successes:

- Achieved ~65% methanol selectivity and ~17% CO<sub>2</sub> conversion via iterative catalyst optimization.
- Demonstrated catalyst durability with stable long-term operation.
- Successful scale-up through collaboration with commercial manufacturers ensuring batch consistency.
- Strong interdisciplinary coordination enabling effective knowledge exchange and problem-solving.

### Challenges:

- Balancing methanol selectivity and suppressing side reactions required extensive fine-tuning.
- Maintaining catalyst nanostructure uniformity at scale demanded stringent quality control.
- Precise thermal management necessary under mild reactor conditions to avoid hotspots.
- Variability in renewable hydrogen purity and supply posed operational challenges.
- Ensuring methanol purity met fuel and chemical standards required comprehensive testing.
- Coordinating multiple stakeholders required structured communication and timeline management

## FUTURE PLANS

**Outline plans for further improvements or extensions of the initiative (max 200 words)**

Building on the successful development and pilot-scale deployment of the highly selective catalyst for low-carbon methanol production, the initiative aims to advance through the following key phases:

- Scale catalyst synthesis and methanol production from pilot (10 kg/day) to commercial multi-ton capacity.
- Optimize catalyst manufacturing workflows and reactor design for large-scale continuous operation.
- Strengthen integration with renewable hydrogen facilities for steady, high-purity feedstock.
- Implement advanced process intensification, automation, and real-time data analytics at pilot and commercial plants.
- Develop catalyst regeneration and recycling protocols to extend lifespan and reduce costs.
- Investigate catalyst performance with varied CO<sub>2</sub> sources and impurity profiles to enhance robustness.
- Explore downstream methanol conversion into value-added chemicals (e.g., olefins, formaldehyde).
- Engage industry, and academic partners for large-scale demos and regulatory support.
- Conduct extended life-cycle assessments and techno-economic analyses to validate environmental and economic benefits.





*Fixed bed twin reactor setup*



*Gas Analyzer Liquid Analyzer*



# Transforming Refinery Off-Gases into Valuable Hydrogen

Bharat Petroleum Corporation Ltd  
Dr. Chanchal Samanta  
Dy. General Manager – R&D

Circular Economy

BharatH<sub>2</sub>Sep is BPCL's asymmetric hollow-fiber membrane system that economically recovers hydrogen from low-pressure, impurity-rich refinery off-gases. Operating with <25 psig pressure drop and no recycle-gas compressor, the unit pilot-tested at Kochi's VGO-HDS achieved >95 mol % purity and 80–95% recovery at 100 kg/hr. A 1,000 kg/hr commercial study projects annual savings of ₹25 crore, payback < 3 months, and 10,000 t CO<sub>2</sub> cuts, advancing efficient H<sub>2</sub> reuse and India's net-zero goals.

## BACKGROUND & CONTEXT

Hydrogen (H<sub>2</sub>) plays a vital role in the global energy transition as a clean and versatile fuel. In petroleum refineries, H<sub>2</sub> recovery is strategically important due to: (a) high internal demand, (b) the need to reduce fresh hydrogen production by reusing residual streams, and (c) attractive return on investment (ROI), given hydrogen's high cost. However, recovery from off-gases remains challenging due to low H<sub>2</sub> concentrations, low pressures, and contaminants such as hydrocarbons, H<sub>2</sub>S, moisture, and amines.

Conventional technologies like Pressure Swing Adsorption (PSA) and Cryogenic Distillation (CD) are often unviable for these streams because of high capital and operational costs. Consequently, H<sub>2</sub>-rich off-gases are frequently diverted to fuel systems, resulting in resource loss.

This study introduces BharatH<sub>2</sub>Sep Technology, an advanced membrane-based solution designed for cost-effective hydrogen recovery. It employs asymmetric hollow fiber membranes with dual selective layers and ultra-thin walls, enabling high permeability



and selectivity—five times greater for H<sub>2</sub> over C<sub>1</sub>–C<sub>5</sub> hydrocarbons than conventional membranes. The system maintains a low pressure drop (<25 psig), supporting energy-efficient separation.

Pilot-scale validation (100 kg/hr) at the Vacuum Gas Oil Hydrodesulfurization (VGO-HDS) unit of BPCL Refinery demonstrated enhanced H<sub>2</sub> purity (from 65–85 mol% to >95 mol%) and recovery rates of 80–95%. A key advantage is the ability to operate within existing pressure conditions (feed: 2–35 barg; permeate: 1.10–30 barg), allowing direct integration with the refinery's H<sub>2</sub> header without the need for recycle gas compression (RGC), thus reducing both capital and operating costs.

A commercial-scale evaluation (1000 kg/hr) showed annual savings of INR 25 crore, <3 months payback, and a 10,000-ton CO<sub>2</sub> emission reduction. BharatH2Sep provides a scalable, efficient solution that supports refinery decarbonization and India's Net Zero targets.

## OBJETIVES

- Meet the target of hydrogen purity (>95 mol%) from refinery Off-gas (H<sub>2</sub> ~70-75 mol%) & reduce loss of valuable hydrogen gas from VGO HDS Plant
- Reduce the CO<sub>2</sub> emissions associated with hydrogen production
- Technology demonstration on real feed condition of refinery

## METHODOLOGY

### Technology Design & Development:

- Advanced asymmetric hollow fiber membranes with dual selective layers were designed to maximize H<sub>2</sub> selectivity and permeability while minimizing flow resistance and pressure drop (<25 psig).
- Membrane materials were selected

based on chemical compatibility, thermal stability, and performance against typical refinery off-gas contaminants (e.g., H<sub>2</sub>S, hydrocarbons, moisture).

### Laboratory Evaluation:

- Bench-scale tests were conducted to determine membrane performance under simulated refinery off-gas conditions.
- Selectivity towards H<sub>2</sub> over C<sub>1</sub>–C<sub>5</sub> hydrocarbons was found to be 5–10× higher than conventional commercial membranes (e.g., polysulfone, polyimide).

### Pilot-Scale Demonstration:

- A 100 kg/hr pilot plant was installed at the VGO-HDS unit of BPCL Refinery.
- Field trials evaluated H<sub>2</sub> purity, recovery efficiency, and system integration with refinery headers (feed: 2–35 barg; permeate: 1.1–30 barg).
- Operational data confirmed H<sub>2</sub> enrichment from 65–85 mol% to >95 mol%, with 80–95% recovery.

### Techno-Economic Analysis:

- A commercial-scale model (1000 kg/hr) was developed, incorporating equipment sizing, energy savings, and integration without recycle gas compression (RGC).
- Cost-benefit analysis showed annual savings of INR 25 crore, <3 months payback period, and CO<sub>2</sub> reduction up to 10,000 tons/year.

## CHALLENGES

During the planning and execution of the BharatH2Sep pilot plant trial at the VGO-HDS unit, several technical and operational challenges were encountered:

### Hydrocarbon Liquid Ingress into Membrane System



One of the most critical issues observed during early trials was the deterioration in membrane performance due to the carryover of hydrocarbon liquid along with the off-gas stream. The presence of liquid-phase hydrocarbons not only reduced membrane selectivity and permeability but also risked irreversible damage to the membrane structure.

- **Root Cause:** Insufficient vaporization of the off-gas stream under certain operating conditions led to partial condensation, allowing liquid hydrocarbons to enter the membrane skid.
- **Mitigation Strategy:** To address this, heat tracing and thermal insulation were implemented along the entire gas transfer line and membrane module housing. This ensured the off-gas stream remained fully in the vapor phase, eliminating the possibility of condensation and protecting membrane integrity during continuous operation.

### **Pressure Matching with Hydrogen Header Without Compression**

Integrating the membrane system directly with the refinery hydrogen header (operating at ~20 barg) without a recycle gas compressor posed a significant design constraint. The challenge was to optimize the membrane skid's performance within the narrow available pressure window (feed: 30–35 barg, permeate: 21–33 barg).

- **Mitigation Strategy:** The system was designed with low pressure drop membranes (<25 psig) and optimized flow configuration to utilize the available pressure differential effectively. This avoided the need for energy-intensive compression, preserving the project's economic viability.

### **Space and Utility Constraints at Site**

Implementing a pilot unit within the live

process environment of a refinery posed logistical challenges related to space, utilities, and tie-ins.

- **Mitigation Strategy:** The pilot plant was designed as a modular skid-mounted unit to minimize space requirements and facilitate quick on-site installation with minimal disruption to ongoing operations.

Overall, a cross-functional approach involving process engineering, operations, instrumentation, and site safety teams helped ensure that the challenges were systematically addressed, enabling successful demonstration and scale-up planning of the BharatH2Sep technology.

## **IMPLEMENTATION**

### **Timeline & Phases**

- **Conceptualization & Design (Q3–Q4 2023):**

The initial phase focused on the design of asymmetric hollow fiber membranes with dual selective layers and ultra-thin walls to enhance H<sub>2</sub> permeability and selectivity. Lab-scale membrane testing was conducted to assess performance with simulated off-gas compositions containing hydrocarbons, H<sub>2</sub>S, and moisture.

- **Pilot Plant Fabrication (Q1 2024):**  
Based on lab results, a 100 kg/hr pilot membrane skid was engineered and fabricated in partnership with a membrane technology vendor. The system included gas conditioning, membrane modules, instrumentation, and safety systems.
- **FAT & Site Preparation (Q2 2024):**  
Factory Acceptance Testing (FAT) was successfully completed with the participation of the MR technical team. Simultaneously,



space allocation, utility access, and tie-in planning were conducted at the VGO-HDS unit of BPCL Refinery.

- Installation & Commissioning (Q3 2024):

The pilot unit was installed as a modular skid with minimal interface to live systems. Pre-commissioning checks and leak tests were carried out before initiating field trials.

- Field Trial Execution (Q3–Q4 2024):

The pilot unit was operated continuously for 30+ days. Performance metrics such as H<sub>2</sub> purity, recovery efficiency, pressure drop, and system stability were monitored in real-time.

- Scale-Up Planning (Q1 2025 onward):

Based on pilot success, techno-economic evaluation and basic engineering for a 1000 kg/hr commercial unit were initiated.

### Stakeholders Involved

The success of BharatH<sub>2</sub>Sep was driven by active collaboration among multiple stakeholders:

- CRDC (R&D Team): Technology conceptualization, membrane development, and performance validation.
- BPCL-Kochi Refinery (Process Unit Owner): Site support, integration with VGO-HDS unit, and trial operation.
- E&C (Engineering & Construction): Design review, skid installation, and utility tie-ins.
- Instrumentation & Control Teams: Data logging, pressure/flow monitoring, and safety interlocks.
- Vendor Partner: Membrane fabrication, skid assembly, FAT support, and post-installation service.

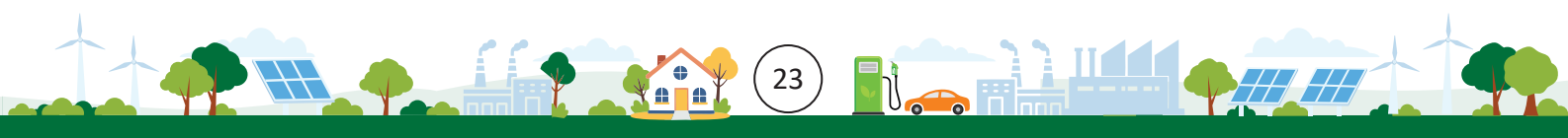
### Challenges Encountered & Mitigation

- Hydrocarbon Liquid Ingress: Initial trials showed performance loss due to liquid hydrocarbons entering the membrane. This was mitigated by installing heat tracing and ensuring complete vaporization of off-gas prior to membrane entry.
- Pressure Compatibility: Matching the system’s permeate pressure with the hydrogen header (20 barg) without using a compressor was a critical constraint. This was addressed through low-pressure-drop membrane design and optimal feed/permeate flow control.
- Site Constraints: Limited space and utility availability at the VGO-HDS unit required the unit to be skid-mounted and compact, enabling seamless integration with existing infrastructure.

Through structured execution, cross-functional collaboration, and innovative problem-solving, BharatH<sub>2</sub>Sep was successfully piloted and is now progressing toward commercial-scale deployment, supporting hydrogen efficiency and carbon reduction goals in refineries.

### INVESTMENTS

Cost Component	Amount (₹ in Lakhs)
Capital Expenditure	50 Lakhs
Operational Expenditure (annual)	Negligible
Human Resources	-
Technology Acquisition	Indigenous development
R&D and Innovation	25 Lakhs
Others (please specify)	05 Lakhs
<b>Total Investment</b>	<b>80 Lakhs</b>



## Quantitative Outcomes

Parameter	Before Neuron	After Neuron	Improvement (%)
GHG Emissions (tCO <sub>2e</sub> )	6,48,000 Kg of CO <sub>2</sub> emission	Reduced to 3,24,000 Kg of CO <sub>2</sub> emission	50% reduction from 100 Kg/hr of feed stream (30 wt% of H <sub>2</sub> ); Basis; 1 Kg of H <sub>2</sub> ~ emitted 10 Kg of CO <sub>2</sub> emissions (Production)
Waste Generation (tonnes)	720 Kg of H <sub>2</sub> /day using in Fuel gas network	360 Kg of H <sub>2</sub> /day recovered and utilised in process	50% improvement in hydrogen utilisation
Cost Savings (₹ in Lakhs)	1,44,000/- per day loss	72,000/- per day benefits by hydrogen recovery	50% improvement

## QUALITATIVE OUTCOMES

The implementation of the BharatH2Sep hydrogen recovery technology not only delivered strong technical and economic results but also led to several non-quantifiable, strategic, and organizational benefits that will have a lasting impact on future refinery operations and innovation culture.

- **Technology Demonstration and Confidence Building**

Successful piloting of an indigenous membrane technology at a live refinery site instilled confidence in adopting **Make-in-India solutions** for core process applications. It validated the potential of advanced membrane-based gas separation as a reliable alternative to capital-intensive conventional technologies like PSA and cryogenic distillation.

- **Cross-Functional Collaboration**

The initiative fostered seamless collaboration among R&D, refinery operations, process engineering, E&C, instrumentation, and vendor teams. This cross-disciplinary coordination enhanced team synergy and knowledge-sharing, setting a benchmark for future innovation-driven projects.

- **Operational Awareness and Process Integration**

Integration of the pilot unit into a running process unit deepened site teams' understanding of off-gas composition, handling challenges, and membrane operating principles, leading to improved awareness of system-level energy and material efficiency opportunities.

- **Sustainability and Policy Alignment**

The project reinforced the refinery's alignment with India's Net Zero goals, emphasizing carbon abatement and resource circularity. It also enhanced the organization's internal focus on energy transition and low-carbon pathways.

- **Platform for Future Scale-Up**

The initiative established a strong foundation for future deployment of modular hydrogen recovery systems across multiple refinery units, potentially leading to broader organizational transformation in hydrogen management practices.

Overall, BharatH2Sep delivered substantial qualitative value by demonstrating technological self-reliance, promoting sustainability awareness, and fostering a



collaborative, innovation-focused work culture.

## INNOVATION & UNIQUENESS

- Ideal gas selectivity of H<sub>2</sub> towards CH<sub>4</sub> is 5-6 times higher than commercially available membranes. This provides higher H<sub>2</sub> purity (>96 mol%) and recovery (>90 %) per membrane module.
- Least pressure drop of H<sub>2</sub> separation/enrichment- Eliminates the additional requirement of compressor. Hence, capital expenditure reduces by >60% and operating expenditure reduces by >90%.
- Robust polymeric membrane-handling different impurities of Off-gas (hydrocarbons, H<sub>2</sub>S, moisture, amines etc.). Life of membrane is > three years.

## SCALABILITY & REPLICABILITY

The BharatH<sub>2</sub>Sep technology has been designed with a clear focus on scalability and adaptability, making it highly suitable for deployment across a wide range of refinery units and similar industrial environments.

### Scalability

The pilot unit, demonstrated at 100 kg/hr capacity, has already been evaluated for commercial scale-up to 1000 kg/hr. The modular design of the membrane system allows it to be scaled linearly by adding parallel membrane banks, without significant changes to process control or utility requirements. The low pressure drop (<25 psig) and ability to operate within existing refinery pressure envelopes (feed: 2–35 barg; permeate: 1.1–30 barg) make it highly compatible with standard process units, eliminating the need for compression systems in many cases. This feature significantly reduces capital cost, enhancing viability at commercial scale.

## Replicability

The success of BharatH<sub>2</sub>Sep at BPCL's Kochi Refinery establishes a strong reference case for replication across:

- Other hydrogen-producing units such as hydrocrackers, reformers, and hydrotreaters within the same refinery
- Additional BPCL refineries (Mumbai, Bina)
- Other Indian and global refineries facing similar off-gas management challenges

The technology is feed-flexible and can handle a variety of off-gas compositions with hydrocarbons, H<sub>2</sub>S, and moisture, making it suitable for different process streams. The skid-mounted, plug-and-play configuration simplifies installation even in space-constrained brownfield environments.

Furthermore, the initiative aligns with national goals such as Make in India and Net Zero by 2070, and can contribute meaningfully to corporate ESG commitments by enabling resource recovery and emissions reduction.

In summary, BharatH<sub>2</sub>Sep offers a highly scalable and easily replicable solution for hydrogen recovery that can be deployed across multiple locations and industrial contexts with minimal customization.

## KEY LEARNINGS

The implementation of the **BharatH<sub>2</sub>Sep** hydrogen recovery initiative provided several critical insights- both from its technological successes and operational challenges—that can inform future deployments and similar innovation-led projects.

- **Proof of Indigenous Innovation:**

The project successfully demonstrated the performance of an indigenously developed membrane technology under real refinery conditions, validating its



effectiveness for hydrogen recovery from low-pressure, impurity-laden off-gas streams.

- **Operational Integration Without Compression:**

A major breakthrough was achieving direct integration with the hydrogen header without requiring a recycle gas compressor (RGC), thanks to the membrane's low pressure drop design. This significantly lowered both capital and operating costs.

- **Cross-Functional Collaboration:**

Strong coordination between R&D, refinery operations, E&C, instrumentation, and vendor teams was key to timely execution and performance optimization, establishing a collaborative model for future pilot-to-plant transitions.

- **Platform for Scale-Up:**

The successful pilot trial established confidence in the technical scalability and economic viability of the solution for larger capacities (e.g., 1000 kg/hr and beyond).

Overall, BharatH2Sep reaffirmed the importance of robust process understanding, adaptive engineering, and proactive problem-solving in translating lab-scale innovations to impactful field applications.

## FUTURE PLANS

Building on the successful pilot implementation of BharatH2Sep, the next phase focuses on commercial-scale deployment of a 1000 kg/hr membrane-based hydrogen recovery unit at the VGO-HDS plant. Detailed engineering and procurement are underway, with commissioning targeted within the next fiscal year.

Further improvements will focus on:

- Membrane durability enhancement through advanced material

formulations to extend operational life under varying off-gas compositions.

- Automation and real-time monitoring to optimize separation efficiency and enable predictive maintenance.
- Hybrid system development combining membrane separation with other technologies (e.g., PSA or catalytic purification) to broaden applicability across streams with lower H<sub>2</sub> concentrations.

Additionally, plans are in place to replicate the technology across other hydrogen-producing units such as hydrocrackers and reformers in BPCL's refineries at Mumbai and Bina. Collaborative discussions are also being initiated with other PSU refineries for wider adoption.

The initiative will be aligned with the organization's broader decarbonization roadmap and Net Zero commitments, contributing to energy efficiency, emissions reduction, and circular resource utilization.

In parallel, R&D efforts will continue to explore membrane-based solutions for CO<sub>2</sub> capture and other gas separations, extending the impact of the core technology platform.





## Biogas Plant for Kitchen

INDIAN GAS EXCHANGE LIMITED  
Shri Rajesh Mediratta  
MD & CEO

Circular Economy

IGX funded a 200-kg biogas plant at Srikakulam kitchen, Andhra Pradesh, converting organic food waste into biogas that replaces 10–12 kg LPG daily. The system cuts greenhouse emissions, lowers energy costs, and saves up to ₹2.89 lakh annually, funds redirected to bolster the school mid-day meal program, fusing sustainability with community welfare.

### BACKGROUND & CONTEXT

The Srikakulam community kitchen prepares thousands of nutritious meals daily for the Mid-Day Meal Programme. This large-scale operation generates substantial biodegradable waste — including vegetable peels, cooked food scraps, ganji water, used kitchen oil, and other organic matter.

Before this initiative, such waste was transported off-site for disposal, leading to additional logistical costs and contributing to environmental impact. Meanwhile, cooking operations relied almost entirely on LPG as the primary fuel source, resulting in high fuel expenses and increased greenhouse gas

emissions. These two challenges — waste management and heavy reliance on fossil fuel, highlighted a clear opportunity for intervention.

IGX was committed to combining environmental sustainability with social impact, identified the Srikakulam kitchen as an ideal site for a renewable biogas system due to its available space and high meal volumes. The solution is a biogas plant that converts organic waste into clean cooking fuel and directly replaces LPG consumption.

Based on Andhra Pradesh's prevailing LPG price of ₹104 per kg, replacing 10–12 kg of LPG daily with biogas would save ₹1,040–



₹1,248 each day. Over 230 operational days in a year, this translates into estimated savings of ₹2.41–₹2.89 lakh annually. These funds can be redirected towards enhancing kitchen efficiency or can be used to expand the other similar impact initiatives.

The project addresses two critical drivers for change:

- Environmental stewardship — reducing waste sent for disposal, lowering carbon emissions, and promoting renewable energy integration.
- Social responsibility — ensuring cost savings are reinvested into child nutrition and education, thus creating lasting community benefits.

## OBJECTIVES

### Environmental objectives:

- Replace 10–12 kg of LPG usage daily with biogas.
- Convert kitchen waste into a renewable, usable energy source.
- And thus, reduce greenhouse gas emissions from kitchen operations.

### Social objectives:

- Lower waste handling and transportation requirements.
- Generate annual cost savings to reinvest in similar programs.
- Demonstrate a scalable and replicable sustainability model for large-scale kitchens.

Promote environmental awareness and sustainable practices within the community.

## METHODOLOGY

IGX funded and supported the installation of a 200 kg/day biological methanation-based biogas system capable of processing multiple biodegradable feedstocks, including vegetable peels, cooked food waste, ganji

water, and organic wastewater. The system is designed for high biogas yield, odorless operation, minimal maintenance, and low power consumption.

## CHALLENGES

- Aligning procurement and installation of the biogas plant, training kitchen staff for optimal plant operation, and managing commissioning timelines (50–60 days for gas generation).

### Mitigation:

- Advance project planning, vendor pre-qualification, coordination through its operations team, dedicated training sessions for kitchen personnel, and close monitoring during the initial commissioning phase.
- IGX: ensuring Funding support.

## IMPLEMENTATION

### Project Timeline & Activity

- Dec 2024 – Jan 2025: Procurement process.
- Feb 2025: Delivery of biogas to Srikakulam kitchen.
- Mar 2025: Installation of biogas
- Post-Apr 2025: Commissioning and biogas generation

### Stakeholders:

- IGX: Funding support
- Akshaya Patra Foundation: Project monitoring and reporting, Site readiness, daily operations and management.

## INVESTMENTS

Cost Component	Amount (₹ in Lakhs)
Capital Expenditure	29.58 Lakh
Technology Acquisition	Included in Capex
<b>Total Investment</b>	<b>29.58 Lakh</b>



## QUANTITATIVE OUTCOMES

Before implementation (tCO<sub>2</sub>e/yr) :-

- Annual LPG displaced: 10–12 kg/day × 230 days = 2,300–2,760 kg/yr. (Project input.)
- A. LPG CO<sub>2</sub> avoided: 2,300–2,760 kg × 3.12585 / 1,000 = 7.19–8.63 tCO<sub>2</sub>/yr.
- Methane energy constant (India): NCV(CH<sub>4</sub>)=35.9 MJ/Nm<sup>3</sup> (BEE methodology)
- Biogas quality (MNRE): ~60% CH<sub>4</sub> (biogas is 55–65% CH<sub>4</sub>)
- Biogas NCV used: 0.60 × 35.9 = 21.54 MJ/Nm<sup>3</sup>.
- Biogas volume needed (energy equivalence): LPG energy / 21.54 = (2,300–2,760 kg × 49.538 MJ/kg) / 21.54 = 5,289.57–6,347.49 Nm<sup>3</sup>/yr. (MoEFCC LPG CV as above)
- CH<sub>4</sub> captured (mass): Biogas × 60%

$$\times \rho_{\text{CH}_4@STP} \approx 0.7168 \text{ kg/Nm}^3 = 2.27\text{--}2.73 \text{ t CH}_4/\text{yr}$$

- GWP<sub>100</sub> for CH<sub>4</sub> (India, CCTS/AR6 default): 29.8 tCO<sub>2</sub>e/t CH<sub>4</sub>
- B. Methane avoidance: 2.27–2.73 t CH<sub>4</sub> × 29.8 = 67.6–81.2 tCO<sub>2</sub>e/yr.
- Total GHG reduction (A + B): 74.8–89.8 tCO<sub>2</sub>e/yr.

After-implementation(tCO<sub>2</sub>e/yr):-

- Captured CH<sub>4</sub> = 2.27–2.73 t/yr (from above)
- Residual emissions reflect methane slip = CH<sub>4</sub>\_mass × slip% × 29.8  
s = methane slip fraction (%)  
= CH<sub>4</sub>\_mass(t/yr) × s × GWP<sub>100</sub>(CH<sub>4</sub>)  
= CH<sub>4</sub>\_mass × s × 29.8  
Plant leakage @ ~5%
- Low = 2.27 × 0.05 × 29.8 = 3.39 tCO<sub>2</sub>e/yr
- High = 2.73 × 0.05 × 29.8 = 4.07 tCO<sub>2</sub>e/yr

Parameter	Before Implementation	After Implementation	Improvement (%)
GHG Emissions (tCO <sub>2</sub> e)	~74.8–89.8	99.99%	84.21%
Waste Generation (tonnes)	Higher (biodegradable waste disposed off-site)	46 t/yr diverted to biogas generation (200 kg/day × 230 days ÷ 1000)	On-site utilization of biodegradable waste
Slurry Management	NA (slurry not generated under LPG cooking)	Slurry generated as byproduct of biogas process reused as manure/fertilizer for crops grown locally; these crops are used in the kitchen for cooking	-
Operational Efficiency	Fuel price exposure;	Captive renewable fuel;	-
Cost Savings (₹ in Lakhs)	0	2.41 –2.89	-

## INNOVATION & UNIQUENESS

- Dual-impact approach: environmental gains + community welfare.
- Ability to handle diverse organic waste streams for maximum energy recovery.

## SCALABILITY & REPLICABILITY

The Srikakulam Biogas initiative serves as a replicable model for large-scale community kitchens, with the following enablers:

- Biological methanation is a mature, reliable process that can be deployed in diverse geographies.
- The plant can operate on various organic wastes, making it adaptable to different kitchen waste profiles.
- Tangible cost savings, GHG emission reductions, and waste diversion make the case compelling.

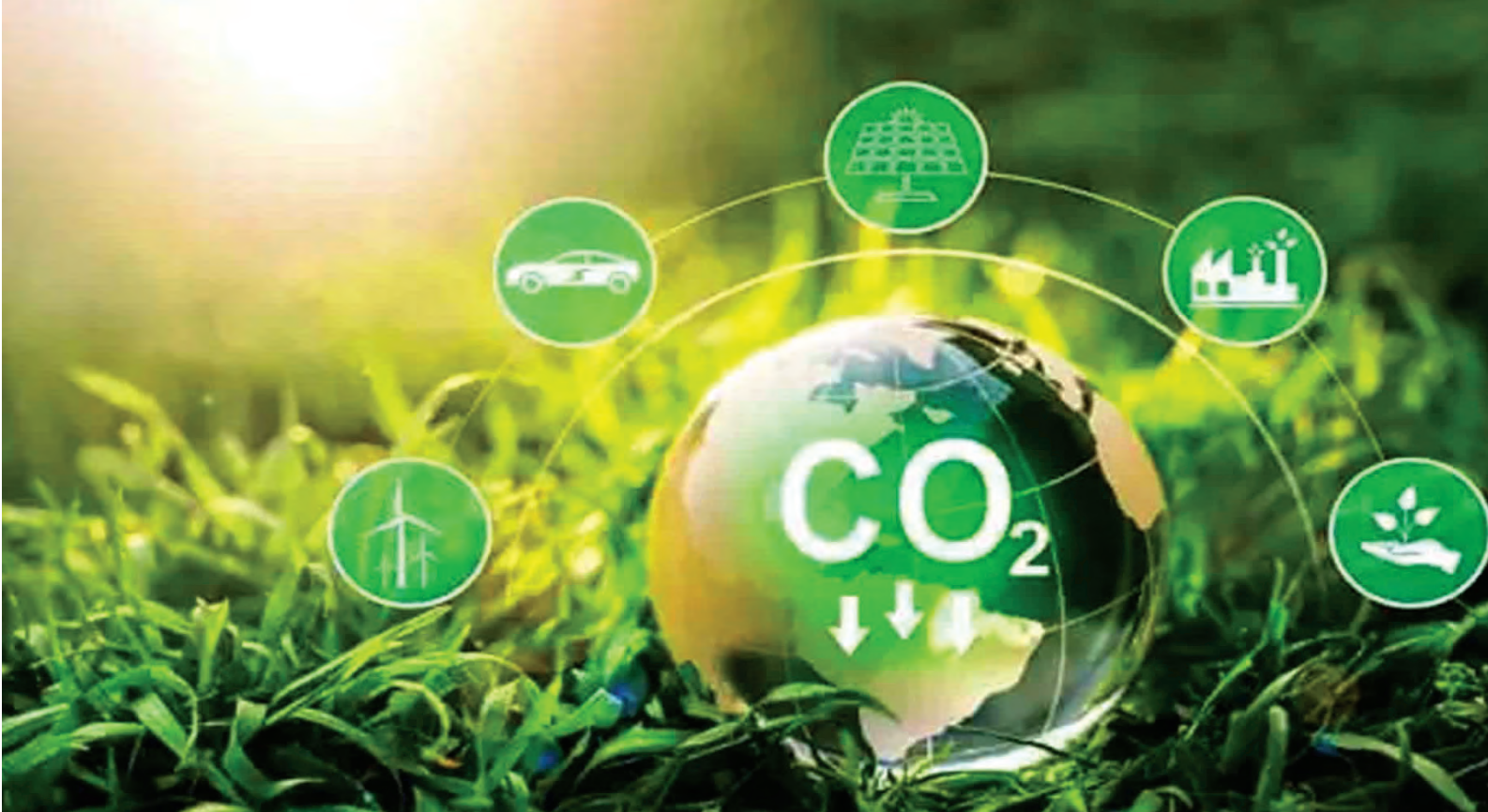
## KEY LEARNINGS

- Projects that address environmental challenges while delivering direct community benefits generate stronger stakeholder engagement and long-term value.
- Demonstrating measurable savings combined with environmental benefits makes the project a success and strengthens the case for scaling up initiatives in other kitchens.

## FUTURE PLANS

IGX is dedicated to promoting sustainable practices that have a positive impact on both society and the environment. This initiative is a significant step towards achieving these goals, as we work to introduce innovative and eco-friendly solutions. By transitioning to biogas-powered kitchens, the community will be able to cook nutritious meals for millions of children while actively contributing to the fight against climate change. This project reflects social responsibility and sustainability, creating a long-lasting impact on both the environment and the communities we serve.





# CO<sub>2</sub> Capture using Novel Solvent and CO<sub>2</sub> Conversion to Formic Acid

Bharat Petroleum Corporation Ltd  
Dr. Chanchal Samanta  
Dy. General Manager-R&D

Circular Economy

The project presents an innovative integrated carbon capture and utilization (ICCU) process that employs heat-stable amine solvents to capture CO<sub>2</sub> and uses novel air-stable, water-soluble iridium catalysts featuring proton-responsive ligands to directly hydrogenate the captured CO<sub>2</sub> to formic acid. This single-step approach operates under mild conditions (around 50°C, 40 bar H<sub>2</sub>), achieving high turnover numbers (TON >20000) and excellent selectivity (>97%), while eliminating energy-intensive CO<sub>2</sub> desorption and compression steps. The process offers a sustainable, low-carbon alternative to conventional fossil-based formic acid production with reduced cost and environmental impact.

## BACKGROUND & CONTEXT

Situation Before the Initiative: Challenges and Drivers for Change

Prior to the development of integrated carbon capture and utilization (ICCU) using novel amine-based solvents and iridium-catalysed hydrogenation, the production of formic acid was predominantly based on traditional chemical processes, especially the two-stage BASF route involving carbonylation of

methanol with carbon monoxide, followed by hydrolysis to formic acid. This method required highly pure carbon monoxide (CO, >99.5%), entailed significant safety and infrastructure costs relating to the handling, storage, and compression of toxic CO gas, and contributed to carbon emissions due to reliance on fossil-derived feedstocks

Efforts to directly convert CO<sub>2</sub>—a potent greenhouse gas—into valuable chemicals



like formic acid faced several significant technical and economic challenges:

- The intrinsic thermodynamic and kinetic stability of CO<sub>2</sub> made direct hydrogenation into formic acid or formate salts exceedingly challenging, often resulting in low conversions and efficiencies even when advanced catalysts were used.
- Earlier attempts using both homogeneous and heterogeneous catalysts struggled with stability, selectivity, and practical catalyst recycling. Many catalysts were air- and moisture-sensitive, demanding stringent handling, and often exhibited limited turnover numbers (TONs) and product selectivity
- Conventional carbon capture and utilization approaches required separate stages for CO<sub>2</sub> absorption (with amines) and desorption, followed by compression and use in downstream hydrogenation processes. This multi-step pathway increased both capital and operational expenditures due to extra energy input, utility requirements, and complex system design.
- Environmental Drivers: Increasing industrial demand for formic acid (CAGR >4% projected to 2035), coupled with global commitments to carbon neutrality and lower greenhouse gas emissions, created significant incentive to replace fossil-derived processes with sustainable, circular carbon utilization technologies

These hurdles drove the search for integrated processes that could combine efficient CO<sub>2</sub> capture using novel amine-based solvents directly with one-pot catalytic hydrogenation to formic acid, using

robust, high-performance catalysts able to operate under practical conditions, thereby minimizing process complexity, energy input, and total carbon footprint

## OBJECTIVES

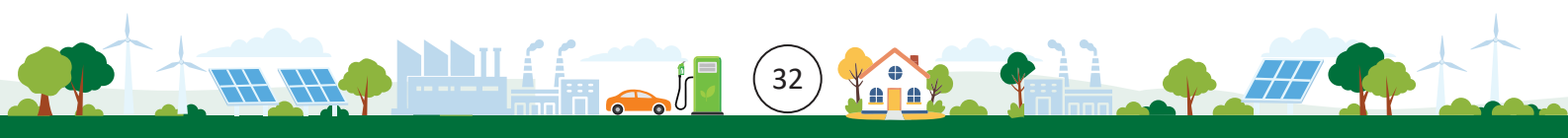
- Develop an Integrated CO<sub>2</sub> Capture and Conversion Process
- Design and Synthesize Novel Iridium Catalysts
- Achieve High Catalytic Performance
- Optimize Process Parameters
- Produce a Sustainable Alternative to Conventional Routes
- Demonstrate Practical Feasibility and Scalability

These objectives collectively aim to advance low-carbon chemical manufacturing by combining novel solvent chemistry with innovative catalyst design to efficiently convert captured CO<sub>2</sub> into valuable formic acid.

## METHODOLOGY

The project aims to develop an integrated, sustainable process for converting captured CO<sub>2</sub> directly into formic acid, thereby circumventing the conventional multi-step approach of two-stage BASF route involving carbonylation of methanol with carbon monoxide to form methyl formate, followed by hydrolysis of methyl formate to formic acid. However, the current approach utilizes CO<sub>2</sub> as C1 source to produce formic acid and thus provides a sustainable solution. Specifically, our approach combines:

- **Novel amine solvents for CO<sub>2</sub> Capture:** Use of heat-stable aqueous novel amine solvents to absorb CO<sub>2</sub> efficiently at moderate conditions. Moreover, the amine solvent was carefully optimized to reduce the corrosion of the equipment. The developed amine based system



demonstrated significantly reduced corrosion when compared to the commercial amine (MEA) used for CO<sub>2</sub> capture.

- **Integrated Utilization:** Direct hydrogenation of the amine-captured CO<sub>2</sub> to formic acid in situ using a water-soluble, air-stable iridium catalyst. The iridium catalyst developed remarkable air and moisture stability, operability under mild temperature (around 50 °C), and pressures (up to 40 bar pressure of H<sub>2</sub>). Moreover, the Ir based catalyst demonstrates high turnover numbers (TONs >20,000) in the hydrogenation of amine-captured CO<sub>2</sub> to formate.
- **Continuous stirred tank reactor (CSTR)** systems are employed to enable simultaneous capture of CO<sub>2</sub> in the amine solution and its catalytic hydrogenation. This combined system improves efficiency by avoiding extra stages such as solvent regeneration, CO<sub>2</sub> gas purification, and storage.

Thus, this integrated process eliminates energy-intensive regeneration steps and additional CO<sub>2</sub> handling, simplifying the overall process and reducing costs and carbon footprint.

Moreover, this integrated process represents an innovative route towards carbon-neutral chemical manufacturing, leveraging:

- State-of-the-art catalyst design to overcome CO<sub>2</sub> activation challenges.
- Synergistic integration of CO<sub>2</sub> capture and hydrogenation in a single step.
- Resource-efficient operating conditions and stable catalyst systems.

- Potential for scalable industrial application with simplified plant operability and reduced environmental impact

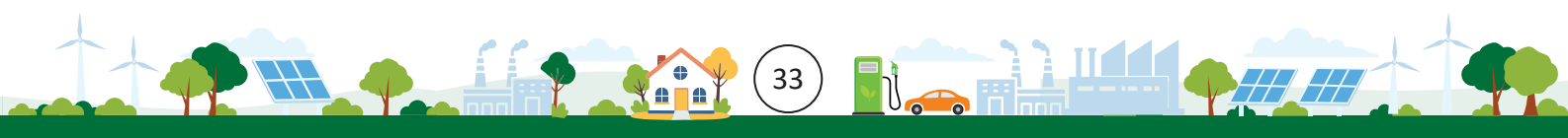
Therefore, this approach effectively addresses key barriers in carbon capture and utilization and showcases a promising alternative to fossil-based formic acid production routes reliant on toxic and expensive carbon monoxide feedstocks

## CHALLENGES

The key bottleneck is the Thermodynamic and Kinetic Stability of CO<sub>2</sub>. CO<sub>2</sub> is a highly stable molecule thermodynamically and kinetically, making its direct hydrogenation to formic acid challenging. Activation and conversion of chemically bound CO<sub>2</sub> from novel amine-based solvents required catalysts capable of overcoming these energy barriers efficiently.

However, this challenge was addressed by the design and synthesis of novel iridium-based catalysts with proton-responsive ligand which increased the electron density at the metal centers, significantly enhancing catalytic activity. The synergistic ligand design allowed for easier CO<sub>2</sub> activation, enabling hydrogenation under mild conditions (around 50 °C, 40 bar pressure), thereby effectively addressing the kinetic and thermodynamic challenges.

The second concern was on the catalyst stability and selectivity. Many previous catalysts for CO<sub>2</sub> hydrogenation suffered from low air and moisture stability, catalyst degradation, poor selectivity, and difficulty in recycling under aqueous conditions. This project synthesized air-stable and water-soluble iridium complexes using specially designed ligands that provided strong electron donation and stability in aqueous media. These catalysts showed excellent longevity and remarkable selectivity (>97%) for formic acid production, thus overcoming typical catalyst stability concerns.



The third concern was on the development of Integrated Process Design Complexity. Traditional CO<sub>2</sub> utilization processes require multiple sequential steps including CO<sub>2</sub> absorption into amines, desorption via energy-intensive regeneration, gas compression, and downstream conversion steps. This multistage setup increases energy consumption, operational complexity, and capital expenditure.

This project developed a continuous stirred tank reactor (CSTR) based integrated approach combining CO<sub>2</sub> capture and hydrogenation in a single vessel. By using heat-stable amine solution, the captured CO<sub>2</sub> was directly converted to formic acid without the need for desorption or compression steps, simplifying the process and reducing cost and plant footprint considerably.

Lastly, industrial adoption requires the process to outperform or at least match existing technologies in terms of cost, complexity, and environmental footprint. By eliminating desorption, gas compression, and the use of hazardous pure CO gas, this integrated process reduces energy consumption and safety hazards. The use of durable catalysts tolerant to air and moisture, moderate reaction conditions, and commercially available amines made the technology promising for industrial scale-up with lower overall carbon footprint.

## IMPLEMENTATION

The initiative successfully progressed from conceptualization and catalyst design through to process integration and validation within approximately 30 months (early 2023 to mid-2025), driven primarily by the BPCL R&D team with multidisciplinary support. Key challenges related to catalyst stability, process complexity, and reaction optimization were methodically overcome through innovative ligand design and integrated reactor strategy, culminating in a promising low-carbon footprint process for sustainable formic acid production from captured CO<sub>2</sub>.

The outcomes, including catalyst design, process integration, and performance, were published in peer-reviewed journals and resulted in patent applications (Indian Patent Application Number 202411082853-Solvent composition for developing efficient carbon capture technology, Indian Patent Application No. 202311063234 - Method of carbon dioxide hydrogenation to formic acid production through integrated carbon dioxide capture and conversion and Indian Patent Application No. 202311057923 - A method of direct hydrogenation of carbon dioxide for formic acid using iridium catalysts) to protect intellectual property.

## INVESTMENTS

Cost Component	Amount (₹ in Lakhs)
Capital Expenditure	45 (CSTR reactor)
Operational Expenditure (annual)	25 (cost of chemicals, H <sub>2</sub> and CO <sub>2</sub> )
Human Resources	30
Total Investment	100

## QUALITATIVE OUTCOMES

### Advancement of Sustainable Chemistry:

The initiative significantly contributes to the field circular economy by providing a novel method to convert a greenhouse gas (CO<sub>2</sub>) directly into a useful low-carbon chemical (formic acid) in an integrated manner. This approach exemplifies circular carbon utilization, supporting global carbon neutrality goals and fostering environmentally responsible manufacturing.

### Innovative Catalyst Design and Understanding:

Development of air-stable, water-soluble iridium catalysts with proton-responsive imidazoline–amide ligands advances fundamental knowledge in catalyst design, especially in stabilizing catalysts under aqueous, air-exposed conditions. This fundamental insight enriches the catalysis community's toolset for CO<sub>2</sub> activation and has broader implications beyond formic acid synthesis.



**Simplification and Integration of Process Steps:** By merging CO<sub>2</sub> capture and conversion in a single reactor without the need for energy- and cost-intensive CO<sub>2</sub> desorption and compression steps, the project introduces a conceptual innovation in process integration. This simplification reduces operational complexity, enhances process safety by avoiding handling of toxic CO gas or pressurized CO<sub>2</sub> streams, and sets a precedent for future integrated carbon capture and utilization technologies.

**Industrial Compatibility and Scalability Potential:** The use of commercially viable heat-stable amine solvents and milder reaction conditions with robust catalysts underline the practical feasibility of this technology. Although quantitative scale-up data is not detailed, the initiative builds confidence for industrial stakeholders about adaptability, encouraging further investments and fostering collaboration between industry and academia. Enhanced Safety and **Reduced Environmental Risks:** Replacing hazardous carbon monoxide-based processes with a CO<sub>2</sub>-based route inherently improves workplace safety and reduces environmental hazards. The method also mitigates risks associated with solvent regeneration emissions and CO<sub>2</sub> transportation. Creation of Intellectual Property and Scientific Knowledge: The initiative has generated valuable intellectual property (patent filings) and peer-reviewed scientific publications, enhancing institutional reputation and positioning the organization as a pioneer in advanced carbon capture and utilization research.

## INNOVATION & UNIQUENESS

### **Integrated CO<sub>2</sub> Capture and Utilization (ICCU) Process:**

The project pioneers a one-pot integrated process that merges CO<sub>2</sub> capture in heat-stable aqueous amine solvents directly with catalytic hydrogenation to formic acid. This integration eliminates the need for

conventional energy-intensive steps such as solvent regeneration (CO<sub>2</sub> desorption), gas compression, and CO storage, significantly simplifying the process and reducing both operational costs and carbon footprint.

### **Novel Air-Stable, Water-Soluble Iridium Catalysts:**

The use of iridium complexes bearing proton-responsive imidazoline–amide ligands is a key innovation. These ligands increase electron density around the metal center through deprotonation, enhancing catalytic activity and selectivity. The catalysts exhibit exceptional air and moisture stability, operate efficiently under mild conditions (around 50 °C and 40 bar), and deliver record-high turnover numbers (TON>23,000 in integrated capture-conversion), which surpass many existing catalytic systems.

### **Use of Heat-Stable Amines (e.g., Triethylamine) at Commercial Concentrations:**

Employing commercially viable, heat-stable amine solvents such as triethylamine at practical molarities (1–2 M) for CO<sub>2</sub> capture ensures industrial relevance while facilitating direct conversion of captured CO<sub>2</sub> without regeneration steps. Triethylamine notably forms zwitterionic adducts with CO<sub>2</sub> that enhance solubility and catalyst compatibility

### **Sustainable Alternative to Conventional CO-Based Processes:**

By utilizing CO<sub>2</sub> instead of toxic, high-purity CO gas as feedstock, the process reduces safety risks and environmental hazards while aligning with circular carbon economy goals.

## SCALABILITY & REPLICABILITY

The work on integrated carbon capture and utilization (ICCU) for formic acid production demonstrates strong potential for scale-up and replication across various locations and contexts due to several factors:

- **Use of Commercially Viable Materials:** The process employs heat-stable amine based solvents at



industrially relevant concentrations (1–2 M), which are commercially available and widely used in existing gas treatment facilities, facilitating ease of adoption.

- **Robust and Air-Stable Catalysts:** The iridium catalysts featuring proton-responsive ligands are highly stable in aqueous, air-exposed environments and operate efficiently under moderate conditions (about 50 °C and 40 bar pressure). This robustness simplifies catalyst handling and reduces operational challenges at larger scale.
- **Energy and Cost Efficiency:** Eliminating energy-intensive and costly steps like solvent regeneration, CO<sub>2</sub> desorption, and gas compression leads to lower operational expenses, favouring economic viability during scale-up.
- **Applicability to Diverse CO<sub>2</sub> Sources:** The technology can be integrated with existing CO<sub>2</sub>-emitting processes (e.g., flue gases), making it adaptable to various industrial environments and geographical contexts. The initiative's use of commercially relevant materials, robust catalysts, simplified integrated process design, and compatibility with existing industrial infrastructures position it well for scalable and replicable deployment in diverse global contexts seeking sustainable CO<sub>2</sub> utilization pathways.

## KEY LEARNINGS

- **Development of Highly Active and Stable Iridium Catalysts:**

The project successfully synthesized air-stable, water-soluble iridium complexes with proton-responsive ligands. The catalyst demonstrated

exceptional catalytic performance, achieving record-high turnover numbers of TONs >20,000 in integrated CO<sub>2</sub> capture and conversion systems. This level of activity and stability under mild conditions (50 °C, 40 bar pressure) surpasses many existing catalysts in the field.

- **Integrated CO<sub>2</sub> Capture and Conversion Process:**

By combining CO<sub>2</sub> absorption using heat-stable amine solvent directly with catalytic hydrogenation in a continuous stirred tank reactor, the process avoids energy- and cost-intensive CO<sub>2</sub> desorption, compression, and storage steps. This integration simplifies plant design, reduces operational footprint, and enhances overall process economics.

- **High Selectivity and Product Concentration:**

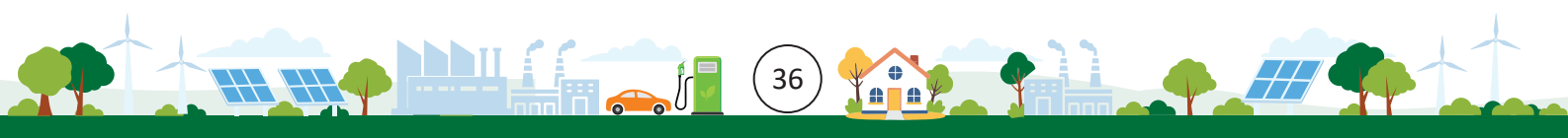
The method achieves excellent formic acid selectivity (>97%) with product concentrations exceeding 0.5 M, sufficient for practical downstream applications and potential scale-up.

- **Process Feasibility under Commercial Conditions:**

The use of commercially viable amine concentrations (1 M), moderate temperature and pressure, and air-stable catalysts confirms the industrial applicability and readiness for scale-up.

- **Scale-Up and Industrial Adaptation:**

While lab-scale demonstration is promising, translating to industrial scale involves challenges related to continuous operation stability, catalyst recycling, and solvent management that warrant further study.



## FUTURE PLANS

### Continuous Process Development and Scale-Up:

Advancing reactor design and operation strategies, particularly optimizing continuous stirred tank reactor (CSTR) conditions for long-term stable operation, catalyst recycling, and solvent regeneration within the integrated system to enable industrial-scale implementation

### Integration with Renewable Hydrogen Sources:

Coupling the ICCU process with green hydrogen generation technologies for truly sustainable and carbon-neutral formic acid production

### Techno-Economic and Life Cycle Assessment:

Conducting detailed economic and environmental impact analyses to identify optimization opportunities and establish commercial viability





# **Emission Reduction**



# Environmental and Fuel Efficiency Enhancement through Dual-Fuel DEG Retrofit

GAIL (India) Limited  
Shri Yedukondalu Midasala  
Chief Manager

Emission Reduction

Implementation of Dual-Fuel Kit on Emergency Diesel Generator to Reduce Diesel Use, Optimizing Emergency Power Backup, Enhanced Fuel Efficiency and Emission Reduction at GAIL Jhabua.

## BACKGROUND & CONTEXT

At GAIL Jhabua Compressor Station, the Diesel Engine Generator (DEG) used for emergency power backup traditionally runs solely on diesel. To optimize fuel consumption and reduce environmental impact, a dual-fuel kit has been installed on the DEG, enabling it to operate on a blend of 60% natural gas and 40% diesel. This modification significantly lowers diesel consumption while simultaneously reducing emissions associated with diesel combustion, contributing to cleaner and more sustainable operations.

The GAIL Jhabua Compressor Station plays

a critical role in maintaining uninterrupted natural gas transmission operations. Ensuring reliable emergency power backup is essential for safeguarding compressor operations, safety systems, and essential services during grid outages. For this purpose, a Diesel Engine Generator (DEG) is installed at the station, operating exclusively on high-speed diesel (HSD).

However, diesel fuel is not only expensive but also contributes significantly to environmental pollution through emissions of carbon dioxide (CO<sub>2</sub>), nitrogen oxides (NO<sub>x</sub>), sulfur oxides (SO<sub>x</sub>), and particulate matter. In line with GAIL's commitment to sustainability, energy efficiency, and



reduction of greenhouse gas emissions, the station identified an opportunity to reduce its dependency on diesel by exploring alternative, cleaner fuel options.

Natural gas, which is already handled at the compressor station, offers a cleaner-burning alternative with lower emissions. By retrofitting the existing DEG with a dual-fuel kit, the system can now operate on a blend of approximately 60% natural gas and 40% diesel. This innovative approach enables substantial diesel savings while ensuring reliable emergency power generation.

The project aligns with GAIL's broader vision of adopting environmentally responsible practices and enhancing operational efficiency through energy optimization measures.

## OBJECTIVES

**Reduction in Diesel Consumption:** To minimize dependency on high-speed diesel (HSD) by enabling the Diesel Engine Generator (DEG) to operate on a dual-fuel mode using approximately 60% natural gas and 40% diesel.

- **Emission Reduction and Environmental Sustainability:** To significantly reduce harmful emissions such as CO<sub>2</sub>, NO<sub>x</sub>, SO<sub>x</sub>, and particulate matter by replacing a major portion of diesel with cleaner-burning natural gas.
- **Operational Cost Optimization:** To lower overall fuel costs associated with emergency power generation by utilizing natural gas, which is more economical and abundantly available at the compressor station.
- **Enhancing Energy Efficiency:** To improve the overall energy efficiency of emergency power generation systems through hybrid fuel utilization.
- **Leveraging Existing Resources:**

To effectively utilize the in-house availability of natural gas at the compressor station, thereby reducing the logistics and storage burden related to diesel handling.

- **Demonstration of Replicable Innovation:** To develop a successful case study that can be replicated across other GAIL locations or similar industrial setups for greener and more economical power backup solutions.
- **Alignment with Sustainability Goals:** To contribute to GAIL's corporate sustainability goals, including energy conservation, operational excellence, and carbon footprint reduction.

## APPROACH & IMPLEMENTATION METHODOLOGY:

- **Feasibility Assessment and Technical Evaluation:** Conducted a detailed feasibility study to assess the compatibility of the existing Diesel Engine Generator (DEG) with dual-fuel technology. Evaluated fuel injection patterns, engine load profiles, and safety parameters. Engaged OEM recommendations and third-party expert consultations for technical validation.
- **Selection of Dual-Fuel Kit and Vendor Finalization:** Identified suitable dual-fuel conversion kits that enable seamless mixing of natural gas with diesel. Selected a reliable vendor with prior experience in industrial-grade dual-fuel conversions. Ensured the kit complied with safety standards (PESO, OISD guidelines) and engine performance requirements.
- **Design & Engineering Customization:** Customized the fuel control system to regulate



the appropriate gas-to-diesel ratio (targeted at 60:40). Designed necessary piping modifications, control valves, and flame arrestors for safe gas injection. Integrated sensors and monitoring instruments to ensure real-time performance tracking.

- **Installation and Integration:** Isolated the DEG during a planned maintenance window to avoid operational disruption. Installed the dual-fuel kit components including gas train, mixers, and control panels. Ensured proper insulation, leak testing, and electrical interlocks for safety compliance.
- **Trial Runs and Performance Optimization:** Conducted initial test runs at varying loads to calibrate the fuel mixture and engine performance. Monitored parameters such as fuel consumption, emissions, engine temperature, and combustion stability. Fine-tuned the system to achieve optimal efficiency and emission targets.
- **Safety Checks and Risk Mitigation:** Carried out Hazard and Operability Analysis (HAZOP) and safety audits before commissioning. Trained the operating staff for dual-fuel system handling, emergency shutdown, and fire protection protocols. Incorporated gas leak detectors and auto-cutoff systems for enhanced operational safety.
- **Monitoring & Documentation:** Developed a system for continuous monitoring of diesel vs. gas usage and emission data. Maintained performance logs to analyse fuel savings and engine health over time. Documented the entire process for internal learning and external benchmarking.

## CHALLENGES:

- **Technical Compatibility with Existing DEG:**

**Bottleneck:** Existing diesel generator was not originally designed for dual-fuel operation.

**Mitigation Strategy Adopted:** A detailed compatibility study was undertaken with OEM consultation. Dual-fuel kits with proven adaptability to similar engine types were selected.

- **Combustion Stability and Load Variability:**

**Bottleneck:** Maintaining efficient combustion and power output while operating with variable gas-diesel ratios.

**Mitigation Strategy Adopted:** Real-time tuning of the control system was done during trial runs. The fuel mixing system was calibrated for load adaptability, ensuring consistent performance at different load conditions.

- **Safety Risks due to Gas Injection:**

**Bottleneck:** Injection of natural gas in an engine system designed for diesel posed fire and explosion risks.

**Mitigation Strategy Adopted:** Gas leak detection systems, flame arrestors, and emergency shutdown interlocks were integrated. Safety audits and mock drills were conducted as part of commissioning.

- **Limited Expertise and Manpower:**

**Bottleneck:** Station personnel had limited experience with dual-fuel systems.

**Mitigation Strategy Adopted:** Hands-on training sessions were arranged by the vendor. Standard operating procedures and emergency protocols were developed and disseminated.



## IMPLEMENTATION SCHEDULES:

Phase	Timeline	Activities
Phase 1: Feasibility Study	Month 1	Compatibility check, stakeholder discussions, cost-benefit analysis
Phase 2: Kit Finalization	Month 2	Vendor selection, technical specifications, procurement process
Phase 3: Engineering Design	Month 3	Gas train layout, control system design, safety compliance
Phase 4: Installation & Testing	Month 4–5	Physical installation, trial runs, calibration, troubleshooting
Phase 5: Safety Training & SOPs	Month 5	Operator training, emergency SOP preparation, HAZOP analysis
Phase 6: Commissioning	Month 6	Final performance validation, monitoring system setup, documentation

## INVESTMENTS

Cost Component	Amount (₹ in Lakhs)
Capital Expenditure	27 lakhs
Total Investment	27 lakhs

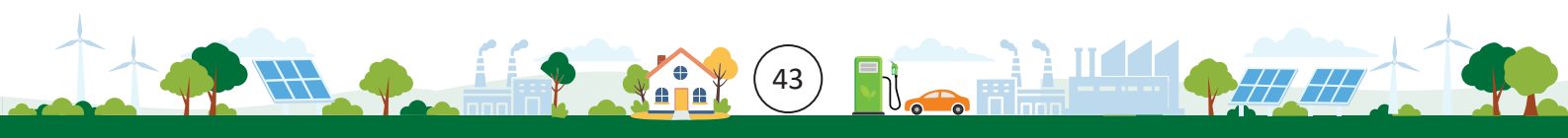
## QUANTITATIVE OUTCOMES

Parameter	Before Implementation	After Implementation	Improvement (%)
GHG Emissions (tCO <sub>2</sub> e) Reduction of diesel 6000litre per year	20	0	100%
Operational Efficiency Improvement <b>Before:</b> 100% diesel operation <b>After:</b> Approx. 40% diesel, 60% natural gas <b>Diesel Saved:</b> ~60% per hour of generator operation. Assuming 200 hours/year operation <b>Fuel Saved:</b> ~6,000 liters/year	6000	0	100%
Cost of Energy Saved (₹ in Lakhs) diesel saved 60million kcal of diesel at 10000kcal GCV	5.23	0	100%

## QUALITATIVE OUTCOMES

- Environmental Stewardship and Green Image:** Demonstrated GAIL's proactive approach toward

sustainable operations and environmental responsibility. Improved the station's green credentials by reducing reliance on



fossil fuels and lowering pollution levels. Enhanced compliance with internal ESG (Environmental, Social, and Governance) targets.

- **Improved Energy Awareness among Staff:** Fostered a culture of energy consciousness within the station. Field personnel and operators gained hands-on exposure to cleaner fuel technologies and efficient practices.
- **Enhanced Safety and Risk Management:** Implementation of advanced safety systems (leak detection, flame arrestors, shutdown logic) elevated the safety standard of emergency power operations. Conducting HAZOP and emergency response training increased preparedness among staff.
- **Technological Upgradation of Legacy Equipment:** Transformed conventional diesel-only infrastructure into a smart, fuel-flexible, and efficient system. Showcased the viability of modernizing legacy systems through retrofit rather than replacement.
- **Operational Flexibility:** Provided the ability to switch between full diesel and dual-fuel modes depending on availability, load, or emergency conditions. Reduced dependence on diesel procurement during fuel supply disruptions.
- **Inter-Departmental Collaboration and Learning:** Involved cross-functional collaboration between operations, maintenance, instrumentation, and safety departments. Strengthened internal coordination and shared learning on technical project execution.
- **Institutional Learning for Future Projects:** Created a replicable framework, documentation, and

case study for similar projects at other locations. Encouraged management support for future energy efficiency and decarbonization projects.

## INNOVATION & UNIQUENESS OF THE PROJECT:

- **First-of-its-Kind at GAIL Jhabua:** This project marks the first successful implementation of a dual-fuel Diesel Engine Generator (DEG) system at GAIL Jhabua, pioneering a new approach to cleaner emergency power generation within the GAIL network.
- **Utilization of In-House Natural Gas:** The project innovatively leverages the in-house availability of natural gas from the compressor station for power generation, reducing reliance on external diesel supply and associated logistics.
- **Plug-and-Play Dual-Fuel Integration:** Instead of investing in new gas generators, a cost-effective retrofit solution was adopted by installing a plug-and-play dual-fuel kit. This preserved existing infrastructure while enhancing performance.
- **Smart Fuel Ratio Management:** The dual-fuel system is equipped with real-time fuel mix control, allowing dynamic adjustment of the gas-diesel ratio based on load demand and combustion efficiency, ensuring engine safety and optimized performance.
- **Alignment with Net-Zero & ESG Goals:** The initiative aligns with GAIL's broader sustainability roadmap, especially in reducing carbon footprint and improving ESG (Environmental, Social, Governance) performance, setting an example for other units.



## SCALABILITY & REPLICABILITY

**Scalability:** The dual-fuel concept is highly scalable across other GAIL installations where emergency diesel generators are in use. Applicable for various capacities of DEGs ranging from small backup units to large standby power systems.

**Replicability:** Standardized retrofit procedure and modular design of the kit enable easy replication at other compressor stations, terminals, or pipelines. Minimal civil or structural modifications are required, making replication fast and economical.

**Potential Beneficiaries:** Other GAIL sites with diesel generators, PSU oil & gas companies (ONGC, IOCL, BPCL, etc.), Industrial facilities with captive power setups.

## KEY LEARNINGS & CONCLUSION

### LEARNINGS:

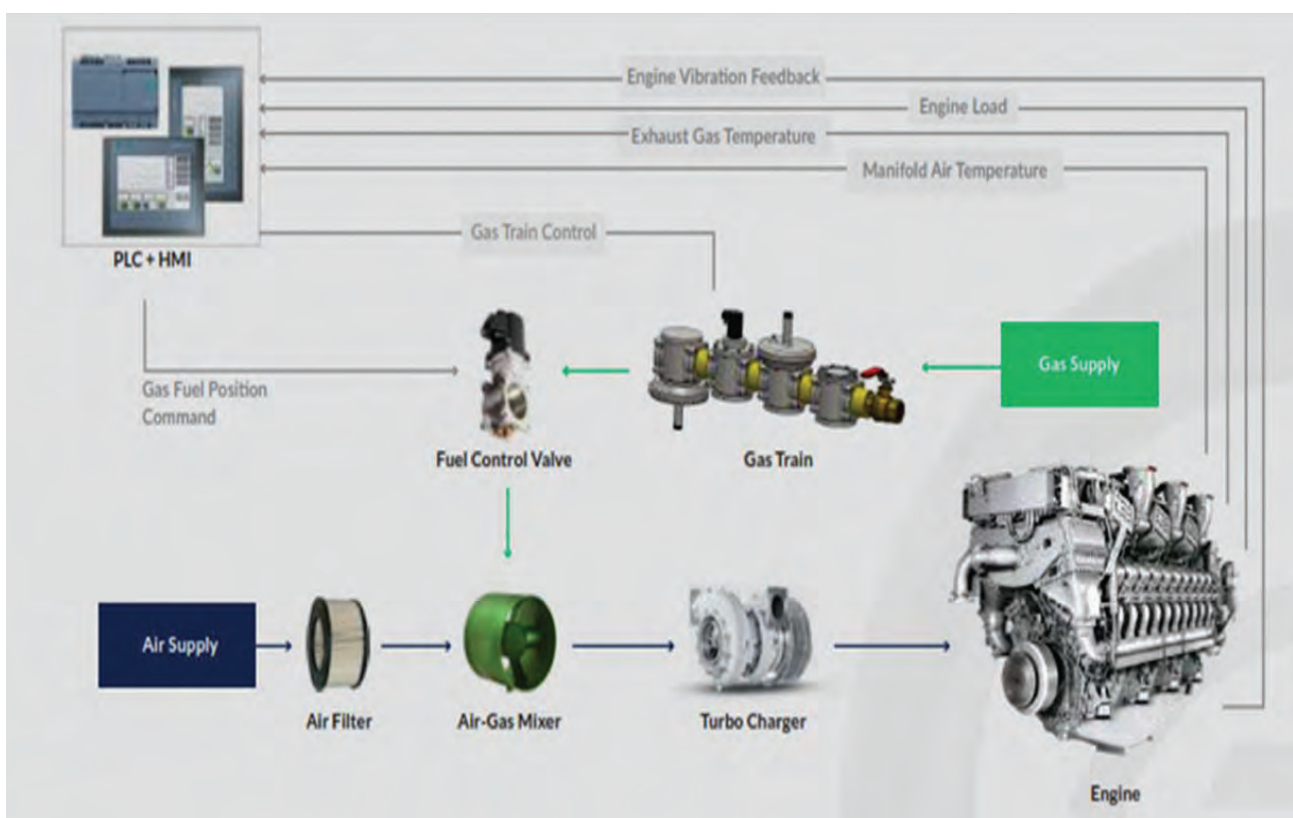
- **Engine Compatibility is Critical:** Not all diesel engines can be easily converted; a thorough pre-assessment is essential.
- **Operator Training Drives Success:**

Seamless operation post-installation requires hands-on training and robust SOPs for operators and maintenance staff.

- **Gas Quality and Supply Pressure Matter:** Consistent quality and regulated pressure of natural gas are essential to ensure stable dual-fuel operation.
- **Retrofitting is Cost-Effective but Technically Sensitive:** Dual-fuel retrofitting is economically viable, but demands meticulous attention to design, safety, and control logic.
- **Monitoring Systems are Essential:** Real-time data logging and fuel consumption monitoring are vital for tracking savings and system health.

### CONCLUSION

The dual-fuel conversion of the Diesel Engine Generator at GAIL Jhabua has proven to be a practical, innovative, and environmentally responsible solution for emergency power needs. It has resulted in significant



diesel savings, emission reductions, and operational cost benefits. This project exemplifies how legacy systems can be modernized sustainably through smart engineering interventions, contributing meaningfully to GAIL's energy optimization and decarbonization journey.

## FUTURE PLANS

Opened doors to replicable innovation across other compressor stations facing similar challenges.

### IMPACT ASSESSMENT : BEFORE VS AFTER IMPLEMENTATION

Parameter	Before Implementation	After Implementation
<b>DEG Fuel Type</b>	100% Diesel	60% Natural Gas + 40% Diesel (approx.)
<b>Annual Diesel Consumption</b>	10,000 litres/year	4,000 litres/year
<b>CO<sub>2</sub> Emissions (tons/year)</b>	26 tons	11 tons, 15 tons/year Reduction
<b>Particulate Matter</b>	High	Significantly Lower
<b>NO<sub>x</sub>, SO<sub>x</sub></b>	Higher	Lower due to gas substitution
<b>Generator Reliability</b>	High	Maintained
<b>Combustion Efficiency</b>	Diesel only	Improved (cleaner gas combustion)
<b>Fuel Flexibility</b>	No	Yes (dual-mode capability)





# AI/ML-Driven Flare Monitoring and Root Cause Identification to Reduce F&L

Mangalore Refinery and Petrochemicals Ltd.  
Shri Haradi Ashok Anand  
Chief General Manager (Process Engg.)

Emission Reduction

Industrial flaring causes significant emissions, energy waste, and operational losses. While flare flow meters quantify total gas volumes at the header or unit level, they cannot pinpoint which equipment triggers each event, and installing acoustic sensors at every connection is prohibitively expensive. This solution combines existing process historian data with advanced AI/ML models to isolate and diagnose the root causes of each flare episode in real time, enabling targeted maintenance, reduced emissions, and improved efficiency without investing in additional field hardware.

## BACKGROUND & CONTEXT

Flaring is a critical challenge in industrial operations, contributing to environmental emissions, energy losses, and operational inefficiencies. Flare flow meters help in quantifying flaring at the header or unit level, providing valuable data for monitoring overall flare volumes. However, they are limited in their ability to identify the root cause of flaring within a unit. Acoustic sensors, often used to detect leaks from pressure safety valves (PSVs) or other systems connected to the flare, can provide

additional insights but are costly to install across all flare connections.

This innovative approach eliminates the need for extensive additional hardware by leveraging existing process data and AI/ML technologies. The algorithm analyzes real-time process parameters to detect anomalies and pinpoint the root cause of flaring events. By utilizing available data, this solution reduces unaccounted flaring, minimizes emissions, and supports organizations in achieving their net-zero goals, all while



avoiding the high costs associated with widespread sensor installations.

## OBJECTIVES

To address the following key challenges:

- **Quantification vs. Root Cause Identification:** While flare flow meters quantify flaring at the header or unit level, they cannot identify the specific source or root cause of flaring within a unit.
- **High Costs of additional Sensors:** Acoustic wireless sensors, commonly used to detect leaks from PSVs or other systems connected to the flare, are expensive to install across all flare connections, for comprehensive monitoring.
- **Environmental and Economic Impact:** Unaccounted flaring leads to increased emissions, operational inefficiencies, and financial losses, hindering progress toward net-zero goals.
- **Delayed Corrective Actions:** Without real-time root cause identification, flaring events often persist longer than necessary, increasing emissions and energy losses.

## METHODOLOGY

- An AI/ML-based application has been developed in-house for real-time flare monitoring and root cause identification. The solution leverages advanced AI/ML technologies to address the challenges of real-time flare monitoring.
- Various Machine Learning techniques and models are employed to analyze process data and identify the root causes of flaring events. Statistical methods for time-series analysis are integrated to detect deviations in process parameters, enabling accurate identification of flaring

events and their contributing factors.

- The solution has been integrated with a dashboard, providing automated alerts and actionable recommendations.

## CHALLENGES

- Data availability and handling on real time.
- Eliminate spurious correlations or noise in data.

## IMPLEMENTATION

- The in-house initiative was implemented across all three flares corresponding to the three phases of the MRPL refinery complex. Activities began in January 2025 and were completed in July 2025 through a phased rollout.
- Implementation was executed by the in-house team. The application is monitored by the Encon team, Process Engineers, and the Plant Operations team.
- Key considerations during implementation included ensuring the availability of all relevant sensor data and managing high-volume, real-time data. The application employs advanced techniques and hybrid ML algorithms to eliminate spurious correlations and improve the accuracy of identifying real contributors to flaring.

## INVESTMENTS

Cost Component	Amount (₹ in Lakhs)
Human Resources	-(In house team of 5 members.)
Technology Acquisition	-In house developed
R&D and Innovation	-In house R&D/ Innovation team
Total Investment	No investment as it is 100% in-house developed.



## QUANTITATIVE OUTCOMES

Provide measurable results achieved through the initiative

Parameter	Before Implementation	After Implementation	Improvement (%)
Cost Savings (₹ in Lakhs)	Cost savings of ₹10–15 crore were realized by opting out of wireless sensor installation.		

## QUALITATIVE OUTCOMES

- The solution provides actionable insights into flaring events and their root causes in real-time.
- Enables immediate identification and eliminate unwanted flaring.
- Enables identification of passing valves/PSVs which otherwise were contributing to unaccounted flaring.

## INNOVATION & UNIQUENESS

This is a first-of-its-kind solution that identifies contributors to flaring using AI/ML without any additional hardware. No comparable commercial solution is available in the market.

Conventional practice relies on installing wireless acoustic sensors to detect leaks in valves and PSVs. Due to high investment cost, these are typically deployed only on selected connections, making comprehensive coverage impractical. Manual checks across all locations are also difficult and cannot be performed regularly. In contrast, the developed solution uses existing process data to pinpoint contributors to flaring in real time, enabling immediate visibility across all connected loops without incremental instrumentation.

The application employs advanced techniques and hybrid ML algorithms to eliminate spurious correlations and improve the accuracy of identifying true contributors to flare. This combination of hardware-free deployment, real-time root cause identification, and data-driven

precision constitutes the core innovation and differentiator of the initiative

## SCALABILITY & REPLICABILITY

The solution is software-driven, leverages existing process data, and requires no additional hardware, making it inherently scalable. It has already been implemented across three flares in a phased manner, demonstrating that the same approach can be extended to additional flares or units using the established methodology.

## KEY LEARNINGS

Key learnings from this initiative include that while flare flow meters quantify overall flaring, they lack root cause identification, and costly acoustic sensors are not feasible for comprehensive coverage across all units. This highlights the need for a hardware-free solution leveraging existing process data and AI/ML for real-time root cause identification, which is crucial for prompt corrective actions and reducing unwanted flare emissions. Successful implementation depends on ensuring real-time data availability and effectively eliminating spurious correlations.

Preliminary results demonstrate its transformative potential in reducing unaccounted flaring, minimizing emissions, and improving operational efficiency. By leveraging existing process data, the solution eliminates the need for additional costly sensors, making it both efficient and cost-effective. It provides actionable insights into flaring events and their root causes, enabling

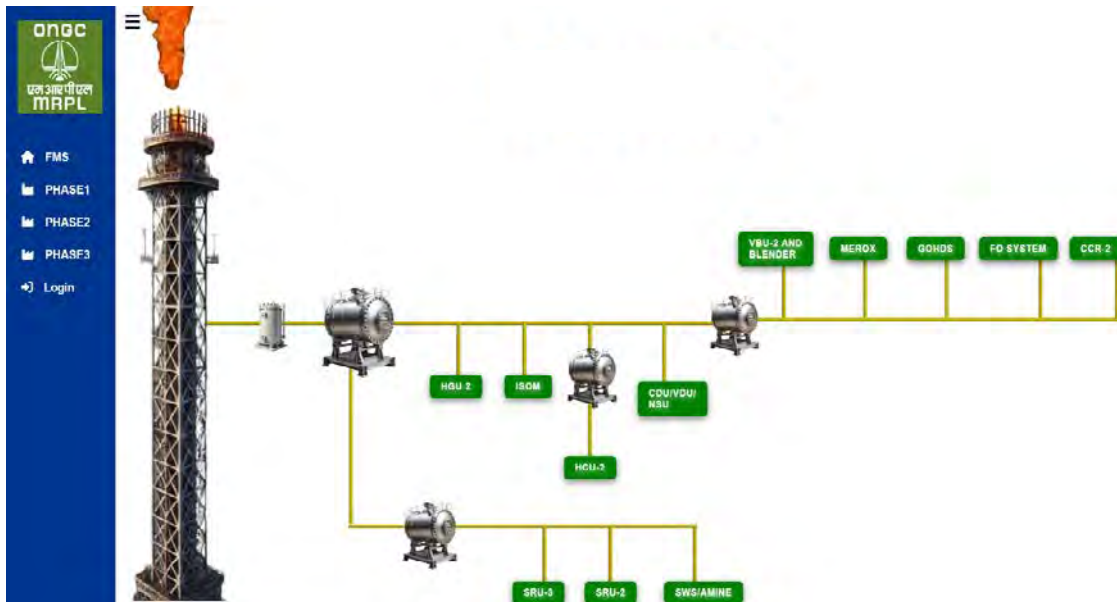


faster corrective actions and improved decision-making. This solution demonstrates the power of AI/ML in driving sustainable industrial practices, offering a scalable and impactful approach to addressing flaring challenges.

### FUTURE PLANS

Video-based analytics for quantifying flaring from camera footage is in the advanced stage

of deployment. Phase-3 flare of MRPL, which has both flare flow meters and a camera, will be used to train and validate the model against metered data. Following successful testing, the model will be deployed to other flares without flow meters to enable quantification of total flaring alongside the existing identification of contributors.



Flare monitoring dashboard-1



Flare monitoring dashboard-2





# 100 TPD Cattle Dung Based Compressed Biogas (CBG) Plant

Indian Oil Corporation Limited  
Shri Nitin Verma, SM  
Shri Sumit Dabas, Manager

Emission Reduction

A 100 TPD cattle dung based CBG plant has been successfully commissioned at Adarsh Gaushala, Gwalior, Madhya Pradesh under IndianOil's CSR initiative. The plant processes cattle dung and organic waste to produce clean CBG, along with byproducts like solid and liquid organic manure, contributing significantly to waste management, renewable energy integration, circular economy and environmental sustainability.

## BACKGROUND & CONTEXT

Prior to the project, Gwalior Municipal Corporation (GMC) faced major challenges in the disposal of cattle dung and organic waste, leading to unhygienic conditions and environmental degradation. Recognizing this need, IndianOil, under its CSR initiative, partnered with Gwalior Municipal Corporation to set up a biogas plant that would convert waste into Compressed Biogas. The project aligns with national missions such as Swachh Bharat, Waste to Wealth, GOBARdhan and Clean Energy,

aiming to create a replicable urban waste to energy model.

## OBJECTIVES

Environmentally sustainable practices:

- To reduce greenhouse gas emission
- Reduction of CH<sub>4</sub> emission for which is a major contributor to GHG gases
- To facilitate waste reduction / reuse / recycling to build a circular economy, and ensure waste



disposal in an environmentally safe manner

- To pursue clean energy options including renewable energy and other low carbon solutions.

## METHODOLOGY

The project was developed using IndianOil's in-house technology and followed an execution model where the detailed design and engineering were carried out based on the basic design and engineering prepared by IndianOil's R&D team. Based on the same the Project was executed in conventional mode with separate Civil, Mechanical/Process and Electrical packages. The plant has been constructed across 5 acres at Adarsh Gaushala, with cattle dung and organic waste collected and sourced by Gwalior Municipal Corporation. A mesophilic anaerobic digestion process is being used in the digester. Post digestion, biogas is purified using water scrubber technology by removing the impurities i.e. CO<sub>2</sub> and H<sub>2</sub>S. The purified gas is compressed and stored in cascades, with provision for direct vehicle refuelling. A dedicated dispensing station has also been set up adjacent to the Plant.

## CHALLENGES

The project encountered difficult soil conditions due to the site being a reclaimed pond. Additional challenges included water seepage, mobility problems in marshy soil, and delayed statutory approvals. These were mitigated through suitable design, dewatering systems, and careful planning.

## IMPLEMENTATION

The project was initiated in April 2023 and inaugurated by Hon'ble Prime Minister on 02.10.2024. IndianOil was responsible for design, funding, and execution. GMC arranged for land, feedstock, and utilities. Stakeholders included design consultants, contractors, and Gaushala management.

## INVESTMENTS

Cost Component	Amount (₹ in Crore)
Capital Expenditure	31 Crore
Operational Expenditure (annual)	2.99 Crore

## QUANTITATIVE OUTCOMES

Parameter	Before Implementation	After Implementation	Improvement (%)
GHG Emissions (tCO <sub>2</sub> e)	Not Tracked	Reduced Significantly	1.65 MMT/Year
Energy Consumption	-	Renewable Energy Generation	-
Water Consumption (KL)	High (Freshwater Use)	Reduced (Recycled Use)	>70%
Waste Generation	High	Utilized	>90%
Operational Efficiency	-	Achieved	High
Cost Savings (₹ Lakhs)	-	-	-

## QUALITATIVE OUTCOMES

- Improved hygiene and waste management at Adarsh Gaushala.
- Reduction in air and water pollution in surrounding areas.
- Job creation for plant operations and maintenance.
- Availability of clean transport fuel and organic fertilizer.
- Demonstrated city-waste to city-transport model.

## INNOVATION & UNIQUENESS

- Use of water scrubber technology for low methane slip.
- Fully SCADA-integrated control and monitoring system.
- 100% standby systems for uninterrupted operation.
- Unloading pits having large capacity for more than 1 day storage and thereby resulting in settlement of the silt at the bottom.



## SCALABILITY & REPLICABILITY

The Gwalior model provides a technically viable, cost-effective template. It can be replicated by other ULBs to process cattle dung/organic waste and generate renewable energy. The project also supports India's goals under the National Bio-Energy Mission.

## KEY LEARNINGS

- Recycled water use reduces resource stress and emissions.
- Plant layout planning is key to operational efficiency.

- Timely stakeholder engagement supports smoother approvals.

## FUTURE PLANS

- Scale-up to rated capacity by increasing the feedstock input.
- Optimization of FOM production, enrichment and marketing.
- Replication of this model in other cities with similar waste streams.





# Pilot Demonstration of Super Absorbent Polymer Production

**Bharat Petroleum Corporation Limited**  
**Shri Satheesh Kumar K P**  
**Chief General Manager I/C (Projects)**

**Emission Reduction**

BPCL Kochi Refinery has developed India's first indigenous Super Absorbent Polymer (SAP) technology, converting refinery hydrocarbons into high-value, hygiene-grade SAP. A 20 kg / h pilot plant commissioned in January 2022 produced SAP that met diaper-maker trials. With no external benchmark, BPCL designed the entire process—PFD, P&ID, equipment selection, and commissioning—in-house, showcasing technical prowess and paving the way for commercial production and import substitution.

## BACKGROUND & CONTEXT

Development of Super Absorbent Polymer (SAP) Technology at BPCL Kochi Refinery

BPCL Kochi Refinery has access to petroleum hydrocarbons, which are traditionally sold in the market to meet the energy demands of consumers. Recognizing the potential for value

addition, BPCL explored the conversion of these hydrocarbons into Super Absorbent Polymer (SAP)—a high-demand product with significant market value, especially in the hygiene industry where it is used as an absorbent medium in items such as diapers and sanitary products.

To advance this initiative, BPCL successfully developed indigenous SAP production technology. A pilot plant with a capacity of 20 kg/hr was commissioned at Kochi Refinery in January 2022. The SAP produced from this unit was offered to local diaper manufacturers for trial use, and the results were encouraging, with successful performance at the vendor's site.

The execution of this project posed several challenges, primarily due to the absence of any prior reference or benchmark. Despite this, BPCL undertook the complete design and engineering of the unit in-house. The Process Flow Diagram (PFD) and Piping



& Instrumentation Diagram (P&ID) were prepared and finalized internally by BPCL's technical team. Equipment selection, procurement, and commissioning were carried out with meticulous planning and innovation.

This achievement marks a significant milestone in BPCL's efforts toward product diversification and value creation from refinery streams. The successful development and demonstration of SAP technology not only showcases BPCL's technical capabilities but also opens up new avenues for commercial production and market expansion in the hygiene product sector.

## OBJECTIVES

- To check the feasibility of producing SAP from BPCL KR.
- To gain sufficient knowledge for setting up of Commercial plant
- To access customer feedback of our SAP product
- To scale up SAP production based on BPCL -in house technology
- To License SAP production technology
- To improve design based on practical knowledge gained through Pilot plant running

## METHODOLOGY

### Approach and Strategy

BPCL Kochi Refinery adopted a strategic approach to enhance value from petroleum hydrocarbons by converting them into high-value specialty products. Recognizing the growing demand for Super Absorbent Polymer (SAP) in the hygiene industry, BPCL initiated an in-house R&D effort to develop indigenous technology for SAP production. The project was aimed at product diversification, innovation, and tapping into new market segments.

### Technology Development

The SAP technology was developed entirely in-house by BPCL. This included the formulation of the polymer chemistry, process design, and operational parameters required for consistent and high-quality SAP production. The technology was tailored to utilize refinery-grade hydrocarbons as feedstock, ensuring compatibility with existing resources and infrastructure.

### Pilot Plant Setup

A pilot plant with a capacity of 20 kg/hr was commissioned at Kochi Refinery in January 2022. The plant served as a proof-of-concept for the developed technology and enabled real-time testing and validation. The Process Flow Diagram (PFD) and Piping & Instrumentation Diagram (P&ID) were designed and finalized internally, showcasing BPCL's engineering capabilities. Equipment selection was done based on process requirements, with a focus on scalability, safety, and performance.

### Processes Involved

The SAP production process involved multiple stages including:

- Polymerization of hydrocarbon-based monomers.
- Cross-linking to achieve the desired absorbency and gel strength.
- Drying and granulation to produce SAP in usable form.
- Quality testing to ensure product performance meets industry standards.

Each process step was optimized for throughput, consistency, and product quality. The pilot plant was equipped with instrumentation for real-time monitoring and control.

### Resources Utilized

The project leveraged BPCL's internal resources including:

- R&D expertise in polymer chemistry and process engineering.



- Engineering design teams for plant layout and equipment integration.
- Operational staff for operation and trial runs.
- Local vendor collaboration for product trials and feedback.

The SAP produced was offered to local diaper manufacturers for trial applications. The trials were successful, validating the product’s performance and market potential.

## CHALLENGES

One of the key challenges was the absence of prior reference or benchmark for such a conversion process. BPCL overcame this by relying on internal innovation, rigorous testing, and iterative design improvements. The successful commissioning of the pilot plant without external technical support highlights BPCL’s capability in developing and executing complex chemical processes.

Secondly, it was identified that certain impurities in feed affect the polymerization process kinetics by destroying the free radical catalysts and are thus detrimental towards the SAP quality and process performance. Thus, to understand the extent of quality improvement with purified feed, it was decided to perform trials using purified feed. There are no manufacturers of purified feed in India. Thus, for this trial, feed was procured from the market and further purified at vendor site to remove impurities at a desired level. During trials, various critical process parameters such as neutralization percentage, drying temperature and time etc. were adjusted. This was required, as the feed quality was changed, which had affected the polymerization kinetics. It was observed that with polymerization was much more stable and consistent compared to previously observed polymerization. Upon detailed analysis, it was found that SAP produced from purified feed exhibited superior on properties Centrifugal Retention Capacity (CRC), Residual Monomer (RM) and gel strength Absorption Under Load (AUL),

which are critical for SAP performance.

## IMPLEMENTATION

BPCL Kochi Refinery Project team executed the SAP pilot plant Project. Availability of equipment was the challenge for the capacity of pilot plant.

## INVESTMENTS

Cost Component	Amount (₹ in Lakhs)
Capital Expenditure	1000 Lakhs
Operational Expenditure (annual)	-
Human Resources	BPCL 1 and Contractor 3
Technology Acquisition	BPCL owned technology
R&D and Innovation	BPCL owned technology
Others (please specify)	-
Total Investment	1000 Lakhs

## QUALITATIVE OUTCOMES

Production of SAP in KR will help in developing new ancillary industries thereby creating new Job opportunities and overall economic development of area. Indigenous production will help bring down cost of hygiene products and reduce India’s import bill substantially. This project is the initiative towards Atmanirbhar Bharat.

## INNOVATION & UNIQUENESS

This process is independently developed by BPCL, and pilot plant is also set up.

## SCALABILITY & REPLICABILITY

SAP is currently being almost fully imported in India. SAP market stood at INR 2.14 billion in 2019, expected to increase to 6 billion INR by 2030.



Usage of SAP for adult diapers is expected to drastically increase in Kerala as by end of decade 20.9% of Kerala's population will be aged above 60 years. Usage of SAP is expected to increase substantially in female hygiene product as in our country, only 36% of its 355 million menstruating females are using napkins (remaining use old cloth, rags, husk or ash.).

An independent agency, M/s Mordor Intelligence Pvt Ltd, has carried out market study of SAP. SAP market is set for robust growth in year between 2024-2035 at an average CAGR of more than 6.1%. Solution is to have indigenous production of Hygiene Grade SAP, which will develop new ancillary Industries in Kerala.

## KEY LEARNINGS

- **Indigenous Technology Development**  
BPCL successfully developed SAP production technology in-house, showcasing strong R&D and engineering capabilities without relying on external technical support.
- **Pilot Plant Commissioning**  
A 20 kg/hr pilot plant was commissioned at Kochi Refinery in January 2022. The plant was designed, engineered, and executed internally, including preparation of PFD and P&ID.
- **Successful Product Trials**  
The SAP produced was tested by local diaper manufacturers, and the trials were successful, validating product quality and market readiness.
- **Value Addition from Refinery Streams**  
The project demonstrated how petroleum hydrocarbons can be converted into high-value specialty products, opening new avenues for

revenue and diversification.

- **Cross-functional Collaboration**

The project involved seamless coordination between R&D, engineering, operations, and vendor engagement, reflecting strong internal collaboration.

## CHALLENGES

- **Lack of Prior Reference**

The absence of existing benchmarks or reference designs made the project technically demanding, requiring innovative problem-solving and iterative design.

- **Equipment Selection and Integration**

Choosing and integrating suitable equipment for a novel process was complex, especially without established standards or vendor experience.

- **Process Optimization**

Achieving consistent product quality and process stability required multiple trials and refinements, especially in polymerization and drying stages.

- **Market Validation**

Engaging with vendors for product trials and feedback was critical but required persistent effort to ensure acceptance and performance validation.

## FUTURE PLANS

BPCL is working on design 20 KTPA SAP plant which would be first commercial plant based on in-house technology.





# Making LNG Reach Isolated LPG Cylinder Consumers by using Centralized LNG Cylinders.

AGP City Gas Pvt. Ltd. (THINK Gas)  
Shri Abhilesh Gupta  
MD & CEO

Emission Reduction

THINK Gas piloted LNG delivery to remote Bhopal customers by supplying fuel in 200-L vacuum-insulated cylinders. By replacing LPG, they cut emissions, improved energy efficiency, and lowered consumer costs, proving isolated users can be served economically without conventional pipeline infrastructure.

## BACKGROUND & CONTEXT

In the Bhopal region, several consumers are situated in locations where extending the PNG network is neither viable nor economical. These consumers are wholly dependent on LPG. In the view of that, THINK Gas started supplying LNG to these customers via small, portable cylinders. As, one LNG cylinder meets approximately the same daily fuel demand as five standard LPG cylinders. Switching to LNG will lead to reduced emissions, lower operating costs, and decreased fuel transportation frequency. However, regulatory frameworks do not yet support this model. THINK Gas was granted permission to execute the project only

as a pilot, and the activity was paused upon completion.

## OBJECTIVES

The overall objective of this pilot is described below.

- To make LNG reach small consumers located in far flung areas without access to natural gas infrastructure.
- Reduction of emissions
- Portability and flexibility
- Support energy transition
- Reliable supply model
- Cost Savings





**1No of MICROCYL Replaces 5 Nos. of 14.2 Kg. LPG Cylinders**

## METHODOLOGY

**Approach & Technologies:** For the pilot project, THINK Gas arranged 5 PESO-approved LNG cylinders, each with a capacity of 200 water liters and special insulation to keep the gas cold. These cylinders were filled with LNG at the company's Bagroda station using a pressure-based method. After filling it, they were taken to the consumer's location using a truck with a crane. To measure how much LNG was inside, we checked the weight before and after filling it. Since adding a smell (odorant) to LNG wasn't possible, we used remote gas detectors at the site for safety.

**Process:** The Pilot Project was planned to be carried out as per the following steps:

**Step 1: Testing of cylinders at Bagroda for determining the holding period (Zero withdrawal Test).**

The LNG Cylinders were filled with LNG via pressure differential method, and the cylinders were left un-disturbed. The test was conducted to find out the holdup period of these cylinders. The holdup period determines how many days it takes for the pressure to reach set pressure of vent valve (20Kg/cm<sup>2</sup>) for a filled cylinder without any withdrawal of gas from it.

**Step 2: Testing of cylinder at Bagroda to determine the average pressure rise with average withdrawal of gas.**

The subject test was conducted to simulate the gas evacuation from the cylinders (as if at the customer facility) and to find out the pressure rise in the cylinder during actual use. The gas was withdrawn at a rate of approx. 6.0 kg/day (~8.0 SCMD). The pressure rise of the LNG Cylinder was monitored to find out the holdup time. The subject test was conducted again at different withdrawal rates of approx. 7kg/day. The pressure rise of the LNG Cylinder was again monitored to find out the holdup time.

**Step 3: Start of the Actual Pilot Project (Transportation and testing of cylinder at consumer end.)**

THINK Gas initiated the pilot project of the supply of Natural Gas through LNG Cylinders to commercial consumers. The first LNG Cylinder was filled with approximately 58.0 kg of LNG. The Cylinder was transported by transporter and connected to the customer facility by THINK Gas trained O&M personnel under the supervision of O&M and HSSE. The LNG Cylinder/ regulator system was kept in the barricaded well-ventilated area at the consumer's facility. The pressure



monitoring was carried out for all 05 nos. of LNG Cylinders under trail to determine the performance of pilot project.

**Resources Utilized:** The pilot project used LNG cylinders, a weighing scale, a scissor lift, gas hoses, gas detectors, and some basic civil setup at the site. Around 2 to 3 THINK Gas team members were involved in handling and carrying out the entire pilot project.

## CHALLENGES

THINK Gas faced several challenges while carrying out the pilot project, mainly related to permissions and safety. Some of the key issues were:

- **No Clear Guidelines:** There are currently no clear rules or guidelines in place for supplying LNG through small cylinders. This made it difficult for the authorities to give official approval, even for a pilot.
- **Leak Detection Without Odor:** Unlike LPG, LNG doesn't have a strong smell. There's no proven odorant available for LNG, so we had

to rely on gas detectors to ensure safety, especially since using LNG in closed spaces is not recommended.

- **Handling Cryogenic Equipment:** LNG is stored at extremely low temperatures, so the cylinders need special care, trained manpower, and proper safety protocols.
- **Measuring Gas Transfer:** There's no standard method yet for measuring and recording how much gas is being delivered through these cylinders (called custody transfer), which is important for billing and records.

## IMPLEMENTATION

To help small industrial and commercial consumers in and around Bhopal who don't have access to a gas pipeline, THINK Gas came up with a practical solution which was supplying LNG through portable cylinders.

THINK Gas bought 5 PESO-approved LNG cylinders (each with 200-liter capacity) and approached PESO, Nagpur, for permission to carry out this initiative. Since this was a new concept, PESO allowed us to run it only as



a pilot project and asked us to test it first at Bagroda LNG station.

**What THINK Gas did:**

- We set up the trial infrastructure at Bagroda LNG station.
- Carried out tests to understand how long the cylinders could hold LNG without losing pressure.
- Tested how the pressure behaved when gas was withdrawn, simulating real usage conditions.
- Once confident, we started the pilot project by supplying cylinders to a real customer.

Each cylinder was filled with LNG, then transported safely using a crane-mounted truck. Our trained team connected it to

the customer’s site with proper safety precautions (like ventilation areas and gas detectors).

The pilot project took around 6 months to complete.

**KEY STAKEHOLDERS**

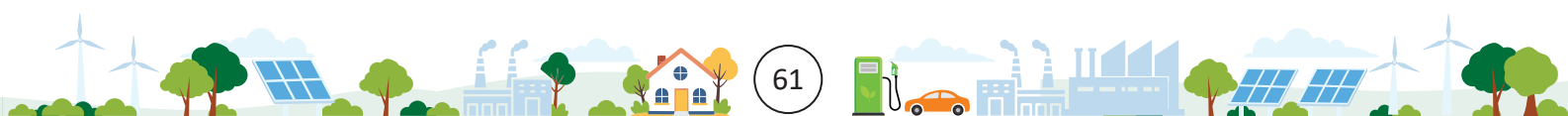
- THINK Gas team – responsible for handling, operations, and safety.
- Transporters – to deliver and pick up the LNG cylinders.
- Customer – who agreed to try the LNG cylinder instead of LPG.

Convincing the customer to use LNG instead of LPG was a challenge, but the successful trial showed it could work as a safe and cost-effective alternative.



**INVESTMENTS**

Cost Component	Amount (₹ in Lakhs)
Capital Expenditure	Around 25 lacs
Operational Expenditure (annual)	Not applicable. As activity was done only as a pilot project for a short period.
Human Resources	2 persons
Technology Acquisition	In-house along with OEM (INOX)
R&D and Innovation	Development of vacuum insulated cylinders
Others (please specify)	NA
Total Investment	For Pilot project only about 25 lacs. About 3 Cr for full scale facilities



## QUANTITATIVE OUTCOMES

Parameter	Before Neuron	After Neuron	Improvement (%)
GHG Emissions (CO <sub>2</sub> )	~3.0 kgCO <sub>2</sub> /kg LPG burned	~2.75 kg CO <sub>2</sub> /kg LNG burned	8~9
Energy Consumption (units)	46.1MJ/Kg	50 M/Kg	8~9
Water Consumption (KL)	Nil	Nil	NIL
Waste Generation (tonnes)	Negligible solid waste	Negligible solid waste	NIL
Resource Utilization	1-2	1-2	NIL
Operational Efficiency	~80–85% (depending on burner design)	~90–95% (more efficient combustion)	8~10
Cost Savings (₹ in Lakhs)	89 INR/kg	72.57 INR/Kg	15~20

## QUALITATIVE OUTCOMES

The pilot project delivered multiple real-world benefits in safety, efficiency, and environmental performance beyond just cost savings. Some of the outcomes are mentioned below:

- **Cleaner Fuel, Better Air:** LNG burns more cleanly than LPG, releasing less CO<sub>2</sub>, NO<sub>x</sub>, SO<sub>x</sub>, and almost no soot or smoke. This leads to better air quality and less harm to the environment.
- **No Pipeline Needed:** Since gas is delivered through cylinders, there's no need to wait for pipeline infrastructure. This ensures uninterrupted supply even in remote or hard-to-reach areas.
- **Consistent Gas Quality:** Because LNG is transported in a sealed liquid form, it stays clean and free from dust or moisture, unlike some pipeline gas that may get contaminated.

- **Safer for Users:** LNG is lighter than air, so in case of a leak, it disperses quickly into the atmosphere instead of collecting on the ground. This reduces fire risks compared to heavier fuels like LPG.
- **No Pilferage or Losses:** The consumer has full control over the gas stock, minimizing chances of pilferage or hidden leakages, which are sometimes possible in traditional supply systems.

## INNOVATION & UNIQUENESS

**INNOVATION:** THINK Gas introduced a first-of-its-kind model by delivering natural gas through small, portable LNG cylinders—making clean fuel accessible even to remote consumers without pipelines. The cylinders were specially designed with vacuum insulation and safety systems like pressure relief valves and venting mechanisms to manage LNG's extremely cold temperature safely.

**UNIQUENESS:** Unlike LPG and CNG, LNG needs cryogenic storage at very low temperatures. These LNG cylinders are built to handle this safely, without requiring high pressure like CNG. The solution allows even small users, like hotels or industries in isolated areas, to use natural gas without waiting for a pipeline—giving them access to cleaner, more efficient energy with minimal infrastructure.

## SCALABILITY & REPLICABILITY

This LNG cylinder-based model is highly scalable and easy to replicate:

- **Scalable:** Supply can be increased by simply adding more cylinders based on consumer demand—no need for heavy infrastructure or large investments.
- **Replicable:** The same approach can be adopted in other cities, rural areas, islands or industrial zones where pipeline connectivity is not feasible.
- **Quick to Deploy:** Since it avoids pipeline laying and major construction, this model can be rolled out quickly to new locations.
- **Low Setup Cost:** Minimal infrastructure is required, making it ideal for small hotels, apartment complexes, industries, or even telecom tower operators looking for a reliable and cleaner fuel source.

## KEY LEARNINGS

Based on the insights gained during the pilot project, the key learnings identified are as follows

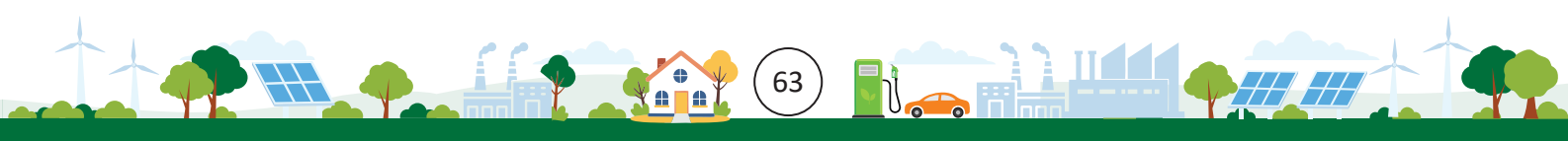
- **Cylinder-Based LNG is Practical:** LNG cylinders are a viable solution for reaching consumers without pipeline access, especially in remote or difficult-to-reach areas.

- **Storage Efficiency Matters:** Cylinder insulation and design play a big role in minimizing gas losses (BOG – boil-off gas) and extending hold time.
- **Logistics & Safety Are Critical:** Safe transportation, handling, and storage need strict protocols and trained manpower to ensure reliability and compliance.
- **Consumer Awareness is Essential:** Educating customers on safe usage, pressure indicators, and identifying signs of leakage (like icing or dew) is key to operational success.

## FUTURE PLANS

Based on the key learnings, THINK Gas has planned other provisions which includes:

- **Expand LNG Cylinder Supply** to small hotels, residential societies, commercial kitchens, and small industries currently dependent on LPG.
- **Establish Training and Awareness Programs** to educate end-users on safe handling, storage, and usage of LNG cylinders.
- **Develop Dedicated Cylinder Logistics and Filling Hubs** to streamline distribution and improve turnaround time for cylinder refills.
- **Coordinate with Regulatory Authorities** to formalize approvals and integrate LNG cylinder supply into policy frameworks for wider adoption.





# Development of FCC Bottoms Cracking Additive (BHARAT BCA)

Bharat Petroleum Corporation Ltd  
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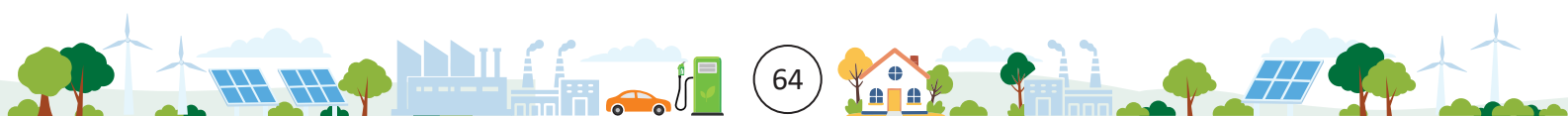
Emission Reduction

The BHARAT BCA is an indigenously developed FCC bottoms cracking additive designed to enhance the conversion of heavy hydrocarbons into lighter, higher-value products such as gasoline, LPG, and diesel. Developed since 2017 through extensive R&D, scale-up, and commercial trials at Mumbai Refinery, the additive improves refinery economics by increasing product yields, reducing coke and heavy cycle oil formation, and lowering greenhouse gas emissions. Featuring a mesoporous alumina matrix with optimized acidity, BHARAT BCA demonstrates significant financial and environmental benefits while promoting “Make in India” innovation and scalability across refineries. BHARAT BCA made a financial benefit of Rs. 49.5 Cr in 6 months of operation.

## BACKGROUND & CONTEXT

Before the initiative, catalytic cracking units (FCC) faced significant challenges in processing heavier feedstocks, particularly the heavy clarified oil (bottoms). The small pore size of conventional Y-zeolite FCC catalysts limited the conversion of these heavy molecules (425°C+ fractions), leading to lower yields of lighter, valuable products

and higher production of less-desirable heavy products such as heavy cycle oils (HCO) and coke. This negatively impacted refinery economics and resource utilization. Additionally, increasing environmental concerns and the necessity to enhance operational efficiency drove the need for innovative solutions. There was no suitable locally developed additive to enhance



bottoms cracking selectively. Import reliance on imported additives also posed economic and supply chain risks. These challenges motivated the development of an indigenous FCC Bottoms Cracking Additive (BHARAT BCA) tailored for refinery feedstock and conditions to improve bottoms conversion and fuel yield while reducing coke and environmental emissions, delivering significant financial and operational benefits.

## OBJECTIVES

- Develop an indigenously formulated FCC bottoms cracking additive (BCA) to enhance conversion of heavy clarified oil fractions into lighter hydrocarbons.
- Improve yields of high-value products such as gasoline, LPG, and diesel while reducing heavy cycle oil (HCO) and coke yields.
- Scale up additive production from laboratory to commercial quantities with consistent quality.
- Integrate BCA into existing refinery FCC units without operational disruptions.
- Demonstrate sustainable financial benefits through increased product yield and reduced operational costs.
- Promote indigenous innovation aligned with “Make in India” goals.

## METHODOLOGY

The development of BHARAT BCA followed a systematic, multi-stage process from concept to commercial deployment

### Formulation Development (2018 – 2020):

Over 70 additive formulations were created in the laboratory, varying raw materials such as alumina sources (pseudo boehmite, boehmite, gamma-alumina), binders (phosphate, colloidal silica, polysilicate), clay (kaolin, bentonite), and acidity modifiers (formic, acetic, phosphoric, nitric acids).

These materials were selected to create a mesoporous matrix with large pores (50-80Å) and sufficient acidity to pre-crack large hydrocarbon molecules.

### Laboratory Testing:

Each formulation was evaluated for physical properties (BET surface area, pore volume, average pore size, particle size distribution, bulk density, loss on ignition, attrition resistance) and their ability to reduce bottoms yield in catalytic cracking trials.

### Scale-Up and Production:

The five best formulations were shortlisted, and the top two were scaled to 5 kg batches, followed by a final optimum formulation scaled up to 100 kg. Subsequently, 50 tons of the optimized additive were manufactured in 5-ton batches by M/s Sud-Chemie, subjected to quality control, and shipped to Mumbai Refinery

### Commercial Trial (Oct 2024 – Mar 2025):

The additive was introduced into the Catalytic Cracking Unit (CCU) at Mumbai Refinery starting October 1, 2024. Key parameters such as riser outlet temperature (ROT), catalyst circulation rate (CCR), feed rate, and catalyst-to-oil ratio (CTO) were continuously monitored to assess performance. Product yields and bottoms conversion metrics were measured monthly and compared against baseline operation before BCA implementation.

### Operational Monitoring:

Feedstock was low sulfur vacuum gas oil and slurry. Data analysis focused on conversion rates, product yield improvements (gasoline, LPG, diesel), coke and heavy cycle oil reduction, and overall value addition.

## CHALLENGES

**Formulation Optimization:** Achieving a balance between high acidity for cracking activity, tuned porosity and mechanical strength to withstand FCC conditions required extensive trial and error. Initial formulations suffered from poor attrition



resistance which risked additive loss.

**Scale-Up Consistency:** Manufacturing the additive at commercial scale while maintaining consistent porosity, acidity and physical properties posed process control challenges.

**Integration With Existing Catalysts:** Coordinating BCA use with existing FCC catalyst required careful operational tuning to avoid disruptions or unintended effects.

**Fluctuating Operating Conditions:** Daily variation in ROT, catalyst circulation, and feedstock properties complicated performance assessment, demanding averaging over months for reliable conclusion

**Operational Acceptance:** Securing buy-in from refinery operations and maintenance teams was critical, requiring extensive data sharing and engagement

**Environmental Compliance:** Ensuring no adverse environmental impact during trials involved additional monitoring and controls

**Strategies Adopted to mitigate challenges:**

- Rigorous laboratory testing narrowed the formulations to those with optimal physical and chemical properties.
- Close coordination with manufacturing partner ensured quality standards during scale-up.
- Operating parameters were closely monitored and adjusted to maintain FCC stability.
- Frequent communication with refinery stakeholders established confidence and operational readiness.
- Trial data were statistically analysed to account for variability and confirm additive benefits

## IMPLEMENTATION

The BHARAT BCA initiative was implemented following these phases:

**2018–2020:** Laboratory development of over 70 formulations to optimize the additive matrix, acidity and catalyst activity.

**2020–2023:** Pilot scale-up of the best formulations to 5 kg and 100 kg batches with comprehensive physical and activity testing of the catalyst at BPCL R&D.

**Early 2024:** Manufacturing scale-up of 50 tons batches at M/s Sud-Chemie in 5-ton increments with rigorous quality control performed at BPCL R&D, Greater Noida.

**October 1, 2024:** Formal inauguration of commercial additive use at Mumbai Refinery CCU, attended by senior refinery and R&D management, followed by presentation and knowledge sharing sessions.

**October 2024:** March 2025: Continuous commercial trial implementation, monitoring daily FCC parameters such as ROT, catalyst circulation rate, feed rate, and catalyst-to-oil ratio. Monthly evaluation of product yields (gasoline, LPG, diesel), coke and bottoms yields compared against baseline data.

**Stakeholders:** BPCL R&D teams, Mumbai Refinery Operations, Manufacturing partners (M/s Sud-Chemie), senior management from BPCL, and Technology teams collaborated extensively.

**Challenges during Implementation:**

- Ensuring consistent additive dosing in FCC operation and maintaining quality control during large-scale batches.
- Managing day-to-day operational fluctuations with data analysis tools to confidently attribute results to the additive.
- Providing updates to operational teams to integrate BHARAT BCA into refinery procedures.

These efforts culminated in robust validation of the additive’s commercial benefit and operational stability



## INVESTMENTS

Cost Component	Amount (₹ in Lakhs)
Capital Expenditure	264 (to prepare 5 tons of catalyst)
Operational Expenditure (annual)	6 (for continuous addition of catalyst in Mumbai refinery)
Human Resources	100 (Manpower cost)
R&D and Innovation	30
<b>Total Investment</b>	<b>400</b>

## QUANTITATIVE OUTCOMES

Provide measurable results achieved through the initiative

Parameter	Before Implementation (Sep 2024)	After Implementation (Mar 2025)	Improvement (%) / Value Addition
Bottoms Yield (HCO+CLO)	12.15%	~9.56%	~21.2% reduction (2.59 units)
Gasoline Yield (%)	42.17%	41.76%	Increased by up to 1.47 units
LPG Yield (%)	17.95%	15.62%	Increased by 1.14 units
Diesel Yield (DG Yield)	4.43%	5.02%	Increase of up to 0.85 units
Coke Yield (%)	4.69%	3.88%	Reduction by 0.81 unit
FCC Conversion (%)	69.24	66.28	Slight decrease post-February due to feed variation
Value Addition (₹ Crore)	Base	<b>₹49.5 Cr over 6 months</b>	Significant financial benefit
GHG Emission (CO/CO <sub>2</sub> )	Not quantified	Reduction inferred due to coke reduction	Expected decrease

## QUALITATIVE OUTCOMES

The BHARAT BCA initiative delivered numerous qualitative benefits:

- Enhanced refinery operational flexibility by enabling heavier feed processing and improving catalyst efficiency.
- Increased confidence in indigenous R&D capabilities, fostering technology self-reliance aligned with 'Make in India'.
- Strengthened collaboration between R&D, manufacturing, and operations teams through joint trial management.
- Positive environmental impact through reduced coke formation and associated greenhouse gas emissions.
- Improved resource utilization, transforming heavier, low-value streams into lighter, high-value fuels.
- Stimulated capacity building in catalyst formulation and scale-up processes.

- Promoted a culture of innovation and continuous improvement at the refinery.
- Raised India's standing in advanced refining technologies by successfully commercializing a homegrown FCC additive.

## INNOVATION & UNIQUENESS

BHARAT BCA stands out due to its:

- **Mesoporous Matrix:** Uses a novel mesoporous alumina structure with large pores (50-80Å) tailored for cracking large hydrocarbon molecules like the heavy clarified oil.
- **Optimized Acidity:** Balanced acidity through precise optimization of formulation enabling selective pre-cracking while minimizing coke yield.
- **Mechanical Strength:** Achieved a unique combination of physical properties and catalytic activity, critical for FCC operating conditions.
- **Indigenous Development:** Conceptualized, developed, tested, and commercialized entirely within India by the BPCL R&D team, reducing dependency on imports.
- **Multi-Stage Scale-Up:** Demonstrated successful transition from lab formulations to 50-ton manufacturing batches maintaining consistent performance.
- **Economic and Environmental Synergy:** Simultaneously improved refinery economics through yield enhancement while lowering environmental footprint.
- **Tailored for Refinery Feedstocks:** Specifically designed for Indian crude qualities and refinery configurations, ensuring local adaptability.

- **Integration Capability:** Easily integrates with existing catalyst systems, demonstrated by co-usage with commercial FCC catalyst without operational hiccup.

## SCALABILITY & REPLICABILITY

The BHARAT BCA initiative is highly scalable and replicable:

- The additive manufacturing process can be expanded beyond 50 tons, supported by scalable formulations and batch sizes.
- Other FCC units processing similar heavy feedstocks across India and internationally can adopt this additive with minimal customization.
- The development approach serves as a blueprint for indigenous additives to target specific feedstock challenges elsewhere.
- Continuous operational data and feedback loops enable refinement and tailored deployment per refinery conditions.
- The initiative can stimulate the development of additional locally made refinery additives and catalysts.
- Potential to license or commercialize indigenous BCA for wider industrial adoption, supporting India's energy technology export ambitions.
- The success story encourages integration of R&D innovation within daily refinery operations as a model for other process improvements.

## KEY LEARNINGS

- Balancing catalytic activity and physical durability requires extensive iterative testing and scale-up validation.



- Close coordination among R&D, manufacturing, and operations is essential for successful implementation.
  - Operational fluctuations must be accounted for analytically when attributing benefits to process additives.
  - Indigenous innovation in complex refinery catalysts is feasible and economically rewarding.
  - Continuous monitoring and transparent data sharing build stakeholder confidence.
  - Early engagement of all stakeholders smooths trial adoption and integration.
  - Environmental benefits can complement financial gains, boosting sustainability credentials.
  - Larger field trials over extended periods are necessary to validate long-term performance and durability.
  - Adapting additive formulation to feedstock variability is critical for maintaining product yields.
  - Make in India initiatives enhance national technological sovereignty and economic competitiveness.
- industrial demand.
  - Use of BHARAT BCA in other Indian refineries
  - Conduct extended operational trials to further optimize dosage and integration protocols.
  - Develop additive variants tailored to evolving crude slate characteristics and FCC unit designs.
  - Strengthen collaboration with international partners to benchmark performance and explore export opportunities.
  - Enhance R&D efforts towards next-generation catalysts with even higher mechanical stability and selectivity.
  - Integrate data-driven refinery process control to optimize additive impact continuously.
  - Expand sustainability metrics monitoring including detailed emissions and waste reduction analyses.
  - Facilitate technology transfer and knowledge sharing across Indian refineries to promote wider adoption.
  - Pursue certification and recognition through national and international awards platforms.
  - Invest in training programs to build expertise in catalyst innovation and commissioning.

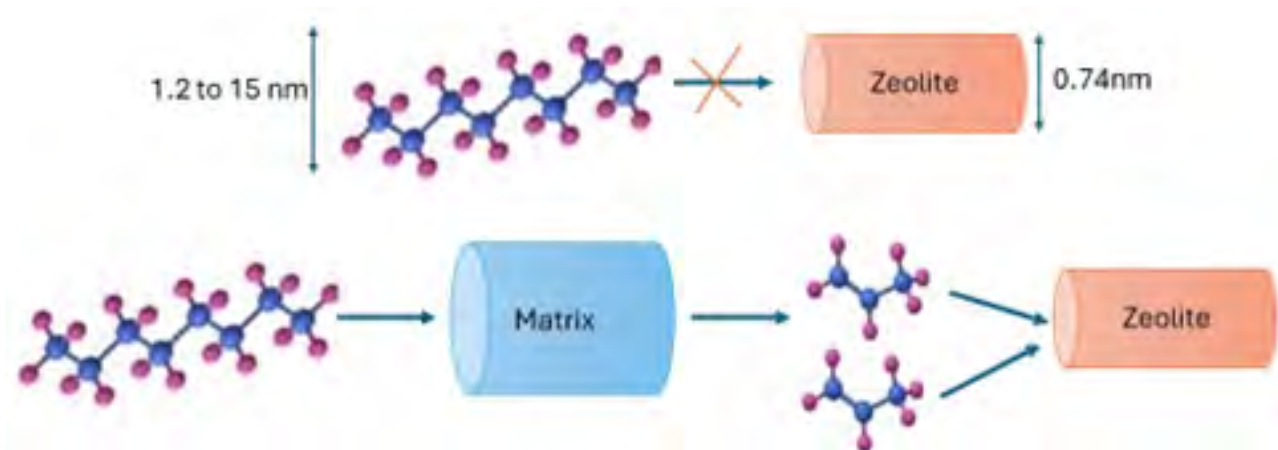
## FUTURE PLANS

- Scale up BHARAT BCA production to meet broader refinery and

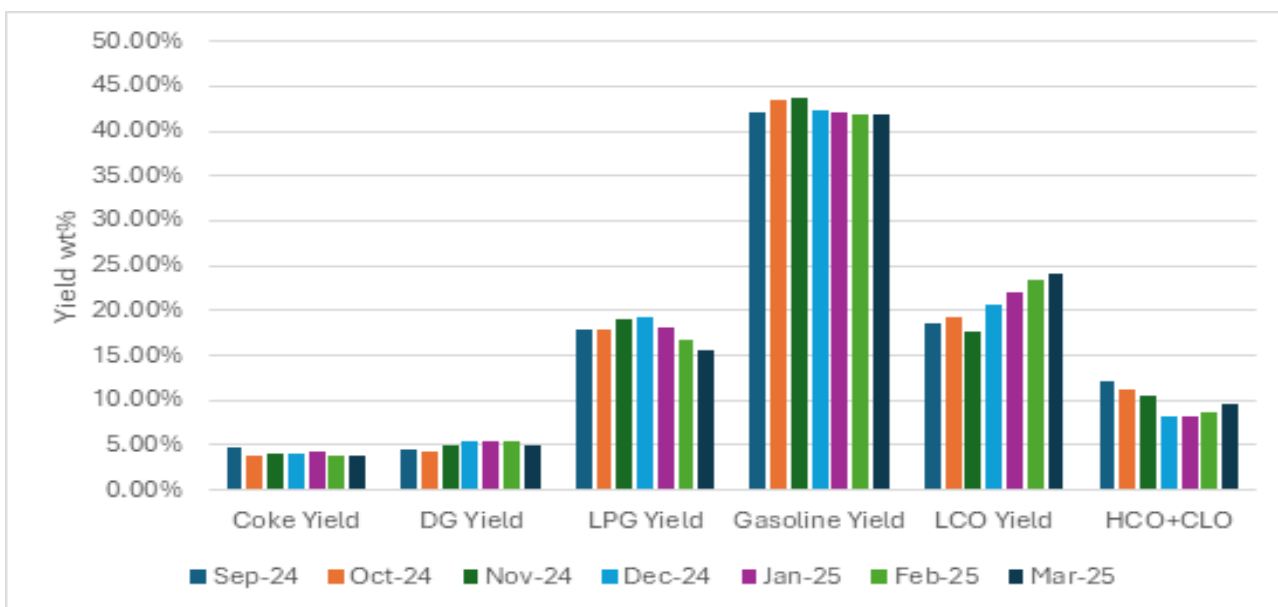


Commercial use of BCA at BPL Mumbai Refinery





Effect of Catalyst in Cracking Heavier Hydrocarbons



Change in Product Yields due to BCA addition

	Sep-24	Oct-24	Nov-24	Dec-24	Jan-25	Feb-25	Mar-25
Feed	3220.67	3193.13	2994.75	2933.98	3172.75	3228	3359
ROT	513	512	514	513.60	515.34	512	512
CTO	5.6	5.7	5.7	5.3	5.4	5.5	5.6
Coke Yield	4.69%	3.73%	4.12%	4.08%	4.30%	3.9%	3.88%
DG Yield	4.43%	4.30%	4.87%	5.39%	5.50%	5.5%	5.02%
LPG Yield	17.95%	17.91%	19.09%	19.23%	18.10%	16.7%	15.62%
Gasoline Yield	42.17%	43.52%	43.64%	42.42%	42.00%	41.9%	41.76%
LCO Yield	18.61%	19.32%	17.76%	20.64%	22.00%	23.4%	24.16%
HCO+CLO	12.15%	11.22%	10.53%	8.23%	8.10%	8.7%	9.56%
Conversion	69.24	69.46	71.71	71.13	69.9	67.9	66.28

Average Product Yields after BCA addition at CCU in Mumbai Refinery



## Impact Assessment Reports

	₹/Ton	Month	NVA
Coke	4244	September	Base
DG	40868	October	+ ₹3.7Cr
LPG	53062	November	+ ₹7.1Cr
Gasoline	67948	December	+ ₹7.8Cr
LCO	66347	January	+ ₹8.0Cr
HCO+CLO	40873	February	+11.3Cr
		March	+11.6Cr
		Total	₹49.5Cr

Benefit based on average product yields

## बीपीसीएल ने रिफाइनरी में एडिटिव भारत बीसीए की घोषणा की



### संवरा न्यूज

मुंबई, 19 अक्टूबर : भारत पेट्रोलेियम कॉर्पोरेशन लिमिटेड (बीपीसीएल), एक महारत्न कंपनी ने गर्व से अपने स्वदेशी रूप में विकसित एफसीसी बॉटम्स कैकिंग के व्यावसायिकरण मुंबई रिफाइनरी में एडिटिव भारत बीसीए की घोषणा की है। ये नवाचार टिकाऊ और लागत प्रभावी शोधन प्रौद्योगिकी के प्रति प्रतिबद्धता बीपीसीएल का एक महत्वपूर्ण कदम है। भारत बीसीए उत्प्रेरक, बीपीसीएल के कॉर्पोरेट अनुसंधान और विकास केंद्र (सीआरडीसी) द्वारा विकसित किया गया है, जिसे आमतौर पर भारी सफाईकृत तेल के रूप में जाना जाता है, के संचालन को अनुकूलित

करने के लिए इंजीनियर किया गया है। बॉटम्स, उच्च मूल्य वाले हल्के उत्पादों में। यह नवप्रवर्तन महत्वपूर्ण वित्तीय लाभ प्रदान करता है परिचालन दक्षता में सुधार करके और शोधन प्रक्रिया में लागत कम करके। कार्यकारी निदेशक (मुंबई रिफाइनरी) अश्वराम राज भंडारी ने कहा कि द भारत बीसीए का व्यावसायिकरण अग्रणी नवाचार के प्रति बीपीसीएल की प्रतिबद्धता को दर्शाता है और टिकाऊ प्रचार। भारत बीसीए उत्प्रेरक का औपचारिक शुभारंभ कार्यकारी निदेशक (एमआर), आर एंड डी के प्रमुख और सुनील राठौर द्वारा एडिटिव सफाईकृत तेल के उत्पादन के साथ किया गया।

## बीपीसीएल मुंबई रिफाइनरी ने स्वदेशी एफसीसी बॉटम्स कैकिंग एडिटिव 'भारत बीसीए' के वाणिज्यिक उपयोग का किया उद्घाटन

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## Testimonials

“FCC catalyst, 'BHARAT-BCA,' was developed to convert Clarified Oil (CLO) into gasoline and successfully scaled up for plant trials. A commercial trial at Mumbai Refinery demonstrated a 2% reduction in CLO and a 1.75% increase in gasoline yield, resulting in value addition of Rs. 49.5 crore.

– BPCL Annual Report FY 2024-2025





# Innovative Carbon Capture and Conversion to Carbonate: BPCL's Pathway to Net Zero Emissions

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Dy. General Manager - R&D

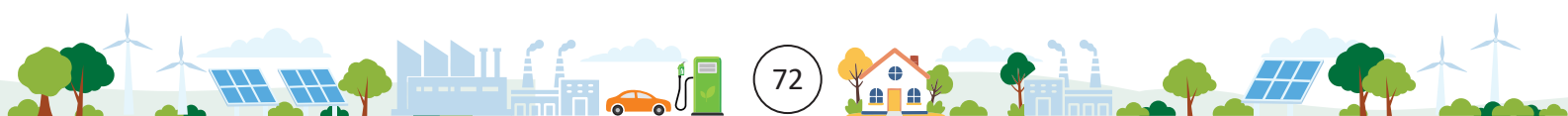
Emission Reduction

In line with India's Paris Agreement commitment, BPCL targets Net Zero Scope-1 and Scope-2 emissions by 2040. The initiative commercializes an innovative CCU technology developed with M/s UrjanovaC to capture CO<sub>2</sub> cost-effectively in water and convert it into valuable calcium carbonate under ambient conditions. This modular, proprietary catalytic process eliminates the need for CO<sub>2</sub> compression and storage while enabling waste-to-wealth carbon utilization, thus providing a scalable, sustainable solution demonstrated via a 50 kg/day model and progressing towards a 10 TPD industrial plant at Mumbai Refinery.

## BACKGROUND & CONTEXT

India's commitment to reduce greenhouse gas (GHG) intensity by 33-35% relative to 2005 levels by 2030 entails a fundamental transformation of the energy sector. BPCL has committed to achieving net zero carbon emissions from Scope-1 and Scope-2 sources by 2040. Carbon Capture Utilization (CCU) is a critical pillar of BPCL's decarbonization strategy, focusing on reducing capture costs and converting captured CO<sub>2</sub> into valuable products. Traditional amine-based CO<sub>2</sub>

capture technologies are energy-intensive, costly, and generate hazardous wastes, limiting widespread adoption. The CCU technology developed by M/s UrjanovaC, incubated at IIT Bombay's NCoE-CCU, offers a novel aqueous-based solution that captures CO<sub>2</sub> using a proprietary catalyst under ambient conditions and simultaneously converts it into calcium carbonate (CaCO<sub>3</sub>). This process uses inexpensive solvents like such as water with less than 10% caustic solution, integrates waste resources



from plant sites, and avoids storage and compression of CO<sub>2</sub> gas. The technology achieved 10–15% higher capture efficiency than amine-based systems while reducing environmental impact and improving economic viability.

## OBJECTIVES

- Achieve BPCL's Scope-1 and Scope-2 net zero target by 2040 through cost-effective CCU technology deployment.
- Validate commercially viable CCU technology capturing CO<sub>2</sub> and converting it to CaCO<sub>3</sub> and Na<sub>2</sub>CO<sub>3</sub> for industrial use.
- Demonstrate 50 kg/day pilot and upscale to 10 tons/day captures units at Mumbai and Bina refineries.
- Prepare detailed project reports (DPRs) covering engineering design, CAPEX/OPEX, market analysis, and environmental compliance.
- Facilitate indigenous innovation and knowledge transfer through collaboration with startup M/s UrjanovaC

## METHODOLOGY

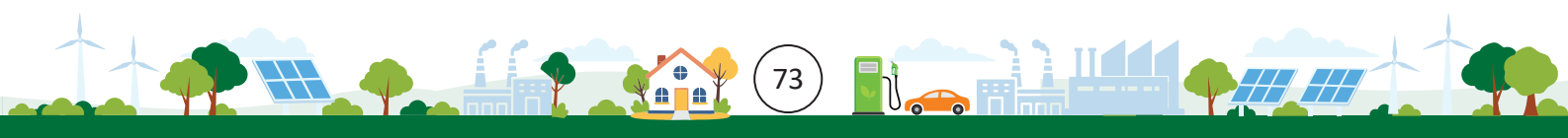
- Planning deployment of modular, retrofit-friendly CCU units at multiple refinery stacks. CRDC signed MoU with M/s UrjanovaC to jointly develop and demonstrate catalytic carbon capture and conversion technology using water as a solvent.
- Developed a performance working model capable of capturing 50 kg/day CO<sub>2</sub>, validated at BPCL R&D facility and showcased during India Energy Week 2025.
- Using a patented catalyst, CO<sub>2</sub> from flue gases or ambient air is absorbed into aqueous medium under ambient pressure and temperature,

followed by conversion to CaCO<sub>3</sub>.

- Pilot testing to optimize process parameters, water utilization (~10–15 liters/kg CO<sub>2</sub>), energy consumption (~1 kWh/kg CO<sub>2</sub>), and waste handling.
- Ongoing preparation of detailed feasibility and project reports for a 10 TPD demonstration plant at Mumbai Refinery.
- Economic and market analysis done for CaCO<sub>3</sub> and Na<sub>2</sub>CO<sub>3</sub> products to ensure commercial viability.

## CHALLENGES

- Scale-Up Complexity: Transitioning from a 50 kg/day pilot to a 10 TPD industrial plant requires overcoming engineering, performance, and safety challenges at larger scale.
- Integration with Refinery Operations: Seamlessly incorporating the CCU process into existing refinery systems without disrupting operations is technically demanding.
- CO<sub>2</sub> Capture Efficiency: Maintaining consistent CO<sub>2</sub> absorption and conversion amid variable feed gas quality and impurities requires robust process
- Cost Management: Balancing capital and operational costs to ensure economic viability despite eliminating CO<sub>2</sub> compression/storage expenses is critical.
- Product Quality & Market: Ensuring calcium carbonate produced meets industry standards and developing sustainable markets for this byproduct are essential for project success.
- Regulatory Compliance: Securing environmental approvals and meeting safety and emissions standards can be challenging and time-intensive.



- **Modularity & Replicability:** Adapting the modular technology for deployment at other sites depends on local conditions and infrastructure.
- **Skilled Workforce:** Staff training to operate and maintain the complex catalytic process effectively is necessary.
- **Monitoring & Reporting:** Accurate measurement and verification systems must support BPCL's Net Zero emissions commitments.
- **Alignment with Broader Initiatives:** The CCU project must integrate with BPCL's overall decarbonization strategies, including renewables and green hydrogen adoption.

## IMPLEMENTATION

civilian high-altitude communities are planned to maximize impact and operational sustainability

Phase	Timeline	Activities & Stakeholders
Planning & MoU Signing	Dec 2024	Agreement with M/s UrjanovaC to collaborate on CCU technology
Pilot Model Development & Validation	Early 2025 – June 2025	50 kg/day pilot setup tested & validated at BPCL R&D, IEW-2025 showcase
Feasibility & DPR Preparation	July 2025 – Dec 2025	Engineering design, market analysis, environmental compliance studies
Demonstration Plant Setup Planning	2026 – Mar 2027	Final Investment Decision and start construction of 10 TPD CO <sub>2</sub> capture unit
Stakeholders	BPCL CRDC, M/s UrjanovaC, IIT Bombay (NCoE-CCU), Mumbai & Bina Refinery teams	-

## INVESTMENTS

Cost Component	Amount (₹ in Lakhs)	Remarks
Capital Expenditure	750.00	Estimated CAPEX ~ \$10 million USD for 10 TPD unit
Operational Expenditure (Annual)	150.00	Estimated OPEX including utilities, maintenance
Human Resources	50.00	Technical team, operations, project management
Technology Acquisition	100.00	Proprietary catalyst, equipment procurement
R&D and Innovation	80.00	Process development, pilot operation, validation
Others (Safety, Compliance, etc.)	30.00	Environmental management, monitoring, documentation
<b>Total Investment</b>	<b>1,160.00</b>	Approximate total investment for scale-up

## PARAMETERS & IMPROVEMENTS

Parameter	Before Implementation	After Implementation	Improvement % / Remarks
GHG Emissions (tCO <sub>2</sub> e)	High Scope-1 & 2 emissions from refinery flue gases	Significant reduction due to CO <sub>2</sub> capture and utilization	Estimated 3.3 KTPA CO <sub>2</sub> e savings at Mumbai Refinery
Energy Consumption (kWh/kg CO <sub>2</sub> captured)	NA (no capture)	~1 kWh per kg of CO <sub>2</sub> captured	Competitive energy efficiency compared to amine tech
Water Consumption (L/kg CO <sub>2</sub> )	NA	10–15 liters per kg with recycling potential	Water recycled or discharged safely per source
Waste Generation (tons)	Hazardous amine handling and CO <sub>2</sub> emissions	Eliminated hazardous amines; converts CO <sub>2</sub> into valuable CaCO <sub>3</sub>	Substantial environmental risk reduction
Resource Utilization	CO <sub>2</sub> vented	CO <sub>2</sub> converted into CaCO <sub>3</sub> / Na <sub>2</sub> CO <sub>3</sub> products	Waste-to-wealth circular economy
Operational Efficiency	No carbon capture	Modular, retrofit-friendly units with dual capture and conversion	Higher operational feasibility and lower footprint
Cost Savings (₹ Lakhs)	NA	Lower CAPEX/OPEX relative to traditional capture solutions	Estimated 20-40% CAPEX and 10-30% OPEX savings

## QUALITATIVE OUTCOMES

- Demonstrated indigenous innovation in CCU technology with scalable modular design.
- Eliminated need for CO<sub>2</sub> storage, compression, and hazardous solvent handling, enhancing operational safety.
- Strengthened BPCL's reputation as a sustainability leader showcasing breakthrough technology at India Energy Week 2025.
- Fostered successful collaboration between public sector research and private start-up ecosystem (IIT Bombay incubated).
- Enabled reliable waste-to-wealth circular economy by producing commercially valuable CaCO<sub>3</sub> and Na<sub>2</sub>CO<sub>3</sub>.

- Provided enabling platform for future large-scale CCUS adoption aligned with India's climate commitments.

## INNOVATION & UNIQUENESS

- Aqua-based, ambient temperature and pressure catalytic CO<sub>2</sub> capture and conversion process.
- Patented proprietary catalyst enables simultaneous capture and mineralization of CO<sub>2</sub> to calcium carbonate.
- Utilizes inexpensive solvents (water with <10% caustic) and industrial wastewater as medium.
- Eliminates energy and cost-intensive CO<sub>2</sub> compression, storage, and hazardous amines handling.



- Compact modular design with 10x smaller footprint than conventional amine-based capture plants.
- Dual product flexibility ( $\text{CaCO}_3$  and  $\text{Na}_2\text{CO}_3$ ) with extensive industrial applications.
- Scalable from pilot through TRL-8 to commercial scale deployment.

## SCALABILITY & REPLICABILITY

This CCU technology is highly scalable, suitable for BPCL refineries across India and beyond. Its modular, retrofit-friendly design enables targeting multiple emission sources with minimal infrastructure modification. The use of earth-abundant materials and diverse solvent options make it adaptable to varying industrial contexts and feedstocks. Integration within refinery ecosystems supports circular economy principles and industrial symbiosis. The project's success can catalyze replication in other sectors such as cement, steel, and power generation where  $\text{CO}_2$  emissions are substantial, aiding India's broader net-zero agenda.

## KEY LEARNINGS

- Indigenous CCU technology can outperform traditional  $\text{CO}_2$  capture in efficiency, cost, and environmental impact.
- Early-stage collaboration with incubated

start-ups accelerates innovation translation.

- Pilot demonstration and public showcasing increases stakeholder confidence and buy-in.
- Detailed DPR and techno-commercial analysis are crucial for scaling and investment decisions.
- Modular and flexible design aids integration at various industrial sites minimizing downtime.
- Waste-to-wealth conversions significantly enhances economic viability of CCU projects.

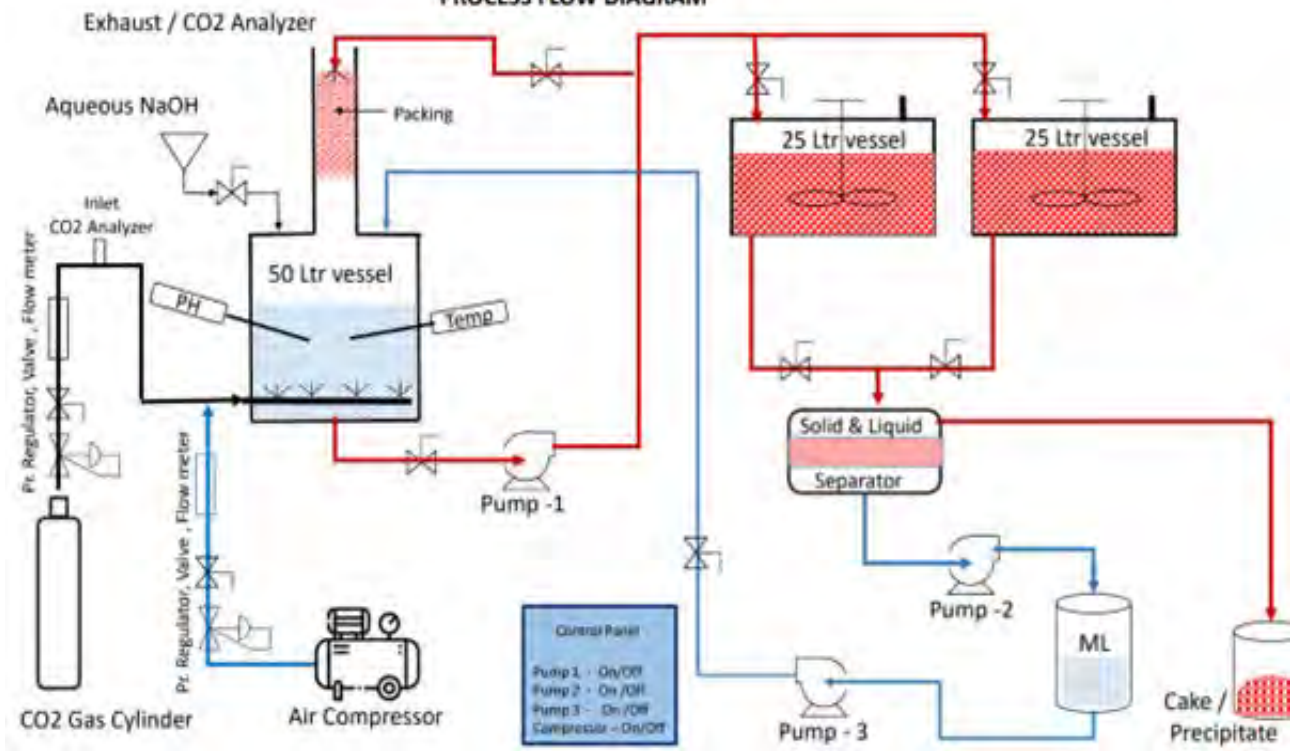
## FUTURE PLANS

- Complete detailed feasibility and DPR for 10 TPD units at Mumbai and Bina refineries.
- Construct and commission 10 TPD demonstration plants by March 2027.
- Explore market expansion for  $\text{CaCO}_3$  and  $\text{Na}_2\text{CO}_3$  products across industries.
- Advance catalyst and capture process R&D to improve efficiencies and reduce costs.
- Scale technology up to 200 TPD and beyond, targeting comprehensive refinery and industrial emission management.



*Representative images of trials conducted*

### PROCESS FLOW DIAGRAM





# Development and Deployment of High-Efficiency LPG Variant with Lightweight Composite Cylinder for uses at Sub-Zero High-Altitude

Bharat Petroleum Corporation Ltd  
Dr. Chanchal Samanta  
Dy. General Manager-R&D

Emission Reduction  
Energy Efficiency

This initiative develops and tests a high-efficiency LPG variant in combination of a novel additive and lightweight HDPE cylinder for use at sub-zero, high-altitude environment. Field trials in Sikkim showed improved vaporization, complete combustion, stable flame, and reduced cylinder weight-enhancing safety, easy handling of fuel and improved efficiency fuel for Army personnel in low-oxygen mountain environment.

## BACKGROUND & CONTEXT

At high-altitude locations (10,000 feet and above) like those in Sikkim, the Indian Army has traditionally relied on Superior Kerosene Oil (SKO) for cooking and heating purposes. While SKO has been the standard fuel, it poses significant challenges, primarily due to its incomplete combustion which generates a strong kerosene odor and smoke. This smoke is not just unpleasant but also potentially harmful, especially in low-oxygen, subzero environments characteristic of high-altitude settings. The health and comfort of

personnel stationed in these remote and challenging terrains are thus compromised.

Recognizing these drawbacks, the Indian Army has displayed keen interest in replacing SKO with Liquid Petroleum Gas (LPG) cylinders as a cleaner, safer, and more energy-efficient alternative. However, deploying LPG at high altitude presents its own technical challenges. Standard LPG is a mixture of propane (C3) and butane (C4), with boiling points of approximately  $-42^{\circ}\text{C}$  and  $-1^{\circ}\text{C}$  respectively. When exposed to the extreme cold and oxygen-scarce conditions



typical at elevations above 10,000 feet, incomplete vaporization of butane leads to a decline in vapor pressure inside the cylinder. This results in residual, unused fuel and suboptimal combustion, reducing heating efficiency.

These challenges necessitate thorough field trials to assess and improve the performance of LPG, particularly focusing on the exhaust process and flame consistency under subzero conditions. The goal is to identify LPG variants or additive formulations that can enhance fuel utilization, ensure better flame stability, and deliver a reliable cooking solution adapted to the harsh parameters of high-altitude operations.

Accordingly, BPCL initiated trial runs with lightweight LPG cylinder (6.3-6.6 kg) at select army consignment points in Sikkim during October 2024. The trials aimed to gather empirical data on LPG consumption, flame performance, and operational feasibility to guide potential full-scale transition from SKO to LPG, improving health outcomes while maintaining logistical and operational efficiency in high-altitude deployments.

## OBJECTIVES

- Assess the feasibility of replacing SKO with lightweight LPG cylinders for cleaner, safer cooking at high-altitude army posts.
- Evaluate LPG combustion efficiency and performance, including additive blends, in subzero, low-oxygen environments.
- Analyze LPG usage, flame stability, and regulator compatibility during field trials.
- Collect field data and user feedback to guide deployment and identify improvement areas.

## METHODOLOGY

The trial of lightweight LPG cylinders at high-altitude army consignee locations in Sikkim was conducted to evaluate the performance

of a novel LPG formulation designed to optimize fuel consumption and combustion efficiency under sub-zero temperature and low oxygen conditions. The methodology employed a combination of laboratory-scale testing, customized LPG solutions, advanced cylinder technology, and field monitoring to assess operational effectiveness.

## Preliminary Laboratory Evaluation by BPCL R&D

Before initiating field trials, BPCL R&D conducted controlled laboratory experiments to assess the efficacy of an in-house additive formulation in enhancing LPG performance. Both base LPG and additive-dosed LPG cylinders were subjected to simulated cold conditions by placing them in a chiller using an isopropanol bath maintained at  $-10^{\circ}\text{C}$ . Periodic sampling of the vapor phase was carried out for both cylinders until complete depletion of LPG content, with each sample analyzed through Gas Chromatography (GC).

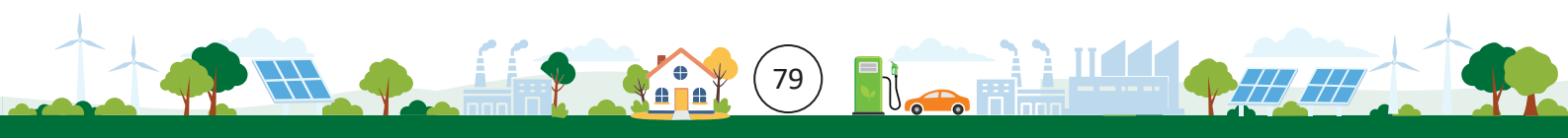
The results showed a significant improvement in fuel recovery for the additive-dosed LPG cylinder, which achieved  $> 98\%$  total LPG recovery due to enhanced vaporization of butane (C4), compared to  $< 96\%$  recovery for the base LPG. These encouraging findings supported the decision to proceed with field trials, where real-world factors such as low-oxygen content and low air density at high altitudes could further challenge fuel efficiency.

## Trial Locations and Duration

Field trials were conducted across multiple high-altitude locations near Changu-Yathang in East Sikkim during 15th–16th and 18th–19th October 2024, at altitudes ranging between 12,500 ft and 15,000 ft. The ambient temperature varied from  $4^{\circ}\text{C}$  to  $-3^{\circ}\text{C}$ , offering realistic high-altitude atmospheric conditions for evaluating LPG performance.

## Cylinder Technology

The LPG cylinders used were lightweight composite cylinders constructed from High-Density Polyethylene (HDPE), each weighing



approximately 6.4 kg. These were selected for their suitability in high-altitude terrains where portability, durability, and safety under environmental stress are critical.

### LPG Formulation

Standard LPG, composed of propane (C3) and butane (C4), suffers from uneven vaporization in cold climates due to butane's higher boiling point (-1°C). The in-house additive developed by BPCL R&D helped overcome this challenge by enhancing the vaporization of butane, enabling a more balanced and complete combustion. This specialized hydrocarbon matrix additive improves overall fuel utilization, especially under sub-zero, low-pressure environments.

### Burner and Regulator Setup

M-35 type burners were used during the trials, along with two regulator types—screw-type high-pressure and click-on adapter regulators. The screw-type regulator demonstrated superior flame stability and larger flame size, making it more compatible with the additive-dosed LPG and thus recommended for deployment.

### Operational Process and Data Collection

Cooking trials were conducted for 2 to 3 hours per session, with cylinder weight recorded before and after each use to measure fuel consumption. Ambient temperature and altitude data were logged continuously. A Standard Operating Procedure (SOP) and structured data collection forms ensured consistency in trial execution and recording. Key data points included:

- Initial and final cylinder weights
- Gas consumption (kg)
- Ambient temperature
- Flame characteristics and usability feedback

### Performance Assessment

Performance was evaluated through:

- Flame quality and stability in enclosed and open settings

- Residual LPG measurements indicating combustion efficiency
- Qualitative feedback on user comfort, safety, and ease of use

Additive-enhanced LPG showed stable blue flame combustion, minimal residual gas, and full compatibility with existing cooking systems, affirming its effectiveness under real-world high-altitude conditions.

### Resources and Collaboration

The trials were executed by a joint team comprising BPCL LPG Technology and R&D experts and Army officers from the 13 MAHAR unit. This collaborative approach ensured both technical validation and practical insights, critical for assessing large-scale deployment potential.

### CHALLENGES

Conducting field trials for a novel LPG formulation and lightweight HDPE cylinders in high-altitude, sub-zero environments posed several logistical, technical, and operational challenges. These challenges were systematically addressed through proactive planning and adaptive strategies.

### Environmental and Altitude Constraints

- Bottleneck: The extreme climatic conditions at altitudes ranging from 12,500 to 15,000 feet presented harsh environmental challenges. Sub-zero temperatures (down to -3°C), reduced atmospheric pressure, and low oxygen levels impacted both human operability and operational performance of LPG combustion.
- Impact: These factors caused inefficient vaporization of butane due to its higher boiling point (-1°C) resulting in residual LPG and incomplete combustion. Adverse weather also affected transportation and handling of cylinders.
- Mitigation: Trials were scheduled during relatively stable weather



windows in October 2024 to optimize safety and performance measurements. The use of specialized hydrocarbon matrix additives was a critical technical innovation to enhance LPG vaporization and combustion in these conditions. Lightweight HDPE cylinders were deployed to ease handling at altitude.

### **Material and Cylinder Technology**

- **Bottleneck:** Designing and fabricating LPG cylinders from composite HDPE materials to reduce weight while ensuring safety and durability under high-altitude environmental stresses was a significant technical hurdle.
- **Impact:** Conventional steel cylinders are heavy and exacerbate logistical challenges at remote high-altitude posts, but composite materials required rigorous testing for strength, leakage, and thermal resistance.
- **Mitigation:** The BPCL R&D team applied advanced material engineering and rigorous preliminary lab tests to validate cylinder integrity. Field trials further confirmed operational compatibility with Army equipment.

### **Fuel Formulation and Combustion Efficiency**

- **Bottleneck:** Achieving complete utilization of LPG components, especially butane, in sub-zero temperatures was problematic due to differential boiling points leading to residual fuel wastage.
- **Impact:** Incomplete combustion reduces fuel economy and increases safety risks from gas accumulation.
- **Mitigation:** The introduction of an in-house proprietary hydrocarbon matrix additive proved effective in enhancing vapor pressure and

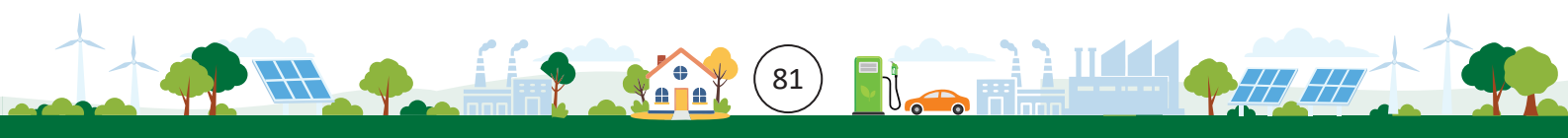
combined recovery of propane and butane fractions. This was complemented by choosing the right regulator — the commercial screw-type high-pressure regulator — which maintained consistent gas flow and flame stability.

### **Operational and Logistical Planning**

- **Bottleneck:** Ensuring coordinated participation between BPCL technical teams and Army personnel across remote high-altitude locations posed logistical and communication challenges.
- **Impact:** Synchronization of trial conduct, data collection, and adherence to Standard Operating Procedures (SOP) was critical to gather reliable performance data.
- **Mitigation:** Detailed SOPs and structured data collection forms were prepared and distributed to Army officers to standardize the trial process and ensure uniform data capture across days. Training and briefing ensured that Army personnel could operate equipment reliably and provide timely feedback.

### **Limited Trial Duration and Data Volume**

- **Bottleneck:** The relatively short trial period (four days on-site) constrained the amount of data and variability in environmental factors that could be evaluated.
- **Impact:** Limited data points could affect comprehensive validation of residual LPG absence and performance consistency.
- **Mitigation:** A one-month extended trial with continuous data collection by Army teams was recommended using the tools provided, aimed at building confidence in the technology through long-term performance monitoring.



## Additional Challenges and Considerations

- **Safety Management:** Ensuring that new cylinder materials and LPG formulations met stringent safety standards under extreme conditions was paramount, addressed through rigorous risk assessments and real-time monitoring.
- **User Adaptation:** Familiarizing Army personnel with the new lightweight cylinders and regulator configurations required timely training and feedback mechanisms.
- **Supply Chain and Maintenance:** Establishing robust supply and maintenance processes for novel cylinders and regulators in remote locations needed strategic planning for scalability.

## IMPLEMENTATION

The initiative to trial lightweight LPG cylinders with a specialized additive formulation at high-altitude Army locations in Sikkim was executed through a well-coordinated, multi-phase approach from planning to field evaluation. The primary objective was to validate the performance of composite LPG cylinders and enhanced hydrocarbon matrix under extreme sub-zero and low oxygen conditions typical of the East Sikkim region.

### Timeline

- **Planning and Preparation:**  
August to September 2024: Initial laboratory testing of the hydrocarbon additive and composite cylinder materials was conducted by the BPCL R&D team. Simultaneously, coordination with the Indian Army's 13 MAHAR unit was established to identify suitable trial locations and operational windows.
- **Field Trial Execution:**  
15th–16th and 18th–19th October

2024: Actual trials were conducted at multiple high-altitude sites near Changu-Yathang, Sikkim, at elevations between 12,500 and 15,000 feet. These two phases allowed comprehensive assessment under varying temperature (4°C to -3°C) and altitude conditions.

- **Extended Monitoring:**

October to November 2024: Post field trials, Army officers continued the trial using the provided Standard Operating Procedure (SOP) and data collection forms for ongoing data capture and performance validation over one month.

### Stakeholders Involved

- **Bharat Petroleum Corporation Limited (BPCL):**

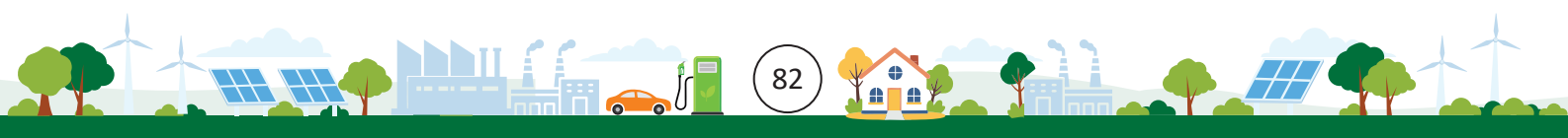
The BPCL team, led by R&D managers and technical experts, managed LPG formulation, lightweight cylinder design, and trial oversight. Key personnel included Dr. Vivek Rathore (DGM R&D), Dr. Raj Kumar Das, and Mr. Dharmendra Pandey.

- **Indian Army (13 MAHAR Unit):**

Army personnel, including Major Nikita Nayar and Major Anuj, facilitated real-world field testing, operational handling, and data collection across high-altitude kitchens and open spaces. Their feedback was critical in assessing user adaptability and performance consistency.

- **Logistics and Support Teams:**

Responsible for transport of cylinders and equipment under harsh terrain and climate conditions, ensuring timely availability and safety compliance at remote trial sites.



## Implementation Process

- **Equipment Deployment:**

Lightweight HDPE LPG cylinders (weighing approx. 6.4 kg) and M-35 burners were transported and installed at designated sites. Two types of regulators (commercial screw-type high-pressure and click-on adapter) were tested to optimize flame quality and fuel combustion.

- **Data Collection and Monitoring:**

Uniform SOPs and structured forms ensured systematic recording of cylinder weight (before and after use), gas consumption, ambient temperature, and observational remarks. Data was gathered daily over trial days and during extended one-month monitoring to verify LPG utilization and residual levels.

of cylinders. These were mitigated by scheduling trials during relatively stable weather periods and deploying lightweight cylinders for ease of transport.

- Coordinating between BPCL technical teams and Army personnel across remote locations posed communication and logistical challenges, which were overcome through detailed pre-trial briefings, SOPs, and real-time feedback mechanisms.
- Ensuring consistent regulator performance required field adjustment and selection, leading to the recommendation of the screw-type high-pressure regulator for future deployments.

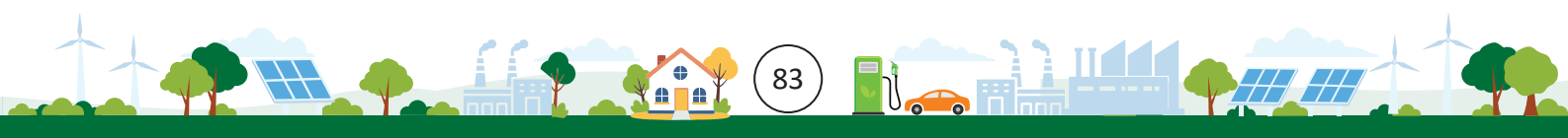
## Challenges Encountered

- Harsh sub-zero temperatures and low oxygen levels impacted fuel vaporization and manual handling

This implementation framework demonstrates a robust collaboration between BPCL and the Indian Army to test and gradually roll out advanced LPG technology suited for challenging high-altitude environments.

## INVESTMENTS

Cost Component	Amount (₹ in Lakhs)
Capital Expenditure	48.00 (Cost of 300 lightweight HDPE LPG cylinders approx. ₹16,000 per cylinder)
Operational Expenditure (annual)	15.00 (Logistics, transportation, fuel supply, consumables, and field operations)
Human Resources	10.00 (BPCL technical team, Army personnel support, training, and management)
Technology Acquisition	5.00 (Licensing, procurement of specialized regulators, M-35 burners, and additives)
R&D and Innovation	8.00 (Development and testing of specialized hydrocarbon matrix additive and material engineering)
Others (please specify)	4.00 (Safety compliance, data collection tools, documentation, and reporting)
<b>Total Investment</b>	<b>90.00 (Sum of above cost components)</b>



## QUANTITATIVE OUTCOMES

Parameter	Before Implementation	After Implementation	Improvement (%)
GHG Emissions (tCO <sub>2</sub> e)	Higher (due to incomplete combustion and fuel wastage)	Lower (improved fuel utilization, reduced residual LPG)	Estimated 10-15% reduction due to complete combustion and optimized fuel vaporization
Energy Consumption (units)	Higher, due to inefficient LPG combustion and flame instability	Lower, due to improved combustion efficiency and constant flame	Approx. 10-20% reduction based on fuel savings observed in trial
Water Consumption (KL)	Baseline water use in kitchens (standard consumption)	Expected to remain similar, as no direct impact reported	No significant change expected
Waste Generation (tonnes)	Higher cylinder handling waste, residual LPG disposal issues	Reduced residual LPG minimizes hazardous waste; lightweight cylinders ease handling and reduce damage risk	Estimated reduction in hazardous waste; approximate 5% improvement
Resource Utilization	Conventional steel cylinders, partial LPG utilization	Lightweight composite cylinders, specialized LPG additive enhancing full fuel usage	Approx. 15-20% better fuel recovery and logistics efficiency
Operational Efficiency	Lower due to heavy cylinders, inconsistent flame, longer cooking times	Higher due to lightweight cylinders, consistent regulation, and improved flame stability	Approx. 15% improvement in manpower efficiency and reduced cooking durations
Cost Savings (₹ in Lakhs)	Higher due to fuel wastage, transport inefficiency	Cost savings expected from fuel efficiency and reduced transport burden	Estimated ₹10-15 Lakhs annual saving (subject to operational scale)
Others (please specify)	Conventional steel cylinders, safety risks due to heavy handling and residual LPG	Enhanced safety from composite cylinders (lighter, durable) and stabilized combustion	Significant safety improvement noted

## QUALITATIVE OUTCOMES

The initiative to deploy lightweight composite LPG cylinders combined with a specialized hydrocarbon additive for improved fuel utilization in high-altitude, sub-zero environments has yielded significant qualitative benefits beyond measurable efficiency gains.

## Enhanced User Comfort and Safety

The lightweight composite cylinders (approximately 6.4 kg) drastically reduced manual handling efforts for Army personnel operating in challenging mountainous terrain at altitudes above 12,500 feet. This reduction in cylinder weight eased logistics, decreased physical strain on users, and



minimized risk of accidents or injuries due to cumbersome steel cylinders.

### **Improved Combustion Stability and Cooking Experience**

Consistent and stable blue flames were observed in enclosed kitchens even under sub-zero conditions, ensuring uninterrupted cooking operations. The use of the commercial screw-type high-pressure regulator further improved flame quality and size, enabling faster cooking times and better heat distribution. This reliability enhanced personnel morale by reducing cooking-related inconveniences.

### **Operational Feasibility and User Acceptance**

The trial demonstrated compatibility of the lightweight cylinders and novel LPG additive with existing Army burner and regulator systems without requiring major equipment modifications. Positive feedback from personnel indicated high adaptability and acceptance of the new LPG solution, paving the way for smoother future deployment.

### **Safety Assurance in Hazardous Environments**

Optimized fuel combustion with minimal residual LPG reduced the risk of gas accumulation and potential leakage, thereby enhancing operational safety at remote high-altitude posts. The robust construction of composite cylinders further ensured durability under extreme weather conditions, contributing to overall risk mitigation.

### **Strengthened Collaboration and Knowledge Transfer**

The initiative fostered effective collaboration between BPCL technical teams and Army units, enabling real-time exchange of operational insights and quick troubleshooting. The use of standardized operating procedures and feedback mechanisms helped build mutual confidence in technological innovations suited for extreme operational environments.

## **INNOVATION & UNIQUENESS**

This initiative stands out for its pioneering combination of lightweight high-density polyethylene (HDPE) composite LPG cylinders and a specially developed in-house hydrocarbon matrix additive, tailored specifically for high-altitude, sub-zero environments. The innovation addresses a critical operational challenge—inefficient utilization of LPG due to butane’s higher boiling point causing residual fuel wastage in cold, low-pressure conditions.

The proprietary hydrocarbon additive enhances LPG vaporization, optimizing recovery of both propane and butane fractions, which significantly improves combustion efficiency and fuel utilization in extreme climates. This tailored LPG formulation, coupled with robust composite cylinders weighing approximately 6.4 kg (considerably lighter than conventional steel cylinders), facilitates easier manual handling and logistics for Army personnel operating at altitudes above 12,500 feet.

Furthermore, the initiative’s use of a commercial screw-type high-pressure regulator ensures consistent and enhanced flame stability, reducing cooking duration and fuel consumption. The seamless compatibility with existing Army burners avoids the need for major equipment changes, ensuring practical and scalable deployment.

Overall, this integrated approach—merging material science, chemical innovation, and field-optimized equipment—delivers a unique and highly effective solution to a long-standing challenge faced in rugged, cold-climate military operations.

## **SCALABILITY & REPLICABILITY**

The successful trial of lightweight HDPE LPG cylinders combined with a specialized hydrocarbon additive in high-altitude, sub-zero conditions demonstrates strong potential for scaling up and replicating this initiative across other challenging locations



and contexts. The lightweight cylinders significantly ease transportation and handling logistics in remote mountainous regions, which often poses a bottleneck with conventional steel cylinders. Furthermore, the proprietary LPG formulation enhances fuel utilization and combustion efficiency under cold, low-oxygen environments, making it suitable for diverse high-altitude terrains such as the Himalayas, northern Himalayan military outposts, and even civilian settlements in cold climates.

The initiative's compatibility with existing burner and regulator systems minimizes the need for major equipment overhauls, facilitating smoother adoption and operational integration. Detailed Standard Operating Procedures (SOPs) and data collection protocols developed during the trial provide a replicable framework to ensure consistent evaluation and feedback during scale-up phases.

With appropriate stakeholder engagement - particularly collaboration between petroleum firms and defence or local authorities - the technology can be adapted and deployed effectively in other high-altitude regions. The prospect of reduced fuel wastage, improved safety, and operational efficiency creates a compelling case for broader application, including remote humanitarian missions, disaster relief kitchens, and eco-sensitive mountain communities.

Overall, the initiative exhibits robust replicability and scalability prospects, promising sustainable LPG solutions tailored for cold, difficult-to-access environments.

What metrics should be used to evaluate the success and sustainability of the initiative beyond initial deployment

## KEY LEARNINGS

The trial of lightweight HDPE LPG cylinders combined with a specialized hydrocarbon additive at high-altitude army locations in Sikkim yielded valuable insights. A primary success was the effective combustion

performance of the novel LPG formulation in sub-zero temperatures up to  $-3^{\circ}\text{C}$  and altitudes above 12,500 feet, confirming improved vaporization and reduced residual fuel. The lightweight composite cylinders significantly eased handling and logistics challenges faced by Army personnel in rugged terrain, enhancing manpower efficiency and safety.

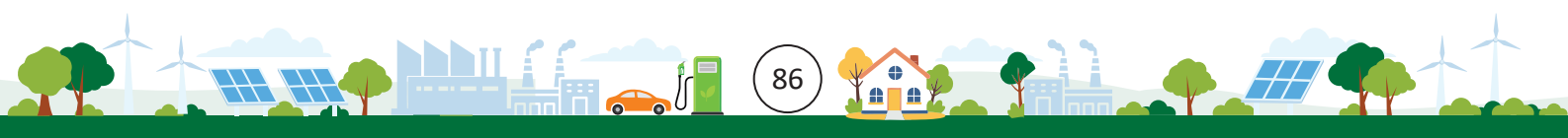
Use of the commercial screw-type high-pressure regulator proved critical in achieving consistent flame stability and optimal fuel consumption, outperforming alternative regulator types. Compatibility with existing Army burners underscored practical deployment feasibility without major equipment modifications.

Key challenges included the environmental difficulties of low oxygen and extreme cold, which were mitigated by careful timing of trials and technical innovations such as additives and cylinder materials. Coordination between BPCL and Army teams underscored the importance of detailed SOPs and structured data collection to ensure reliable performance assessment.

The initiative also highlighted the need for extended monitoring to conclusively confirm residual LPG elimination and build confidence for scaling up. Overall, these learnings demonstrate a promising pathway to implementing sustainable, efficient LPG solutions for high-altitude and cold environments.

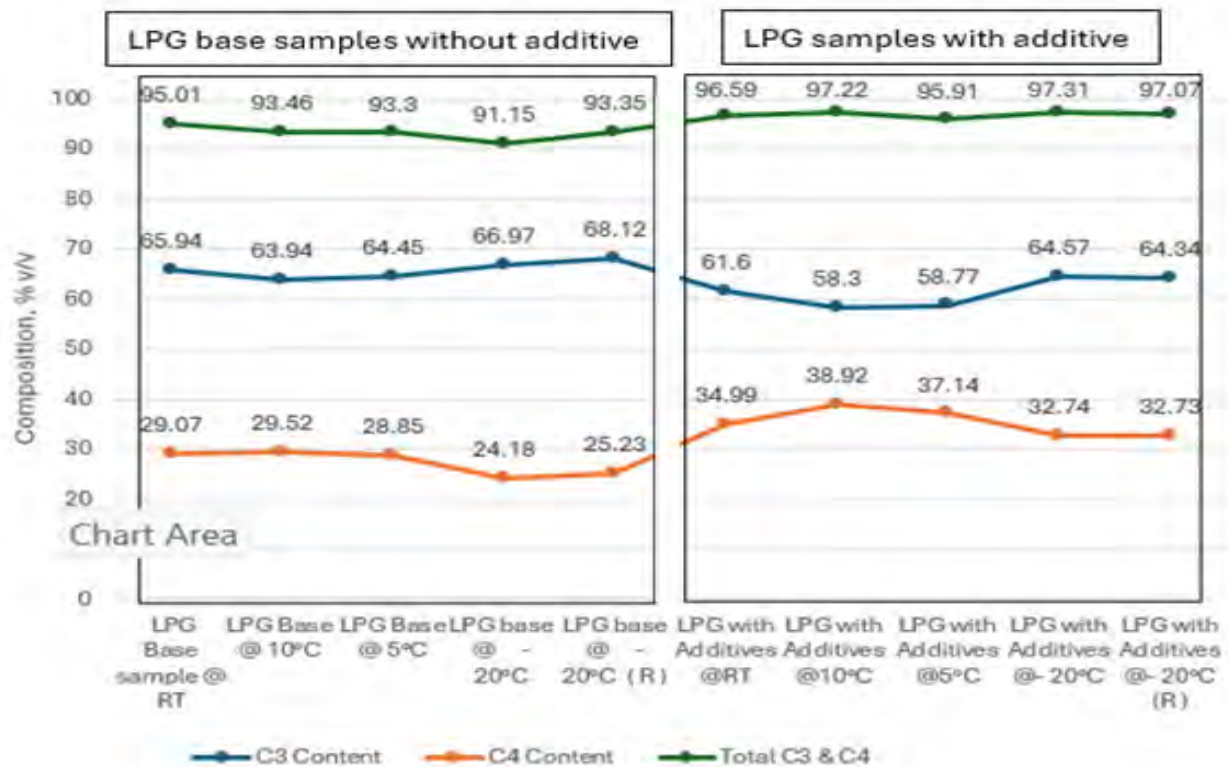
## FUTURE PLANS

Building on the successful trial, the initiative aims to conduct extended and larger-scale field evaluations across diverse high-altitude locations to validate long-term performance and residual LPG elimination. Further R&D will focus on optimizing the hydrocarbon additive formulation and advancing composite cylinder materials for enhanced durability. Training modules and SOP refinements will be developed for wider Army deployment. Additionally, exploring

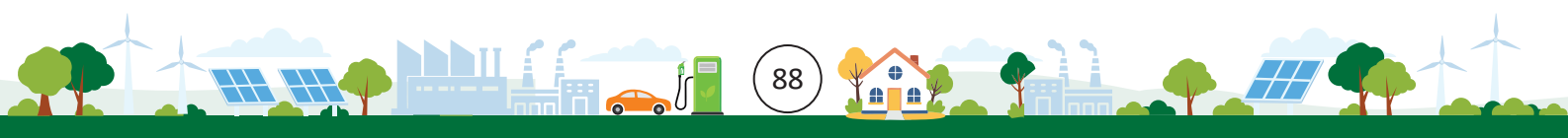


integration with other fuel-efficient burner technologies and expanding use to civilian high-altitude communities are planned

to maximize impact and operational sustainability.



Date	Gross wt. of the cylinder, Before start Kgs	Gross wt. of cylinder in end of operation, Kgs	Gas consumption, Kgs	Temp during trial	Duration of cooking
16.10.24	10.000	8.375	1.625	- 1 oC	3 Hrs
17.10.24	8.375	6.750	1.625	- 3 oC	2 Hrs 50 min
18.10.24	6.750	5.750	1.000	0 oC	2 Hrs 50 min
19.10.24	5.750	4.125	1.625	- 2 oC	2 Hrs 50 min
20.10.24	4.125	2.500	1.625	- 2 oC	2 Hrs 50 min
21.10.24	2.500	1.500	1.000	- 1 oC	2 Hrs
22.10.24	1.500	0.500	1.000	0 oC	2 Hrs 50 min



# **Energy Efficiency**



# BHARAT FURNO CHEM – A Cleaning Chemical for Refinery Furnaces

Bharat Petroleum Corporation Ltd  
Dr. Chanchal Samanta  
Dy. General Manager- R&D

Energy Efficiency

BPCL's refineries needed a safer way to clean furnace tubes online. Soot, metal oxides and acidic deposits cut heat-transfer, spiking tube temperatures, fuel use, costs and emissions, while shutdown-based water or sand blasting halted production. Existing chemical cleaners relied on explosive and sale-restricted ammonium nitrate, inflating price and logistics pain. BPCL R&D therefore created BHARAT FURNO CHEM—an inexpensive, locally sourced, ammonium-nitrate-free formulation that restores efficiency without shutdowns, trimming fuel consumption and environmental impact in under 100 words.

## BACKGROUND & CONTEXT

Before the initiative to develop BHARAT FURNO CHEM, oil refineries, including BPCL's facilities at Kochi and Mumbai, faced critical operational challenges related to furnace and heater efficiency. Furnaces, heaters, and boilers in refineries use heavy oil or gas for firing, but deposits such as soot particulates, metal oxides, and acidic residues accumulate on the inner tube walls over time. These deposits significantly impair heat transfer efficiency, causing an

increase in the arch and skin temperatures of the furnace tubes. Consequently, more fuel is consumed to maintain the desired temperature for processing fluids such as crude oil and its derivatives.

This inefficiency had multiple adverse effects: increased fuel consumption led to higher operational costs, decreased production efficiency due to overloaded heaters, and heightened environmental pollution through increased emissions. Additionally, traditional furnace cleaning methods, including high-



pressure water blasting or sand blasting, required shutdowns for cleaning, which resulted in costly production interruptions and maintenance downtime.

Online chemical cleaning methods that avoid process shutdown were preferred but faced limitations. Most commercially available chemicals relied on ammonium nitrate and magnesium nitrate; however, ammonium nitrate is explosive and restricted by Indian regulations, limiting local sourcing and cumbersome supply chains due to reliance on imported additives. This created a cost and availability challenge, emphasizing the need for a safer, cost-effective, and locally sourced chemical formulation.

The drivers for change were thus clear: to develop a novel, inexpensive, and efficient online chemical cleaning solution that could clean furnace tubes without shutdowns, reduce fuel consumption, improve heat transfer, and ultimately increase refinery throughput, while being environmentally friendly and compliant with local regulations. This motivated BPCL's Corporate R&D Centre to innovate and develop BHARAT FURNO CHEM, aiming to address these operational, economic, and environmental challenges

## OBJECTIVES

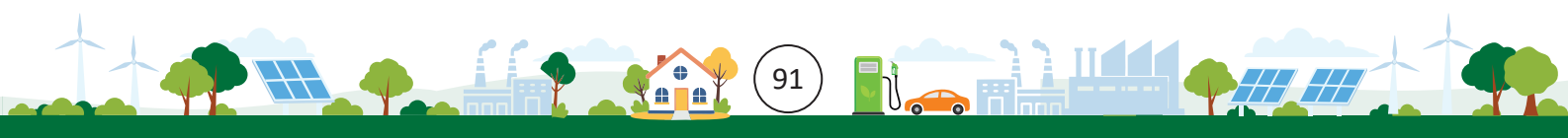
- **Develop a novel, cost-effective chemical formulation** for online cleaning of refinery furnace and heater tubes that is safe, efficient, and locally manufacturable, avoiding the use of explosive and banned chemicals like ammonium nitrate.
- **Enhance heat transfer efficiency** in refinery furnaces and heaters by effectively removing deposits such as soot particulates, metal oxides, and acidic residues on the inner tube surfaces.
- **Reduce furnace arch and skin temperatures** significantly through improved tube cleanliness,

thereby lowering fuel consumption required to maintain process fluid temperatures.

- **Enable online chemical cleaning without requiring shutdowns** of refinery units, thus avoiding costly production interruptions and maintenance downtime.
- **Improve refinery throughput and operational efficiency**, specifically by increasing the processing capacity of crude oil or reduced crude oil (RCO) due to better heat transfer conditions.
- **Achieve substantial fuel savings**, reducing overall fuel oil and fuel gas consumption, leading to significant financial benefits.
- **Minimize environmental impact** by reducing carbon dioxide emissions linked to decreased fuel consumption in refinery firing operations.
- **Demonstrate and validate the chemical formulation via plant trials** at BPCL Kochi and Mumbai refineries to quantify performance improvements and savings.
- **Develop scalable production processes** for the cleaning chemical to support sustained industrial usage.
- **Ensure the cleaning chemical is environmentally benign**, leaves no residue, and does not compromise furnace or tube integrity through corrosion.

## METHODOLOGY

The initiative started with the identification of the problem: unwanted deposits like soot particulates, metal oxides, and acidic residues accumulate on furnace and heater tube surfaces during heavy oil or gas firing. These deposits reduce heat transfer efficiency, increase fuel consumption,



cause environmental pollution, and lower production efficiency.

Recognizing the limitations of existing commercial cleaning chemicals—largely based imported chemicals—the BPCL Corporate R&D Centre focused on developing a safer, cost-effective, and locally sourced chemical formulation suitable for online cleaning without requiring refinery shutdowns.

### **Chemical Formulation and Experimental Work**

Multiple chemical formulations were prepared using combinations of metal nitrates, organic chemicals, and mild bases. The final and most effective formulation consisted of:

- Organic nitrate (organic component): serves as an oxidant helping to burn off soot deposits.
- Metal nitrate (metal salt): decomposes at high temperature (~800–900°C) to magnesium oxide which reacts with acidic deposits on metal surfaces, cleaning the tubes.
- The solution's pH was maintained around 8 using a mild base, optimizing chemical stability and performance.

Thermal degradation profiles of these formulations were analyzed using Thermogravimetric Analysis (TGA) to confirm decomposition behaviour in oxidizing atmospheres at high temperatures.

### **Scale-up and Chemical Preparation**

The successful laboratory formulation was scaled up for industrial application:

- Initial batches of 2000 liters were prepared in 10 sub-batches of 200 liters each at BPCL Sewree R&D facility.
- Larger batches of 6000 liters concentrated chemical were prepared at BPCL Wadilube blending facility in three 2000-liter sub-batches.

The chemical was diluted with water before injection into furnaces.

### **Application Methodology**

The chemical was injected as an aqueous solution into operational furnace tubes via strategically located peep holes at radiation and convection sections of the furnace. Various nozzle types were used to ensure proper spraying and uniform coverage on metal tube surfaces.

### **Plant Trials and Performance Monitoring**

Two major plant trials were conducted:

#### BPCL Mumbai Refinery Trials (2019-2020):

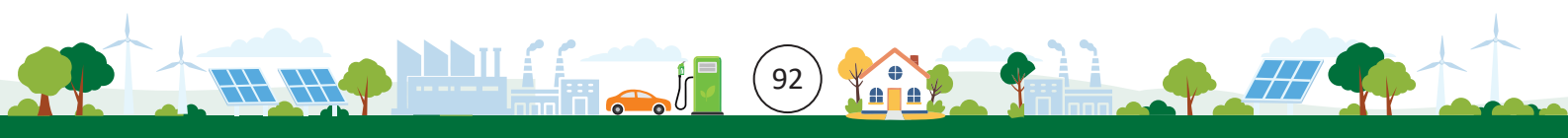
- Initial trial with 3600L diluted chemical showed a reduction of 1.5% in arch temperature.
- Larger trial with 8000L diluted chemical resulted in continuous arch temperature reductions of around 40°C.
- RCO (Reduced Crude Oil) throughput increased by approximately 672.5 tons per day.
- Fuel consumption (fuel oil + fuel gas) decreased by about 2.4 tons per day, translating to estimated daily fuel savings of Rs. 48,000.

#### BPCL Kochi Refinery Trial (May 2023):

- 7200L of diluted chemical was injected over three days.
- Arch temperature reduced by over 40°C and skin temperature reduced by about 15°C.
- Effective cleaning demonstrated under real operating conditions on DHDS furnace.

### **Resources and Collaboration**

- BPCL Corporate R&D Centre led the research and chemical development.
- Manufacturing and scale-up were performed at Sewree R&D and Wadilube facilities.



- Plant trials and performance data collection were conducted at BPCL Mumbai and Kochi refineries in collaboration with refinery technology and operation teams.
- Various expert teams coordinated to monitor furnace data—arch temperature, skin temperature, feed and fuel supply, and heat duty—to evaluate cleaning effectiveness and process improvements.

## CHALLENGES

### Bottlenecks Faced

- **Dependence on Imported Chemicals and Limited Local Suppliers and High Cost:**

The existing commercial furnace cleaning chemicals are, supplied by very few vendors in India, contributing to supply chain vulnerabilities and escalating costs. This was a key concern in developing a cost-effective cleaning solution for refinery applications.

- **Ensuring Effectiveness Without Plant Shutdown:**

Furnace and heater tubes must be cleaned without shutting down operations to avoid costly production losses. Developing an “online” cleaning chemical that works effectively at high furnace temperatures (~700–850°C) and can be injected continuously or periodically posed a technical challenge.

- **Scaling Up from Laboratory to Industrial Quantities:**

Chemical formulations developed at lab scale needed to be effectively scaled up to volumes sufficient for plant application, requiring robust manufacturing practices and quality control to maintain consistency and performance.

- **Chemical Compatibility and Corrosion Risks:**

The cleaning chemical could not compromise the integrity of furnace tubes. Potential corrosion or adverse reactions had to be carefully evaluated and controlled during formulation development.

- **Demonstrating Observable and Quantifiable Benefits:**

It was important to design plant trials that convincingly and reliably demonstrated reductions in arch and skin temperatures, improved heat transfer, fuel savings, and increased throughput. Gathering and analysing operational data under varying furnace load and feed conditions was complex.

### Strategies Adopted to Overcome Bottlenecks

- **Formulating a Cost-Effective, Locally Sourced Chemical:**

BPCL Corporate R&D Centre carried out extensive research to identify the most effective formulation by utilizing commercially available and inexpensive chemicals. The formulation avoided reliance on imported chemical, reducing costs by around 50% compared to commercial chemicals. This supported long-term sustainability and scalability within India.

- **Methodical Scale-Up and Manufacturing Collaboration:**

The chemical was manufactured in incremental scaled batches (200L lab batches scaled to 2000L and 6000L industrial scale) under controlled conditions at BPCL Sewree R&D and Wadilube blending facilities. This controlled scale-up ensured consistent chemical quality for plant trials.

- **Carefully Designed Plant Trials and**



### Data Analysis:

Plant trials were conducted in two major refineries—Mumbai and Kochi—using different furnaces and feed rates. Chemical injection methods utilized diverse nozzle types through peep holes to ensure even application. Comprehensive temperature, fuel, feed, and heat duty data before and after cleaning enabled clear quantification of benefits, including average 40°C reduction in arch temperature, significant reduction in fuel consumption, and increased crude throughput by over 670 TPD.

- **Booster Dose Strategy:**  
Following initial success, booster doses were planned and injected to sustain cleaning effects and enhance fuel switching (significant replacement of fuel oil by fuel gas), demonstrating operational flexibility.
- **Safety and Corrosion Monitoring:**  
Corrosion studies and thermal degradation analyses were conducted as part of the experimental design to ensure furnace tube metal integrity was maintained, thereby mitigating operational risks.

## IMPLEMENTATION

Implementation Timelines:

- **Laboratory Development (Pre-2019):**  
BPCL's Corporate R&D Centre (CRDC) initiated research on a novel, cost-effective furnace cleaning chemical as an alternative to imported commercial product. Various chemical formulations were synthesized, optimized, and extensively characterized in the lab using thermogravimetric analysis

(TGA) between 30–900°C to confirm thermal behaviour under oxidizing conditions.

- **Scale-up and Initial Trials (2019):**  
In mid-2019, the chemical formulation was scaled up from laboratory batches (200L each) to a 2000L batch, prepared at BPCL Sewree R&D facility. This batch was diluted and injected into the CDU3 F102 furnace at BPCL Mumbai Refinery over August 29-30, 2019. Initial results demonstrated a 1.5% reduction in arch temperature, validating chemical efficacy under real conditions.
- **Second Trial and Booster Dose (January – March 2020):**  
Encouraged by initial performance, a larger 6000L batch (in three 2000L sub-batches) was produced at BPCL Wadilube blending facility. Around 4000L was diluted to 8000L for injection into the VDU3 F102 furnace at Mumbai Refinery during January 6-9, 2020. This trial showed substantial furnace performance improvements, including a 40°C reduction in arch temperature and a throughput increase of 672.5 tons per day of reduced crude oil (RCO). A booster dose of 4000L was injected in March 2020, further optimizing fuel consumption and throughput.
- **Kochi Refinery Trial (May 2023):**  
The chemical was later deployed in BPCL Kochi Refinery's DHDS furnace over three days (May 18-20, 2023). This trial involved 7200L of diluted chemical being injected via peep holes using varied nozzles. The furnace arch temperature was reduced by 42°C and skin temperature by 15°C, reaffirming the effectiveness across different refinery units.



### Stakeholders Involved

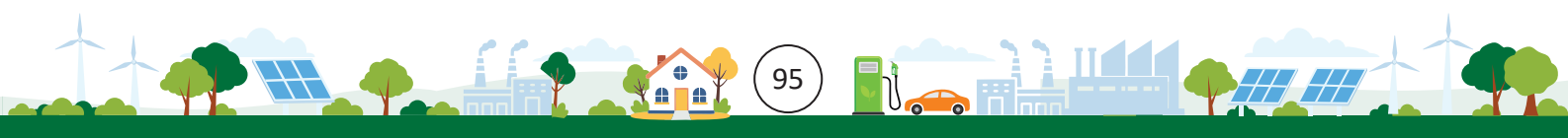
- **BPCL Corporate R&D Centre (CRDC):**  
Led chemical research, formulation development, lab testing, scale-up supervision, and data analysis throughout the project.
- **BPCL Mumbai and Kochi Refineries:**  
Hosted plant trials, provided operational data, facilitated chemical injection logistics, and assisted in performance monitoring.
- **Sewree R&D and Wadilube Blending Facilities:**  
Supported scale-up manufacturing of chemical batches under CRDC supervision, ensuring quality and consistency.
- **Operations and Engineering Teams at Refineries:**  
Collaborated closely to integrate chemical injection into furnace operating processes without shutdowns, managing injection equipment and scheduling.

### Challenges Encountered

- **Chemical Safety Compliance:**  
Developing a chemical free of explosive and corrosive additives while maintaining performance was a major challenge. This mandated innovative chemistry utilizing organic nitrate and metal nitrates.
- **Manufacturing at Scale:**  
Scaling the novel formulation from lab scale to multi-thousand-liter batches required precise process control and coordination across multiple blending facilities.
- **Injection Technique Optimization:**  
Ensuring effective dispersion inside high-temperature furnace tubes without shutdown involved selection and testing of various nozzles and injection points for uniform chemical coverage.
- **Data Collection and Analysis:**  
Capturing reliable, representative furnace performance data under varying crude throughput, heat duty, and fuel mix conditions was complex but essential to quantify chemical impact convincingly

## INVESTMENTS

Cost Component	Amount (₹ in Lakhs)
Capital Expenditure	0
Operational Expenditure (annual)	15 (mostly for the procurement of chemicals and service line up for chemical injection)
Human Resources	24
R&D and Innovation	1 (procurement of chemicals for R&D development)
<b>Total Investment</b>	<b>40</b>



## QUANTITATIVE OUTCOMES

Parameter	Before Implementation	After Implementation	Improvement (%)
GHG Emissions (tCO <sub>2</sub> e)	Not explicitly quantified, but higher due to more fuel consumption	Estimated reduction by 8,760 tons CO <sub>2</sub> per year per refinery if Bharat Furno chem is used in 4 major refinery furnaces	Estimated significant reduction due to lower fuel use
Energy Consumption (fuel units - Fuel oil + Fuel gas)	Higher fuel consumption for maintaining heat transfer efficiency (e.g., Mumbai refinery VDU 3 furnace fuel approx. 68.7 T/D)	Estimated reduced fuel consumption by approx. 2.4 T/D (energy units reduced) leading to ~2,920 tons fuel savings/year/refinery	Fuel savings approx. 3.5% (Fuel oil and gas combined)
Resource Utilization	Use of expensive imported chemicals	Developed chemical is ~50% cheaper and locally sourced	Cost of chemical reduced from Rs. 51.5 to Rs. 11.5 per Liter
Operational Efficiency	Reduced due to deposits causing heat transfer blockage; furnace arch temperatures around 848.9 °C	Arch temperatures reduced by ~40°C (e.g., Mumbai VDU3 F102: 848.9°C → 808.1°C); skin temperature reduced by 15°C (Kochi DHDS)	Improved heat transfer, enabling approx. 672.5 TPD increase in crude throughput at Mumbai Refinery
Cost Savings (₹ in Lakhs)	Higher operational fuel and chemical costs	Estimated annual savings (estimated for four major furnaces in refinery)	NIL

## QUALITATIVE OUTCOMES

### Enhanced Operational Efficiency and Continuity

By enabling online chemical cleaning of refinery furnace tubes without the need for shutdown or process interruption, the initiative helped maintain continuous refinery operation.

### Improved Furnace Health and Reduced Risk

The novel chemical formulation cleans deposits like soot, metal oxides, and acidic residues efficiently without leaving any residues inside the furnace. The non-corrosive and stable chemical composition ensured minimal risk of damage to the metal tubes, enhancing furnace lifecycle and

reducing maintenance risks.

### Cost-Effective Indigenous Solution

Development of a locally sourced, cost-effective alternative to imported chemical strengthened supply chain resilience and industrial self-reliance. This reduced dependence on limited vendors and imported chemical, ensuring economic sustainability and easier procurement.

### Recognition and Industry Leadership

The project received the “Innovative Environmental Project” award by the Confederation of Indian Industry (CII) in 2021, enhancing BPCL’s reputation for innovation and leadership in environmentally responsible refinery technologies.

## Ease of Implementation and Replicability

The chemical's compatibility with standard furnace injection methods and use across multiple refineries demonstrated ease of industrial adoption and scalability, promising wider industry uptake and operational improvements.

## INNOVATION & UNIQUENESS

### Innovative Aspects

- **Novel Chemical Formulation:**

The cleaning chemical developed combines organic nitrate and metal nitrate in an aqueous solution with a controlled pH. This composition is distinct from conventional commercial chemicals that primarily use ammonium nitrate, which is difficult to store and handle.

- **Safe and Cost-Effective Alternative:**

BHARAT FURNO CHEM utilizes locally available, inexpensive materials, avoiding dependency on imported chemical. This significantly reduces the chemical cost by approximately 75%, enabling broader adoption while maintaining high performance, thus meeting operational and economic objectives simultaneously.

- **Online Cleaning Capability:**

BHARAT FURNO CHEM enables online chemical cleaning during furnace operation. This prevents costly interruptions, maintaining refinery throughput and improving energy efficiency continuously.

- **Proven Industrial Scale-Up and Performance:**

The initiative successfully scaled from lab formulations to batches of several thousand Liters produced at BPCL blending facilities. Comprehensive plant trials at Mumbai and Kochi refineries

demonstrated robust and repeatable reductions in arch temperatures (by 40°C), skin temperature (15°C), improved crude throughput (~670 TPD increase), and significant fuel savings, validating its effectiveness at commercial scale.

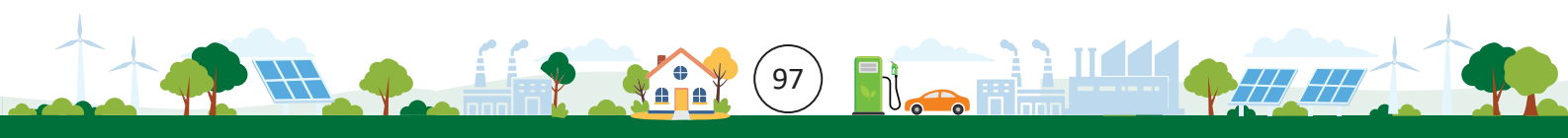
## Unique Features of BHARAT FURNO CHEM

- Combination of organic nitrate and metal nitrate for dual function.
- Safe, cost-effective, indigenously developed formulation replacing hazardous imported chemicals.
- Online application that minimizes refinery downtime.
- Demonstrated efficacy supported by large-scale plant trials with measurable operational and environmental benefits.
- Recognition through the Innovative Environmental Project award by CII in 2021.

## SCALABILITY & REPLICABILITY

### Scalability

- **Successful Scale-Up Demonstrated:** The formulation was initially developed at laboratory scale and then scaled up to industrial volumes—batches of 2,000L and 6,000L—produced at BPCL's Sewree R&D and Wadilube blending facilities. These batches were successfully deployed in large-scale plant trials at Mumbai and Kochi refineries, demonstrating reliable production and handling at scale.
- **Simple Manufacturing Process:** The chemical formulation involves commercially available, inexpensive raw materials and a straightforward aqueous mixing process at a controlled pH. The manufacturing steps are amenable to further scale-up without complex or capital-intensive equipment.



- **Standardized Application Methodology:** The chemical cleaning can be applied via aqueous injection through existing furnace peep holes using various nozzle types, a method that can be readily adapted to furnaces in other refineries without substantial infrastructure modifications.

### Replicability in Other Locations and Contexts

- **Broad Applicability Across Refineries:** The cleaning chemical was successfully trialed in different refinery units handling wide throughput ranges (Mumbai: 18,000–22,000 TPD crude; Kochi: 5,000–6,000 TPD DHDS feed). This indicates its suitability for variable furnace sizes, fuel mixes (fuel oil and gas), and operational conditions common across petroleum refineries.

- **Environmentally Safe and Cost-Effective:** The chemical formulation avoids hazardous chemicals, making it compliant with Indian regulatory restrictions and likely acceptable in other jurisdictions as well. Its significant cost advantage (50% cheaper) promotes commercial viability for diverse oil refining operations aiming at operational efficiency and emissions reductions.

### **KEY LEARNINGS**

#### Key Successes

- **Development of a Novel, Cost-Effective Cleaning Chemical:** BPCL's Corporate R&D Centre successfully formulated a novel furnace cleaning chemical, which is 50% cheaper than commercial chemicals.
- **Effective Online Chemical Cleaning:** The chemical enabled online cleaning without furnace shutdown, avoiding costly plant interruptions. This continuous cleaning method is operationally advantageous and prevents heat transfer losses due to deposits.

- **Significant Performance Improvements:**

Plant trials at Mumbai and Kochi refineries demonstrated:

- Reduction in arch temperature by ~40°C and skin temperature by 15°C, indicating improved heat transfer.
- Increase in crude throughput (~672.5 TPD) due to enhanced furnace efficiency.
- Fuel savings of about 2.4 tons per day, translating into estimated financial savings of Rs. 48,000 per day per refinery and annual fuel savings of 2,920 tons.
- Environmental benefits with significant CO<sub>2</sub> emission reduction (~8,760 tons/year)

- **Scalability and Commercial Viability:**

Successful scale-up from lab to large industrial batches (thousands of liters) and easy integration into existing furnace systems highlight commercial readiness.

- **Recognition:**

The project was awarded the “Innovative Environmental Project” by CII in 2021, validating its innovation impact.

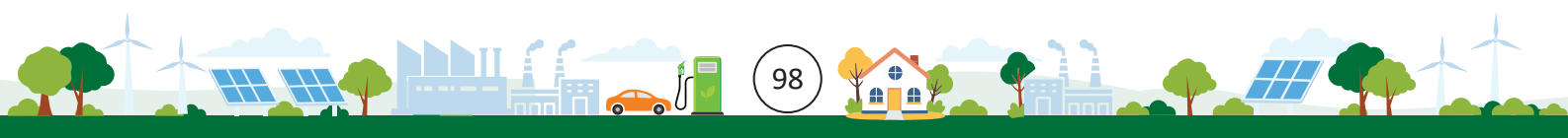
#### Challenges and Learnings

- **Regulatory and Safety Constraints:**

Need to develop a chemical which can be made readily and is cheaper than commercial chemical posed a significant challenge. The team successfully formulated an alternative formulation that meets the criteria.

- **Chemical Injection Optimization:**

Achieving effective and uniform chemical spraying inside furnaces required selection and testing of different nozzle types and injection points to maximize cleaning efficiency.



- Data Analysis Complexity:**  
 Interpreting plant operational data was complex due to ongoing variations in furnace feed, heat duty, and fuel composition. Robust data collection and control methodologies were critical to validate performance gains.
- Supply Chain Considerations:**  
 Ensuring consistent local availability of chemical raw materials and maintaining quality at scale required coordination between R&D, blending facilities, and refinery operations.
- Expanded Plant Trials:** Conducting additional trials across more refinery units and diverse furnace types to validate broad-spectrum applicability, including different fuel types and operating conditions.
- Corrosion and Material Compatibility Studies:** Extending corrosion tests to ensure long-term compatibility with various furnace tube materials under diverse operational scenarios to guarantee equipment integrity.

## FUTURE PLANS

- Optimization of Chemical Formulation:** Further refining the chemical composition to enhance cleaning efficiency, reduce required dosage, and improve stability during storage and handling.
- Commercial Scale Production Enhancement:** Scaling up chemical production capabilities while ensuring quality consistency, safety, and cost-effectiveness to support wider refinery adoption.
- Integration with Digital Monitoring:** Exploring integration of chemical injection with advanced furnace monitoring systems for real-time optimization of cleaning cycles.

## SUPPORTING MATERIALS



Plant trial at Kochi



Chemical production at Wadilube



Plant trial at Mumbai Refinery

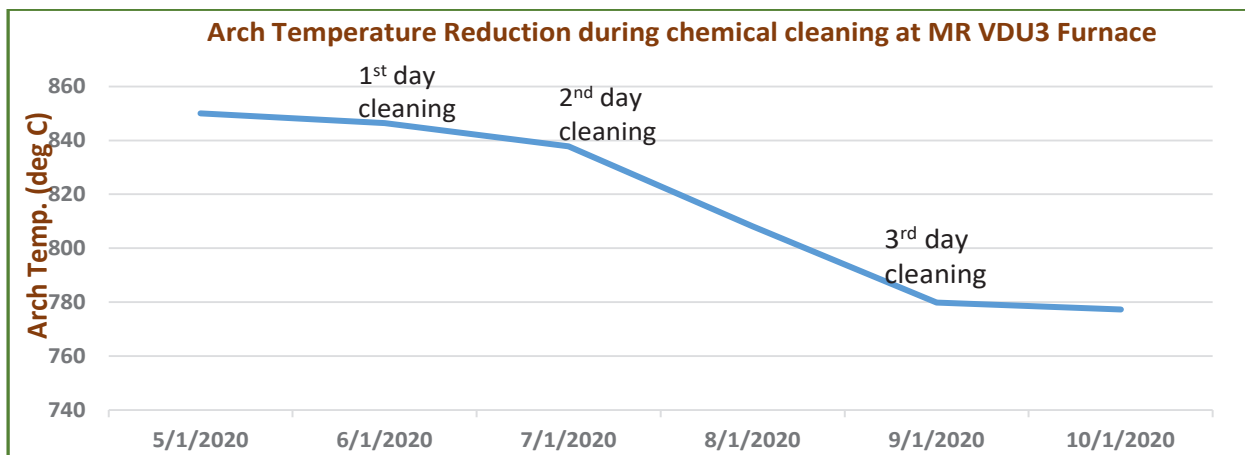
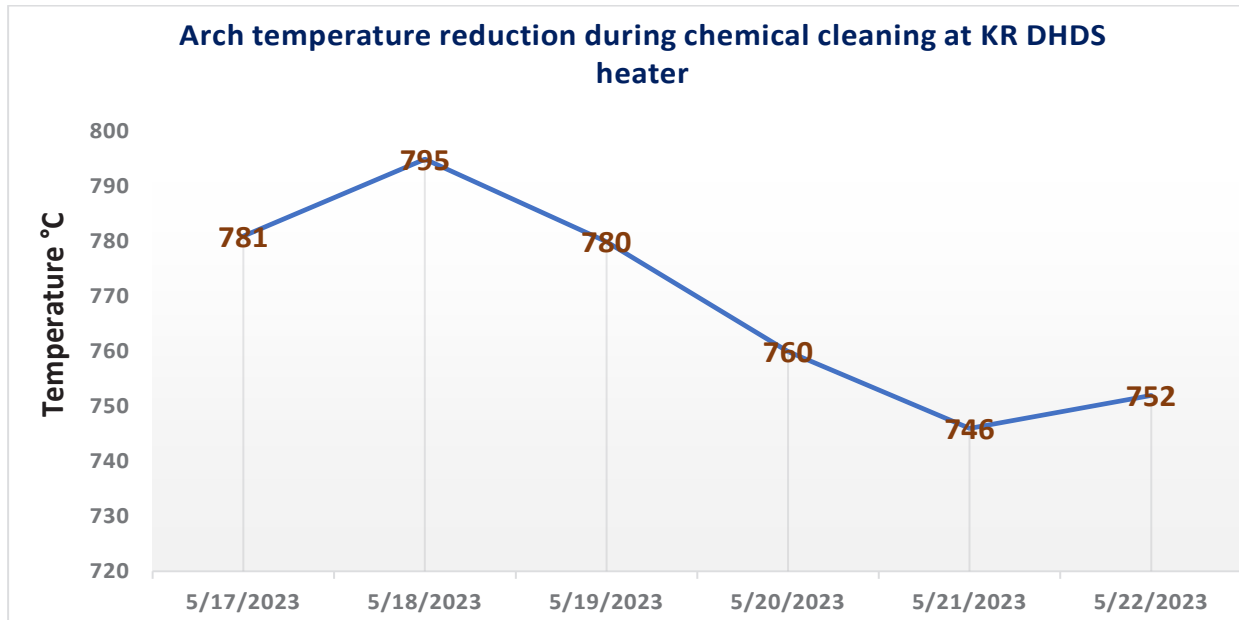


DHDS heater Kochi



Chemical injection into DHDS heater

## TECHNICAL DIAGRAM



## Impact Assessment Reports

Furnace Cleaning Chemical	Cost (Rs) / Lit
BHARAT FURNO CHEM	11.5
Commercial Chemical	51.5
Savings (Rs. per Lit)	30.0
<b>Savings on chemicals</b>	
Average estimated quantity of chemical used in a typical refinery in India	<b>60000 Lt / Year.</b>
Total savings on chemical per year for one refinery.	<b>Rs. 1800000 / year</b>
<b>Savings on Fuel</b>	
Savings on fuel (due to better heat transfer resulting in lower fuel consumption)	<b>Rs. 200000/day (4 TPD fuel oil savings)</b>
Yearly savings on Fuel	<b>Rs. 7.3 Cr</b>
Total Savings per refinery	<b>Rs. 7.5 Cr</b>





# Pipeline Heat Tracing from Steam to Electric System

**Bharat Petroleum Corporation Limited**  
**Shri Ravindra K Kubade**  
**General Manager I/C (Technology)**

**Energy Efficiency**

Conversion of Steam Tracing on 9.2 km pipelines of VGO and Fuel oil service to Electric heat tracing. This eliminated a dedicated tracing steam header with average steam flow of 5.5TPH with additional operating load of 320kW electricity.

## BACKGROUND & CONTEXT

BPCL-Kochi refinery has huge network of outside battery limit (OSBL) piping due to size of the refinery. Various benchmarking studies have revealed that the tracing steam load is a major reason for the energy gap compared to best-in-class energy performance. Refinery had taken up an ambitious project for converting the entire steam traced OSBL pipelines to electrical heat tracing and tender was floated for appointing a Project Management Consultant for same. However, there was no response for the tender. Hence the project was taken up in smaller phases for implementation by in house engineering team

## OBJECTIVES

- Steam loss reduction and header loss minimization by reducing steam network
- Superior insulation to minimize heat loss from pipelines
- Temperature control for pipelines

## METHODOLOGY

All steam traced OSBL pipelines were identified and dedicated steam headers for tracing steam was listed. Orifice meters were installed to measure the steam consumption in the common header. A Piperack having one of the longest dedicated tracing headers



which supplies steam to VGO and FO line was identified for phase 1. Site visit was done with various Electrical heat tracing suppliers and technical feasibility was ensured. Economic feasibility was established using steam flowmeters readings and projected operating electrical operating load based on heat loss calculation and line operating philosophy.

## CHALLENGES

- No prior experience of conversion from steam tracing to Electric tracing: Procedure prepared in consultation with vendors and other refineries
- Working on live pipeline: Job safety plan was made for safely working on live pipelines
- Issues due to wet insulation: Proper weather shelters were made for storage and installation sites.
- Temperature monitoring and identification of failures: RTD based control and HMI included in design

## IMPLEMENTATION

BPCL – Kochi refinery engineering team prepared the detailed scope of work with basic design of electrical heat tracing system for temperature maintenance application. A

dual layered insulation of 25mm inner layer of rockwool and 25mm outer layer of PIC was used along with aluminium cladding. Heat loss was calculated using worst possible ambient condition and 20% safety margin was used for selection of heating cables and numbers of runs. Self-regulating cables were used for heating with duplex RTDs in each circuit. The RTD readings display, and control were envisaged in the control room for real time monitoring.

Capex approval was obtained for the project from Capital budget for 2023-24 and 2024-25. The job was executed in two steps. 3 VGO lines with total length of 5.8km were converted by an established EHT solution supplier. Once performance was found to be satisfactory, Fuel oil line also was converted through another tender which was executed by another established EHT solution supplier. The steps involved in projects were installation of transformers, Power cables, distribution boards and local control panels, removal of existing insulation and tracers, surface preparation, installation of heating cables and RTDs, Application of pipe sections of inner rockwool layer, outer PIC layer, Aluminium cladding for weather proofing, testing and commissioning of electrical and instrumentation systems. The job was completed in June 2025, and the tracing header was isolated thereby saving 5.5 TPH of LP steam.

## INVESTMENTS

Cost Component	Amount (₹ in Lakhs)
Capital Expenditure	1838
Operational Expenditure (annual)	92
<b>Total Investment</b>	<b>1838</b>

## QUANTITATIVE OUTCOMES

Parameter	Before Implementation	After Implementation	Improvement (%)
GHG Emissions (tCO <sub>2</sub> e)	11000	2100	81



Parameter	Before Implementation	After Implementation	Improvement (%)
Energy Consumption (Fuel equivalent MTOE/Annum)	1838	500	85
Water/Steam Consumption (MT/Annum)	48180	0	100
Cost Savings (₹ in Lakhs)		902	

## QUALITATIVE OUTCOMES

Lower maintenance requirement for frequent replacement of faulty steam traps and other direct leaks from steam system. Lower noise pollution by eliminating steam trap discharges in the area

## INNOVATION & UNIQUENESS

Working on live pipeline by isolating small sections of steam tracing, removing tracers, installing electrical heating system, completion of insulation and commissioning of system without any outage or process disturbances.

## SCALABILITY & REPLICABILITY

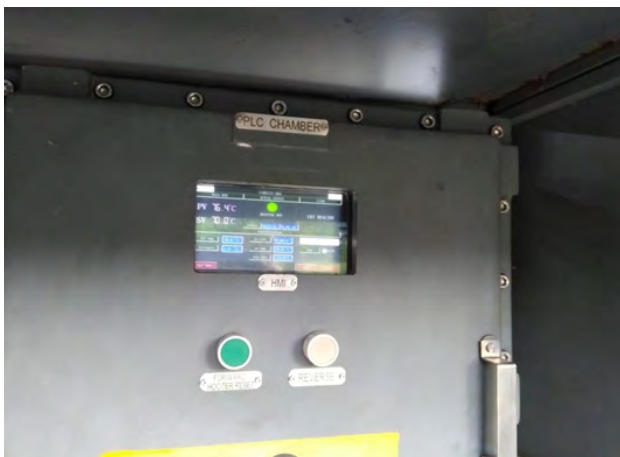
The project is scalable and replicable for the entire OSBL piping network with steam tracing and even for ISBL piping with approved cables and fittings for respective hazard area classification.

## KEY LEARNINGS

- Estimation of tracing steam load
- Design of electrical heat tracing for temperature maintenance application
- Working on live pipeline for conversion
- Tackling the challenges due to rainy seasons
- Best practises in instrumentation and control

## FUTURE PLANS

Successful completion of Phase 1 project has given confidence to go in a bigger scale in subsequent phases. Phase 2 for 17.7 km of pipeline already under implementation. Phase 3 for 22.5 km has been approved and phase 4 for 28km piping is under conceptual stage. Investment approval has already been obtained for these projects.



*LDP typical arrangement*



*RTD based Temperature control*





Steam tracers removed from pipelines



Power Distribution





# Advanced Process Control (APC) Implementation in Motor Spirit Block (MSBP) to Produce Food Grade Hexane

Bharat Petroleum Corporation Limited  
Shri Koteswara Rao G  
Dy. General Manager (Optimisation)

Energy Efficiency

BPCL Kochi Refinery's in-house APC for the new MSBP complex stabilised FGH quality, added 5 TMT/year PENEX DIH feed capacity, and saved 0.9 TPH fuel ( $\approx$  INR 44 crore/year) through optimised reboiling, better CCR heat recovery, and lower HOT. AI/ML-driven automation now ensures consistently stable, reliable operations, proving a scalable, self-sufficient digital transformation.

## BACKGROUND & CONTEXT

The MSBP block at BPCL Kochi Refinery comprises three critical units: NHT, Penex, and CCR, which together transform naphtha into valuable fuel components.

The Naphtha Hydrotreater (NHT) removes impurities such as sulfur, nitrogen, and metals from light petroleum naphtha through hydrogenation. This purification protects downstream catalysts and improves naphtha quality, making it suitable for further processing or blending into gasoline.

The Penex unit is a catalytic isomerization

facility that converts normal paraffins into higher-octane isoparaffins. At BPCL Kochi, Penex also produces Food Grade Hexane (FGH) and isomerate simultaneously, enhancing gasoline quality and offering valuable hexane for food and industrial use.

The Continuous Catalytic Reformer (CCR) upgrades low-octane naphtha fractions into high-octane reformate via continuous catalyst regeneration. The reformate is a premium gasoline blend-stock rich in aromatics and essential hydrocarbons.

The MSBP complex was commissioned in September 2021, introducing new



operational dynamics. By January 2022, the Penex unit started dual production of FGH and isomerate, enabling the shutdown of the older ISOM unit dedicated to FGH, which saved significant energy.

However, this advancement brought challenges. Maintaining the stringent FGH quality standard alongside isomerate production was difficult due to complex process interactions and variability. Penex operated in two modes:

- FGH Mode: Focused on FGH quality but requiring lower feed rates, limiting throughput.
- Isomerate Mode: Higher feed rates for isomerate, with less emphasis on FGH quality.

When FGH failed quality tests in FGH mode, it was downgraded to lower-value naphtha, causing losses and underutilized capacity.

To overcome these issues, the refinery needed to ensure consistent FGH quality, maximize dual-product yields, and leverage energy gains from the ISOM shutdown. This drove adoption of an Advanced Process Control (APC) system integrated with AI/ML, aimed at stabilizing performance, optimizing throughput, and delivering sustainable economic and energy benefits.

## OBJECTIVES

- To ensure consistent and superior FGH (Food Grade Hexane) product quality, meeting stringent specification requirements.
- To maximize FGH yield, optimizing the production process for higher value output.
- To minimize fuel and energy consumption through advanced process controls and efficiency enhancements.
- To achieve stable and reliable plant operation, reducing variability and process upsets.

- To maximize overall plant capacity, enabling higher feed processing rates and greater throughput

## METHODOLOGY

To address the challenges in maintaining product quality and optimizing operations at BPCL Kochi Refinery's MSBP complex, an in-house Advanced Process Control (APC) system was developed and implemented. APC leverages real-time data, predictive modelling, and control algorithms to maintain operational targets despite disturbances.

APC operates by managing three categories of variables:

**Manipulated Variables (MVs):** These are the controllable parameters of the process, analogous to adjustable handles, such as valve positions or heater settings, which the APC adjusts to influence the process.

**Controlled Variables (CVs):** These represent critical process measurements that must be kept within desired limits to ensure product quality and stable operations, such as temperature, pressure, and product quality indicators.

**Feed Forward Variables (FFs):** These are external or anticipated disturbances impacting the process, like ambient temperature or feed flow changes. APC uses FFs proactively to adjust the controls before deviations occur.

The APC continuously adjusts MVs to keep CVs on target while using FFs to predict and mitigate disturbances early, enhancing stability and product consistency.

Dividing the MSBP Complex into Five APC-Controlled Zones:

The MSBP unit was segmented into five distinct operational areas, each governed by its own APC controller customized with specific MVs, CVs, FFs, and predictive process models:

- Penex DIH column
- NHT



- CCR
- Penex Reactor
- Hot Oil Heater

This modular approach allowed precise control tailored to each section's unique requirements.

### **Focusing on Penex DIH: The Key to FGH Quality**

Because FGH quality depended predominantly on Penex DIH performance, APC implementation began there. During the typical six-month APC project timeline, inferential models (predictive analytics using historical data) supported operators in estimating product quality, enabling informed decisions before APC full deployment.

### **First Trial and Learning**

The first APC trial for Penex DIH commenced in May 2022 under FGH mode. Initial results showed occasional sub-par FGH quality samples. Investigation revealed that environmental factors, especially nighttime or heavy rain conditions, caused a significant drop in column top temperature, while the bottom temperature remained high, causing instability in the column operation. The control system's attempts to compensate inadvertently worsened conditions.

### **Solution and Improvements**

To address this, ambient air temperature was incorporated as a feed forward variable, enabling the APC to proactively adjust operating parameters before temperature swings impacted the process. Furthermore, fin fan speeds were controlled by APC to maintain temperature stability. This refined control strategy led to consistent achievement of FGH quality specifications, validating the approach.

### **Scaling APC Across the MSBP Complex**

Following Penex DIH success, APC controllers for the remaining four sections were simultaneously developed and commissioned by two dedicated teams.

To expedite deployment and optimize resources:

Existing company servers were leveraged rather than procuring new hardware.

- The APC software chosen was Aspen DMC, integrated seamlessly with the Schneider Foxboro Distributed Control System.
- The entire project was executed in-house without reliance on external consultants, showcasing internal expertise.

By September 2022, the full APC suite across the MSBP complex was successfully operational, delivering stable operations, enhanced product quality, optimized energy usage, and increased throughput.

## **CHALLENGES**

Implementing Advanced Process Control in the BPCL Kochi Refinery's MSBP complex presented a unique set of bottlenecks, addressed through targeted strategies to ensure successful deployment and sustainable benefits.

- **Integrating APC with a New DCS Platform**

A key challenge was that this was BPCL's first experience interfacing APC with a Schneider Distributed Control System (DCS) in the MSBP unit. While the Schneider DCS is highly customizable, its complexity added considerable risk during integration. Seamless and reliable communication between the APC and DCS was essential for both process optimization and plant safety. A critical requirement was ensuring "bump-less transfer" between automatic (APC) and manual (DCS) operation modes—meaning the plant should switch modes without any abrupt changes that might endanger operation or cause process upsets.



Strategy: The instrumentation team, new to APC-DCS integration, was provided with close, step-by-step mentoring. Innovative approaches were adopted, including simulation and staged testing, to perfect data mapping, alarm handling, and transfer logic, ensuring the system could transition smoothly under all operating conditions.

- **Limited Experience and Operator Readiness**

Since this was the first APC initiative in the MSBP complex, both plant engineers and operators lacked prior hands-on experience. Early in project execution, a knowledge gap became evident—not only in terms of routine operation, but also in troubleshooting connectivity and understanding the logic behind APC interventions.

Strategy: Comprehensive, customized training programs and workshops were organized, focusing on both fundamentals and advanced APC functionalities. This practical exposure quickly upskilled the team, enabling them to monitor, adjust, and troubleshoot the system confidently.

- **Technical Connectivity Issues**

Initial commissioning encountered frequent communication glitches, with inconsistent data reads and writes between the APC and DCS layers. These disruptions threatened real-time control reliability, potentially compromising product quality and plant stability.

Strategy: The team employed creative problem-solving to diagnose root causes—including network bottlenecks, protocol mismatches, and hardware interface limitations. Solutions ranged from reconfiguring

communication protocols and optimizing data refresh rates, to using redundant paths for critical signals. These actions stabilized system performance and enabled uninterrupted APC-DCS interaction.

- **Mindset Shift Toward High-Performance Automation**

APC empowers a plant to operate closer to optimal limits, extracting maximum value. However, for operators accustomed to conservative operations, this represented a significant change—heightening anxieties about safety margins and process risks. A recurrent issue was the omission or misconfiguration of dynamic safety limits when switching between product modes (FGH or isomerase).

Strategy: The system was designed to auto-configure safety parameters depending on the product mode, reducing manual intervention and risk of error.

- **Achieving Unprecedented Product Quality**

FGH production from a conventional distillation unit is inherently challenging, requiring the tightest product specifications. Even process licensors expressed doubt about consistently achieving this with standard hardware.

Outcome: Leveraging the precision, predictive control, and adaptive features of APC, BPCL not only sustained high FGH quality but also lowered energy consumption and elevated plant efficiency. The initiative set a new industry benchmark—transforming a demanding operational challenge into a showcase of innovation and teamwork.



## IMPLEMENTATION

Following the commissioning of the MSBP unit in September 2021 and the successful stabilization of its processes, the initiative to implement Advanced Process Control (APC) commenced in January 2022. This initiative aimed to optimize energy usage and ensure reliable, stable plant operation. As the first-ever APC deployment interfacing with a Schneider DCS at the Kochi Refinery, significant efforts were dedicated to designing and establishing a robust, seamless connection between the two systems.

From the outset, new DCS logic and operator graphics were developed entirely from scratch, guided by thorough discussions to guarantee smooth transitions between APC and manual DCS modes. The priority was safe and secure integration, which proved challenging due to persistent connectivity issues between DCS and APC in the initial months. Resolution was achieved through close collaboration with both M/S Schneider (DCS vendor) and M/S Aspen (APC vendor).

The initial focus of APC commissioning was the Penex DIH section due to specific operational challenges:

- Stringent product specifications for FGH IBP/recovery.
- Occasional off-spec product results in FGH mode.
- Delays in achieving on-grade FGH production.
- Reduced throughput during FGH mode.
- Opportunities to minimize product giveaway.
- Clear potential for energy conservation.

To address these points, inferential models for FGH quality were initially developed offline as operator guidelines and subsequently integrated as controlled variables in the Penex DIH APC upon its commissioning in May 2022. Comprehensive APC strategies were formulated collaboratively among the APC team, manufacturing, and process engineering groups, with all planned APC controllers for the MSBP complex aligned under these shared objectives.

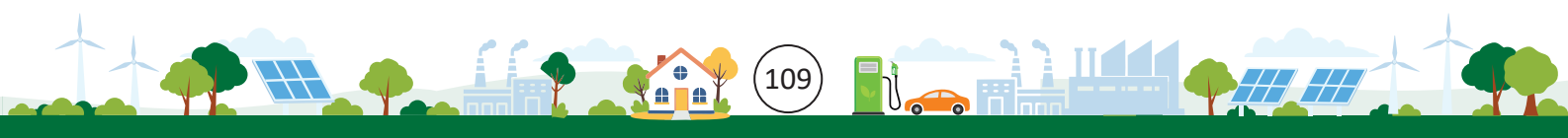
A key milestone was the MSBP APC becoming the first major process controller in the refinery to operate centrally from a single CimIO server, given the MSBP complex's unique architecture. Strategy development, step testing, and model building for all five APC controllers proceeded in parallel, enabled by two dedicated teams working in close coordination. As soon as the necessary DCS interface was established for each section by the instrumentation group—supported by Schneider engineers—sequential commissioning of controllers took place.

Success hinged on sustained support across multiple departments: Operations, Instrumentation, Information Systems, and Process Engineering all played vital roles in troubleshooting, implementing enhancements, and ensuring every commissioning landmark was met.

This multidisciplinary, collaborative approach led to a smooth rollout of APC across the MSBP complex, setting a new standard for process optimization, efficiency, and cross-functional teamwork at BPCL Kochi Refinery.

## INVESTMENTS

Cost Component	Amount (₹ in Lakhs)
Operational Expenditure (annual)	90 Lakh
<b>Total Investment</b>	<b>INR 90 Lakh</b>



## QUANTITATIVE OUTCOMES

Parameter	Before Implementation	After Implementation	Improvement (%)
Cost Savings (₹ in Lakhs)	21428	17017	20.6%

## QUALITATIVE OUTCOMES

The implementation of the APC system has transformed operations at the MSBP complex beyond measurable performance indicators. The most significant outcome has been a substantial enhancement in the consistency and reliability of FGH product quality. Operators now have greater confidence in achieving stringent product specifications, leading to improved customer trust and strengthening BPCL's reputation in high-purity markets.

Process stability has been markedly elevated. By automating critical decision-making and minimizing manual interventions, the APC has reduced process fluctuations, resulting in smoother, more predictable plant operations.

Moreover, the new control environment has encouraged greater collaboration among operations, instrumentation, and engineering teams. The hands-on experience with advanced automation and data-driven decision tools has upskilled personnel, expanding their ability to harness digital technologies for future initiatives. Operator mindset has shifted—from cautious, reactive control toward confident, high-performance operation—thanks to transparent system logic and automatic safeguard measures.

The APC implementation has also enhanced plant safety. With more stable operations and automated control of safety-critical parameters, the likelihood of process upsets and unplanned shutdowns has significantly decreased. The plant now operates closer to its optimal limits, yet with greater security, reinforcing a culture of operational excellence.

Finally, these improvements have set a benchmark for future digitalization projects

in the refinery, demonstrating the power of in-house expertise and teamwork. The initiative has not only delivered tangible results, but has also fostered a spirit of innovation, continuous learning, and shared ownership across BPCL Kochi Refinery's workforce.

## INNOVATION & UNIQUENESS

The APC implementation at BPCL Kochi Refinery's MSBP complex stands out due to its entirely in-house development, eliminating reliance on external vendors. This approach has significantly enhanced the reliability, maintainability, and lifecycle performance of the control system, fostering deep ownership and nimbleness in troubleshooting and upgrades.

A distinctive feature of this initiative is the detailed, site-specific study of column dynamics, enabling precise customization of the APC strategies tailored explicitly to BPCL's operational context. Unlike generic off-the-shelf solutions, the APC is finely tuned to account for the unique behavior and constraints of each unit, ensuring optimal control and product quality.

A pioneering innovation was the development of automated mode changeover within the APC system itself, achieved without consuming additional Distributed Control System (DCS) resources. This seamless automation manages transitions between FGH and isomerate production modes, with the flexibility for operators to override preset parameters via the control panel. Corresponding manipulated variables (MVs) adjust dynamically and smoothly, maintaining stability and avoiding disturbances during mode switches.

Integration of advanced AI and Machine



Learning (ML) models—developed in-house by the BPCL Kochi Refinery digital team—further elevates the system. These data-driven predictions provide forward-looking quality estimates that feed into APC control decisions, enabling proactive adjustments rather than reactive corrections. This fusion of APC with AI/ML represents a cutting-edge advancement in refinery process automation.

Addressing one of the toughest control challenges, the FGH distillation cut demands 95% of samples fall within a narrow 6°C deviation. Traditional controls focused mainly on draw temperatures struggled to maintain this precision. The novel APC approach tightly regulates reflux flow—sometimes prioritizing this over draw temperature controls—achieving tight quality control unattainable by conventional methods.

Together, these elements demonstrate a unique blend of deep process understanding, resourceful engineering, and digital innovation, positioning this initiative as a benchmark for refinery automation excellence.

## SCALABILITY & REPLICABILITY

The successful implementation of Advanced Process Control (APC) in the MSBP unit at BPCL Kochi Refinery (KR) has demonstrated strong potential for scaling and replication across diverse refinery and petrochemical operations. Building on the MSBP experience, APC was extended seamlessly to multiple other units within BPCL KR, including the refinery's first petrochemical complex — PDPP. These expansions have collectively delivered substantial energy and operational savings, amounting to approximately INR 108 Crores annually.

Currently, BPCL KR boasts APC coverage across all major processing units, underlining the scalability of the in-house developed solution. Each implementation has followed a standardized but customizable framework,

ensuring that designs are tailored to the specific process dynamics and control challenges of each unit, while leveraging proven strategies and tools from prior projects. This modular and knowledge-driven approach has minimized ramp-up time and maximized impact.

Notably, innovations such as automated mode changeover, initially developed for the MSBP unit, have been successfully adapted and deployed in other complex units like the Kero Hydro Desulfurization (KHDS) unit. Furthermore, integration of AI/ML-based quality and process predictions with APC has been expanded to critical feed streams, exemplified by its application in Diesel Hydro Treating (DHDT). This highlights the replicability of advanced digital methodologies across varied operational contexts.

The fully in-house execution model has been a key enabler of scalability, fostering a culture of continuous learning, agility in customization, and rapid problem-solving. This renders the APC initiative highly transferable not only within BPCL KR but also as a replicable blueprint for other refineries aiming to enhance process stability, product quality, and energy efficiency through sophisticated control technologies.

Overall, the initiative showcases a scalable, replicable, and sustainable pathway for refinery digital transformation and operational excellence.

## KEY LEARNINGS

The APC implementation has proven its capability to stabilize complex refinery processes, significantly enhancing energy efficiency and improving product first-time-right (FTR) quality. One critical insight was recognizing the significant impact of ambient temperature variations on the naphtha column separation. By incorporating ambient temperature as a feed-forward variable and adjusting control strategies accordingly, the system effectively neutralized these



fluctuations, leading to more stable and consistent column performance.

Another important learning pertains to the crucial role of the reflux-to-feed ratio in tightly controlled distillation operations. Proper manipulation of this ratio helped prevent the problematic feedback loops commonly encountered—where high re-boiling rates would force high reflux rates, or vice versa, at constant operating temperatures—thereby avoiding instability and optimizing separation efficiency.

The automation of mode changeover through APC emerged as a game-changer. This innovation ensured that transitions between FGH and isomerase modes occurred smoothly, with the plant quickly attaining stable operating conditions and minimizing the time before producing on-grade samples. Automating this complex switch reduced operator reliance and human error, resulting in improved operational reliability and product consistency.

Challenges experienced during the project, such as connectivity issues between APC and DCS, and initial operator unfamiliarity with APC principles, underscored the importance of cross-functional collaboration and comprehensive training. The in-house, vendor-independent development approach fostered deep internal expertise, empowering teams to creatively troubleshoot and customize solutions specific to the plant's needs.

Overall, the initiative demonstrated that carefully tailored, data-driven process control, augmented by digital innovations such as AI/ML predictions and adaptive automation, can substantially elevate refinery performance — both in quality and energy metrics — while promoting a culture of continuous improvement and technological confidence.

## FUTURE PLANS

Building on the successful implementation of Advanced Process Control (APC) at BPCL Kochi Refinery, the next phase of the initiative aims to further elevate plant performance and optimize energy savings through deeper integration with advanced digital technologies. APC, fundamentally a statistical process control tool, will be enhanced by combining it with AI/ML-driven predictive analytics and first-principle-based simulation models. This hybrid approach is expected to provide more accurate, proactive adjustments, enabling finer control and reducing variability even further.

A key focus is the integration of APC with Real Time Optimization (RTO), which dynamically adjusts operational setpoints based on continuously updated economic and process constraints. Coupling RTO with machine learning-based quality and performance predictions will empower the plant to operate closer to true optimal conditions while maintaining robust product quality and safety margins.

These planned advancements will help unlock additional energy efficiencies, improve throughput, and increase product consistency, reinforcing BPCL's commitment to sustainable, cutting-edge refinery automation. The strategy also envisions extending these improvements across other units within the refinery, leveraging in-house expertise and modular digital frameworks for scalable, replicable impact.

This forward-looking roadmap positions BPCL Kochi Refinery to continuously push the boundaries of process control innovation, driving higher returns and operational excellence well into the future.



## ANNEXURE 1:

FGH results comparison in pre and post APC period

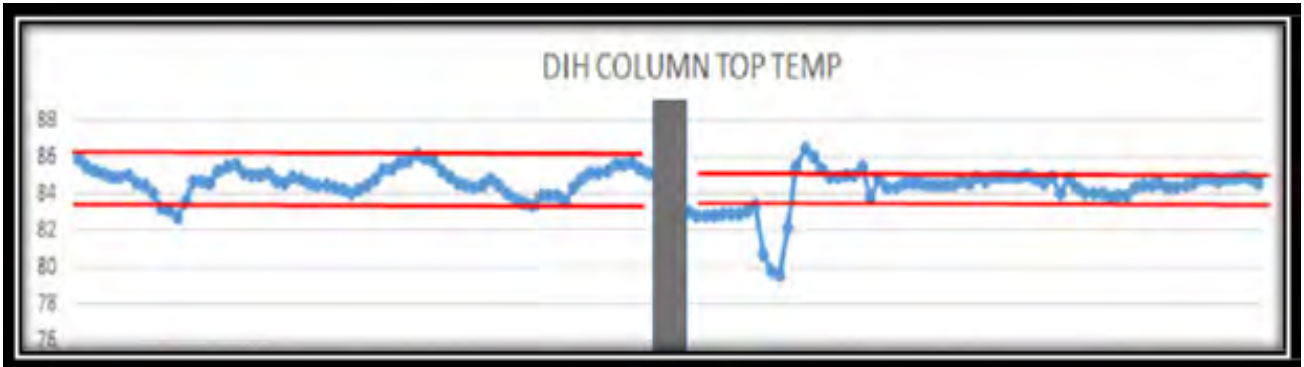
After the implementation of Advanced Process Control (APC) in the Penex DIH unit, several critical operational metrics showed significant improvement:

- **Continuous On-Grade Production:** APC enabled the plant to sustain higher continuous on-grade FGH production, thereby reducing the average run length required for reliable output. This meant the refinery could process more feedstock with fewer interruptions for grade adjustments.
- **Throughput Increase:** The simultaneous optimization of FGH and isomerate flows allowed for higher total throughput without compromising the stringent quality standards of FGH.
- **Energy Efficiency:** By automating and optimizing hot oil reboiling duty and fin fan operation, energy consumption per unit of FGH produced decreased markedly.
- **Faster On-Grade Achievement:** APC drastically shortened the time required to achieve first on-grade FGH output upon mode switch or startup.
- **Product Quality Stabilization:** FGH, known for its narrow and demanding distillation cut, exhibited far tighter control. The number of off-spec batches dropped significantly, as evidenced by a more than 50% reduction in the standard deviation of DIH side cut draw temperature.
- **Operational Consistency:** APC's adaptive strategies led to consistently stable column operation, even under variable ambient and feed conditions, minimizing manual interventions and avoiding the cyclic instabilities previously observed.

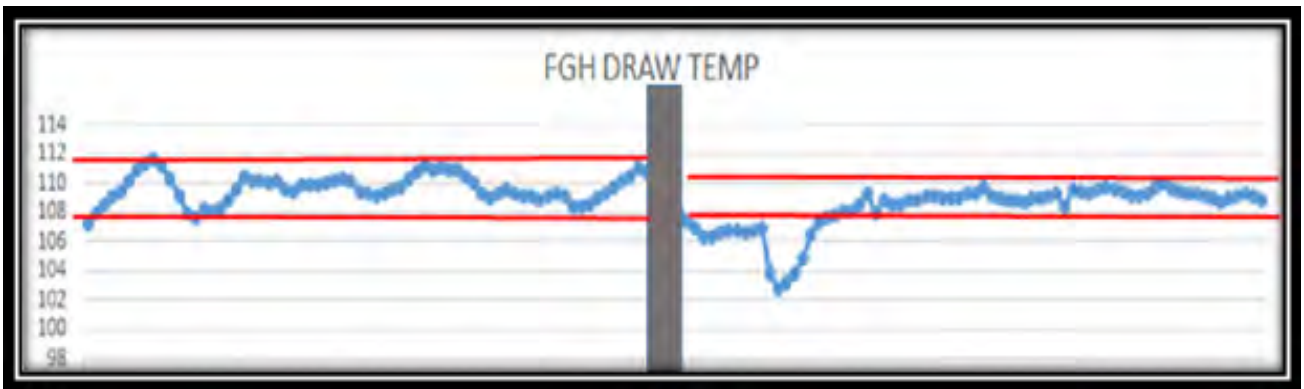
Tank Sample OK Date	With/ WO APC	Run	Run Length	FGH Yield	FGH Yield	Total FGH Sample	FGH Sample off	Side Draw T	unit Charge	AFC Current
			Hour	KL	KL/HR			STDEV	TPH	Amps
07-07-2022	W	1	35	642	18	8	0	0.5	61.0	166
06-07-2022	W	1	48	767	16	12	1	0.5	63.0	202
21-06-2022	W	2	55	833	15	12	0	0.5	60.0	191
07-06-2022	W	3	70	1035	15	16	0	0.6	60.0	145
25-05-2022	WO	4	86	952	11	21	7	1.5	60.0	232
17-05-2022	WO	5	72	990	14	16	5	1.4	60.0	232
10-05-2022	WO	6	76	938	12	20	7	0.9	60.0	230
02-05-2022	WO	7	77	1030	13	20	7	1.0	60.0	230

## ANNEXURE 2:

### Process Stabilization by APC



Left: Pre-APC, right: Post APC



Left: Pre-APC, right: Post APC





# Cooling Effect in Loading Cycle

Aegis Vopak Terminals LTD.  
Shri Rahul Chitroda  
Operation Manager

Energy Efficiency

To avoid the ideal running hours of the compressor for butane tank by cools down the temperature of the tank wall upto -6 to -7 degree Celsius by heat exchanging of the butane from mother tank with the propane of the mother tank.

## BACKGROUND & CONTEXT

On ideal days, the compressor is required to run for the butane tank due to high atmospheric temperatures, which cause the butane in the mother tank to boil. As the product temperature rises, the wall temperature of the mother tank also increases. Consequently, the compressor's running hours are extended, leading to higher carbon emissions and increased noise pollution. To address this, we have introduced a new system designed to cool the wall temperature of the butane tank, thereby reducing compressor usage, emissions, and noise.

## OBJECTIVES

- To reduce power consumption.
- To reduce carbon emission reduction.
- To reduce the running hours of the compressor.

## METHODOLOGY

Butane is supplied to the jetty return line via the in-tank pump from the butane mother tank. In the jetty supply line, propane is delivered through the in-tank pump from the propane mother tank. The propane cargo is diverted to a booster pump, which



discharges into the subcooler. Butane is then directed to the same subcooler, where heat exchange occurs between the butane and the propane from the booster pump.

Through this heat exchange, the butane temperature is reduced from approximately -2 to -3.5 °C down to -15 to -17 °C. The cooled butane then flows to another booster pump, and through its recirculation line, it is returned to the mother vessel. Since the butane is now at -15 to -17 °C and the recirculation line uses the top unloading connection, vapours in the tank begin to condense. After a few hours, this process results in a noticeable reduction in the tank wall temperature.

## CHALLENGES

Always needs to ensure the proper line up.

During the starting of this operation pressure of the tank increases.

## INVESTMENTS

This innovation is done with the availability of the resources. No investment is done.

## QUANTITATIVE OUTCOMES

Parameter	Before Implementation	After Implementation	Improvement (%)
Energy consumption (KW)	19200 KW	0	-
Cost Saving (in Lakhs)	1.63 Lakhs	0	-

## QUALITATIVE OUTCOMES

Improved Operational Stability.

- The tank wall temperature remains more consistent, reducing sudden pressure fluctuations in the butane mother tank.
- Fewer emergency compressor start-ups, leading to smoother plant operation.

Extended Equipment Life.

- Reduced compressor run hours lower mechanical wear and maintenance frequency.
- Pumps and associated piping experience less thermal stress due to more stable operating temperatures.

Enhanced Safety

- Lower vapor generation decreases the risk of overpressure scenarios.
- Less manual intervention is required during high-temperature days, reducing operator exposure to hazardous areas.

Environmental Benefits

- Noticeable reduction in noise pollution from compressors.
- Lower carbon emissions due to reduced energy consumption.

Operational Flexibility

- Ability to run the cooling cycle proactively before extreme temperature conditions occur.

## INNOVATION & UNIQUENESS

Dual-Product Heat Exchange Concept

- Utilizes propane cargo as a natural cooling medium for butane instead of installing separate refrigeration units.

Integration into Existing Infrastructure

- Achieved entirely through reconfiguration of existing pumps, lines, and a newly installed subcooler.
- Minimal downtime and no major structural modifications to mother tanks.

Targeted Cooling via Top Unloading Line

- Strategic use of the top unloading line ensures that subcooled butane



directly condenses vapours at the tank's vapor space, rapidly cooling wall surfaces.

- Can be replicated in any LPG terminal where both propane and butane storage is present.

## SCALABILITY & REPLICABILITY

### Scalability

- The system can be scaled up for larger storage capacities by increasing subcooler size, adding parallel heat exchangers, or upgrading booster pump capacity.
- Flow rates and cooling capacity can be easily adjusted through control valve and pump modifications, enabling use in facilities with varying product throughput.

### Replicability

- The design uses standard LPG handling equipment (in-tank pumps, booster pumps, shell-and-tube heat exchangers, insulated lines) that are readily available worldwide.

## KEY LEARNING

Preventive Cooling is More Efficient than Reactive Compression.

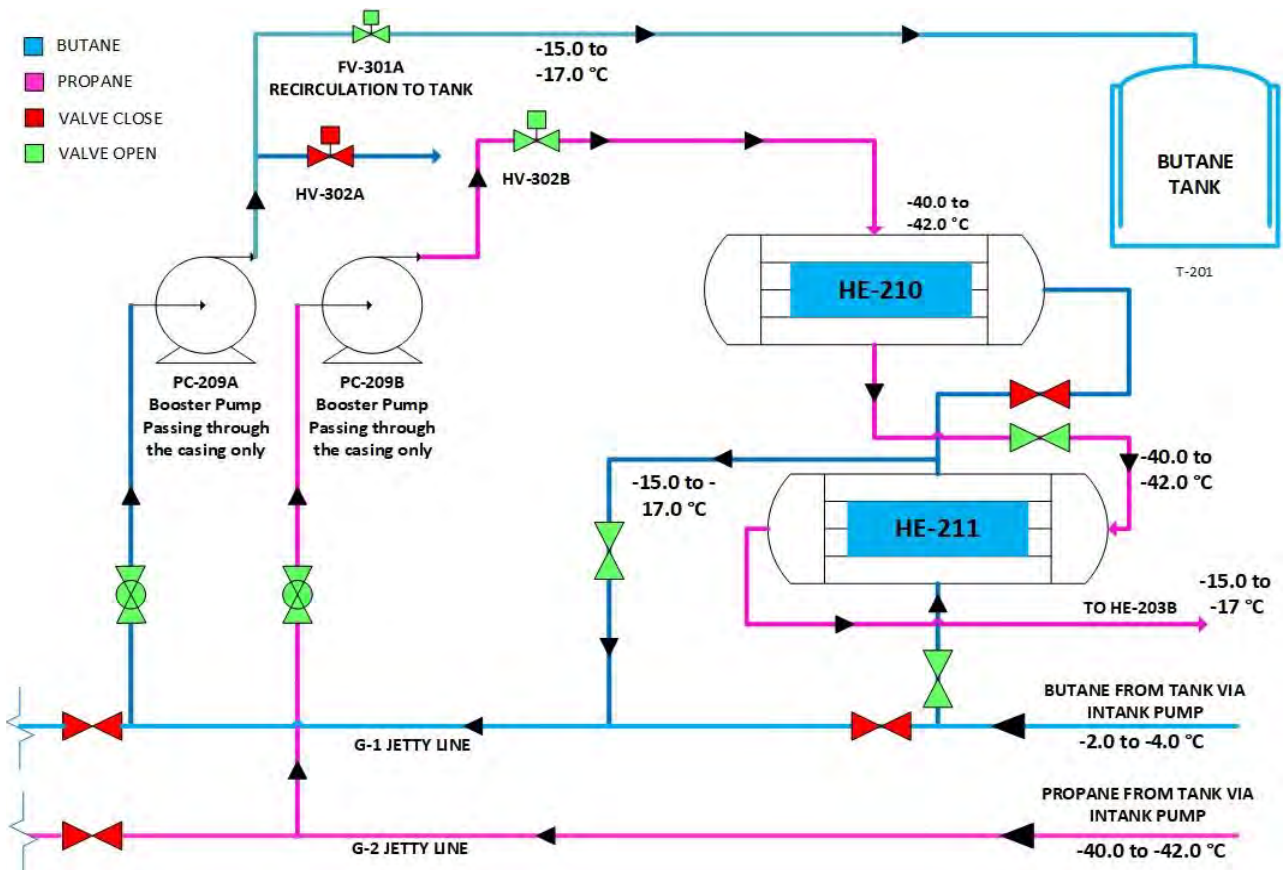
- Lowering the butane tank temperature before vapor pressure rises is more effective and energy-efficient than running compressors after vapours form.

Operational Control is Critical for Performance.

- Continuous monitoring of temperatures and flow rates is essential to maintain optimal cooling without overloading pumps or heat exchangers.

Environmental Benefits Go Hand-in-Hand with Cost Savings.

- Reducing compressor usage not only lowers emissions and noise but also cuts energy costs, creating a dual benefit.





# Trigeneration (CCHP) with Gas Engine-Based Power Generation

Maharashtra Natural Gas Limited (MNGL)  
Shri Pravin Gaikwad  
DGM (Marketing)

Energy Efficiency

Deenanath Mangeshkar Hospital (DMH) has deployed a gas engine-based trigeneration system that captures waste heat from electricity generation for cooling and heating, resulting in substantial cost savings, improved energy efficiency, and reduced reliance on grid power—enhancing operational reliability critical for healthcare services.

## BACKGROUND & CONTEXT

Before implementation, the hospital relied entirely on grid electricity, facing vulnerability to voltage fluctuations, outages and high tariffs (Rs.15/kWh for commercial category)

### Facility context

- Large tertiary-care hospital operating 24x7 with energy-intensive clinical services (OTs, ICUs, diagnostics), central air-conditioning, Central Sterile Supply Department (CSSD), laundry, and kitchens/canteens.

- Pune climate profile (hot summers, humid monsoon) creates a long cooling season; simultaneous needs for electricity, chilled water, and hot water/steam.

### Pre-initiative energy setup (baseline)

- Electricity: Predominantly grid power with diesel generator (DG) sets for backup/peak-shaving during outages. (2.5 MW Electricity load)
- Cooling: Electrically driven centrifugal/screw chillers feeding central chilled-water loops. (Cooling Load - 1000 TR)



- Hot water needs: 90,000 Liter hot water requirement daily

### Challenges faced:

#### **Operational**

- **Grid reliability:** Voltage/frequency fluctuations and periodic outages forced DG starts, risking sensitive medical equipment and OTs.
- **Peak loads:** Daytime peaks from cooling/medical equipment triggered demand charges and occasional DG peaking.
- **Substation:** Challenges primarily related to safety, noise, and space constraints. Safety concerns include the risk of electrical hazards, potential fire hazards, and the need for robust security measures to prevent unauthorized access. Noise pollution from transformers and other equipment can disrupt patient care and staff activities. These challenges highlight the complexities of integrating a substation within a hospital environment.

#### **Cost & efficiency**

- **High energy cost intensity:** Rising tariffs increased operating expenses; electric chillers added significant kWh during peak months.

#### **Environmental & compliance**

- **Emissions footprint:** Diesel combustion elevated local NOx/PM and GHG emissions; stack compliance and spill risk required tighter controls.

#### **Clinical & patient comfort**

- **Thermal comfort risks:** Any chiller or power disruptions directly affected OT/ICU conditions and infection-control parameters.
- **Resilience:** Need for uninterrupted power and cooling for life-critical

services not fully de-risked under the old setup.

### Drivers for change

#### **Reliability & patient safety**

- Deliver **continuous, high-quality power** with grid-independent capability.
- Ensure **redundant chilled-water and assured hot-water/steam** for clinical processes.

#### **Efficiency & cost optimization**

- Increase **total system efficiency** by producing power, cooling, and heat from a single gas-engine prime mover.
- **Cut demand charges** and kWh consumption from electric chillers via **absorption cooling** using recovered engine heat.
- Offset grid kWh with on-site generation (targeting **~2.5 MW**).
- Replace a large share of electric-chiller load with **absorption cooling** driven by recovered heat.
- Reduce **diesel/LPG dependence**, fuel logistics, and storage risks.

#### **Environmental & regulatory**

- Shift to **Piped Natural Gas (PNG)** to lower NOx/PM and CO<sub>2</sub> versus diesel/LPG.
- Improve compliance bearing for air emissions and support corporate sustainability targets (say Scope 1 & 2 reductions).

A trigeneration system was a novel concept for the hospital's engineering team, but economic feasibility was evident:

- On-site generation cost: Rs.7.50/kWh (including natural gas cost)
- Additional investment over grid connectivity: Rs.6 crore (total project cost: Rs.12 crore)
- Annual savings: Rs.3.32 crore (only



from reduced chiller energy costs)

- Payback period: around 2 years

The solution also addressed critical operational concerns such as consistent voltage supply for sensitive medical equipment, reduced UPS dependency, and protection against sudden surges or failures.

## OBJECTIVES

- Ensure consistent, high-quality electricity supply.
- Provide uninterrupted power for critical medical equipment.
- Reduce operational costs by lowering electricity expenses.
- Minimize reliance on UPS and backup systems.
- Protect equipment from voltage surges and fluctuations.
- Avoid the need for large substation infrastructure.
- Offset grid electricity tariff hikes.
- Improve environmental performance by reducing emissions.

## METHODOLOGY

Energy costs are a growing concern for healthcare facilities. In addition, many hospitals have inefficient and crumbling central energy plants. Healthcare owners seek cost effective means of updating aging energy infrastructure, while minimizing risk and positioning vital systems for the future. To meet these needs, Deenanath Mangeshkar Hospital (DMH), Pune decided for Combined Heat & Power (CHP) or cogeneration- complete solution from an MWM.

Implementing a cogeneration system can reduce energy costs and provide superior payback on invested capital. Facilities with access to natural gas can leverage a favourable spark gap, or the price difference between grid-supplied electricity and natural gas. With a CHP pre-packaged power

system, DHM uses less expensive natural gas as fuel in a more efficient power plant. Waste heat created by electricity generation is captured and converted into energy that reduces the need from external sources.

**Technology Selection:** Adopted a gas engine-based trigeneration (CCHP) system integrating power generation, heat recovery, and vapor absorption chillers (VAM).

**Technology Partner:** Green Power International Pvt. Ltd. (EPC & turnkey execution).

### Equipment:

- MWM Gas Engines (1.2 MW capacity each).
- Thermax VAM Chillers for cooling using recovered heat.

### Design Approach:

- Capture exhaust heat from engines to produce chilled water and hot water.
- Replace conventional screw chillers with VAMs to cut electricity usage.
- Modular configuration for scalability and redundancy.

### Implementation Steps:

- Feasibility study and cost-benefit analysis.
- Detailed engineering and layout design.
- Procurement and installation of engines, VAMs, and utility building.
- System integration with hospital's power and HVAC systems.
- Commissioning and performance validation.

DMH has a significant and constant demand for electricity, heating, steam and cooling, and are good prospects for the benefits provided by cogeneration.

The DMH hospital has a capacity of 900 beds, 500 of which are super-specialty beds. Annual overall outpatient attendance is



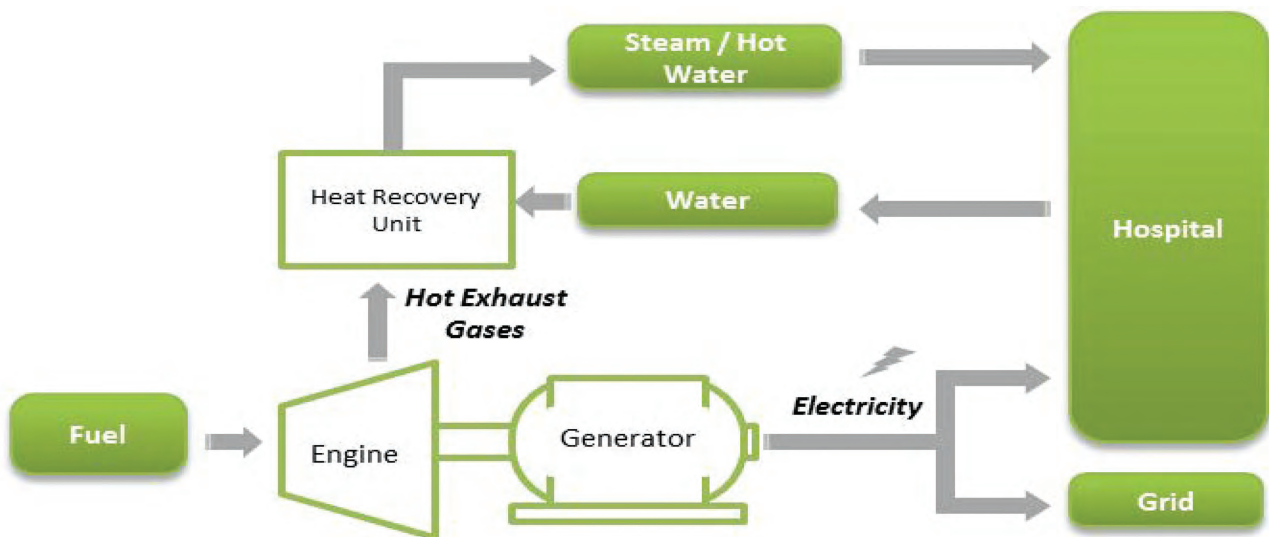
300,000 with 50,000 admissions keeping 20 operating theatres busy six days a week. An intensive care unit (ICU) consisting of a total of 105 beds caters for critical care.

Phase-I accommodation of DMH uses natural light and ventilation, thereby minimizing energy costs. Phase-II, the super specialty wing, is built with green building technology. It generates electricity from compressed natural gas. The heat generated from this electricity is used for vapor absorption and cooling to reduce air conditioning costs. There is a dedicated sewage treatment plant for the recycling, purification and distribution

of water and solar energy for water heating.

### The Resources:

- Each 1.2 MW Engine is connected to 1 No. 352 TR Vapour Absorption Chillers fired on hot gas exhaust and Engine Jacket Hot Water - Total Capacity 1056 TR (2w + 1s).
- Operating Hours Per Annum : 8760 Hrs (24 x 7).
- The entire project has been designed with Primary and Secondary Variable Pumping system installed in the Utility Building.



- The total requirement of the project is 1056 TR in Phase 1 + Phase 2. Presently the installation is (2W + 1S) - 2 Nos. VAM as working & 1 No. as Standby, we also had 2 Nos. 180 TR Water Cooled Screw Chillers as Standby and as backup.
- The Total installation is 1056 TR, with provision of adding another 1.2 MW engine and another 352 TR VAM Working & Standby, taking the total installation to 1408 TR. All 3 VAM as working & Screw Chillers as Standby.
- PHE for hot water generation using engine heat around 50000 Litres per day.

### Overall CCHP system at DMH comprises:

- Gas Genset & Cooling tower (Make - Green Power International).
- Vapor Absorption Machine (VAM), Cooling tower & Pump (Make - Thermax).
- Hot water generation.

**MNGL PNG (piped natural gas) supply** is a single point solution for the above set-up.

### CHALLENGES

The implementation of the **2.5 MW trigeneration system** at Deenanath Mangeshkar Hospital, Pune, was a pioneering initiative aimed at simultaneously generating electricity, chilled water (1,000 TR), and hot



water (90,000 litres/day) using natural gas as the primary fuel. While the project promised significant operational efficiency, energy cost reduction, and environmental benefits, its execution posed multiple challenges that required strategic solutions.

- **Technical Familiarity and Knowledge Gaps**

At the outset, the hospital's engineering team had limited familiarity with trigeneration technology and its operational intricacies. This included understanding optimal load distribution, heat recovery processes, and integration of vapour absorption machines (VAMs) for air conditioning. To overcome this, structured training programs were conducted in collaboration with the technology provider. These sessions covered system design principles, operational control strategies, and maintenance best practices, ensuring the in-house team could confidently operate and troubleshoot the system post-commissioning.

- **Space Constraints within the Hospital Premises**

Hospitals, especially in urban settings, often face acute space limitations for large-scale utility installations. The trigeneration system including gas engines, heat recovery units, and absorption chillers had to be accommodated within just 8,000 sq. ft. (4% of the total hospital area). The design team addressed this by adopting an optimized vertical layout, placing VAM units on the first floor to free up ground space for heavy equipment. This approach not only ensured operational accessibility but also complied with safety and ventilation requirements within the confined footprint.

- **Integration Complexity with Existing Infrastructure**

The hospital's critical care operations could not tolerate downtime, making the integration of on-site generation with the existing grid supply a high-risk challenge. A seamless switchover mechanism was engineered, enabling automatic transition between grid power and trigeneration output without interruptions to life-support systems or essential medical equipment. This required precise synchronization of electrical, chilled water, and hot water supply systems, alongside rigorous commissioning trials to validate reliability.

- **Gas Supply Reliability and Pressure Regulation**

The continuous operation of the trigeneration plant was contingent upon a stable Piped Natural Gas (PNG) supply. Any fluctuation in gas pressure could impact system performance and efficiency. To mitigate this, Maharashtra Natural Gas Limited (MNGL) worked closely with the project team to establish a dedicated gas supply arrangement with pressure regulation equipment installed on-site. Redundant control mechanisms were incorporated to ensure uninterrupted fuel delivery even during peak demand scenarios.

## STRATEGIC OUTCOMES

By addressing these challenges through capacity building, innovative space utilization, robust integration design, and assured fuel supply, the project was successfully implemented without disruption to hospital operations. The trigeneration plant now delivers reliable electricity, air conditioning, and hot water with significantly lower carbon emissions compared to conventional



systems, positioning Deenanath Mangeshkar Hospital as a leader in sustainable healthcare infrastructure.

## IMPLEMENTATION

### Timeline:

- Feasibility & Design: 3 months
- Procurement & Civil Works: 5 months
- Installation & Commissioning: 4 months

### Stakeholders:

- MNGL - Gas supply & technical guidance
- Green Power International Pvt. Ltd. - EPC & execution
- Hospital Facilities Team - Integration & operations

**Outcome:** Fully operational within 12 months, delivering uninterrupted power for 10+ years.

## INVESTMENTS

Cost Component	Amount (₹ in Lakhs)
Capital Expenditure	Rs. 6 Cr. Per 1.2 MW Gas engine with VAM, Chillers & associated equipment
Operational Expenditure (annual)	Rs.1 per kW unit of electricity generated. (Approx. Rs.70 Lakh per annum per 1 MW unit considering daily electricity generation of 19200 kW)
Human Resources	Fully outsourced O&M, in-house monitoring only
Technology Acquisition	Technology Partner-Green Power International Pvt. Ltd. (Specialists in Gas Gensets and EPC Solutions. Turnkey Projects) Engines - MWM, VAM - Thermax
Total Investment	Approx. Rs.18 Cr.

## QUANTITATIVE OUTCOMES

Parameter	Before Implementation	After Implementation	Improvement (%)
GHG Emissions (tCO <sub>2</sub> e)	-	-	Compared to the grid (largely coal-based), natural gas-based trigeneration emits 25-30% less CO <sub>2</sub> per unit of useful energy delivered, aligning with the hospital's sustainability goals.
Energy Consumption (units)	49,000 kW/Day	35,000 kw/Day	28% reduction
Operational Efficiency	-	-	Grid electricity entails transmission losses of 7–9% on average. By generating power on-site, these losses are virtually eliminated. Additionally, waste heat recovery for chilling and heating avoids the energy losses associated with separate chillers and boilers.
Cost Savings (₹ in Lakhs)	Rs.7.82 Lakh/Day	Rs.5.87 Lakh/Day	Significant Opex savings

## QUALITATIVE OUTCOMES

- Uninterrupted, high-quality power for a decade.
- Stable voltage (440V) crucial for sensitive medical equipment.
- Reduced need for large UPS backup.

- Lower noise and vibration compared to diesel gensets.
- Positive environmental impact through reduced grid dependency.

## INNOVATION & UNIQUENESS

- First large-scale hospital trigeneration in Pune region.
- Complete integration of electricity, cooling, and heating from a single fuel source.
- Modular design for easy capacity expansion.
- Seamless grid synchronization for zero downtime.
- Adoption of optimized vertical layout, placing VAM units on the first floor to free up ground space for heavy equipment. This approach not only ensured operational accessibility but also complied with safety and ventilation requirements within the confined footprint.

## SCALABILITY & REPLICABILITY

**Scalability at DMH:** Additional 1.5 MW being installed by Green Power International (GPIPL).

There are 4 major requirements for replicating/scaling of trigeneration system:

- Consistent large cooling and heating requirement, in addition to power requirement by end-user.
- Minimum viable scale equivalent to ~1 MW connected power load, limited by current design of trigeneration systems in India.
- Minimum space requirement of 12m x 15m per MW after accounting for stacking of system.
- Gas prices aligned with electricity rates to maintain viability for end user as gas price is the biggest cost driver for trigeneration systems.

- The business case is strongest where grid tariffs are high, and PNG supply is reliable.

Basis the requirement, 2 potential use-cases with high consistent heating and cooling requirement emerge - hotels and hospitals with minimum 1 MW connected load.

- Hotels have consistent heating demand due to hot-water requirement and laundry operations along with consistent cooling demand.
- Hospitals have consistent heating demand due to hot-water and steam requirement for sterilization, bathing and laundry operations along with consistent cooling demand.

## KEY LEARNINGS

- Early stakeholder buy-in is critical for adoption of new technology.
- Modular and phased execution reduces risk and ensures operational continuity.
- Training local teams ensures long-term performance reliability.

## FUTURE PLANS

We plan to extend the initiative to other high potential customers (large hotels and hospitals) within our GAs. As part of this we plan to do the following:

- Map the potential customers with existing connected load of >1 MW. Additionally, actively map new greenfield establishments upcoming in the region as it is easier to solve for space in greenfield projects.
- Create awareness about the benefits of the solution in one-to-one meetings with the decision makers.
- Jointly deliberate on techno-commercial viability for the customer and support to make it viable.





# Carbon Emission Management in Crude Distillation Unit

Hindustan Petroleum Corporation Limited  
Shri Radha Krishnan  
Senior Manager HSE

Energy Efficiency

This case study discusses various energy efficiency improvement measures taken at design stage in the new CDU-IV at HPCL Visakh Refinery which have resulted in CO<sub>2</sub> emission reduction.

## BACKGROUND & CONTEXT

The energy sector is the largest contributor of global greenhouse gas emissions. As an important stakeholder in an environment conscious industry, improving energy efficiency is a vital avenue for cost-effective reduction of refinery carbon footprint. The potential for energy efficiency improvement exists at majority of the refineries. Lower heater inlet temperature accounts for up to 5% of the total CO<sub>2</sub> emission in a refinery and has a very detrimental impact on Refinery Energy Intensity Index.

## OBJECTIVES

List the specific objectives of the initiative

- Maximization of crude preheat temperature.
- Intense process heat integration to reduce specific steam consumption.
- Improvement in desalting operation to reduce the frequency of pre-heat exchanger cleaning.
- Steam optimization by use of hybrid ejector system in vacuum column.

## METHODOLOGY

- Design Atmos Heater Coil Inlet Temperature is 313 deg C vis a vis conventional crude distillation unit preheat of max upto 300 deg C. This



has resulted in Atmos heater duty reduction by ~20%.

- Crude column overhead vapours are used for preheating the crude, resulting in 8 Gcal/hr reduction in heater duty.
- Process streams such as Kerosene/LGO/HGO-CR are used as re-boiling media instead of stripping steam.
- Two stage Desalter reduces the exchanger fouling tendencies and helped in sustaining the preheat and heater duty in the long run.
- Use of hybrid ejector system (LRVP in final stage).

## CHALLENGES

### Bottlenecks:

- Unavailability of low API crude (high bottom yield) due to Geo-political uncertainties.
- Low SR yield crude processing due to ullage constraint for SR.

### Strategy adopted:

- In time procurement of appropriate spot crudes/opportunity crudes available in the market to be ensured.
- Crude planning has to be inline with design philosophy of CDU-4.

## IMPLEMENTATION

Provide details of how the initiative was implemented, including timeline, stakeholder involved, and any challenges encountered during implementation (max 500 words)

Test Run of CDU-4 has been conducted with Rabi crude. The target preheat of 313deg C was achieved and the subsequent heat integration in crude column overhead and in process streams were achieved. Two stage bi-electric desalter has been commissioned in March-23 and running reliably leading to zero downtime of preheat exchangers.

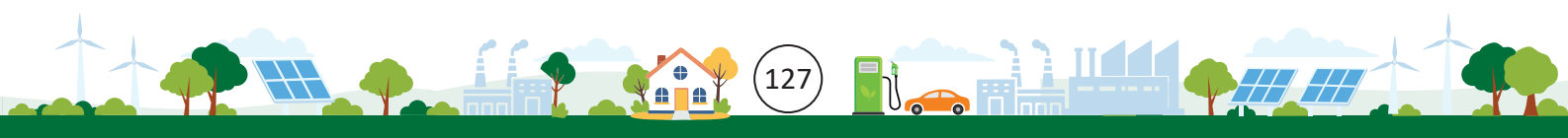
## INVESTMENTS

Cost Component	Amount (₹ in Lakhs)
Capital Expenditure	200000
Operation Expenditure (annual)	9,000Rs./MT
Total Investment	200000

## QUANTITATIVE OUTCOMES

Provide measurable results achieved through the initiative

Parameter	Before implementation	After Implementation	Improvement (%)
GHG Emissions (t CO2e)	-	20,000	-
Energy Consumption (units)	-	7,000	-
Operational Efficiency	-	1.01 (NRGF)	-



## QUALITATIVE OUTCOMES

Implementation of state-of-the-art desalting technology has drastically led to zero downtime of pre-heat exchangers. Intense process heat integration has helped in capacity expansion of refinery without significant increase in carbon footprint of Visakh refinery.

## INNOVATION & UNIQUENESS

The design energy number of CDU-4 as a result of above process heat integration techniques is 1.46 wt% FOE/MT crude oil feed which is the lowest energy number among Indian refinery. Use of hybrid ejector system leading to net steam consumption reduction by 10% in vacuum system.

## SCALABILITY & REPLICABILITY

This proven and reliable process heat integration strategy to reduce the carbon footprint of oil refiners during augmentation of refining capacity with higher bottom yield may prove to be rewarding and sustainable in long run. Addition of pre-flash drum will lead to an additional capacity augmentation.

## KEY LEARNING

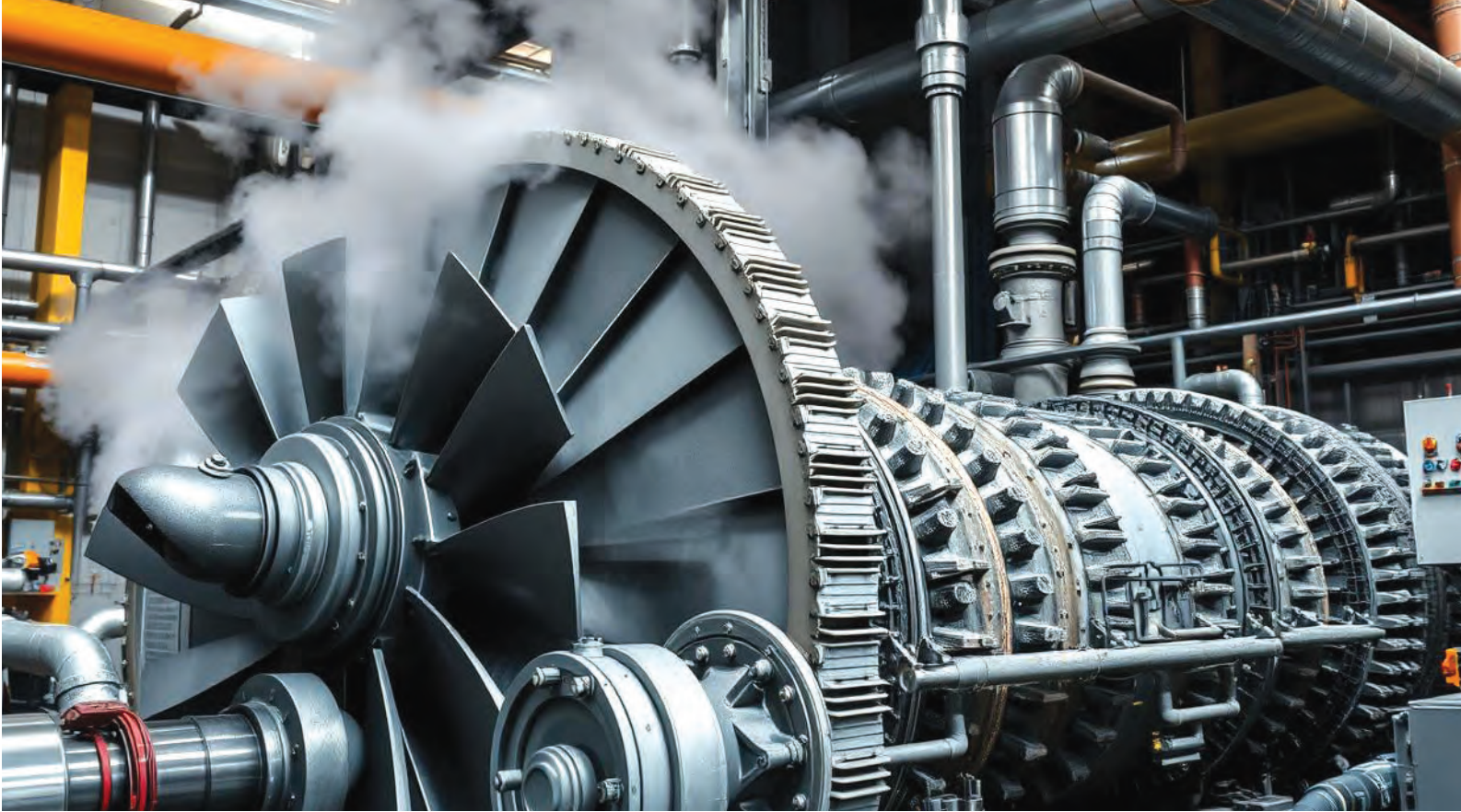
The future of refining operation is evolving continuously in backdrop of being energy efficient and environmentally sustainable. The ever-changing crude characteristics and volatile crude pricing compels refiners to lean towards processing of heavier crudes which possess a significant challenge to crude distillation units from being energy efficient. The above case study has shown us that intense process heat integration with latest desalting technology can be emerged as a game changer for refineries where capacity expansion can be realized within stipulated increase in carbon footprint.

## FUTURE PLANS

Outline plans for further improvements or extensions of the initiative (max 200 words)

1. Addition of pre-flash drum for capacity augmentation.
2. Implementation of organic rankine cycle for power generation from waste heat.





# Real Time Optimization of Power and Steam Generation in Captive Power Plant

Mangalore Refinery and Petrochemicals Ltd.  
Shri Haradi Ashok Anand  
Chief General Manager (Process Engg.)

Energy Efficiency

In refineries and petrochemical complexes, dynamic power and steam demand requires Steam Turbine Generators (STGs) and Gas Turbine Generators (GTGs) to operate at varying loads, where actual efficiencies often deviate despite similar design ratings. To minimize overall fuel consumption costs, a novel algorithm was developed that computes the optimal real-time loading combination of machines. This solution leverages digital twins created through a hybrid approach combining first-principle models with AI/ML techniques, enabling efficient and cost-effective utility generation.

## BACKGROUND & CONTEXT

- Power and steam demand in refineries or petrochemical complexes is dynamic, with STGs and GTGs responding to load variations at different capacities to generate these utilities.
- The objective was to identify, in real-time, whether these machines were operating efficiently and to minimize fuel consumption by optimally loading the machines in tandem with grid power imports, subject to operational constraints.
- While similar machines are expected to have the same isentropic efficiency, actual efficiencies for power and steam extraction



vary. Additionally, the nonlinear relationship between load and SHP inlet flow makes it challenging to manually calculate the optimal loading pattern. This is further complicated by dynamic factors such as fuel costs, grid power costs, machine efficiency, and operational constraints.

- The aspect of explainability in terms of the varying steam levels and power generation cost from individual machines and PRDS so as to give confidence to the panel operator is missing in other market applications claiming power plant optimization capabilities.

## OBJECTIVES

- To compute the optimal loading combination of machines in real-time to minimize overall fuel consumption costs.
- To develop a novel algorithm, combining first-principle models with AI/ML techniques to create digital twins of each machine.

## METHODOLOGY

- MRPL developed digital twins for five Steam Turbine Generators (STGs) using a hybrid modeling approach that combines first-principle models with Machine Learning (ML) techniques. These digital twins calculate the optimal loading combination of STGs in real-time.
- The application fetches real-time power and steam load data from the refinery complex, along with inputs such as fuel costs, grid power costs, operational constraints, and operating costs. It computes the optimal loading pattern among the grid, STGs, and PRDS for steam and power generation.

- Real-time advisories are sent to the operations team via web and mobile interfaces, which also display power and steam generation costs for each machine based on their respective efficiencies. This functionality explains why a specific loading combination is recommended. The application also determines the optimal quantum of power to be imported from the grid, considering fuel costs, grid power costs, and machine efficiencies.
- Additionally, the interface displays marginal costs to explain the nonlinear performance of machines and shows monetary benefits from fuel savings in real-time.

## CHALLENGES

- Data availability and quality are critical for success.
- Accuracy of measurements is essential for reliable optimization.

## IMPLEMENTATION

- MRPL has developed digital twins for all the 5 nos. of steam turbine generators based on a hybrid modelling approach of first principles along with Machine learning models to calculate the optimal loading combination of the STGs on real time basis.
- The application fetches the real time power and steam load of the refinery complex as inputs. Fuel cost, Grid power cost, operational constraints of the machines & PRDS, operating cost are also taken as inputs.
- Real time advisory is made available to operations and process team through web applications.



## INVESTMENTS

Cost Component	Amount (₹ in Lakhs)
Human Resources	-(In house team of 5 members.)
Technology Acquisition	-(In house developed)
R&D and Innovation	-(In house R&D/Innovation team)
Total Investment	No investment as it is 100% in-house developed.

## QUANTITATIVE OUTCOMES

Provide measurable results achieved through the initiative

Parameter	Before Implementation	After Implementation	Improvement (%)
Cost Savings (₹ in Lakhs)	Annual monetary benefit due to this application is estimated at INR 35–55 Crores, depending on marine fuel oil prices.		

## QUALITATIVE OUTCOMES

The benefit in terms of fuel oil saved is approximately 4,350–8,760 tonnes per annum, translating to an MBN saving of 0.22–0.44 for MRPL.

## INNOVATION & UNIQUENESS

The novelty lies in the application of a hybrid model incorporating both first principle concepts as well as Machine Learning (ML) / Artificial intelligence (AI) based algorithms application to compute optimal loading patterns of machines and minimise fuel consumption.

The application also computes and informs the power to be imported from grid based on the fuel cost, grid power cost and efficiency of the machines.

## SCALABILITY & REPLICABILITY

Data availability remains the critical prerequisite for successful deployment. Where relevant sensor and process data are accessible and reliable, the solution can be replicated and scaled effectively.

## KEY LEARNINGS

- Neither first-principles models nor standalone ML models work effectively on their own for this application. A hybrid first-principles + AI/ML model overcame these issues.
- Optimising machines, grid imports and loading based on their efficiency results in significant benefits.

## FUTURE PLANS

Currently this technology has been successfully commissioned in Phase I and Phase II CPP units. Next step is to expand this technology to Phase III and aromatic complex of MRPL and commercialization of this technology to other industries.





# Modification in Pre-Cooling Operation

Aegis Vopak Terminals LTD.  
Shri Marulasiddappa R C  
Dy. General Manager (HSE)

Energy Efficiency

The plan routes warm jetty return propane/butane through a sub-cooler, using cold propane discharged from in-tank pumps, while maintaining conventional precooling of the supply line at a lower flow. This dual approach steadily chills jetty lines, sends cooled product into the mother tanks, and minimizes flash-off vapor. Resulting pressure rises are managed entirely by BOG compressors, eliminating FOG compressor use and lowering carbon emissions—achieving safer, more efficient tank operations.

## BACKGROUND & CONTEXT

Prior to receipt of vessel discharge, Pre-cooling of jetty lines is done to reduce their temperature to prevent thermal stress in CCPL and to avoid pressure surge in Mother tanks due to flash off from inward receipt. On average, precooling operation is done for 12-14 hrs. per vessel regardless of Propane/butane parcel quantity.

Pre-cooling is done by charging propane from Mother tank to jetty supply line, then is received in Jetty return line (G2) via interconnection line from jetty end.

To reduce inward pressure surge due to flash off effect, 1 no of FOG compressor will run entirely during precooling operation, 1 no of BOG Compressor for reducing Flash off and boil off gas generated butane tank (during butane product receipt), 1 no of Propane In-Tank pump for charging jetty supply line, and 1 no of cooling water pump.

## OBJECTIVES

- To reduce power consumption.
- To reduce carbon emission reduction.



## METHODOLOGY

In motive to reduce pressure rise of Propane and Butane mother tanks due to flash off gases from precooling operation, it is proposed to cool Jetty return line warm butane /propane product with Propane In-tank pump discharge in Sub cooler and simultaneously charge Jetty Supply line by conventional Precooling operation, but at reduced flow rate, ensuring steady reduction of temperature in jetty lines.

Propane In-tank pump discharge shall be diverted to Heating train header via chilling supply line to G1 jetty line to sub-cooler gaining additional heat from

warm jetty return product, then routed to propane header, then to LPG blender, and simultaneously shall fill jetty at reduced rate.

Warm propane/butane product shall be routed to mother tanks via sub-cooler thus cooling down, then routed to mother tanks.

## CHALLENGES

Always ensure the proper Line up.

## INVESTEMENTS

This innovation is done with the availability of the resources. No investment is made.

## QUANTITATIVE OUTCOMES

Parameter	Before Implementation	After Implementation	Improvement (%)
Energy consumption (KW)	13,118 KW	7282 KW	44%
Cost Saving (in Lakhs)	1.12 LAKHS	0.62 LAKHS	46%

## QUALITATIVE OUTCOMES

- This operation will generate less flash off vapor, as compared to conventional direct flow of warm jetty line product in tanks, thus, leading to reduced pressure rise, which will be catered by BOG compressors, entirely negating utilization of FOG compressors.
- Another added benefit of this operation is that utilization of additional second cooling water pump and cooling tower fans, for heating in-tank pump discharge, during event of high propane dispatch in both TLFs shall be reduced, as heat is gained from warm Jetty Return products.
- Propane used for cooling of warm jetty line product will be heated in which will then be dispatched to

Truck loading Facility via propane heater by which the cooling water load is proposed to be reduced by the above operation.

- As the operation of modified precooling involves cooling of inward hot vapor/liquid from jetty line by Propane from in-tank pump-which is routed to gantry via Propane heaters, the availability of LPG/Propane Trucks loading operation deems necessary.

## INNOVATION & UNIQUENESS

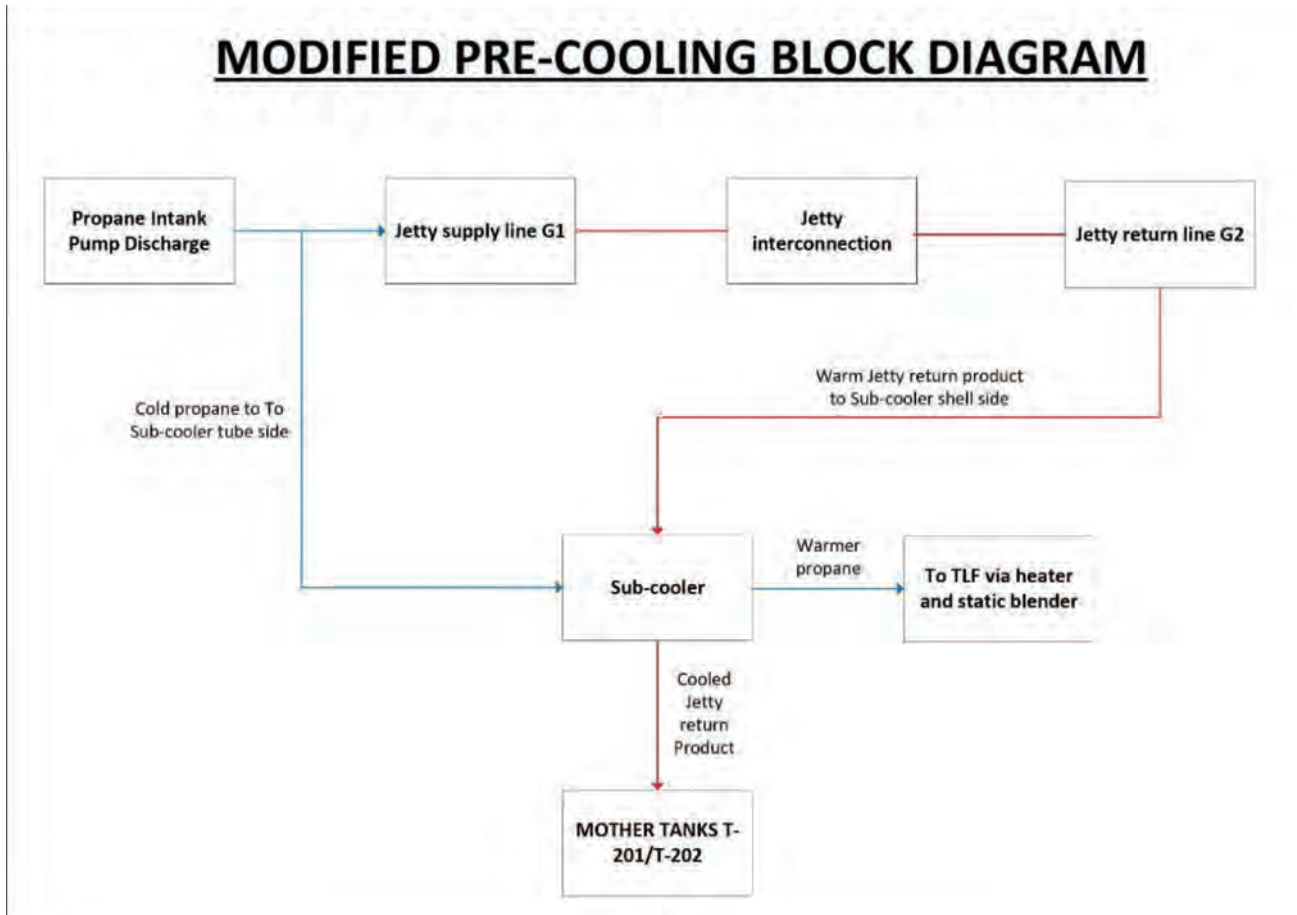
During chilling operation, we don't require to run FOG compressor and also as we reach the -8 to -10 degree Celsius from 20 to 30 degree Celsius in butane product which enters in our Butane mother tank also cools down the temperature of the tank wall. So, the generation of boil off gas reduced.



## SCALABILITY & REPLICABILITY

This is the maximum Efficiency of this operation & to replicate these other terminals need to install a Sub cooler across their jetty pipelines.

## SUPPORTING MATERIALS





# Energy Efficiency Enhancement through Fuel Gas Shift from in Compressor Operations

**GAIL (India) Limited**  
**Shri Yedukondalu Midasala**  
**Chief Manager**

**Energy Efficiency**

**Optimization of Specific Energy Consumption by Switching from High to Low Calorific Value Fuel Gas in Gas Compression.**

## BACKGROUND & CONTEXT

In natural gas compressor stations, fuel gas is a primary energy source for running gas turbines that drive the compression process. The quality and calorific value of this fuel gas significantly impact the overall energy efficiency of the operation. Traditionally, high calorific value gas such as DVPL-1 has been used as fuel due to its stable combustion characteristics. However, this leads to higher specific energy consumption per unit of gas compressed, as well as increased operational costs and carbon footprint.

To address this, an initiative was undertaken to explore alternative fuel gas options available within the pipeline network.

DVPL-2, a lower calorific value gas stream, was identified as a viable substitute with sufficient combustion properties to meet the operational requirements of the compressor units.

This strategic shift aimed to optimize specific energy consumption (SEC) per million standard cubic meters (MSCM) of gas compressed without compromising performance or safety. The change also aligned with broader goals of energy conservation, cost reduction, and environmental sustainability, particularly in the context of India's commitments to reduce energy intensity and GHG emissions in the oil and gas sector.



The project involved detailed analysis of gas quality, turbine performance, fuel-gas interchangeability studies, to ensure seamless integration of DVPL-2 gas. The successful implementation has demonstrated measurable improvements in SEC and has paved the way for replication across similar installations.

## OBJECTIVES

- **Reduce Specific Energy Consumption (SEC):** Achieve a measurable reduction in energy consumption per Million Standard Cubic Meters (MSCM) of gas compressed by utilizing a lower calorific value fuel gas.
- **Optimize Fuel Utilization:** Shift from DVPL-1 (high calorific gas) to DVPL-2 (lower calorific gas) without compromising the efficiency or reliability of gas turbine compressor operations.
- **Improve Cost Efficiency:** Lower operational costs by reducing the consumption of higher-grade fuel gas and improving overall fuel economy.
- **Enhance Sustainability:** Support environmental and sustainability goals by reducing energy intensity and indirect greenhouse gas (GHG) emissions associated with fuel combustion.
- **Ensure Operational Stability:** Maintain or enhance compressor performance, combustion stability, and safety during and after the transition to DVPL-2 gas.
- **Demonstrate Replicability:** Establish a scalable and replicable model for energy optimization that can be implemented at other compressor stations within the network.
- **Comply with Energy Efficiency**

**Mandates:** Align with national and corporate energy conservation mandates, or internal EnMS (Energy Management System) targets.

## METHODOLOGY

### Approach Adopted:

#### *Baseline Assessment and Data Analysis:*

- A comprehensive baseline study was conducted to evaluate the existing specific energy consumption (SEC) levels when using DVPL-1 fuel gas.
- Detailed combustion and turbine performance data were analysed to understand the relationship between fuel calorific value and turbine efficiency.

#### **Fuel Gas Quality Evaluation:**

- online gas chromatograph (GC) analysis were used to determine the calorific values, and combustion characteristics of both DVPL-1 and DVPL-2 gases.
- DVPL-2 was identified as a technically feasible and operationally safe alternative with a lower Gross Calorific Value (GCV) but within acceptable limits for turbine operation.

#### *Combustion Compatibility Study:*

- OEM combustion compatibility guidelines were reviewed to ensure DVPL-2 would not adversely affect turbine performance.
- Historical turbine performance curves and firing margin data were evaluated to confirm adaptability.

#### *Control System Tuning and Instrumentation Adjustments:*

- Minor re-cleaning of fuel gas control valves carried out to ensure stable operation at a different calorific range.
- Continuous monitoring of parameters such as turbine load,



exhaust temperature, and NOx emissions was enabled through the existing PLC systems.

#### **Operational Trial Runs:**

- Trial runs were conducted with support from operations and to validate fuel transition and performance sustainability.

#### **Resource Utilization:**

- Human Resources: Cross-functional team including operations, energy management, turbine specialists, and process engineers.
- Technical Resources: Existing gas chromatograph systems, PLC/SCADA, fuel line infrastructure, and performance monitoring tools.
- Timeframe: The entire shift, including evaluation, trials, and stabilization, was implemented over a period of 3–4 months.

## **CHALLENGES**

#### **Variability in Calorific Value of DVPL-2 Gas:**

**Bottleneck:** The DVPL-2 gas stream had higher fluctuations in calorific value

**Strategy Adopted:** Installed online gas chromatograph (GC) data integration with SCADA for real-time fuel quality tracking. Established operational thresholds for safe calorific value ranges. Developed SOPs to switch back to DVPL-1 in case of significant deviation.

#### **Resistance from Operations Due to Reliability Concerns:**

**Bottleneck:** Operations teams were initially reluctant to switch fuel due to concerns over possible equipment derating or unplanned shutdowns.

**Strategy Adopted:** Conducted technical workshops and shared detailed energy and cost benefit analysis. Arranged pilot testing on one turbine unit with close performance monitoring to build confidence. Shared post-trial success metrics with all stakeholders.

#### **Absence of Historical Performance Data on DVPL-2**

**Bottleneck:** There was no historical performance data for running turbines on DVPL-2 gas at the station, making it hard to predict outcomes.

**Strategy Adopted:** Utilized design documents, regional gas quality data, and similar case studies from other stations. Developed custom data collection formats to capture performance during trial phase using past operational data.

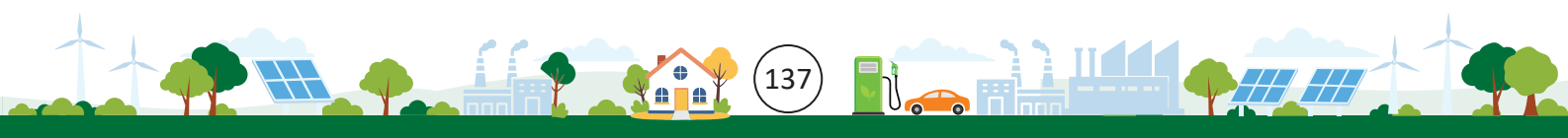
## **IMPLEMENTATION**

#### **Phase 1: Feasibility Study and Planning (Month 1)**

- Collected baseline data on existing fuel gas usage (DVPL-1) and specific energy consumption (SEC) trends across gas compressors.
- Conducted gas quality analysis of DVPL-2 stream using gas chromatograph and compared its calorific value and Wobbe Index with DVPL-1.
- Prepared a detailed implementation roadmap and obtained management approval for pilot testing.

#### **Phase 2: Pilot Testing and Control Tuning (Month 2)**

- Identified one compressor unit for pilot testing under controlled conditions.
- Integrated real-time DVPL-2 gas quality monitoring into SCADA/PLC for dynamic tracking of calorific value.
- Trial runs were conducted at varying load conditions, with continuous monitoring of exhaust temperatures, vibration levels, fuel consumption, and SEC.
- No abnormal behaviour or safety triggers were observed; performance was deemed stable.



### Phase 3: Full-Scale Implementation (Month 3)

- Based on successful pilot results, the DVPL-2 gas stream was gradually introduced to all operational compressors in a phased manner.
- SOPs and fullback procedures were established to revert to DVPL-1 in case of off-spec fuel gas.
- Shift operators and energy teams were trained to interpret new gas quality trends and adjust operations accordingly.
- SEC values and combustion data were tracked daily to ensure the system was optimized.

### Phase 4: Monitoring and Optimization (Month 4–5)

- Post-implementation monitoring showed consistent improvement in SEC values.
- Performance reports were generated weekly and compared against baseline figures.
- Fine adjustments were made to control logic to further optimize gas utilization based on seasonal temperature changes and load conditions.
- GHG emission reductions were also calculated based on reduced fuel usage per MSCM of gas compressed.

### INVESTMENTS

Cost Component	Amount (₹ in Lakhs)
Capital Expenditure	7.7
<b>Total Investment</b>	<b>7.7</b>

### QUANTITATIVE OUTCOMES

Parameter	Before Implementation	After Implementation	Improvement (%)
GHG emission Reduction tCO2 Operational Efficiency Improvement Reduction in Thermal energy consumption per million of gas compressed. GCV of DVPL-2 gas: 9550Kcal/scm GCV of DVPL-1 gas: 9750Kcal/scm.	1705	99.99%	84.21%
Cost of Savings (₹ in Lakhs) Extra energy saved 200Kcal. The average Fuel gas consumption at Jhabua per year was 40Million(mmscm).	275	0	100%
Reduction of Energy consumed in Kcal per Million of Gas compressed. (40x200Kal=8000millionKcal)	8000	0	100%

### QUALITATIVE OUTCOMES

Enhanced Workplace Safety Culture, Improved Equipment Aesthetics and Visual Management, Increased Awareness of Energy Conservation, Better Interdepartmental Collaboration, Skill Development and Knowledge Transfer, Positive Stakeholder Perception, Environmental Stewardship Image.

### INNOVATION & UNIQUENESS

**Customized Pre-Fabricated Insulation Kits:** To accelerate execution and reduce on-site errors, the team implemented pre-fabricated insulation kits (cut-to-size insulation and cladding) based on pipeline layouts and diameters—an uncommon practice in compressor station maintenance.

**Zero-Waste Execution Strategy:** All



## Impact Assessment: Before vs After Implementation

Parameter	Before Implementation	After Implementation
Fuel Gas Type	DVPL-1 (High Calorific Value)	DVPL-2 (Low Calorific Value). Fuel substitution from high to low calorific gas
Gross Calorific Value (GCV)	~9700–9750 kcal/scm	~9500–9550 kcal/scm
Specific Energy Consumption (SEC)	3,90,000/MMSCM of gas compressed	3,82,000/MMSCM of gas compressed. 2% reduction.
Fuel Gas Consumption per MSCM	Higher due to rich fuel	Lower due to optimized combustion. Improved fuel economy.
Compressor Turbine Performance	Stable, but higher energy demand	Stable, with optimized firing margin. Maintained reliability with improved efficiency.
Operational Cost (Fuel Related)	Higher due to richer fuel	Lower due to leaner fuel. Cost savings on fuel consumption
System Stability and Safety	Proven track record with DVPL-1	Stable with DVPL-2 post-control tuning. No adverse effect on operations

dismantled insulation (~60 tons) was disposed of through authorized hazardous waste recyclers with traceable documentation, ensuring full compliance with environmental norms—setting a benchmark in sustainable execution.

**Integration with Energy Performance Benchmarking:** The project was aligned with energy KPIs and sustainability targets. Post-project performance was integrated into the plant’s Energy Performance Index (EnPI) framework, showcasing a measurable approach to insulation efficiency.

### SCALABILITY & REPLICABILITY

The initiative presents a cost-effective, low-risk, and high-impact model that can be quickly rolled out across other compressor stations, delivering energy efficiency, safety enhancement, and GHG reduction at scale. The approach and methodology adopted in this project are highly scalable across other natural gas compressor stations within the organization or industry. Since most such stations operate with similar pipeline

infrastructure and insulation aging issues, the same process can be applied with minor site-specific modifications.

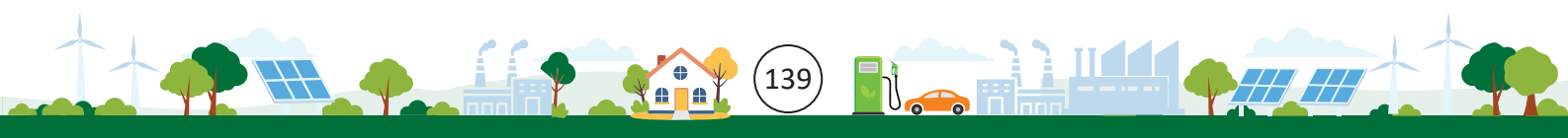
**Standardized Bill of Materials (BOM):** The materials, insulation specifications (e.g., Class X-05), and cladding types used are industry-standard and can be easily sourced and replicated.

**Modular Execution Framework:** The project followed a zone-wise, modular execution plan that can be scaled based on facility size and available shutdown window.

**Pre-fabrication & JIT Supply Model:** This efficient material handling method reduces downtime and is easily adaptable to other sites with minor logistical planning.

### KEY LEARNINGS

- **Data-Driven Planning Maximizes Impact:** Thermal imaging and targeted audits ensured resources were focused on high-loss areas, delivering greater energy efficiency within a limited scope.



- **Parallel Execution Demands Micro-Level Coordination:** Successfully executing insulation work during a planned shutdown requires meticulous sequencing, cross-department coordination, and real-time adjustments.
- **Safety Must Be Engineered into Every Step:** Handling aged insulation involves hidden safety risks. Pre-job hazard assessments, dust containment methods, and strict PPE usage were crucial in avoiding incidents.
- **Pre-Fabrication Significantly Reduces Site Time:** Offsite cutting and preparation of insulation and cladding saved valuable shutdown hours and improved quality consistency.
- **Sustainability Goals Can Be Integrated into Maintenance:** Linking routine insulation replacement with GHG reduction, waste compliance, and EnPI metrics adds strategic value beyond maintenance.
- **Replicable Models Enhance Organizational Learning:** Standardized execution practices and digital documentation developed during this project can serve as a blueprint for future projects across other sites.





# Re-Compression of Stored CNG in Stationary Cascade

Indraprastha Gas Limited  
Shri Aviral Rajeev  
Dy. General Manager

Energy Efficiency

Utilization of Stored CNG in stationary cascade in case of unavailability of Mobile Cascade.

## BACKGROUND & CONTEXT

Mobile Cascade arrive at DB station at pressure of 220 bars and decanted to 30 bars using the hydraulic booster. At this point of time when mobile cascade pressure reaches 30 bars, stationary cascade pressure is somewhere in between 120 bars to 160 bars. In the absence of Mobile Cascade at the Daughter Booster station due to various factors, DB station becomes dry and effects the sale of the station. Though stationary cascade is available at the DB station and filling can be done in vehicles directly through stationary cascade but without using booster and only to certain extent.

## OBJECTIVES

The objective is to consume this residual

pressure in the stationary cascade in absence of Mobile cascade at the DB station and keep the station operational.

## METHODOLOGY

Modification done in P&ID are:

- New gas suction line installed with 2 way valve from stationary cascade medium bank.
- 2 way valves installed in low and medium bank cascade priority.
- NRV installed in suction line.

## IMPLEMENTATION

A Modification is proposed to consume the residual gas in the stationary cascade (Low and Medium Bank) using booster by



connecting the stationary cascade line to the suction line of the Booster as per P&ID

diagram recommended from the OEM.

### INVESTMENTS

Cost Component	Amount (₹ in Lakhs)
Capital Expenditure	Less than 1 lakhs
<b>Total Investment</b>	Less than 1 lakhs

### QUANTITATIVE OUTCOMES

Parameter	Before Implementation	After Implementation
Operational Efficiency	80 hrs dry period	0 hrs dry period

### QUALITATIVE OUTCOMES

- Dry period was reduced to zero against 80 hrs dry in May 25.
- Cost savings against additional MGV hiring of ~Rs 1.16 lacs avoided.
- Better optimization of existing Mobile Cascade fleet.

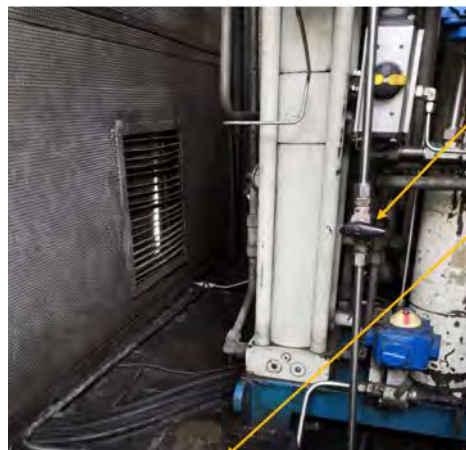
### KEY LEARNINGS

- Dry period was reduced to zero against 80 hrs dry in May 25.
- Cost savings against additional 1 MGV hiring of ~Rs 1.16 lacs avoided.
- Better optimization of existing Mobile Cascade fleet.

### SUPPORTING MATERIAL



- 2 way valve installed in common low and medium bank line going to Cascade from priority.
- Suction line connected from stationary cascade (Medium bank) with 2 way valve



- 2 way valve installed in common low and medium bank line going to Cascade from priority.
- Suction line connected from stationary cascade (Medium bank) with 2 way valve.



# Optimization of Crude Column Pressure at Crude Distillation Unit

Bharat Petroleum Corporation Limited  
Shri Ashok R Chaudhary  
Chief General Manager (Technology)

Energy Efficiency

Lowering CDU-4 crude column pressure from  $\sim 1.90$  to  $1.65 \text{ kg cm}^{-2} \text{ g}$  ( $\leq 41$  API) cut stripping steam by 31 MTPD, heater firing by 18 SRFT/D, and the Energy Intensity Index by 4.7 points (unit) and 0.22 points (refinery). The change saves ₹8.74 lakh/day ( $\sim$ ₹31.9 crore/year) while keeping yields stable; targeting  $\sim 1.60 \text{ kg cm}^{-2} \text{ g}$  is recommended for similar crudes.

## BACKGROUND & CONTEXT

Prior to the optimization initiative, Crude Distillation Unit (CDU) 4 operated the atmospheric crude column (144 C101) at a standard pressure of around  $1.90 \text{ kg/cm}^2 \text{g}$ , in line with the original design specifications for Arab Mix and Mumbai High crudes. While this pressure setting was suitable for the design crudes, it proved to be sub-optimal for processing lighter and more variable blends increasingly being fed into CDU 4, with API gravity extending up to 47.5 in certain cases.

## Key Challenges Faced:

- High Energy Consumption: Operating at higher column pressure demanded more stripping steam and higher charge heater outlet temperatures to maintain separation efficiency, directly impacting fuel consumption and energy intensity.
- Increased Operational Costs: The need for greater steam and fuel input increased the operational costs, leading to inefficiencies in



- energy usage and value loss.
- **Limited Flexibility:** The column's performance under fixed pressure settings constrained operational flexibility, especially with frequent changes in crude blend compositions.
- **EII : CDU 4's Energy Intensity Index (EII)** remained above internal targets, indicating scope for energy performance improvement.

### Drivers for Change:

- **Energy Optimization Mandate:** With a strong organizational focus on energy conservation and carbon footprint reduction, optimizing CDU 4's energy efficiency was a strategic priority.
- **Economic Pressure:** Escalating fuel and steam costs emphasized the need to reduce energy consumption and improve cost-effectiveness of operations.
- **Process Innovation:** Evolving industry best practices encouraged exploration of adaptive process strategies, such as column pressure tuning based on crude characteristics.
- **Sustainability Goals:** Aligning operations with sustainability objectives, including reduction in GHG emissions and resource utilization, provided further impetus to pursue operational efficiency.

These challenges and strategic drivers set the stage for initiating column pressure optimization as a targeted energy-saving intervention.

### OBJECTIVES

- To optimize the column top pressure of CDU4 atmospheric crude column (144 C101) based on the varying crude blend properties.

- To reduce the overall energy consumption by minimizing steam usage and charge heater fuel requirement.
- To improve the separation efficiency and product quality by operating at ideal pressure conditions.
- To lower the Energy Intensity Index (EII) of CDU4, aligning with refinery-wide energy conservation goals.
- To enable flexible operation under different crude blend scenarios, ensuring sustained unit performance.
- To generate measurable cost savings through reduced fuel and utility consumption.

### METHODOLOGY

#### Approach:

- Conducted a comprehensive analysis of the existing column top pressure trends vis-à-vis crude blend characteristics (TBP curve, density, and vapor pressure).
- Identified optimal pressure range for different crude combinations by reviewing historical operations, lab data, and simulation studies.
- Involved cross-functional coordination with Process Engineering, Operations, Planning, and Energy Management Teams.
- Rolled out phased implementation by adjusting column top pressure and monitoring impact on product separation, heater load, and overhead condensing.

#### Technologies Utilized:

- Aspen HYSYS was used to simulate column behavior under varying pressure conditions for different crude blends.
- Advanced Process Control (APC) strategies were aligned to ensure



pressure changes were consistent with real-time plant dynamics.

- Online DCS historian tools (like PI ProcessBook) were used to retrieve and validate historical trends for key parameters.
- Employed energy monitoring dashboards to track EII and steam/fuel consumption post changes.

### Processes Involved:

- Developed a pressure vs. crude blend matrix that defined optimum top pressure setpoints based on key crude parameters.
- Performed real-time testing of top pressure adjustments and observed their effect on overflash, kerosene draw quality, and main column bottom temperature.
- Standardized operation procedures (SOPs) for control room engineers to adapt pressure settings during feedstock changes.
- Ensured all changes were within safe operating limits as per Instrumented Operating Windows (IOW) and Safety Integrity Level (SIL) frameworks.

### Resources Utilized:

- Human Resources: In-house Technology team for analysis and design; Operations team for execution and monitoring; Lab team for product quality validation.
- Technical Resources: Plant DCS, HYSYS simulation licenses, PI Historian tools, and steam/fuel monitoring systems.
- Knowledge Resources: Historical operations data, vendor technical literature for major crudes, CDU4 unit design manuals.
- Time and Coordination: Weekly review meetings, on-field monitoring, and cross-functional team support

ensured successful implementation with minimal disruption.

## CHALLENGES

### Bottlenecks Faced During Planning:

- **Variability in crude mix:**

Frequent changes in crude composition (e.g., varying ratios of high TBP crudes like Arab Heavy or Basrah vs. lighter crudes) made it challenging to define a consistent pressure setpoint.

Strategies to Overcome During Planning:

- **Historical data mining:**

Retrieved 6–8 months of operational data and conducted detailed trend analysis to build initial pressure-crude blend relationship matrices.

- **Simulation validation:**

Used Aspen HYSYS to simulate different crude scenarios and predict pressure impacts, which helped bridge the lack of past documentation.

- **Cross-functional brainstorming:**

Conducted multiple focused discussions with Planning, Operations, and Technical Services teams to validate observations and formulate initial pressure strategies.

Bottlenecks Faced During Execution:

- **Tight product quality specs (especially kerosene and HSD):**

Risk of off-spec product due to altered vapor-liquid equilibrium, especially during pressure optimization trials.

- **Instrumentation response limitations:**

Delays in pressure control loop response or instrumentation accuracy created fluctuations during implementation.



- **Real-time crude switching:**  
Pressure setpoint changes had to align closely with crude tank changes, which occurred dynamically during operations.  
**Strategies to Overcome During Execution:**
- **Phased and controlled trial runs:**  
Implemented pressure changes incrementally with close hourly monitoring to ensure no off-spec production or equipment upsets.
- **Strong operations engagement:**  
Conducted pre-trial briefings and training for panel engineers and shift managers to build confidence and ownership.
- **Instrument tuning and reliability check:**  
Verified calibration and responsiveness of top pressure transmitters and pressure control valves to ensure loop stability.
- **Linking with Planning team schedule:**  
Synced pressure adjustment timings with crude tank farm changeovers to ensure accurate and meaningful outcomes.
- **APC alignment and safety compliance:**  
Reviewed and revised APC limits and ensured all new setpoints remained within IOW limits to avoid process safety risks.

## IMPLEMENTATION

### Timeline of Implementation

The initiative was planned and implemented during February – March 2025 and followed a phased and controlled approach to ensure safety, operability, and performance tracking. The major steps involved:

#### Initial Feasibility Study (Jan 2025):

A process review of the CDU4 column design parameters and operating margins was conducted. Simulations and historical performance data were analyzed to assess feasibility of reducing column pressure without compromising tray hydraulics, separation efficiency, or downstream operations.

#### Stakeholder Consultation & Approval (Late Jan 2025):

The proposal was shared with key stakeholders including:

- Process Engineering Team
- Operations Team
- Energy Cell
- Technical Services
- Instrument & Control (I&C) Team

After a detailed risk-benefit analysis and interdepartmental alignment, the trial was approved.

#### Stepwise Pressure Reduction & Monitoring (Feb 2025):

The column pressure was gradually reduced from 1.90 to 1.65 kg/cm<sup>2</sup>g over multiple operating cycles. Close monitoring was done of:

- Column stability and tray performance
- Charge heater performance parameters (skin temperature, outlet temperature)
- Fuel consumption trends
- Product yields
- Steam load and condenser behavior

#### Performance Analysis (Mar 2025):

Data was collected and compared with baseline operations from March 2024 and early Feb 2025. The analysis showed:

- No impact on product yield or quality
- Reduced fuel firing by 18 SRFT/day
- 31 MTPD reduction in steam usage
- Drop in EII by ~4.7 units
- Daily cost saving of ₹8.74 Lakhs



## QUANTITATIVE OUTCOMES

Parameter	Before Neuron	After Neuron	Improvement (%)
Energy Intensity Index (EII) – Refinery Level	83.40	83.18	0.26
Total Utility Cost, INR Lakhs/ D- Savings	69.30	60.56	12.61

## QUALITATIVE OUTCOMES

In addition to the measurable savings and operational efficiencies achieved through the reduction of crude column pressure in CDU-4, several non-quantifiable but significant benefits were realized:

### Enhanced Operational Stability:

Operating the crude column at a reduced pressure improved temperature profiles and reflux behavior, leading to better column hydraulics and more stable operations. This contributed to fewer disturbances, smoother product draw-offs, and more consistent downstream unit performance.

### Improved Equipment Life and Reliability:

Lower column pressure resulted in decreased thermal and mechanical stress on key equipment such as the fired heater and column internals. This is expected to extend the service life of components, reduce unplanned shutdowns, and lower long-term maintenance requirements.

### Environmental Benefits:

The initiative led to a notable reduction in fuel firing and steam usage, thereby lowering overall emissions of greenhouse gases and other combustion-related pollutants. This supports the refinery's sustainability goals and regulatory compliance with evolving environmental standards.

### Operational Flexibility and Learning:

The successful implementation of this optimization under various crude blends has enhanced operator understanding of column

dynamics and broadened the envelope for safe, efficient operations. It sets a precedent for further energy optimization strategies across similar units.

### Alignment with ESG and Energy Management Goals:

The improvement in Energy Intensity Index (EII) reinforces the refinery's commitment to energy efficiency, aligning with corporate Energy Management System (EnMS) objectives and Environmental, Social, and Governance (ESG) benchmarks.

Overall, this initiative showcases the value of operational fine-tuning and data-driven decision-making in delivering both economic and strategic benefits beyond direct cost savings.

## INNOVATION & UNIQUENESS

In an effort to improve energy efficiency and reduce operational costs in Crude Distillation Unit 4 (CDU4), an innovative initiative was undertaken to optimize the crude column operating pressure. Traditionally operated at 1.90 kg/cm<sup>2</sup>g as per design for Arab Mix and Mumbai High crudes, the column pressure was systematically reduced to approximately 1.65 kg/cm<sup>2</sup>g for processed crude blends with comparable API gravities (30.5–47.5). This optimization was implemented without compromising product yields or distillation performance.

A data-driven approach was followed, with detailed tracking of column pressure, charge heater firing patterns, steam consumption,



product yields, and the Energy Intensity Index (EII). Notably, the initiative led to:

- A reduction in EII by ~4.7 units, indicating a significant enhancement in overall energy performance.
- A drop in MP steam consumption by 31 MTPD and charge heater fuel firing by 18 SRFT/D, while maintaining consistent product yield patterns and quality.
- A 2°C decrease in heater outlet temperature, enabling better equipment longevity and safety.
- Daily operational cost savings of ₹8.74 lakhs, translating to an annualized value addition of ₹31.90 crores.

The unique aspect of this initiative lies in its precision control of column pressure tailored to the crude API gravity range, enabling flexible operation across a diverse slate of feedstocks. It exemplifies a low-investment, high-impact operational strategy that leverages in-depth process analysis and optimization for substantial energy and cost savings. The success of this initiative reinforces the importance of adaptive process control strategies and offers a scalable model for replication across similar refining units.

## SCALABILITY & REPLICABILITY

The successful optimization of crude column pressure in CDU4 presents a strong case for replication across other crude distillation units, both within the Mumbai Refinery and across other BPCL refineries and similar complexes in the industry. The initiative's core strength lies in its data-driven, low-cost, and non-invasive nature, which makes it highly scalable and adaptable across various refinery configurations.

Most crude units are designed with conservative pressure margins to account for broad feedstock variability. However, this

initiative demonstrates that, with detailed monitoring of crude API, flash point, charge heater firing, steam flows, and product yields, column pressure can be dynamically optimized to match feedstock characteristics, significantly improving energy efficiency.

Given that many refineries process similar crudes—such as Arab Light, Arab Heavy, and Mumbai High—this optimization strategy can be directly replicated in units handling comparable blends. Even in units processing heavier or lighter slates, the methodology remains valid, with pressure setpoints adjusted based on real-time crude blend properties.

Furthermore, the approach can be integrated with Advanced Process Control (APC) systems, enabling automatic pressure modulation for enhanced energy savings. Refineries operating multiple CDUs can also benefit from cross-learning and benchmarking pressure-performance profiles, ensuring best practices are uniformly adopted.

The initiative aligns well with the industry's broader goals of energy conservation, emission reduction, and operating cost minimization, while also contributing towards ESG and sustainability benchmarks. With minor instrumentation support and training, it can be scaled across the refining sector without the need for significant capital investment, making it a high-return, easily deployable operational excellence model.

In essence, this initiative sets a precedent for proactive process tuning, providing a blueprint for performance enhancement that can be scaled enterprise-wide or replicated across the global refining network.

## KEY LEARNINGS

The initiative to optimize crude column operating pressure in CDU4 delivered several critical learnings, highlighting both its successes and the challenges encountered during implementation.



## Successes:

- **Energy Efficiency Gains:** A systematic reduction of column pressure from  $\sim 1.90 \text{ kg/cm}^2\text{g}$  to  $\sim 1.65 \text{ kg/cm}^2\text{g}$  resulted in a measurable drop in MP steam consumption by 31 MTPD and charge heater firing by 18 SRFT/D, leading to an estimated reduction of  $\sim 4.7$  points in Energy Intensity Index (EII).
- **Significant Cost Savings:** The optimization yielded daily operating cost savings of ₹8.74 lakhs, equating to an annual value addition of ₹31.90 crores, without compromising distillation efficiency or product yield.
- **Improved Heater Performance:** The charge heater outlet temperature reduced by  $\sim 2^\circ\text{C}$ , offering better control, improved safety, and reduced thermal stress on equipment.
- **Data-Driven Approach:** The initiative reinforced the value of continuous process monitoring and analysis, where API gravity, crude blends, heater parameters, and steam usage were correlated to identify the optimal operating window.

## Challenges:

- **Operational Hesitation:** Initial resistance was observed in adopting a lower pressure setpoint, due to concerns over column hydraulics, product separation, and safety margins.
- **Need for Real-Time Monitoring:** Reliable online data for crude blend API and column pressure was essential. Manual interventions required high operator vigilance,

especially in the absence of advanced automation.

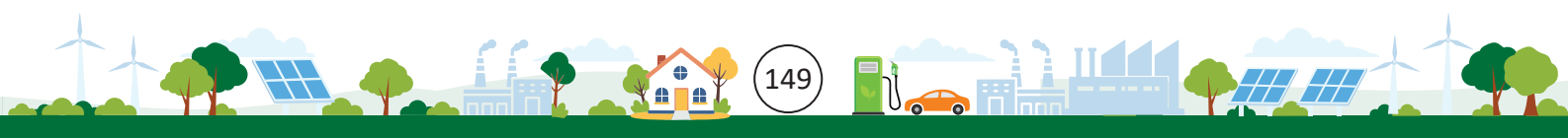
- **Fine-Tuning for Crude Variability:** Frequent changes in crude blend composition demanded constant monitoring and minor adjustments to maintain optimal performance.

The initiative demonstrated that process optimization doesn't always require major CAPEX— with informed analysis and coordination, significant results can be achieved through operational tuning. The experience emphasized the importance of cross-functional collaboration, proactive troubleshooting, and a willingness to challenge traditional operating norms.

## FUTURE PLANS

Building on the success of the crude column pressure optimization initiative in CDU4, several enhancements are planned to sustain and amplify the benefits:

- **Integration with APC Systems:** The first priority is to integrate dynamic pressure optimization into the Advanced Process Control (APC) strategy. This will enable automatic adjustment of column pressure based on real-time crude API, heater firing, and steam flows, minimizing manual intervention and enhancing consistency.
- **Crude Blending Intelligence:** Development of a crude blend tracking system is underway to better correlate column pressure requirements with varying feedstock compositions. This will allow predictive tuning of pressure setpoints in advance.
- **Extension to CDU3 and Other Units:** A similar optimization exercise is planned for CDU3, followed by replication in other distillation units across the refinery, leveraging lessons learned from CDU4.



- Real-Time Dashboards: Implementation of live dashboards for pressure, steam, and heater performance will provide greater visibility to operations and facilitate prompt decision-making.
- Training and SOP Updates: Revised SOPs and structured training modules will be developed to ensure long-term institutionalization of the practice among operations and shift teams.

These planned steps aim to embed pressure optimization as a sustainable, refinery-wide practice, driving continuous energy and cost efficiency.

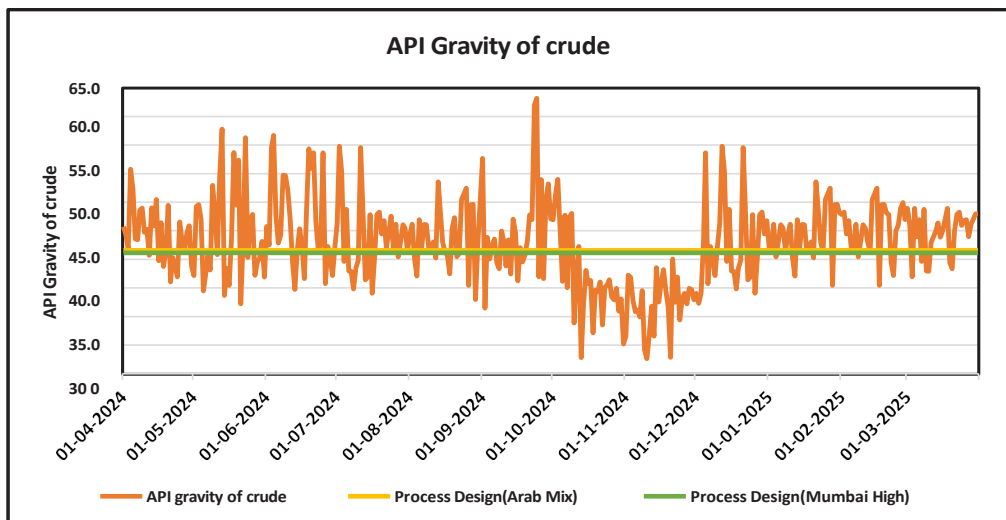
## SUPPORTING MATERIALS

### Recognition/Awards Received

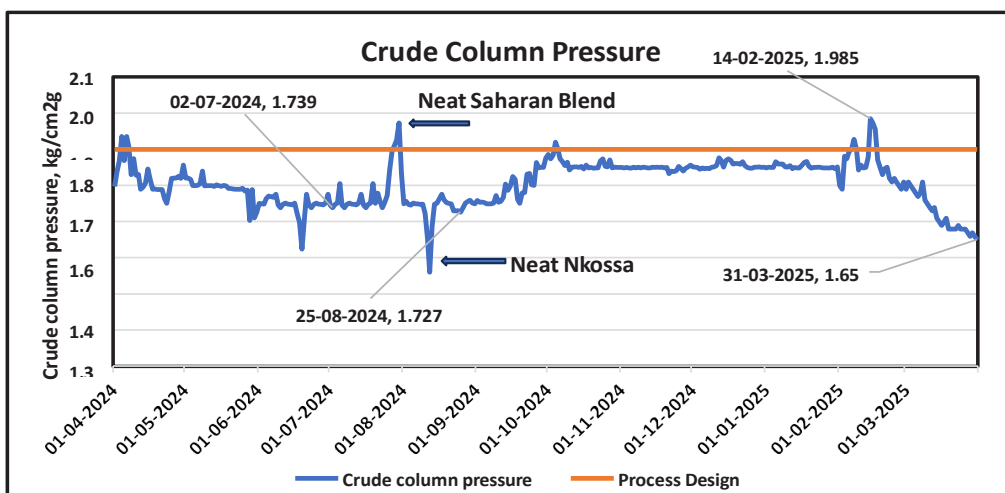
Mr. Pritam Maity's technical abstract titled "CDU4 crude column pressure optimisation at BPCL Mumbai adds annual value of INR 31.9 Crores" has been officially selected for oral presentation at the prestigious ADIPEC (Abu Dhabi International Petroleum Exhibition and Conference) 2025 Downstream Technical Conference, to be held from 3 – 6 November 2025 in Abu Dhabi, UAE.

### Optimization of Crude Column Pressure

CDU 4 typically processes crudes with API gravity in the range of 35.5 – 55.8 (process design 36.6 / 36.2):



In the month of Feb – Mar 2025, crude with API gravity 30.5 – 47.5 were processed. The process design of the atmospheric crude column (144 C101) pressure is 1.90 kg/cm<sup>2</sup>g for the two design cases i.e. Arab Mix (Arab Light: Arab Heavy: 65:35 by wt.) / Mumbai High. Simulation was carried out and subsequently, the pressure of the crude column was reduced, in Feb – Mar 2025, from around 1.90 to 1.65 kg/cm<sup>2</sup>g.



# **Operational Efficiency**



# Deployment of AI-Based CCTV Surveillance

AGP City Gas Pvt. Ltd. (THINK Gas)  
Shri Abhilesh Gupta  
MD & CEO

Operational Efficiency- Digitalization

Valve areas are critical installations in CGD networks and are typically located in remote and unmanned regions. These sites are vulnerable to unauthorized access, vandalism, and unsafe activities. To address this, AI-enabled CCTV cameras were installed and integrated with SCADA to provide real-time surveillance. The AI system detects human presence, motion, and unauthorized activities such as climbing, tampering, or trespassing, and generates instant alerts to the control room, significantly enhancing safety and operational control.

## BACKGROUND & CONTEXT

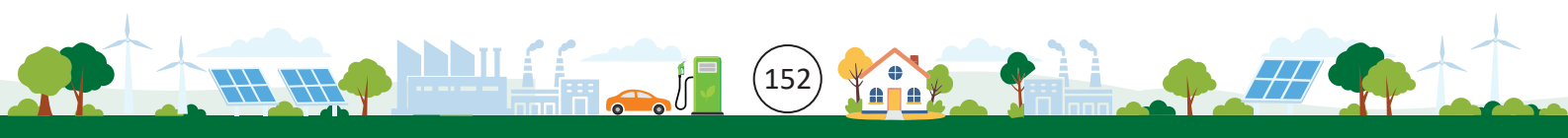
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the control room, significantly enhancing safety and operational control.

## OBJECTIVES

The primary objectives of the initiative were:

- Ensure 24x7 surveillance at remote and unmanned valve stations.
- Detect and alert human intrusion or suspicious activity automatically.
- Prevent vandalism and unauthorized access.



- Integrate live and AI-triggered events into SCADA.
- Improve safety compliance and asset protection.

to avoid false positives (e.g., movement of animals).

- Ensuring SCADA compatibility with video/alert feeds.

## METHODOLOGY

THINK Gas carried out the following methodology:

- Site survey to identify suitable camera placement.
- Installation of AI-enabled outdoor surveillance cameras with human detection features.
- Integration with SCADA alarm system and video feed platform.
- Configuration of alert thresholds (e.g., motion at odd hours, loitering, intrusion).
- SCADA graphics updated to show live video thumbnails and status.
- Alerts configured to trigger pop-ups or alarms at the control room.

## CHALLENGES

THINK Gas faced major challenges which are discussed below:

- Power and connectivity at remote locations.
- Harsh weather conditions affect hardware.
- Network latency or loss during data transmission.
- Initial fine-tuning of AI algorithm

## IMPLEMENTATION

The following steps were implemented in a structured phase wise manner.

- 24 valve stations covered under this initiative across our 19 GAs.
- AI cameras installed with IR/night vision and flameproof enclosures.
- Alerts linked with SCADA and monitored at control centers.
- Real-time monitoring is now active from the central control room.

## INVESTMENTS

Cost Component	Amount (₹ in Lakhs)
Capital Expenditure	36 Lakhs (1.5 Lakhs per station)
Operational Expenditure (annual)	In-House
Human Resources	In-House
Technology Acquisition	Included in camera/NVR cost
R&D and Innovation	-
Others (please specify)	-
Total Investment	36 Lakhs

## QUANTITATIVE OUTCOMES

Parameter	Before Implementation	After Implementation	Improvement (%)
Security Coverage	None	100% surveillance at key valve areas	100%
Incident Response Time	>30 mins (manual detection)	<5 mins (AI alert to SCADA)	>80%
Number of Unreported Events	Several	Zero post-installation	100% improvement
SCADA Integration Level	No Visual Monitoring	Full video and alarm integration	Significant

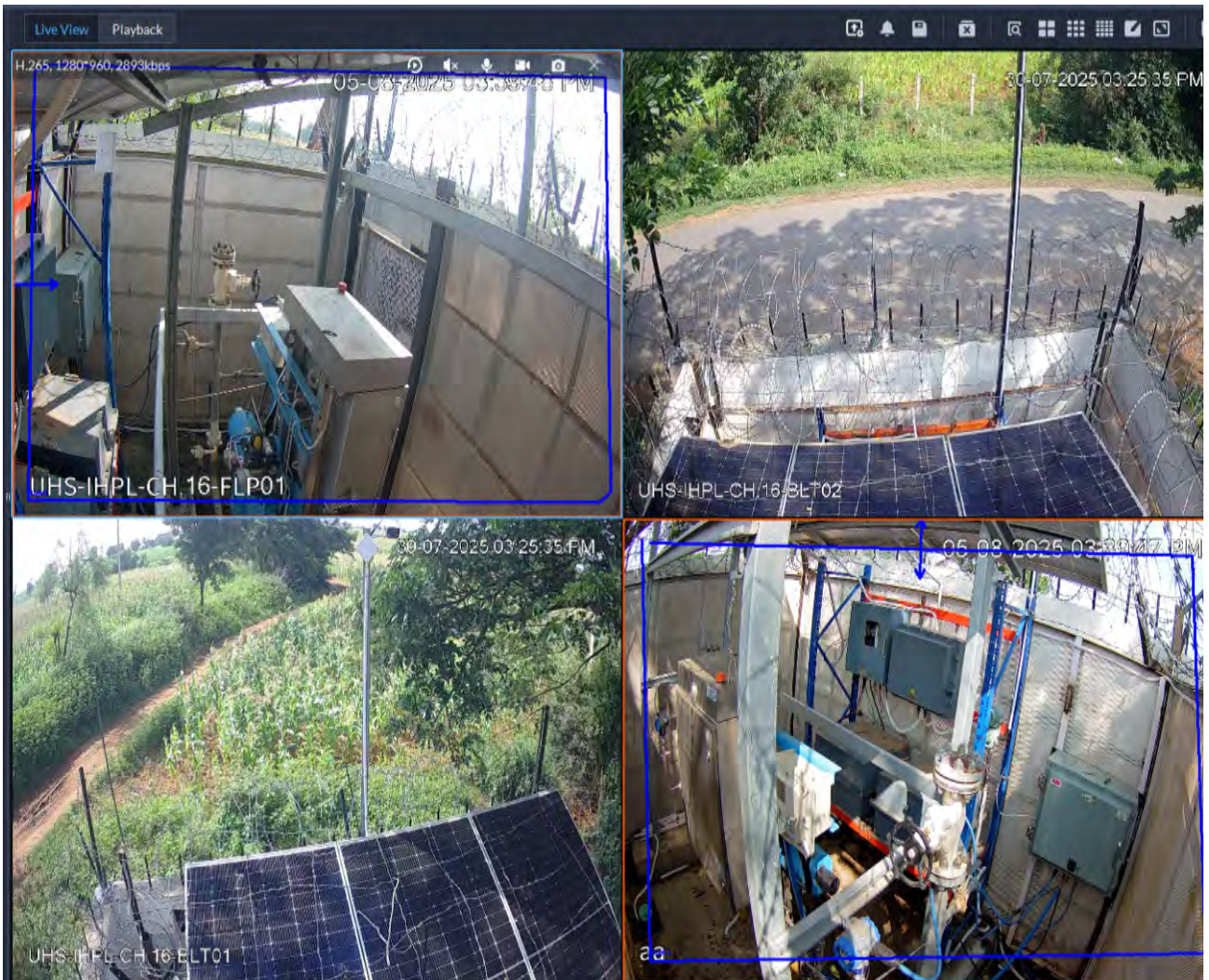


Fig: Deployment of AI-Based CCTV Surveillance at Remote SCADA Valve

## QUALITATIVE OUTCOMES

The pilot provided many qualitative outcomes which are discussed below:

- Improved safety and incident prevention.
- Enhanced SCADA capability with live visuals.
- Peace of mind in monitoring remote and critical locations.
- Reduced physical patrolling cost and effort.
- Supports audit trails and security compliance.

## INNOVATION & UNIQUENESS

This simple yet effective approach helped THINK Gas in utilization of existing assets into better effectiveness by:

- Use of AI for automatic human detection and threat classification.
- Seamless integration with SCADA platform for centralized control.
- Dual-view through mobile/NVR and SCADA screen – redundancy in monitoring.

## SCALABILITY & REPLICABILITY

The modular structure and SOP-based rollout make this initiative highly scalable, as:

- Modular approach can be implemented at any unmanned site.
- Uses solar + battery in remote areas where grid power is unavailable.
- AI-based models are configurable for different types of alerts and behaviors.

## KEY LEARNINGS

THINK Gas concluded that upon successful completion of the pilot, the following key insights were learned:

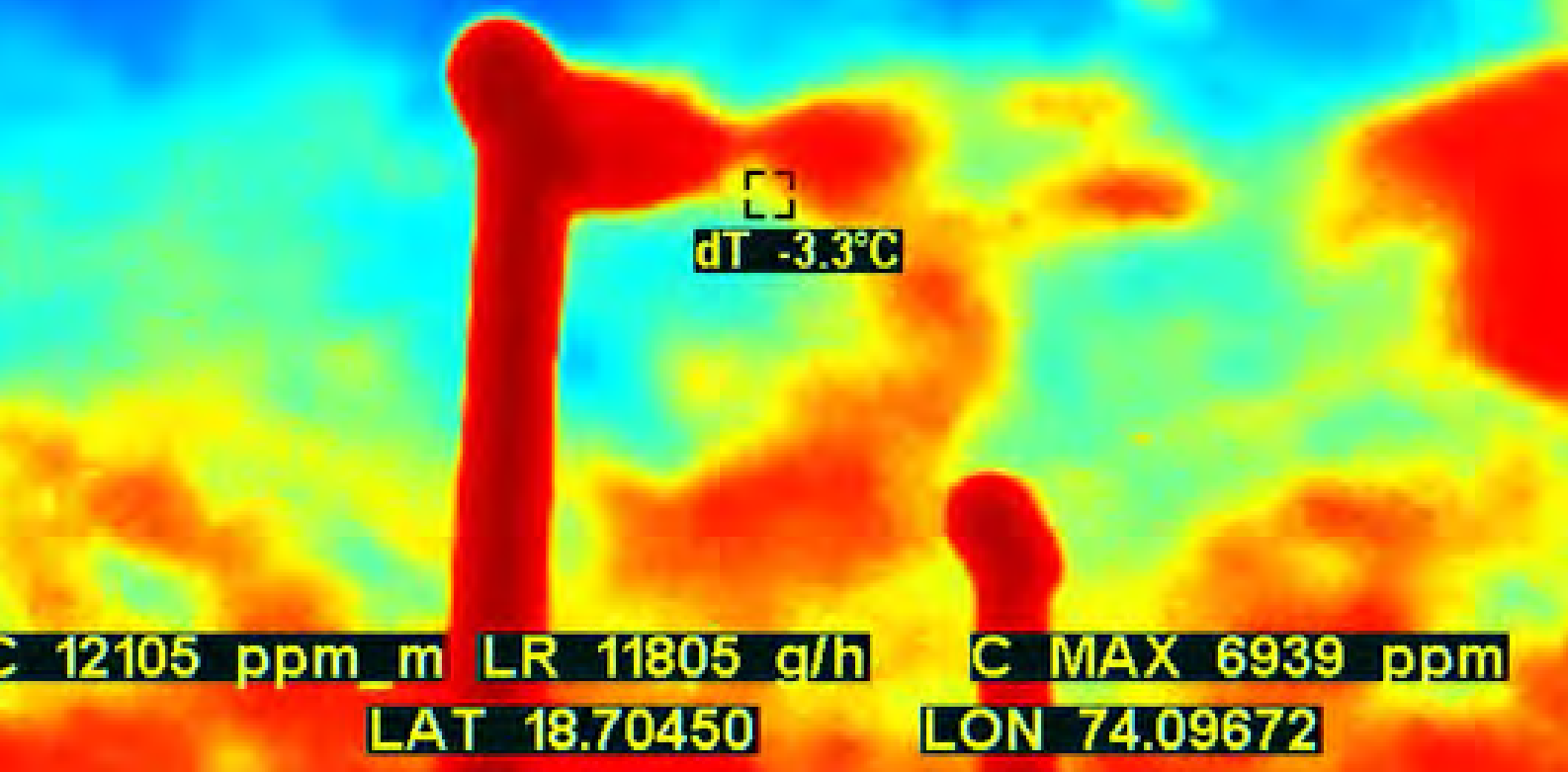
- AI camera alerts reduce reliance on manual monitoring.
- False alarms can be minimized by initial training.
- Integration with SCADA allows operators to make faster decisions.
- Network and power reliability are key to success in remote sites.

## FUTURE PLANS

THINK Gas aims to:

- Expand surveillance to DRS/PRS and other critical unmanned sites.
- Add analytics-based features like PPE detection, crowd gathering alerts.





# Fugitive Emissions Quantification through Quantitative Optical Gas Imaging (QOGI) Technology

Pipeline Infrastructure Limited  
Shri Mukul Singhal  
Senior General Manager

Operational Efficiency-  
Reduction in Emission

Conventional point IR, ultrasonic, and open-path gas detectors need threshold concentration and often miss low-level leaks from welds, bends, or equipment, leaving methane emissions unaddressed and risking safety and the environment. This paper introduces Quantitative Optical Gas Imaging (QOGI) to detect and quantify such fugitive emissions.

## BACKGROUND & CONTEXT

Pipeline Infrastructure Limited (PIL) manages a vast pipeline network, operational since 2008, extending 1,400 kilometers from Kakinada in Andhra Pradesh to Bharuch in Gujarat, including 104 kilometers of spurs and interconnects. This infrastructure features 11 compressor stations (CS) and 31 Metering and Regulating Stations (M&R) across five states and one Union Territory.

Conventional gas detectors such as Point Infrared (IR), Ultrasonic Gas Detectors (UGD), and Open Path Infrared (OPIR) are installed at strategic locations to monitor gas leaks. These conventional detectors require

a minimum threshold of leaking gases for detection and relays information to Fire and Gas detection systems for automated actions. However, these conventional detectors meant for in-situ applications often fail to detect fugitive emissions from non-component sources like weld joints, pipe bends, and station equipment, posing risks to process safety and environmental health due to methane release.

**The initiative reflects PIL's commitment to process safety and proactive approach to detect and arrest fugitive emissions which has a potential for developing into leaks at a later stage.**



## OBJECTIVES

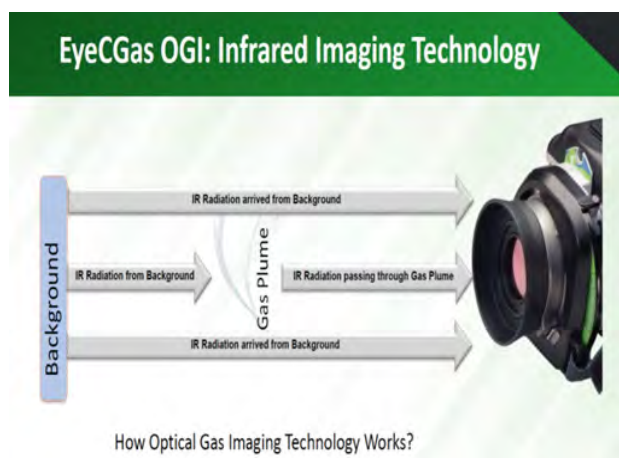
Specific objectives of the initiative are listed below.

- **Identify the fugitive emission sources:** Scan possible leak sources like fittings, flanges, vents, drains etc with the QOGI camera.
- **Quantification of Methane emissions:** Handheld detectors readings to be recorded for identified leak locations during above step.
  - If the reading is greater than 10000 PPMV / 20 % LEL at 1 cm, quantification will be carried out by QOGI camera and classified accordingly.
  - For readings less than 10000 PPMV / 20 % LEL, quantification to be carried out based on empirical formulas.
- Tagging of emission sources: **Leak** locations to be tagged with date, severity clearly demarcated.

## METHODOLOGY

### Technologies:

The infrared spectrum is categorized into short, medium, and long wavelength ranges. Methane predominantly absorbs infrared light in the medium-IR range near 3.3 - 3.4 micrometers. PIL utilized an QOGI camera tuned to this medium-IR wavelength to leverage the methane absorption properties.



This QOGI system, integrating an OGI camera with a tablet computer running proprietary software, analyses IR images to determine the leak intensity pixel-by-pixel and uses algorithms to compute mass leak rates.

## CHALLENGES

Challenges at different phases of the project are given below.

- **Identifying very minor leaks from inaccessible components**
  - Collapsible pipe (5 - 14 Feet) kit made of aluminium fabricated to hold the background sheet with black body coating to optimize background radiation
- **Heat waves interference from hot carbon steel structures nearby**
  - Change the angle of camera to eliminate interference of heat wave effect
- **Ease of identification of detected leak points**
  - Leak locations tagged with date, time, leak number and weather proofed with transparent tapes
- **QOGI camera operating boundary limit is 50 DegC**
  - Umbrella used to prevent exposure to direct sunlight

## IMPLEMENTATION

The scope of work for the methane emissions detection was agreed between PIL and Vendor. Vendor personnel visited PIL facilities for carrying out the detection and quantification through QOGI camera. The site team ensured capturing the leaks with all the details like GPS co-ordinates, leak intensity, equipment description (P&ID details of valves, piping if applicable) etc.

Scanning of the possible leak sources like fittings, flanges, vents, drains etc with the QOGI camera was carried out. Handheld detectors readings were recorded for

identified leak locations. If the reading was greater than 10000 PPMV / 20 % LEL at a distance of 1 cm, quantification carried out by QOGI camera and classified accordingly.

The identified sources were further classified into normal, medium and high categories based on the table below:

Leak Severity	LEL/PPM levels (Indoor)	LEL/PPM levels (Outdoor)	Distance of camera from leak source (M)
High	10% / 5000	40% / 20000	1.5
Medium	5% / 2500	20% / 10000	1.5
Low	2.5 % / 1250	10% / 5000	1.5

- 100% LEL = 5% methane = 50,000 ppm methane

For readings less than 10000 PPMV / 20 % LEL, quantification to be carried out based on empirical formula. Quantification of fugitive emissions based on Annexure 4 OISD Guidelines 224 Page: 27 (Ref US EPA).

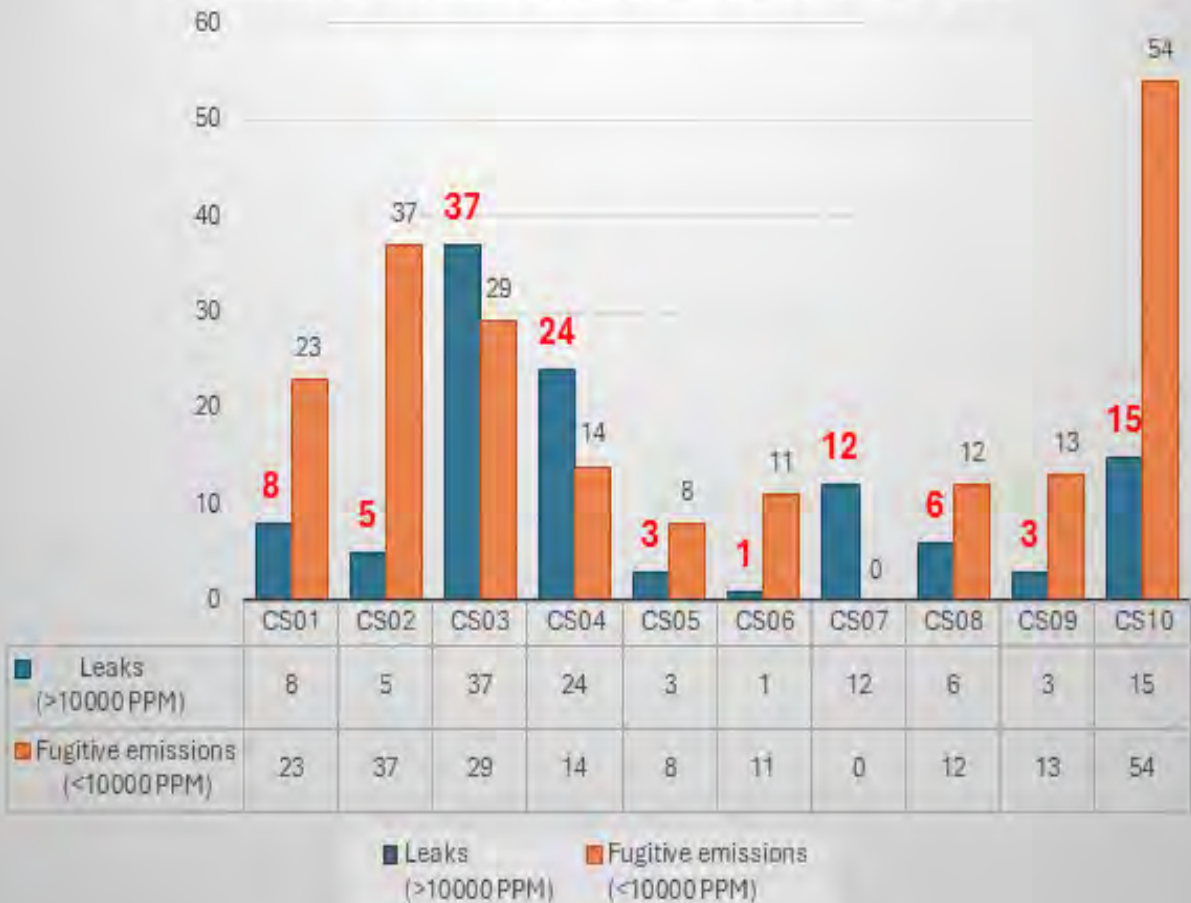
COMPONENT TYPE	SERVICE	CORRELATION #
Valve	Light Liquid (vap pr. > 0.3 kPa)	$(3.84 \times 10^{-5}) \times (\text{ppmv})^{0.74}$
Valves	Gas/ Vapour	$(9.81 \times 10^{-7}) \times (\text{ppmv})^{1.14}$
Valces	Hydrogen	$(1.77 \times 10^{-6}) \times (\text{ppmv})^{0.98}$
Pumps	Light Liquid	$(2.22 \times 10^{-4}) \times (\text{ppmv})^{0.77}$
Pumps	Heavy Liquid	$(3.13 \times 10^{-5}) \times (\text{ppmv})^{0.97}$
Comptessors	Hydrocarbon	$(2.28 \times 10^{-4}) \times (\text{ppm})^{0.77}$
Compressors	Hyd-rogen	$(1.77 \times 10^{-6}) \times (\text{ppmv})^{0.98}$
Safety relif Valves	All	$(2.28 \times 10^{-4}) \times (\text{ppmv})^{0.77}$
Flanges	All	$(1.7 \times 10^{-5}) \times (\text{ppmv})^{0.82}$
Drains	All	$(1.43 \times 10^{-4}) \times (\text{ppmv})^{1.02}$

#### # reference US EPA

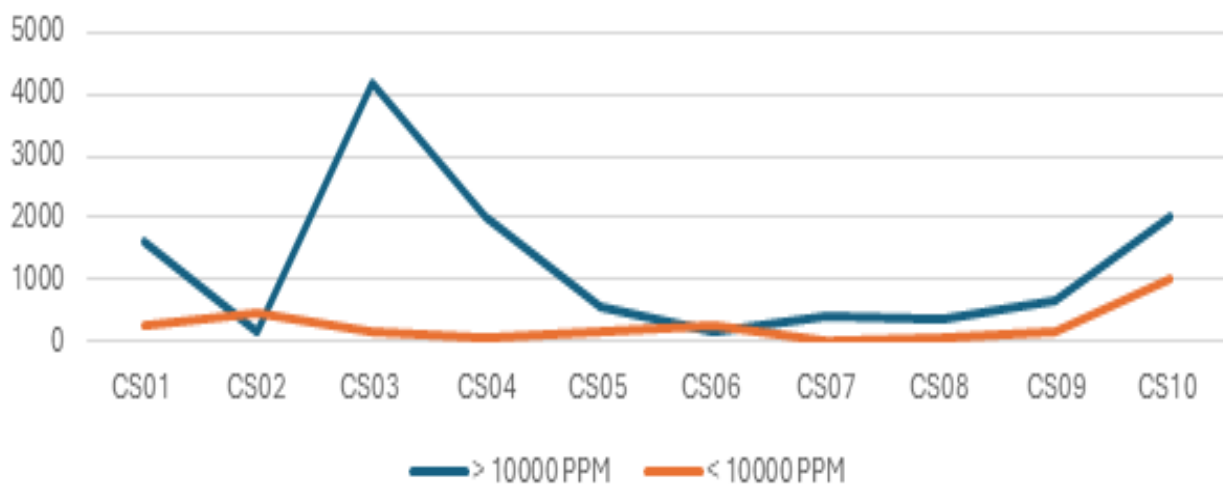
Summary of identified emissions points is mentioned below:



## Methane emission detection\_FY24-25



## CS Wise Quantification SCMD



\*The quantification results of QOGI camera can vary based with ambient conditions. The error percentage can be up to +30% as per open-source data. Also, the tCO<sub>2</sub>e has been calculated based on present leak rates and extrapolating for a 1-year period considering the emissions are continued unless detected.

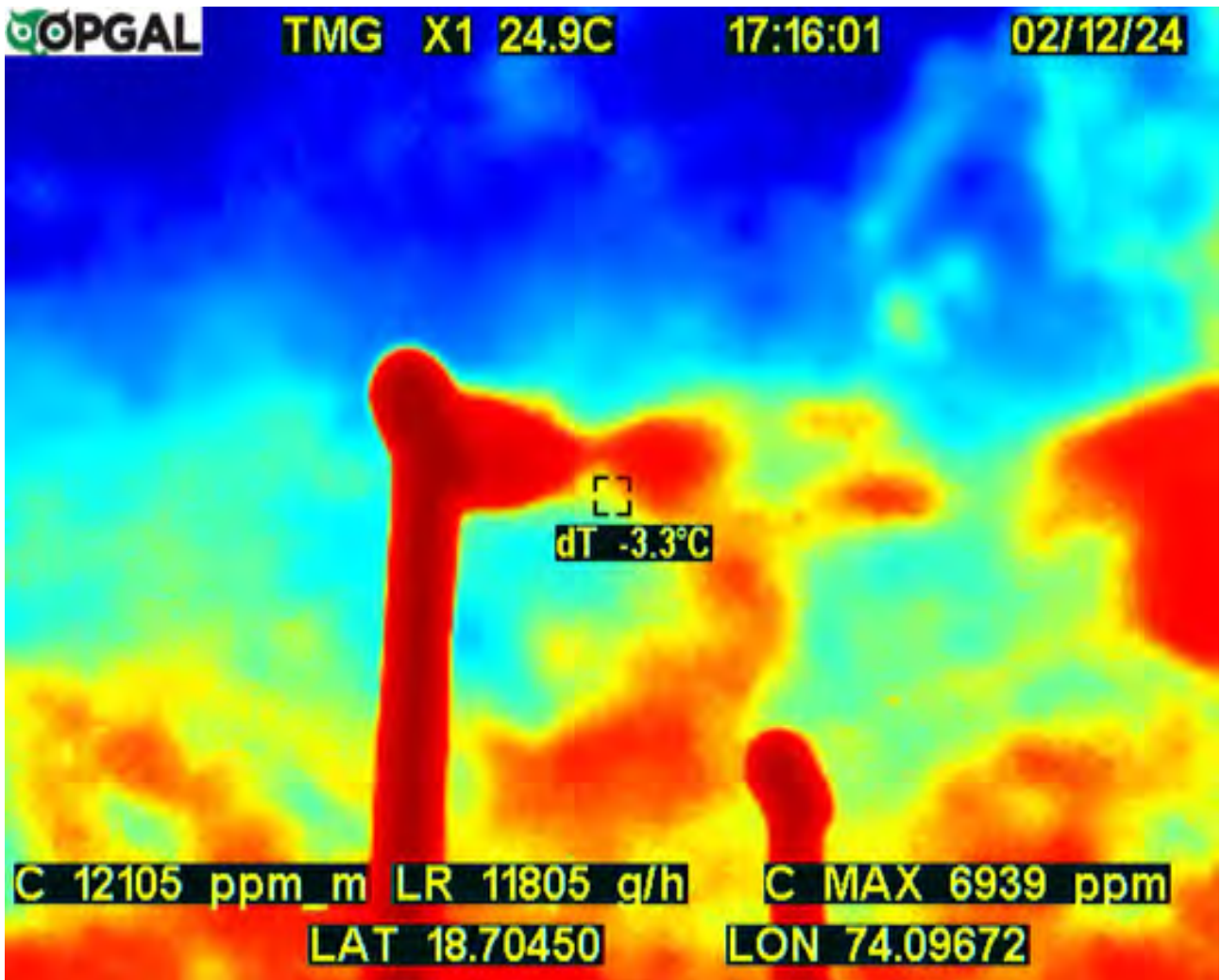


Fig: QOGI Camera Capture

## INVESTMENTS

Cost Component	Amount (₹ in Lakhs)
Capital Expenditure	Nil. QOGI camera services hired annually.
Operational Expenditure (annual)	41
<b>Total Investment</b>	<b>41</b>

## QUANTITATIVE OUTCOMES

Parameter	Before Implementation	After Implementation	Improvement (%)
GHG Emissions (tCO <sub>2</sub> e for 100 years) *CH <sub>4</sub> Global Warming Potential over a 100-year period is 28 times more potent than CO <sub>2</sub> tCO <sub>2</sub> e Formula Used = ((gm/hr measure by QOGI) / 1000) * 24*365*28) / 1000	Unidentified	<b>Identified:</b> 1,06,652 <b>Arrested:</b> *23690 Fugitive emissions arresting is still in progress.	22



## QUALITATIVE OUTCOMES

Non-quantifiable benefits realized through the initiative:

- **Process Safety enhancement:** Ensure detection and arrest of fugitive emissions wherever possible which otherwise poses a threat to safe operating environment.
- **DATA Digitisation:** Visual evidence of leak that can be stored, referred to in future and shared with team members. Leak component/source can be pin pointed
- **Safe distance operations:** Safe distance operation with minimal exposure to leaking gases. Scanning range used for PIL facilities ~2 to 25M

## INNOVATION & UNIQUENESS

Innovative aspects and unique features of the initiative are:

### Innovation:

- **Adaptation of new technology**
  - QOGI is a relatively new technology in Indian context, mainly implemented in North America and Europe for Leak Detection and Repair surveys (LDAR) surveys.
- **Optimization**
  - QOGI is strong as a screening/ LDAR tool and for aggregate/site-level emissions estimates. Actions for arresting the possible emissions sources can be initiated after receiving base line data.

Note: Some emissions points are unavoidable like process vents etc.

### Uniqueness:

- QOGI surveys can be implemented to detect fugitive emissions from non-component sources like weld joints, pipe bends, and station equipment, posing risks to process

safety and environmental health due to methane emissions.

## SCALABILITY & REPLICABILITY

The methane emissions detection survey is being carried out annually for PIL facilities. Similar surveys can be conducted for any Natural Gas handling facility.

## KEY LEARNINGS

Key learnings, including successes and challenges are given below.

- **Importance of Planning**
  - QOGI accuracy depends on the ambient conditions. Meteorological data and site-specific conditions must be kept in mind while scheduling the surveys.
- **Heat waves interference from hot carbon steel structures**
  - Change the angle of camera to eliminate interference of heat wave effect.
- **Identifying very minor leaks from inaccessible components**
  - Collapsible pipe (5 - 14 Feet) kit made of aluminium fabricated to hold the background sheet with black body coating to optimize background radiation.
- **Cross checking the identified points:**
  - Since the accuracy of QOGI can vary with ambient conditions, it is necessary to cross check with handheld detectors.

## FUTURE PLANS

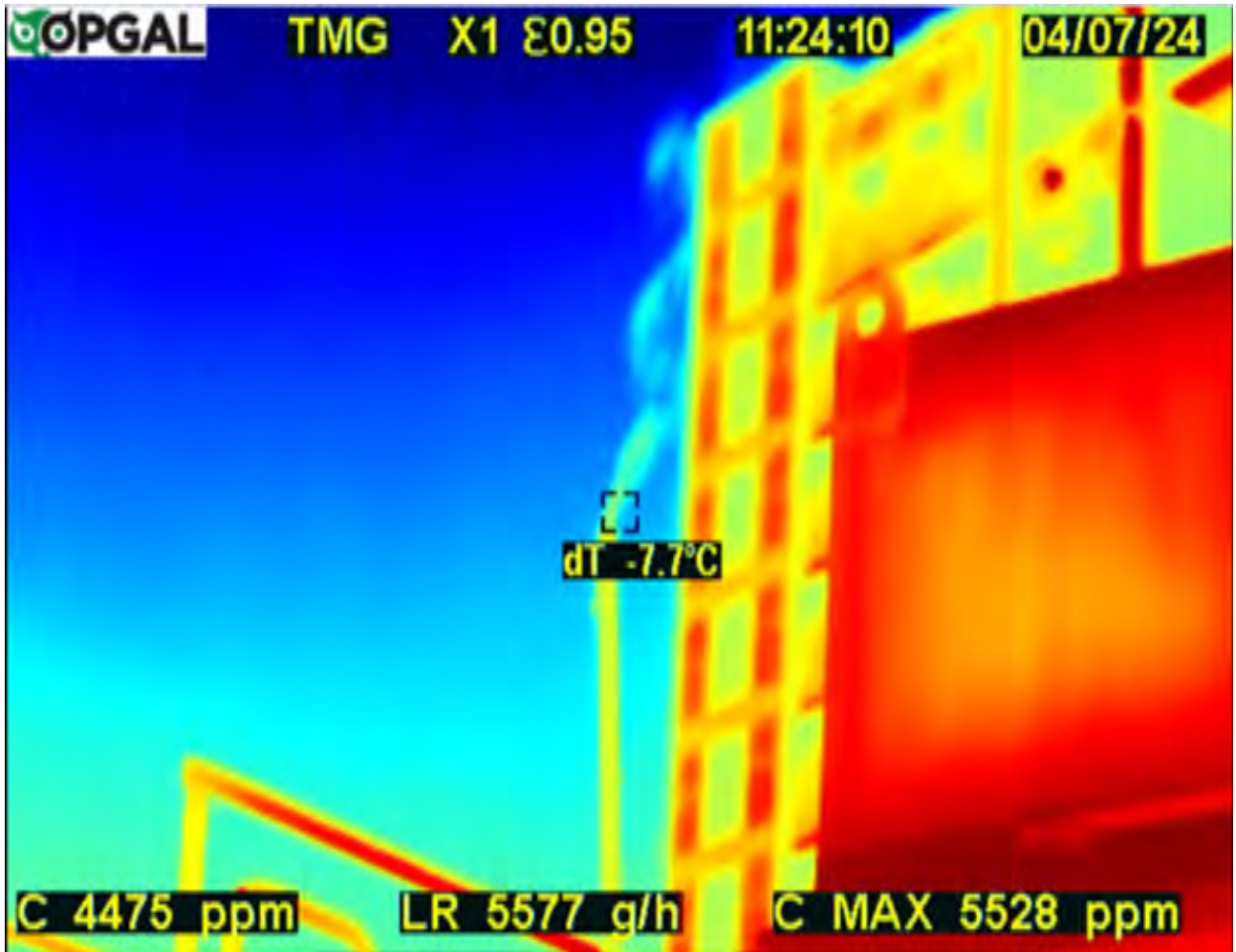
The methane emissions detection survey is being carried out annually for PIL facilities. The identified emissions points are attended based on criticality and feasibility to minimize the emissions to the lowest possible extent. We also plan to capture all the annual survey results on a common platform to incorporate



some analytics like repeat points from previous years, major bad actors etc.

QOGI capture indicating the instantaneous (C) and maximum leak (C MAX) concentration

in ppm, instantaneous leak rate (LR) and deltaT between gas plume and background radiation





# ML Model for Real-time Propylene Purity Prediction

Bharat Petroleum Corporation Limited  
Shri Sainath C  
General Manager (Digital)

Operational Efficiency- Digitalization

Commissioned in 1966 at 50 kbpd, BPCL's Kochi Refinery now handles 15.5 MMTPA (310 kbpd) of 28–45 API crudes with a Nelson Complexity Index of 11.1. It houses a Delayed Coking Unit and an advanced petrochemical complex for specialty propylene derivatives, producing everything from LPG to bitumen. A new AI/ML system predicts and controls product quality in real time, overcoming long-standing quality challenges and boosting operational efficiency.

## BACKGROUND & CONTEXT

BPCL KR produces propylene from the Petrochemical Fluidized Catalytic Cracking Unit (PFCCU) through the Propylene Recovery Unit (PRU). A portion of this output serves as feedstock for the Propylene Derivatives Petrochemical Project (PDPP) complex, while the rest is sold as a finished product. The required purity specification is minimum 99.6%, with any deviation resulting in either off-spec product or quality giveaway.

The Advanced Process Control (APC) inferential provided a broad range of

propylene purity values, varying from 96% to 105%, which often lacks the accuracy needed for precise control. Traditionally, manufacturing and process engineers rely on laboratory results to monitor propylene quality. However, lab analysis is typically conducted only once or twice a day and is subject to delays due to sampling, transportation, and testing time.

When purity deviates from the required specification, the DCS engineer must intervene and take corrective action in the PRU column. In case of off-spec, unit

generally requires 12– 16 hours to bring the purity back within the acceptable range, leading to substantial production loss.

Given these limitations, there was a critical need for a predictive model to provide real-time purity estimation. This real-time prediction enables its use as a controlled variable in the PRU- DMC system.

To address this, a machine learning model based on the Gaussian Process algorithm was developed to predict propylene purity in real-time. A unique deployment model was successfully implemented, integrating multiple technologies and software such as MATLAB, IP21, Excel, Visual Basic, Python and SQL. This first-of-its-kind integration was achieved entirely through in-house efforts.

## OBJECTIVES

- Predict propylene purity in real-time using a Machine Learning model.
- Deploy the model in real time and make the predicted results available on the plant DCS.
- Integrate the predicted purity as controlled variables within the APC to automate and optimize process control.
- Minimize quality giveaways and ensure the off-spec production reduction.

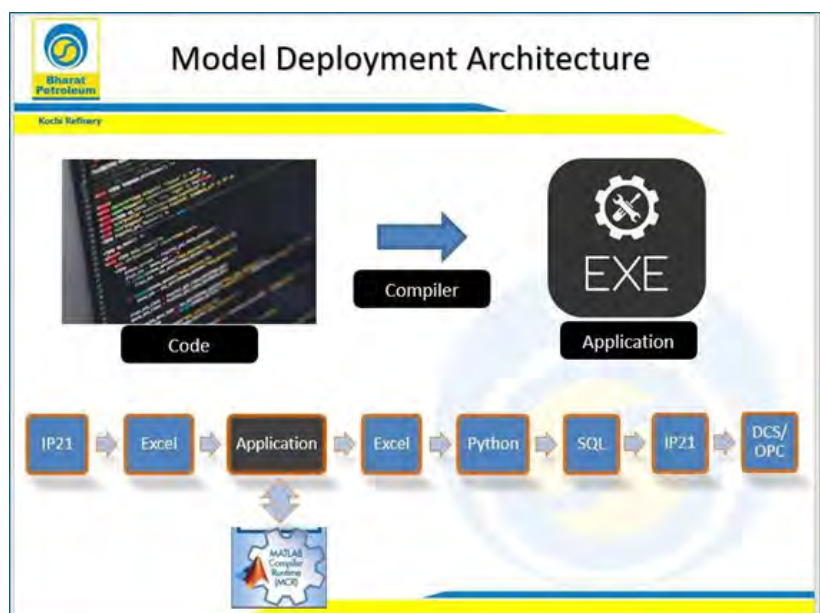
## METHODOLOGY

Machine learning (ML) has emerged as a highly successful artificial intelligence technology that utilizes complex algorithms to learn from historical data, enabling real-time predictions. To embark on an ML project, the availability of digital historical data and robust computing power are essential prerequisites. Fortunately,

BPCL KR possesses Aspen InfoPlus-21, a data historian that stores minute-wise data for various refinery tags, accumulated over years. This vast volume of data presents an exceptional opportunity for ML modeling, leveraging high end computers and sophisticated algorithms.

ML Modeling: In the context of BPCL KR, a comprehensive study of the PFCCU and PRU plants was conducted, identifying 17 critical plant tags. Historical data was extracted from the IP21 data historian for model development which required close coordination with the manufacturing team. Extensive data preprocessing was carried out, involving the treatment of missing values, outlier filtering, timestamp alignment, and transformation of raw sensor data into meaningful features suitable for machine learning. A key challenge was configuring the data flow from IP21 to a MATLAB-based environment, which involved building robust communication pipelines and coding for dynamic data handling. MATLAB provides a wide array of machine learning algorithms, and over two months were spent evaluating and validating various models using performance metrics like  $R^2$  (Coefficient of Determination)

and RMSE (Root Mean Square Error). Based on these metrics, Gaussian process algorithm was found to provide the best fit



for the data, facilitating accurate predictions.

**Model Deployment Architecture:** To harness the benefits of the ML prediction model, a unique deployment architecture was successfully implemented at BPCL KR. This architecture integrates multiple technologies and software tools such as Matlab, IP21, Excel, Visual Basic, Python, SQL, and DMC. We believe this in-house initiative marks the first-ever integration of its kind within BPCL, showcasing the refinery's commitment to cutting-edge technology adoption.

## CHALLENGES

Throughout the various stages of the project, we encountered several challenges and implemented strategies to overcome them:

**Understanding the Problem and Gathering Data:** Initially, we faced the challenge of engaging the plant operation team and gaining their time and attention. To address this, we conducted extensive discussions, clearly explaining the project's goals, expected benefits, and rationale. The plant's digital champion played a crucial role as a change champion, assisting us in accessing data and influencing other team members throughout the project.

**Model Development Challenges:** During the model development phase, we encountered several technical challenges. Initially, we had to identify the critical input parameters affecting propylene purity and corresponding IP21 historian tags, which required close coordination with the operations. We then carried out extensive data cleaning and preprocessing, including handling missing values, filtering out outliers, aligning timestamps, and transforming raw sensor data into usable model features. Configuring input flow to the MATLAB-based server posed another hurdle, along with dynamic coding for data processing. MATLAB's wide array of machine learning algorithms made model selection a complex task. We spent over two months evaluating different algorithms using

performance metrics such as  $R^2$  (Coefficient of Determination) and RMSE (Root Mean Square Error) to ensure the best fit.  $R^2$  helped assess how closely the predictions matched actual outcomes, while RMSE measured the average magnitude of errors. After thorough analysis and validation, we selected the Gaussian Process Regression algorithm.

**Technical Deployment Challenges:** When the model was ready, we encountered technical difficulties in deploying it on the plant's DCS panel. As a workaround, we deployed the model on the cloud and provided access to all stakeholders. Initially, there was some discomfort among plant managers in accessing the machine learning output on the cloud. However, we consistently emphasized and demonstrated the accuracy of the predictions, gradually building confidence among plant personnel.

**Unique Architecture for Plant DCS Integration:** To bring the machine learning predictions to the plant's DCS system, we devised a unique architecture. Through extensive discussions with the IS (Information Systems) department, we could successfully deploy the model on the DCS panel.

**Convincing the Advanced Process Control Team:** Finally, we had to convince the Advanced Process Control (APC) team to consider the machine learning predictions as controlled variables in their processes. To accomplish this, we showcased the robustness and accuracy of the predictions, highlighting how they could enhance the APC system's performance.

## IMPLEMENTATION

In order to deploy the model successfully, the transfer of output from Matlab to IP21 was a crucial step. Despite multiple attempts and extensive discussions with all stakeholders including M/s MathWorks, M/s AspenTech, and BPCL KR Digital/IS, finding a viable solution proved challenging. However, recognizing the importance of transferring the output to the Distributed



Control System (DCS) via IP21, an alternative process was devised. This process involved three key steps where necessary changes were implemented:

- **Installation of Matlab Compiler Runtime (MCR) on a standalone machine:** BPCL has a strict policy regarding the use of permitted software, and MCR installation required special consideration. To overcome this hurdle, a nonstandard software installation form was filled out, presenting MCR as a special case and justifying its importance for the project.
- **Transfer of Matlab output to SQL server using Python automation:** Python, being a freely available programming language, was

selected for this task. Similar to the MCR installation, Python was installed by following the nonstandard software installation form route, ensuring compliance with BPCL's policies.

- **Transfer of output from SQL server to IP21:** This step necessitated further discussions and collaboration with the IS team to establish a seamless connection between the SQL server and

IP21. Through persistent efforts and effective communication, the required changes were implemented successfully.

By making these necessary modifications and overcoming the challenges, we accomplished the deployment of the project.

## INVESTMENTS

Cost Component	Amount (₹ in Lakhs)
Capital Expenditure	4.0 (High end machine cost)
(Remarks: The MATLAB-licensed server hosted on a high- end machine, with all models deployed through a custom in- house architecture)	
Technology Acquisition	0 (existing tools used)
Total Investment	4.0

## QUANTITATIVE OUTCOMES

Parameter	Before Implementation	After Implementation
Others (offspec reduction)	Purity deviations caused substantial production losses	ML-driven process control significantly reduced off-spec generation and increasing revenue potential by ₹2 crore per year by reducing the quality giveaways.

## QUALITATIVE OUTCOMES

**Operational Excellence:** The ML model has significantly enhanced the accuracy of propylene purity prediction, enabling better process control decisions and minimizing product quality deviations.

**Improved Collaboration:** The project fostered cross-functional collaboration between

digital, IS, APC and manufacturing teams, paving the way for a more data-driven work culture.

**Change in Mindset:** Teams began shifting from reactive to proactive decision-making, utilizing predictive insights rather than relying solely on manual control and post-event analysis.



**Upskilling of Workforce:** In-house teams acquired competencies in AI/ML, including model development, validation, and integration into control systems - boosting internal capability for future digital projects.

**Cultural Shift:** The success of this ML model has fostered wider acceptance of AI-driven solutions within operations and control teams.

**Knowledge Building:** Internal teams gained substantial hands-on experience in ML modelling, deployment, and integration.

## INNOVATION & UNIQUENESS

**Closed-loop ML-APC Integration:** This project is the first of its kind in BPCL and, as per our belief, the first in India's downstream oil & gas to integrate a machine learning model directly with an Advanced Process Control (APC) system in a feedback loop, enabling real-time control action based on ML outputs.

## SCALABILITY & REPLICABILITY

**Scaling up the results achieved involves the following plans:**

**Replication:** Based on the success of this project, we replicated the implementation across other purity and quality prediction use cases within our organization. The following new initiatives were successfully developed and deployed.

CDU-3 AGO, CDU-2 HGO, DCU LCGO, CDU-3 VDO, DCU HCGO, and VGOHDT Diesel

### D95 prediction models

MSBP FGH IBP prediction model and PFCCU Depropaniser bottom product quality prediction

**Expansion to Other Predictive Use Cases:** We plan to explore additional predictive use cases by leveraging the same machine learning infrastructure and expertise.

**Continuous Improvement and Training:** To enhance the performance of our machine learning models, we will continue to explore

advanced algorithms, incorporating new data sources, and leveraging emerging technologies to further improve prediction accuracy. We will also invest in training programs and workshops to enhance the skills of our workforce.

## KEY LEARNINGS

Initially, while developing the model, we faced several challenges - including identifying the critical parameters and corresponding IP21 tags, cleaning the data, determining how to provide real time inputs to the MATLAB server, and coding within the MATLAB environment. Selecting and finalizing the appropriate machine learning algorithm also proved to be a complex task. Once that is done, running the developed algorithm on a standalone machine came to us as a second hurdle due to limitation of licenses in Matlab. We identified the availability of Matlab compiler runtime for resolving this problem.

During the implementation phase, we encountered a significant challenge in transferring the prediction output from Matlab to Aspen IP-21 in real-time. Despite engaging in extensive discussions with both M/s Aspentech and M/s MathWorks for a period of more than 6-7 months, we were unable to find a satisfactory solution.

As a workaround, we devised a solution to populate the prediction output on the cloud and shared access with all relevant stakeholders. This innovative idea was generated in-house, reflecting our commitment to finding practical solutions to complex problems. While this approach provided us with immediate access to the prediction output, we recognized the need to integrate it into the plant's Distributed Control System (DCS) for seamless and efficient operations.

To achieve this integration, we developed a unique architecture that involved the collaboration of multiple technologies, including Matlab, Excel, Python, SQL Server,



IP21, and others. This architecture was carefully designed to ensure the smooth flow of data and enable the prediction output to reach the DCS level. The intricacies of this integration were discussed in detail during our internal meetings, as well as at various technical forums and conferences, where we shared our experiences and insights with industry peers.

## FUTURE PLANS

**Wider Model Replication:** Extend this ML-APC framework to other quality-critical parameters such as IBP, D95 and other prediction.

**Improve Accuracy:** Continuously retrain the model using updated data to maintain high accuracy and performance. We are also

planning to convert them into self-learning models.

**Team Training:** Continue training internal teams on ML tools and techniques for wider adoption.

- Certificate of Appreciation from FICCI for propylene purity ML Modeling, Nov'23
- Machine learning initiatives selected for presentation at Energy meet by CHT, Sept'22
- Won the National Awards for excellence in PSU for Digital Initiatives Jul'23
- Presented the Machine Learning-based Quality Prediction Model at India Energy Week (IEW), Feb 2025.





# Digital Transformation for Operational Efficiency

IHB Limited  
Shri Anmol Bara  
Chief Manager (Ops. & HSE)

Operational Efficiency- Digitalization

Implementing Digital control and enhancing operational efficiency in KGPL pipeline through installation of SCADA, PLCs, LDS and eOffice.

## BACKGROUND & CONTEXT

KGPL is one of the longest LPG pipeline projects in India, designed to meet the country's energy requirements by transporting LPG directly to bottling plants located in Uttar Pradesh, Madhya Pradesh, and Gujarat. The project is aligned with the national objective of achieving net zero emissions.

The KGPL pipeline spans a total length of approx. 2800 km, encompassing a robust infrastructure that includes 6 injection points, 7 pumping stations, 22 feeding stations, and 168 sectionalizing valve (SV) stations.

For efficient operation and monitoring of

the cross-country pipeline, it is envisaged to establish a robust Communication Infrastructure for KGPL. A 24-Core Optical Fiber has been laid along the pipeline route, serving as the backbone for data and voice communication between Stations and Repeater Stations. This digital communication system enables round-the-clock monitoring, control, and operation of pipeline parameters.

The SCADA (Supervisory Control & Data Acquisition) system, based on microprocessor PLCs (Programmable Logic Controllers) and has been commissioned for this pipeline and integrated to the Master Control Station (MCS). The SCADA system consists of an MCS at main location and Station Control Centers



(SCC) at attended stations of the pipeline. The heart of the control system at each station is the microprocessor-based PLC (Programmable Logic Controller) system. The PLC collects process data from the field, processes the data & issues commands to the field devices accordingly

Given the linear nature of pipeline networks, they are vulnerable to single points of failure such as OFC cuts, power outages, and telecom equipment failures. To enhance network availability and ensure uninterrupted communication, a backup communication path using MPLS (Multiprotocol Label Switching) technology has been implemented across KGPL locations.

Additionally, IHB Limited has adopted e-Office, a digital document management system that facilitates capturing, archiving, and retrieving documents efficiently. It enables electronic movement of files with comments/remarks, consolidation of related documents, noting, approvals, and final issuance of correspondence, thereby enhancing administrative efficiency and transparency.

## OBJECTIVES

To ensure efficient, secure, and uninterrupted operation and monitoring of the KGPL cross-country pipeline through the deployment of a robust digital communication infrastructure, including a 24-Core Optical Fiber Cable (OFC) and MPLS-based backup communication, integrated SCADA systems with microprocessor-based PLCs, a centralized Master Control Station (MCS), and Station Control Centres (SCCs). The implementation also includes eOffice for digital document management to promote administrative efficiency, transparency, and streamlined workflows.

## METHODOLOGY

To achieve seamless operation, monitoring, and control of the KGPL cross-country

pipeline, the following multi-tiered methodology has been adopted:

### Communication Infrastructure Deployment

- A **24-Core Optical Fiber Cable (OFC)** has been laid along the entire pipeline route to serve as the primary communication backbone.
- This high-capacity OFC ensures secure and reliable transmission of data and voice communication between Main Control and Repeater Stations.

### SCADA System Implementation

- A **Supervisory Control & Data Acquisition (SCADA)** system integrated with **microprocessor-based Programmable Logic Controllers (PLCs)** has been deployed.
- The **Master Control Station (MCS)** is established at the central location, while **Station Control Centres (SCCs)** operate at each attended station.
- PLCs collect real-time field data, process it, and issue commands to field devices for automated control and response.

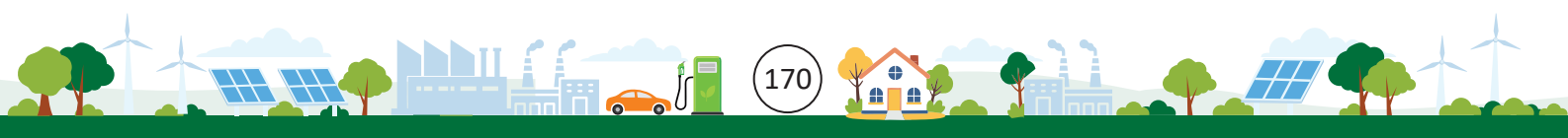
### Redundancy through MPLS

- Given the linear topology of the pipeline, a **Multiprotocol Label Switching (MPLS)** network has been installed to provide **redundant communication paths**.
- This backup ensures continuity of operations in case of primary communication failures due to fiber cuts, power outages, or equipment malfunction.

### Leak Detection System (LDS)

The leak detection capabilities are interdependent on:

- Instrumentation Accuracies: Flow meters, pressure sensors, temperature gauges, etc.



- Pipeline Operation: Transient behavior, flow regimes, valve operations, and other operational dynamics.

An **automated optimization algorithm** is used to determine the best:

- **Response times** (i.e., how quickly the system reacts to a potential leak)
- **Alarm thresholds** (i.e., deviation limits for pressure, flow, or other parameters that indicate a potential leak)

### Adoption of e-Office System

- An **e-Office digital document management system** is used to support administrative operations.
- It allows electronic file movement, digital approval processes, archiving, and retrieval, thereby improving transparency, efficiency, and traceability of documentation.

## CHALLENGES

Despite the robust planning and deployment of advanced technologies, the implementation and operation of the communication and control infrastructure for the KGPL cross-country pipeline faced several challenges. One of the primary concerns was the geographical and environmental diversity of the pipeline route. Laying the Optical Fiber Cable (OFC) across remote, rugged, and often inaccessible terrain posed logistical difficulties, including land acquisition issues, right-of-way permissions, and natural obstacles such as rivers and dense vegetation.

Another critical challenge was ensuring uninterrupted communication and control in a linear network topology, which is inherently vulnerable to single points of failure. Events like fiber cuts, power outages, or equipment malfunction at any node could potentially disrupt the entire network. Addressing this risk required the strategic implementation

of a redundant MPLS communication path and reliable power backup systems, which increased the overall complexity and cost of the project.

Security threats, particularly from unauthorized third-party activities such as excavation and digging near the pipeline, also presented significant challenges.

Integration and interoperability of diverse systems, including SCADA, PLCs, and eOffice, required meticulous configuration, testing, and synchronization to ensure seamless data flow and command execution. Additionally, the project demanded a high level of cybersecurity to protect sensitive operational data and control mechanisms from potential cyber threats, given the increasing digitization and interconnectivity of infrastructure. Implementation of a robust communication and digital management system for KGPL's cross-country pipeline was carried out through meticulous planning, systematic execution, and well-thought-out strategies to overcome potential challenges. The planning phase began with a thorough assessment of existing vulnerabilities in the communication network, such as the risk of OFC cuts, power failures, and equipment malfunctions. Based on this analysis, the team identified the need for a redundant, resilient communication system and digital transformation of administrative workflows. Resources—both technical and human—were allocated, and a phased implementation plan was developed with clear milestones and risk mitigation strategies.

Execution was carried out in stages to ensure minimal operational disruption. The double-armored 24-core OFC was laid along the pipeline to serve as the primary communication backbone. In parallel, MPLS-based network infrastructure was deployed at key locations to act as a failover in case of communication failures.

Simultaneously, the e-Office system will rolled out to digitize document handling processes, including file movement, approvals, and



archiving, thereby improving efficiency and transparency across departments.

To overcome the anticipated challenges, KGPL adopted several strategic measures. A major focus was placed on building network redundancy through MPLS integration, ensuring uninterrupted communication even during fiber outages. A phased rollout strategy allowed for testing, feedback, and refinement at each stage. Long-term support was secured through AMC contracts with vendors, ensuring reliable system maintenance. Continuous monitoring and system reviews were established to drive performance improvements, ensuring the initiative not only met its objectives but remained adaptable to future operational needs.

## IMPLEMENTATION

### Planning and Survey

- Conducted detailed route surveys to identify the optimal path for laying the 24-Core Optical Fiber Cable (OFC).
- Assessed geographical, environmental, and logistical factors including terrain, right-of-way permissions, and accessibility near pipeline stations and repeater points.
- Performed risk assessment to anticipate potential challenges related to communication outages, power failure, and security threats.

### Infrastructure Deployment

- Executed civil works and trenching for secure installation of the OFC along the entire pipeline route.
- Installed industrial-grade telecom and networking equipment (switches, routers, media converters) at all stations and repeater nodes.
- Set up power backup systems, including UPS units and diesel

generators, to ensure continuous power supply to critical communication and control hardware.

### SCADA System Installation

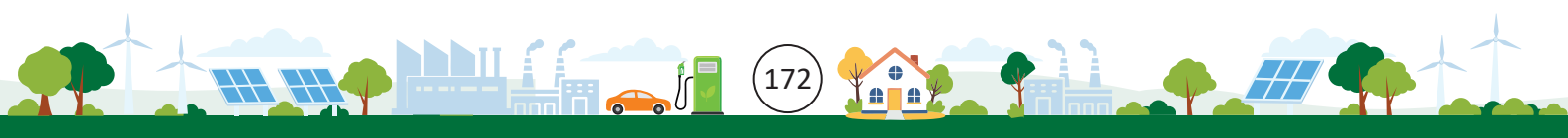
- Deployed microprocessor-based Programmable Logic Controllers (PLCs) at each major station to collect real-time field data and issue control commands.
- Integrated PLCs with field sensors measuring parameters such as pressure, temperature, and flow.
- Established the Master Control Station (MCS) for centralized monitoring and control, supported by Station Control Centers (SCCs) for local operations and redundancy.
- Performed system configuration, calibration, and extensive testing before commissioning.

### Redundancy and Security Enhancements

- Implemented MPLS-based redundant communication paths to provide failover in case of fiber optic cable damage or equipment failures.
- SCADA based LDS has been installed to provide real time alarms for any kind of leakage in pipeline.

### Testing, Training, and Commissioning

- Conducted comprehensive system testing to validate communication, control, security, and administrative functions.
- Provided hands-on training to operators and administrative staff for smooth transition to the systems.
- Officially commissioned the integrated infrastructure, enabling real-time monitoring, control, and administration of the KGPL pipeline.



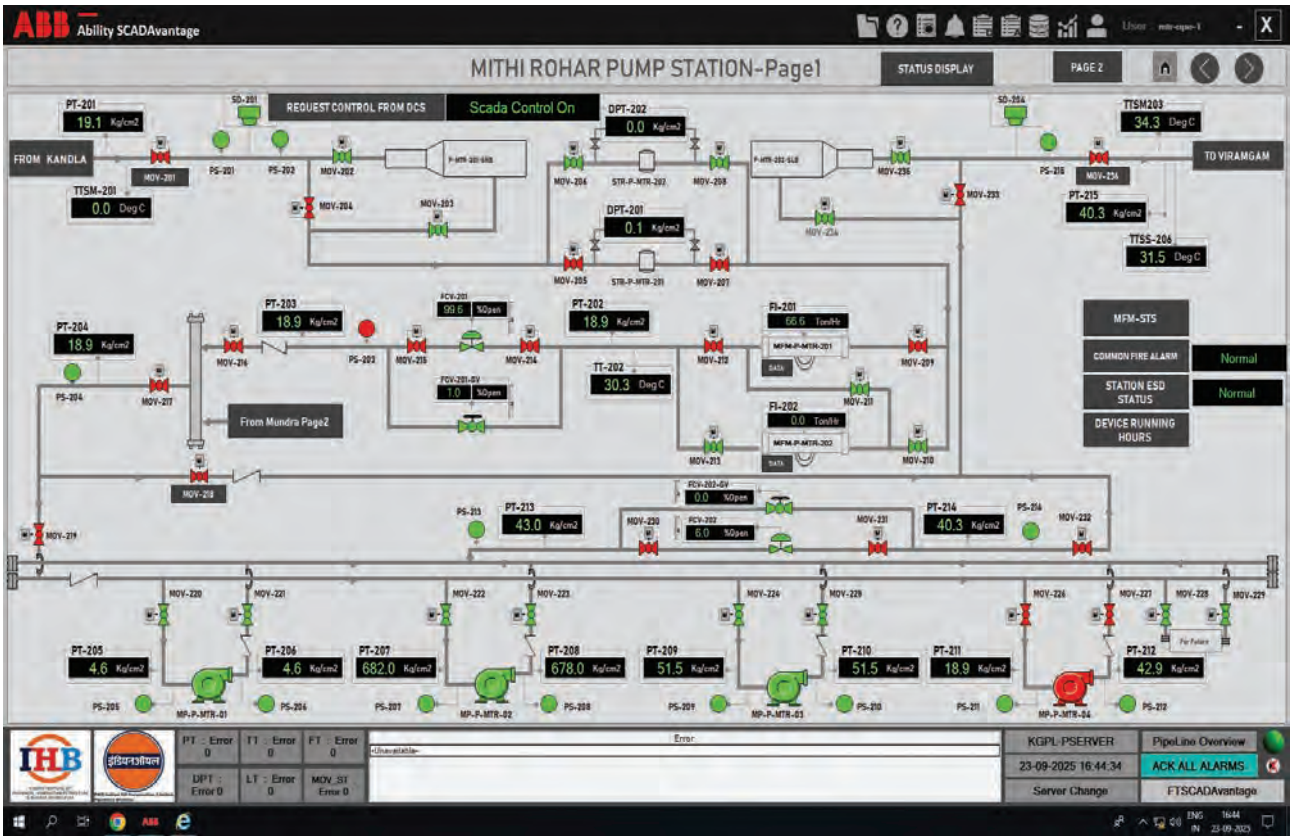


Fig: Mithirohar Pump Station

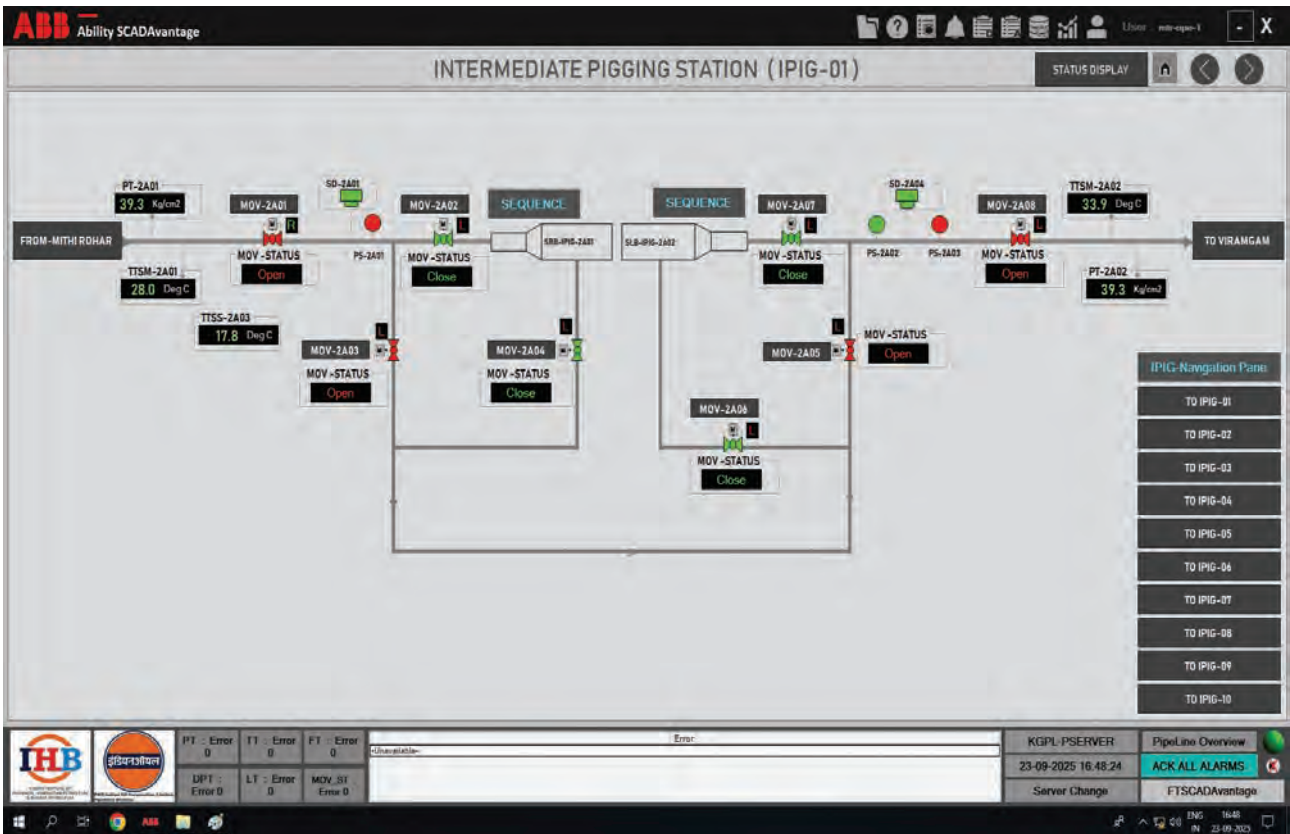


Fig: Intermediate Pigging Station (IPIG-01)



## INVESTMENTS

Cost Component	Amount (₹ in Lakhs)
Capital Expenditure	SCADA: Approx. ₹ 7278.9 Lakhs
	PLC: Approx. ₹ 5170.3 Lakhs
	E-office: Approx. ₹ 32.2 Lakhs
	MPLS: Approx. ₹ 10.2 Lakhs
Operational Expenditure (annual)	SCADA: Approx. ₹ 363.9 Lakhs
	PLC: Approx. ₹ 258.5 Lakhs
	E-office: Approx. ₹ 43 Lakhs
	MPLS: Approx. ₹ 51.7 Lakhs
Human Resources	Included as a part of Capital Expenditure
<b>Total Investment</b>	Approx. ₹ 13,208.7

## QUALITATIVE OUTCOMES

### Enhanced Operational Efficiency and Process Optimization

- Streamlined workflows, reduced manual errors, and optimized resource use led to increased productivity and consistent quality.
- Automation enables faster cycle times, better compliance, and real-time transaction processing.
- Digital tools transform processes from manual to digital, facilitating better supply chain management, production planning, and customer interaction.

### Improved Employee Job Satisfaction and Work Quality

- Digitalization reduces routine manual tasks, enabling employees to focus on higher-value, strategic, and intellectually engaging work.
- Employees report increased job satisfaction from reduced errors and workload, greater work-life balance opportunities, and enhanced role adaptability.
- However, challenges include initial adjustment difficulties, skill gaps,

and the necessity for ongoing training and change management.

### Transformation of Work and Organizational Roles

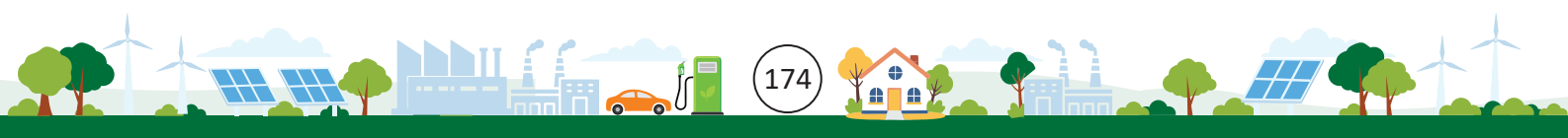
- Job roles evolve, shifting from operational tasks to more strategic, flexible, and knowledge-intensive roles.
- Digitalization affects communication patterns, collaboration, and organizational culture, requiring new management styles emphasizing digital literacy, empathy, and agility.
- Hybrid and flexible work models are increasingly enabled by digital tools, transforming traditional workplace structures.

## INNOVATION & UNIQUENESS

These are new steps towards Digitization and automation which result in achieving operational excellence and reducing human errors in workplace.

## SCALABILITY & REPLICABILITY

The technological framework and infrastructure established for the KGPL cross-



country pipeline have been designed with both scalability and replicability in mind. The modular architecture of the SCADA system, based on microprocessor-based PLCs and distributed control centres, allows for easy expansion of the network. As new stations or pipeline segments are added, additional PLCs and control modules can be integrated into the existing system without major modifications, ensuring consistent performance and seamless interoperability.

Similarly, the communication backbone, built on a 24-Core Optical Fiber Cable and supported by MPLS-based redundancy, has sufficient capacity and flexibility to accommodate future data load increases, new monitoring points, or additional services such as real-time video surveillance, advanced analytics, or remote diagnostics. This ensures the infrastructure remains future-ready and adaptable to growing operational demands.

From a replicability perspective, the systems and processes deployed—SCADA, MPLS, eOffice—are based on industry standards

and commercially available technologies. This makes the entire model transferable to other pipeline projects, industrial corridors, or utility infrastructures with similar requirements. The successful integration of communication, control, security, and digital administration in KGPL serves as a proven reference model that can be tailored and replicated across different geographic regions or operational contexts.

Moreover, the experience gained in addressing technical, logistical, and administrative challenges during this project creates a valuable knowledge base. This can guide future implementations, reduce learning curves, and support faster deployment timelines in similar infrastructure projects, thereby promoting wider adoption of smart pipeline management systems.

## FUTURE PLANS

The project shall be implemented in all future pipelines.

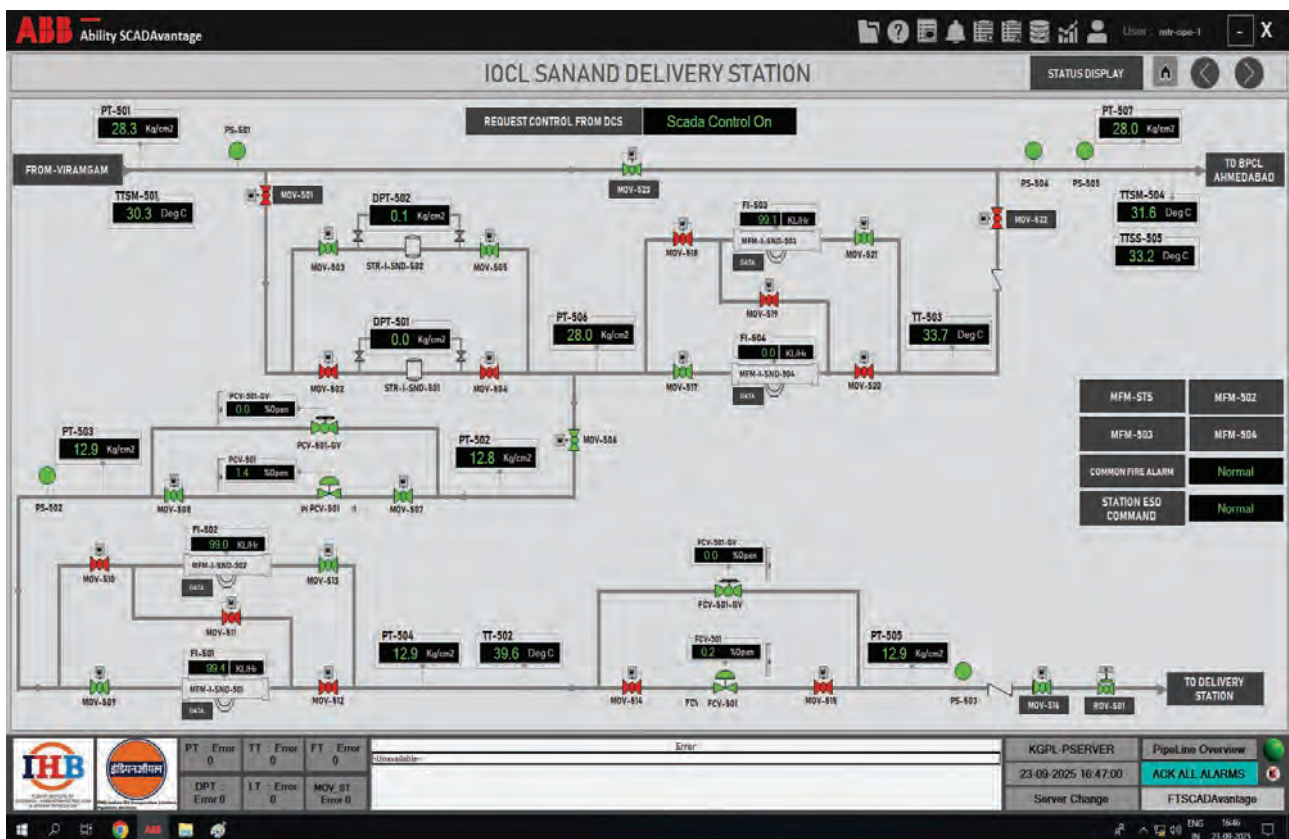


Fig: IOCL Sanand Delivery Station



# Real Time Optimizer for Petro-Fluidized Cracker Unit

Mangalore Refinery and Petrochemicals Ltd.  
Shri Haradi Ashok Anand  
Chief General Manager (Process Engg.)

Operational Efficiency-  
Reduction in Emission

MRPL's Innovation Centre has developed the PFCC Real-Time Optimizer (RTO), among the first AI/ML-based applications to directly control a large commercial unit. The PFCC unit produces multiple streams including LPG, propylene, cracked gasoline, etc. Since manually optimizing operating parameters is impractical, MRPL created hybrid yield-predictive models that combine first-principles with ML algorithms, enabling real-time optimization and improved profitability.

## BACKGROUND & CONTEXT

MRPL Innovation Centre has developed the PFCC Real-Time Optimizer (RTO), one of the first AI/ML-based applications to directly control a large commercial unit. The PFCC unit produces dry fuel gas, LPG, propylene, cracked gasoline, Light Cycle Oil (LCO), and coke, with propylene and cracked gasoline being the most valuable products.

To maximize operating margins, it is humanly impossible to calculate the optimal operating parameters for all variables to achieve the best product yield pattern. To address this,

R&D efforts were undertaken to build yield predictive models using a hybrid approach combining first-principles and ML algorithms. These models were used to develop an RTO application that predicts the economically optimal yield pattern and corresponding operating parameter setpoints.

Initially, the PFCC RTO was deployed as a web-based interface with DCS advisories for operators to take manual control actions. In parallel, hardware modifications were implemented to enable closed-loop control, after which the application was transitioned to fully automated closed-loop control.



## OBJECTIVES

To address the following challenges/issues:

- Market product spreads & feed varies dynamically for PFCC unit.
- To compute and operate at optimal yield in real-time.

## METHODOLOGY

- An RTO was developed in-house to optimize the yield and product properties of the PFCC unit.
- The RTO considers market demand and prices to maximize the margin of the PFCC unit.
- It employs a novel hybrid algorithm combining first-principles and machine learning/AI techniques.
- Real-time operating parameters are generated and displayed on the DCS and web application.
- Closed-loop control has been established for certain sections of the PFCC unit to maximize margins.

## CHALLENGES

Data processing and handling require significant time.

## QUANTITATIVE OUTCOMES

Provide measurable results achieved through the initiative

Parameter	Before Implementation	After Implementation	Improvement (%)
Cost Savings (₹ in Lakhs)	The expected benefits of the PFCC RTO are estimated at INR 30–50 Crores per year.		

## QUALITATIVE OUTCOMES

- Economically optimal yield
- Optimization in real time with no or minimum manual intervention.

## IMPLEMENTATION

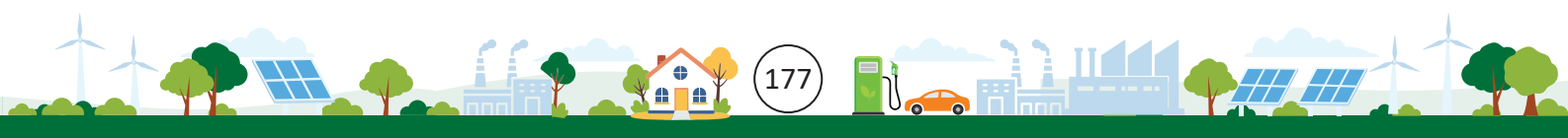
- In house developed Hybrid models that combine AI with first-principles kinetic models have been used for real-time optimization. The initiative started in January 2023 and was deployed in December 2023. Closed-loop control has been implemented for specific sections of the reactor.
- Stakeholders include operations, process and planning departments.
- A web application has been developed to serve as an advisory tool for the operations and process teams. The application also includes an interface to retrieve constraints and pricing from the planning team.

## INVESTMENTS

Cost Component	Amount (₹ in Lakhs)
Human Resources	In house team of 5 members.
Technology Acquisition	In house developed
R&D and Innovation	In house R&D/ Innovation team
Total Investment	No investment as it is 100% in-house developed.

## INNOVATION & UNIQUENESS

- First of its kind novel hybrid algorithm combining first-principles and machine learning/AI techniques to maximize the margin of the PFCC unit.



- This is one of the first AI/ML-based applications known to directly control a large commercial unit in closed-loop control.

### **SCALABILITY & REPLICABILITY**

Concept developed can be easily replicated for any process optimization. It is easily scalable. RTO has to be custom developed for every process.

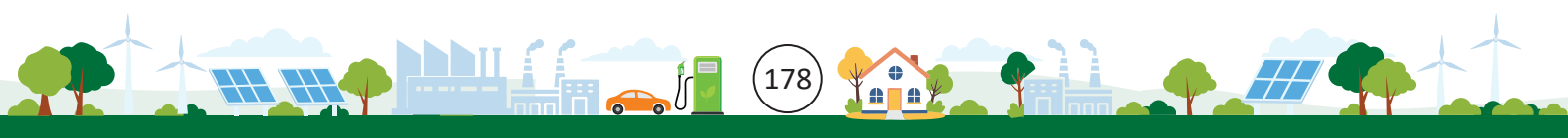
### **KEY LEARNINGS**

- To maximize operating margins, it is humanly impossible to calculate the optimal operating parameters for all variables to achieve the best product yield pattern.

- Neither first-principles models nor standalone ML models work effectively on their own for this application. A hybrid first-principles + AI/ML model overcame these issues.

### **FUTURE PLANS**

RTOs are being developed and extended to other process units. Commercialization of the technology to other industries.





MANUAL

Processes

RPA

Robotic Process Automation

# Digital Transformation of Gas Measurement Validation using Robotics Process Automation (RPA)

Pipeline Infrastructure Limited  
Shri Suprakash Chattopadhyay  
Senior General Manager

Operational Efficiency- Digitalization

PIL automated its gas measurement validation through Python-based RPA, replacing manual, error-prone tasks that relied on disparate reports from flow computers, ultrasonic meters and gas chromatographs. The bot now extracts, checks and consolidates data into validation sheets, drafts joint tickets and updates business portals, delivering higher accuracy, faster turnaround and reduced manpower dependence while establishing a scalable digital model for future network-wide measurement validation.

## BACKGROUND & CONTEXT

Prior to this initiative, the gas measurement validation process at Pipeline Infrastructure Limited (PIL) was **heavily dependent on manual extraction and analysis of metering data** across its vast pipeline network. Flow Computers (FC), Gas Chromatographs (GC), and Ultrasonic Flow Meters (USM) at various Metering & Regulating (M&R) stations generated over 60+ reports daily. These **reports had to be manually downloaded, interpreted, and cross-validated against historical patterns, followed by joint**

**ticketing with customers and entry into the PGTS portal** — all within tight business timelines.

Detecting measurement anomalies, assessing metering drift, or identifying calibration issues required **careful onlooking and additional time**. With the pipeline network expanding and the number of interconnects and CGD customers growing, the measurement validation was reaching an **extensive load for manual efforts & time** consumed. For each new M&R station, the workload increased proportionally, and it was

challenging to complete the measurement validation within business timelines.

These all challenges posed **risks to accurate Unaccounted for Gas (UFG) tracking**.

The increasing operational complexity and urgency to maintain accuracy, efficiency, and stringent timelines prompted the need for automation. This digital transformation was conceptualized not merely as a time-saving tool, but as a strategic enabler for deeper insight into metering system health, anomaly detection, and scalable growth in future. PIL's Gas Measurement team, therefore, embarked on an initiative to restructure and automate this critical process using Robotics Process Automation (RPA).

## OBJECTIVES

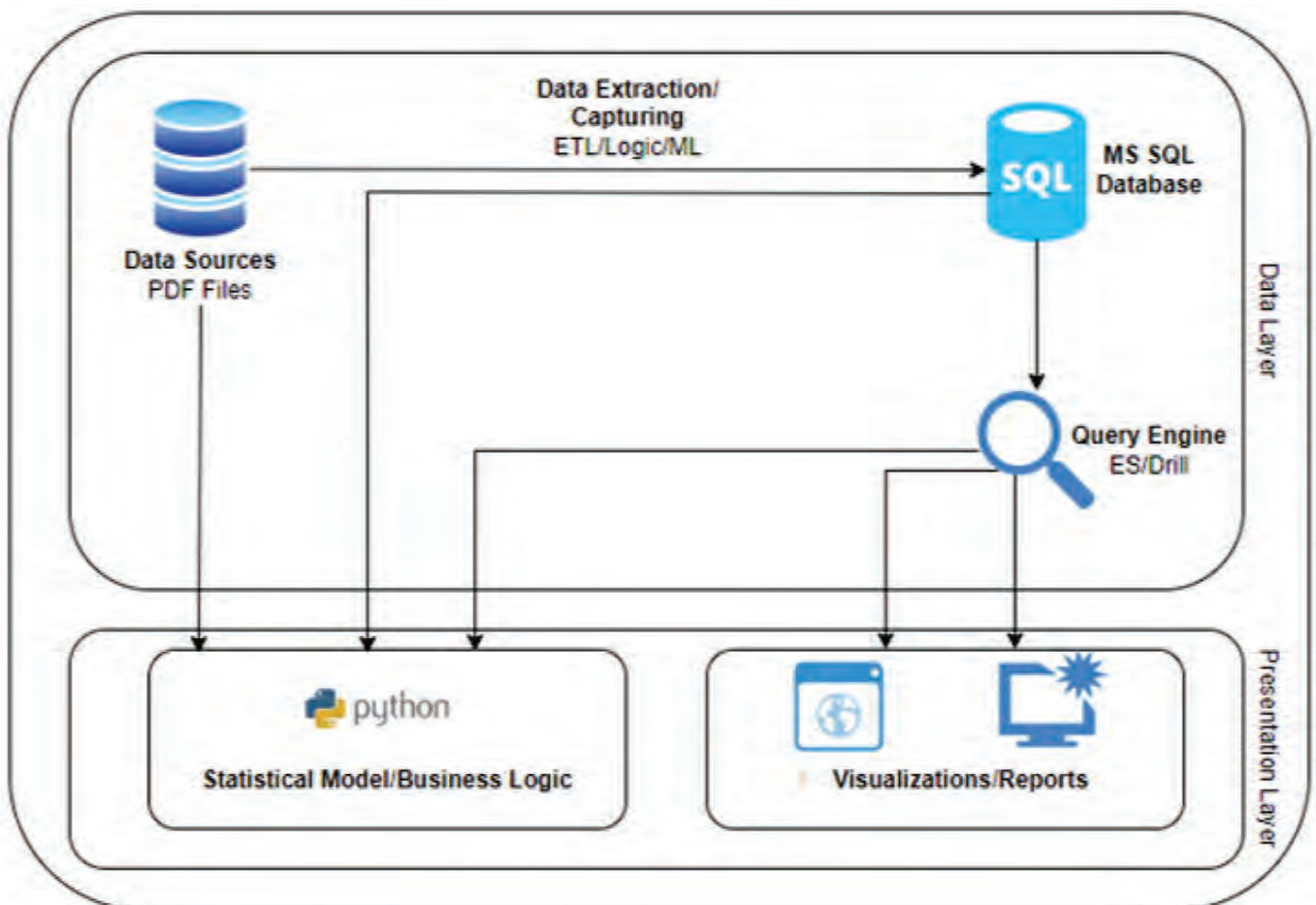
- **To automate the gas measurement validation process** by eliminating manual data extraction, tabulation,

and reporting efforts from Flow Computer (FC), Gas Chromatograph (GC), and Ultrasonic Flow meters (USM).

- **To improve validation accuracy and early anomaly detection** through structured check sheets, historical data trend analysis, and conditional formatting for deviation alerts.
- **To enable scalable and timely validation workflows** across increasing M&R stations, supporting future network expansion while ensuring correctness & efficiency.

## METHODOLOGY

The Measurement Validation Automation initiative at Pipeline Infrastructure Limited (PIL) was executed through a structured, phased methodology that transitioned the manual validation process into an integrated Robotics Process Automation-



based system. The entire approach was anchored on automation of data collection, standardization of validation, scope for manual checks/balance and focussed reporting of measurement data.

### A. High-Level Architecture & Design –

- **User Interface (Frontend):** Built using HTML5, CSS, and JavaScript, this layer represents the user-facing part of the portal. Users interact with the Measurement RPA portal through a web browser.
- **Backend (Application Server):** Developed using Python and Flask, this layer handles business logic, API requests, and communication with the database. It also manages data processing tasks, including the extraction and insertion of data from various sources.
- **Database Layer:** SQL Server 2019 serves as the backend database where all data is stored for processing and Visualizations, etc.
- **Data Sources:** External data sources include the data from PDFs, EXCEL and Manual Data Entry. Data from these sources is regularly ingested into the SQL Server database.

### B. Application Development Process-

#### **i) Stage I – Data Collection Automation**

The automation tool was configured to **download daily reports** and alarms from:

- **Flow Computers (FCs)** in PDF format,
- **Gas Chromatographs (GCs)** 24-hour average reports and alarms,
- **Ultrasonic Flow Meters (USMs)** in Excel format (Archive and Maintenance logs).

A summary page allowed users to select M&R stations and equipment for targeted report downloads, saving time and avoiding unnecessary bulk retrieval.

#### **ii) Stage II – Data Tabulation and Checksheet Generation**

Extracted data from the reports was parsed and tabulated into a **Single-Page Validation Checksheet**, with logic powered by **Python scripts**. This checksheet:

- Displayed **7-day historical trends** and **3-week average data**,
- Incorporated **conditional formatting** to highlight anomalies,
- Pulled data from embedded historical sub-sheets auto-mapped to validation parameters.
- The system allowed users to review and validate data, post which it triggered:
  - **Auto-generation of Joint Tickets,**
  - Entry of validated gas quantities into the **PGTS portal.**

### C. Technologies Used –

- **Frontend:** HTML5, JavaScript, Bootstrap (for portal interface),
- **Backend:** Python 3.9 with Flask (for logic, data transformation),
- **Database:** MS SQL Server 2019 (for storage and query),
- **Visualization:** Power BI and Chart.js (for dashboards),
- **Task Automation:** Windows Task Scheduler (for timed execution).

### D. Resources Utilized -

The implementation relied on a blend of software, infrastructure, and logical components:

- **Software Tools:** Python 3.9, Flask framework, MSSQL Server 2019, and Windows Task Scheduler.
- **Data over FC Lan:** FC reports (PDF), GC reports (PDF), USM logs (Excel), and user-input sheets.
- **Infrastructure:** Centralized deployment on measurement



PCs at POC and access-controlled shared folders.

- **Security and Audit Utilities:** LDAP authentication, MD5 encryption, and activity logging modules.
- **Visualization Libraries:** Chart.js for browser rendering and Power BI for dashboard reporting.

#### E. Final Workflow –

### CHALLENGES

The development and deployment of the Measurement Validation Automation initiative at Pipeline Infrastructure Limited (PIL) involved **navigating multiple layers of challenges — from conceptual uncertainty and system diversity to user-level change resistance and infrastructure limitations.** These were systematically addressed through collaborative strategies, adaptive design, and phased execution.

- **Navigating Conceptual Uncertainty in a New Domain**

When the initiative began, Robotic Process Automation (RPA) was new to the Measurement team. While each M&R station had effective local validation methods,

translating these varied, manual practices into a single automated process required a shift in thinking.

#### **Strategy Adopted:**

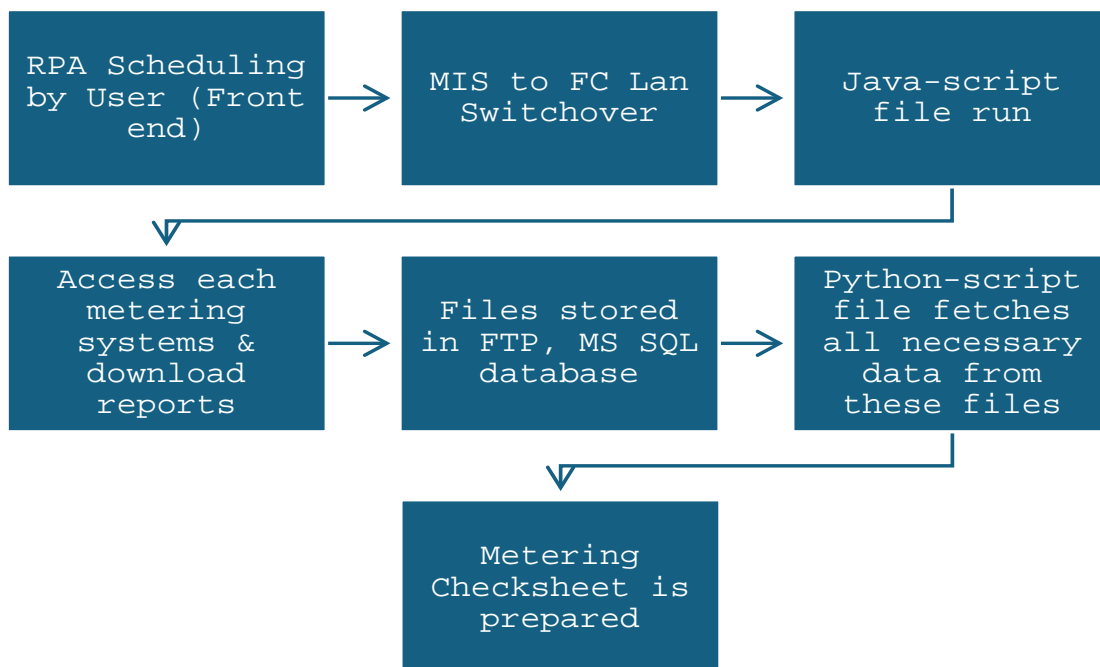
Through knowledge-sharing and process mapping, common parameters — such as tolerance bands, alarm thresholds, and rolling comparison periods — were identified. These formed the harmonized logic that became the backbone of the automated checksheet.

- **Variability in Report Formats Across OEMs**

Different OEMs (FCs, GCs, USMs) generated reports with distinct structures — varying tag names, rows, columns, data etc. A fixed coding logic would have failed frequently or extracted inaccurate data.

#### **Strategy Adopted:**

A modular, site-configurable code was developed. Station-specific templates and tag libraries ensured accurate data extraction regardless of OEM or site-specific configuration.



- **Limited User Familiarity and Behavioural Inertia**

Users were accustomed to manual validation workflows and were initially hesitant to trust automation. Concerns around Measurement correctness and accountability led to slow adoption.

**Strategy Adopted:**

A dual-validation phase was introduced during early pilots, where manual and automated checksheet ran in parallel. A lot of time & efforts devoted into UI refinements, building user confidence through familiarity and gradual onboarding.

- **Absence of Summary alerts / Log files**

The initial tool version lacked feedback mechanisms. Users had to check manually whether a run had completed successfully or if one or more inputs were missed, leading to delays in identifying issues.

**Strategy Adopted:**

Pop-up summary alerts and log files were introduced, providing feedback on run status, errors, and skipped inputs. This improved user trust and process visibility.

- **Coordination Between Measurement and IT Functions**

Aligning domain-specific logic (validation rules, alarms) with IT infrastructure (deployment, access rights, SQL backend) required strong cross-functional collaboration. Differences in role & priorities caused occasional friction.

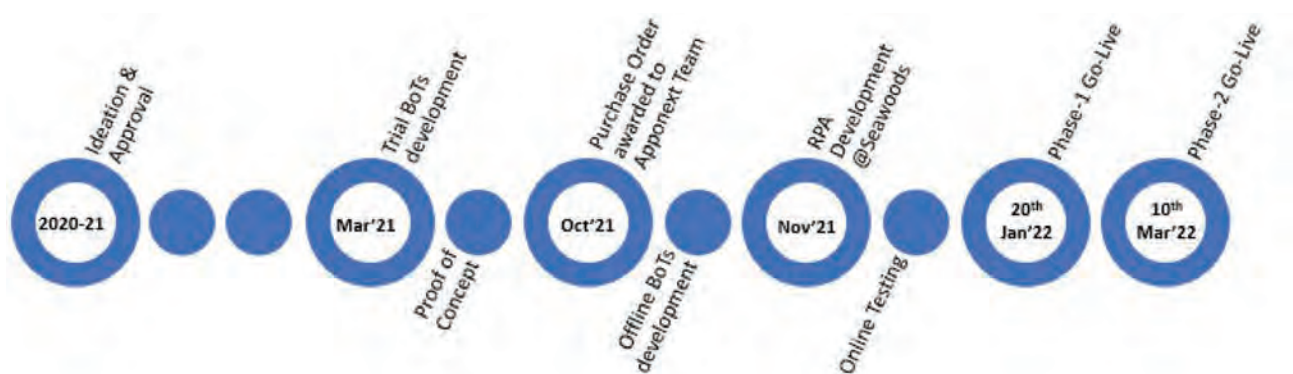
**Strategy Adopted:**

A joint responsibility model was implemented. The Measurement team led logic design and validation; IT handled deployment, access control, and performance monitoring. Weekly sync-ups helped maintain alignment.

**IMPLEMENTATION**

While Ideation & Approval for the initiative happened in 2020-21, the implementation started in a phased manner from early 2021 till final Go-Live in 2022. The process transitioned from concept to pilot to full-scale rollout, incorporating structured technical deployment, functional validation, and continuous user feedback.

**RPA Development timelines –**



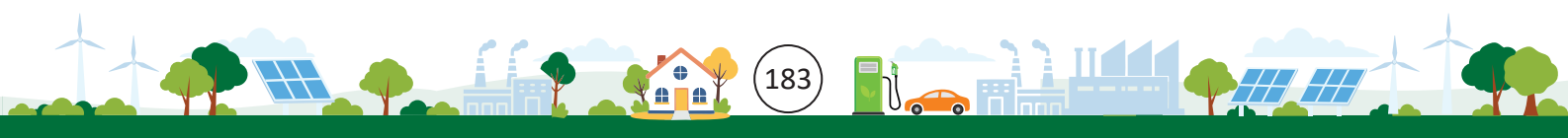
**Stakeholders involved -**

- **Measurement Team:** Designed the business logic for metering validation and guided the configuration of checksheet, PGTS mapping etc.
- **Application Developer:** Designed and programmed RPA scripts (Python - based).

- **IT Admin Team:** Set up SQL backend, ensured deployment across POC.
- **Users:** Participated in pilot testing, feedback loop, and rollout support.

**Key Field Learnings Incorporated During Rollout –**

- **Format Diversity Across Sites -** Though standard instrumentation (like FCs, GCs, and USMs) was used



across the pipeline, station-level configurations, and even firmware versions introduced variability in file structures.

- **Exception Handling and Resilience**

The initial tool was sensitive to even a single missing file, leading to full automation halts. Based on practical testing, the RPA was remodelled to continue with available inputs, and generate an exception summary, so validations weren't blocked due to minor gaps. This not only improved uptime but also boosted user confidence in the system's robustness.

- **Learning Curve for End Users –**

Initially, POC engineers and Measurement Team were more comfortable with legacy Excel-

based validations. The RPA tool's interface, although functional, required a mindset shift. This was addressed through targeted orientation sessions, mock runs, and a guided transition phase where both manual and automated outputs were available in parallel — helping build user trust without disrupting accountability.

### INVESTMENTS

Cost Component	Amount (₹ in Lakhs)
Capital Expenditure	23 Lacs
Operational Expenditure (annual)	5 Lacs
Human Resources	100+ PIL Man-Hrs
<b>Total Investment</b>	23 Lacs CAPEX + 5 Lacs annually recurring OPEX 100+ PIL Man-Hrs

### QUANTITATIVE OUTCOMES

Parameter	Before Implementation	After Implementation	Improvement (%)
Resource Utilization [Man-Hour reduction]	<b>Manual effort across 26 stations [Present delivery M&amp;Rs, 2025].</b> Note: Around 11 Hrs/daily Measurement Validation - Manual works [4 Hrs of Report downloading + 7 Hrs of manual measurement validation (Data collation & excel files preparation)].	Minimal manual intervention; automated data pull, collation, and validation. Note: Validation completion in 4 Hrs/daily.	Approximately <b>60% time saved through RPA implementation based on man-hour reduction.</b>

### QUALITATIVE OUTCOMES

The RPA initiative at PIL introduced a step-change in gas measurement validation by **standardizing processes, reducing manual effort, and improving accuracy.**

Automation enabled **faster detection of**

**anomalies and instrument drifts**, resulting in stronger control over UFG and improved reliability of measurement data.

By taking over repetitive checks and highlighting deviations automatically, the system freed engineers to focus on **analysis,**



root-cause investigation, and preventive action.

Above improvements were driven by several unique, built-in capabilities:

- **Integrated FC/USM/GC Diagnostics with Archiving**

Automatically captures and stores diagnostic data for early anomaly detection and long-term equipment health tracking.

- **FC & GC Alarm Extraction**

Device alarms are logged into the validation sheet, improving visibility and reducing oversight risk.

- **Historical Data Tabulation and Retrieval**

Enables easy access to prior weeks' data, allowing for comparative validation and trend-based insights.

- **CGD Gas Composition Keypad Updation**

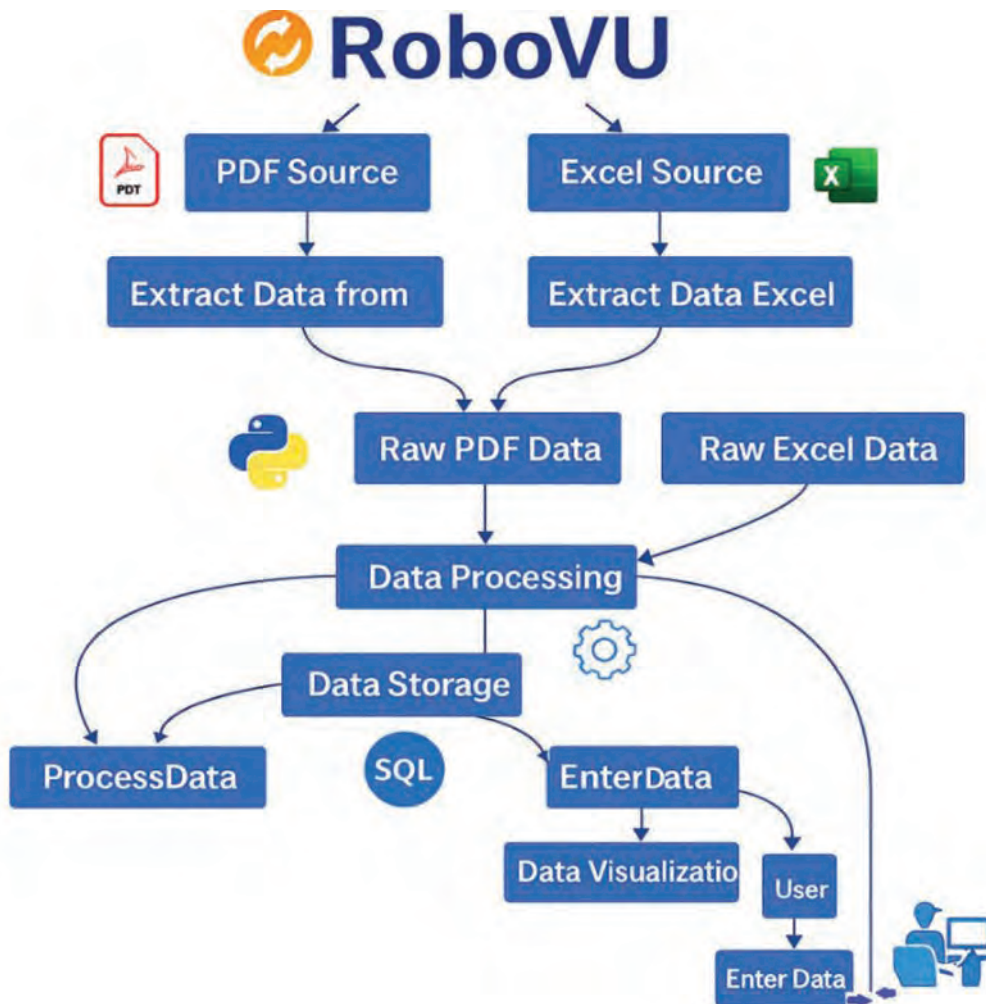
For CGDs lacking online chromatographs, the system allows manual entry of gas composition via keypad, avoiding analysis gaps in custody transfer measurement.

- **Manual Override for Communication Failures**

In case of data loss or connectivity issues, users can manually update values to maintain continuity in validation — ensuring data completeness and traceability.

- **Easy onboarding of New CGDs**

With minimal IT support, users can onboard new CGDs or modify email distribution lists directly from the front end — enhancing flexibility and ownership.



## INNOVATION & UNIQUENESS

The Measurement Validation Automation initiative at PIL distinguishes itself by going far beyond basic scripting or Excel automation. It is built as a modular, web-enabled, and regulation-ready RPA system — a rare implementation in the natural gas sector.

Unlike conventional process automation, this system integrates:

- **Frontend Module:** HTML5, CSS, JavaScript files that handle the user interface.
- **Backend Module:** Flask application that processes user requests, manages business logic, and interacts with the database.
- **Database Module:** SQL Server 2019 with defined tables and stored procedures for data management.
- **Visualization Module:** Power BI files that define dashboards and reports, connected to the SQL Server database.
- **Frontend-Backend Integration:** The frontend communicates with the backend via HTTP requests. Flask routes these requests to the appropriate handlers.
- **Backend-Database Integration:** Flask uses SQLAlchemy or direct SQL queries to interact with the SQL Server database.
- **Database-Visualization Integration:** Power BI Desktop connects to SQL Server via a connector, querying the tables to generate visualizations.
- Reports and check sheet Overview
- The Measurement RPA portal features several reports, each tailored to provide insights from different data sources like pdfs, excel and manual data entry forms.

- **Web-based applications** are designed to present data in an interactive, user-friendly manner

## SCALABILITY & REPLICABILITY

The Measurement Validation RPA solution at PIL has been thoughtfully designed to ensure easy scalability and replicability across a wide range of operational environments.

- The application code operates on a standardized validation logic, while other configurations are fully customizable. This flexible architecture has allowed **smooth deployment across multiple CGD stations**, without requiring changes to the central codebase.
- The process of **extending the tool to new sites is straightforward**. Once report structures and naming conventions are aligned, the deployment can be completed with minimal support — often within a few days. Front-end options like dropdown-based station selection, editable recipient lists, and manual data entry fields further improve cross-site usability.

**From 4 CGDs in 2022 to 13 CGDs in 2025, scaling up & replicating in RPA along with onboarding of new customers have been very easy & smooth.**

## KEY LEARNINGS

The Measurement Validation RPA journey at PIL provided several valuable learnings — both from its successes and the challenges encountered during design and deployment.

A key realization was the importance of **process standardization**. The absence of uniform validation logic across stations initially made automation difficult. Consolidating diverse site practices into a



single logic not only enabled automation but also improved overall process discipline.

From a design standpoint, the benefit of **modular and site-configurable architecture** became evident. By separating core logic from station-specific settings, the tool remained robust yet adaptable — simplifying cross-site deployment and long-term maintainability.

**Cross-functional collaboration** emerged as another success factor. Seamless coordination between the Measurement and IT teams ensured that domain-specific rules and backend execution were aligned throughout. Another major learning was that user adoption is as critical as technical soundness. Early hesitation from users due to lack of transparency and loss of manual control was addressed through a dual-validation rollout, iterative UI enhancements, and continuous feedback. This phased approach proved instrumental in building confidence and promoting ownership.

Finally, the experience reaffirmed the value of incremental innovation. Instead of aiming for a perfect system upfront, the tool evolved in phases — incorporating real-time alarms, diagnostics, manual overrides, and recipient management based on operational feedback. Together, these learnings have created a strong foundation for scaling digital solutions in measurement and other operational domains.

## FUTURE PLANS

With the core RPA system now stabilized and delivering tangible value, several enhancements are being considered to further elevate its functionality and reach.

A key area of focus is

**enabling real-time data integration through Modbus or OPC protocols**, allowing direct fetching of live values from flow computers, chromatographs, and ultrasonic meters. This would eliminate manual report handling and enable more dynamic, continuous validations. The solution is also well-suited for Realtime Measurement Smart Application (RMSA), where automated validation and alerting can support unmanned or intermittently staffed locations.

Plans are also underway exploring AI/ML-based extensions. By analysing historical patterns and deviations, the system could evolve from static logic checks to a more intelligent platform — one capable of learning trends, predicting anomalies, and adapting tolerance thresholds based on actual field behaviour.

Additional integration with enterprise dashboards is also being evaluated to improve visibility and decision support. These planned upgrades aim to transform the current tool into a future-ready, intelligent validation framework — one that grows with operational complexity and contributes to the digital maturity of measurement systems across the organization.





# Implementation of Metering Data Management System

Gujarat State Petronet Limited  
Shri Vinay Kaul  
Sr. Manager

Operational Efficiency - Digitalization

The growing number of small gas customers exposed limitations of GSM/SMS-based meter data, which lacks real-time monitoring, two-way control, and visibility into meter health. Without AMI, staff must visit sites for readings and on-premise GC entry, inflating costs, consuming time, and risking undetected gas losses. Adopting AMI with continuous, two-way communication would enable remote service actions, rapid failure detection, and accurate, live consumption tracking.

## BACKGROUND & CONTEXT

The background of remotely accessing small metering data involves a shift towards Advanced Metering Infrastructure (AMI) which allows system to remotely monitoring the real time metering data and manage customer energy usage. This technology enables two-way communication providing real-time data and facilitating various functions like remote service connection/disconnection, failure and interference in system.

Based on internal analysis it was observed that small customers had been increasing across the gas grid gradually.

Due to the limitation in communication technology with small meters and unavailability of power and network infrastructure for such small meters, organisation was dependent on Global System for Mobile Communications (GSM) technology that allowed SMS based previous gas day reading details. This approach prevented real-time performance and availability monitoring, leading to significant



manual intervention, travel costs, and time to capture authentic readings. It was a complex and time-consuming task involved lot of manpower efficiency.

SMS-based readings made volume tracking impossible, the health of breakdown meters was not visible, that had a potential to further incur to gas loss. And Manual method of GC writing on premise was being practiced.

## OBJECTIVES

The main objectives of Metering Data Management system (MDMS) for small meters are to improve data accuracy, reduce operational costs, and enhance customer service. This includes achieving more efficient data collection, enabling remote connections facilitating better billing and supporting demand-side management.

- **Eliminate Manual Readings:**

MDMS enable accurate, real-time meter readings, eliminating the need for estimations and manual interventions in billing.

- **Automated Data Validation:**

MDMS automate the process of validating meter data, ensuring high-quality data for analysis and decision-making.

- **Faster Response to Issues:**

MDMS enable faster identification and resolution of outages and other issues, leading to improved customer service.

## METHODOLOGY

A detailed architecture and robust design was developed and after understanding of various available technologies and keeping in mind key deliverable for reliability of readings, 100% monitoring accuracy, and secured data transfer, along with authentic and appropriate backup using **solar energy** as a power source.

Implementing a Meter Data Management System (MDMS) for small meters involves

a phased approach encompassing data acquisition, processing, and integration with existing systems. The design ensures that flow metering streams not connected to existing SCADA will be connected through MDMS using wireless technology.

### Major concerns addressed:

- **Secure Data Transmission:** Establish a secure communication channel (e.g., VPN, encrypted protocols) to protect sensitive meter data.
- **Data Polling:** Configure the MDMS to poll meter data at the desired intervals, ensuring reliable and timely data acquisition.
- **Data Validation and Verification:** Implement robust data validation and verification algorithms to identify and correct errors or inconsistencies in the collected data.



## CHALLENGES

Installing metering data management systems (MDMS) for small meters faces unique challenges such as seamless integration with existing meters, data volume, and cost.

Managing the potentially large volume of data from many small meters, and dealing with the high initial and ongoing costs of deployment and maintenance.

**1. Complexity of Integration:** MDMS needs to integrate with various type of meters like ultrasonic meter, turbine flow meter, Rotary Positive Displacement Meters. Installation in customer premises without disturbing metering skids and to be accepted by customers. This integration can be complex, requiring significant effort and expertise.

**2. Proprietary Communication Protocol:** All small meters installed have their own proprietary communication protocol hence, a special drive of upgradation in firmware was carried out in order to smoothen the real time data communication.

## IMPLEMENTATION

Implementing a Metering Data Management system for small meters involves collecting, validating, processing, and storing meter data to support operations, including billing and customer services. This system acts as a central repository for meter data, enabling efficient data management such as data analysis, trend, events, reports.

- **Data Integration:** Integrate real time metering data into the metering data management system by establishing serial communication between meter and wireless router. This included the configuration of various Modbus parameters based on meter compatibility. Authenticity of metering data and daily SMS/ Email based alerts and notifications were crucial.
- **System Configuration:** Configure system to manage data collection,

validation, and processing based on your defined requirements.

- **Develop Interfaces:** Establish connections and interfaces between the MDM system and remote devices through secure VPN and other communication protocol such as Message Queuing Telemetry Transport (MQTT).
- **Set up Data Storage and Retention Policies:** Determine archive management as a systematic process of organizing, preserving, and providing access to records and by restoring the metering data as an historian.

## INVESTMENTS

Cost Component	Amount (₹ in Lakhs)
Capital Expenditure	80 lakhs
Operational Expenditure (annual)	7.5 Lakhs
<b>Total Investment</b>	<b>87.5 lakhs</b>

## QUANTITATIVE OUTCOMES

Parameter	Before Implementation	After Implementation	Improvement (%)
Operational Efficiency	54.28%	99.99%	84.21%
Cost Savings (₹ in Lakhs)	Total Cost = 58.8	Total Cost = 5.54	90.57%

## QUALITATIVE OUTCOMES

Meter Data Management System (MDMS) for small metering can yield several qualitative benefits, including enhanced operational efficiency, improved customer experience, and better data-driven decision-making. These outcomes stem from the system's ability to automate data collection, validation, and analysis, leading to more accurate billing, reduced operational costs and increased customer satisfaction.

- **Reduced Manual Effort:** MDMS automates the process of meter reading, data validation, and billing, minimizing manual intervention

BASF LTD						
GAS METERING DATA		FC01	FC02	GAS COMPONENTS	FC01	FC02
Corrected Flow Rate (SCMH)		797.93	0.00	C6+ (%)	0.0000	0.0000
Uncorrected Flow Rate (AGMH)		20.84	0.00	Methane (%)	96.0668	96.0668
Energy Flow Rate (MMBTU/H)		29.55	0.00	Ethane (%)	2.7058	2.7060
Corrected Volume (SCM)		9090796.00	1470571.63	Propane (%)	0.6366	0.6370
Uncorrected Volume (m3)		227858.34	770938.94	i - Butane (%)	0.1285	0.1280
Energy (MMBTU)		336380.19	1165540.88	n - Butane (%)	0.1728	0.1730
This Hrs. Corrected Volume (SCM)		273.00	0.00	i - Pentane (%)	0.0063	0.0060
This Hrs. Uncorrected Volume (m3)		7.13	0.00	n - Pentane (%)	0.0014	0.0014
Last Hrs. Corrected Volume (SCM)		517.00	0.00	Nitrogen (%)	0.2822	0.2820
Last Hrs. Uncorrected Volume (m3)		13.52	0.00	Carbon Di-Oxide (%)	0.0000	0.0000
This 24 Hrs. Corrected Volume (SCM)		8458.00	0.00	Gas Total (%)	100.0000	100.0000
This 24 Hrs. Uncorrected Volume (m3)		223.84	0.00	Heating Value (Kcal/SCM)	9332.29	9332.24
This 24 Hrs. Energy (MMBTU)		313.22	0.00	Specific Gravity (%)	0.5799	0.5799
Last 24 Hrs. Corrected Volume (SCM)		18035.00	0.00	ZB	0.9978	0.9978
Last 24 Hrs. Uncorrected Volume (m3)		422.89	0.00	ZF	0.9325	0.9334
Last 24 Hrs. Energy (MMBTU)		593.84	0.00	Index Head (P) (P/m3)	21915.93	29458.95
Pressure ( Bar (G) )		38.06	38.99	Index Head (S)(P/m3)	21915.93	29458.95
Temperature (°C)		28.56	29.75	Frequency (P) (Hz)	126.87	0.00
AGA 7 Factor		38.29	38.14	Frequency(S)	126.87	0.00
Battery Voltage (Vdc)		13.32	12.80	PID PV	0.00	0.00

and associated errors. Reducing of field manpower to 60-70 %.

- **Data availability:** Achieved 100% Data availability of metering data at control rooms throughout the seasonal variations. With up to 100 inputs from the single meter providing, there is visibility for monitoring the real time metering data basis through trend analysis and various customised trends. Accurate mode of fetching data will reduce the gas loss that leads to customer satisfaction.
- **Streamlined Operations:** By centralizing data management, MDMS simplifies processes like meter provisioning, connect/disconnect operations, and outage management. It also provides the ability to identify Qmin and Qmax with pattern tracking and selection of proper metering for customers which will helps to address any withdrawal issues.
- **Remote GC writing:** Enabled accurate billing and lead to customer satisfaction.

## INNOVATION & UNIQUENESS

Metering Data Management System (MDMS) for small metering innovations focus on streamlining data collection, enhancing accuracy. Key innovations include the use of **IoT and 4G enabled cellular connectivity** for secure and efficient data transmission, secured **VPN based platforms** for scalability, reduced infrastructure costs, and user-friendly interfaces for customers.

**a. IoT and 4G enabled Cellular Connectivity:** MDMS for small metering leverages the Internet of Things (IoT) and cellular technologies, particularly 4G to connect and manage a large number of meters securely and efficiently. This allows for real-time data transmission from remote locations.

**b. User-Friendly Interfaces:** MDMS for small metering often features intuitive user interfaces (UIs) designed for both utility personnel and end-users. These UIs provide easy access to data to identify any kind of breakdown. Customised dashboards, historian trends, real time GC from meter that increase the accuracy of billing.

## SCALABILITY & REPLICABILITY

### Scalability:

- **Data Volume and Velocity:** It can be installed anywhere to fetch the metering data where power and OFC infrastructure are not available. It has an ability to add any number of new customers within the system. Small metering deployments can quickly generate large volumes of data, especially with the increasing adoption of interval metering. The MDMS is able to efficiently store, process, and analyse this data.
- **Meter Count:** As a utility expands its service area or adds new customers, the number of smart meters will increase. The MDMS is be able to accommodate this growth without performance degradation.

### Replicability:

- **Standardized Architecture:** A well-defined and standardized system architecture makes it easier to replicate the MDMS in different locations.
- **Automated Deployment:** Automation tools can significantly reduce the time and effort required for deploying the MDMS in new locations.

## KEY LEARNINGS

Key learnings for commissioning a Meter Data Management System (MDMS) for small metering projects include ensuring data accuracy, establishing robust communication protocols, implementing effective data validation and estimation processes, and prioritizing data security.

- **Data Accuracy and Validation:** MEters provide real-time usage data, eliminating estimated readings and manual interventions. Automated data validation processes were implemented to identify and correct errors in meter readings promptly.
- **Communication Protocols:**

Secure and Reliable Communication established channels were established between meters, data concentrators, and the MDMS. Very low and fix cost over SMS / VSAT links. Standardized communication protocols to ensure interoperability and seamless data exchange. Real-time Data Transmission ensure timely transmission of data to the MDMS for real-time monitoring and analysis.

- **Data Security:** Encrypt data during transmission and storage to protect sensitive information from unauthorized access. Robust access control mechanisms to restrict access to the MDMS in public domain and assigned data based on user roles and permissions.

## FUTURE PLANS

The future of metering data management systems for small metering includes enhanced analytics, increased automation, and improved integration with systems. Key areas of focus will be on leveraging real-time data for predictive maintenance, personalized feedback to consumers, and demand response programs.

- **Predictive maintenance:** Analysing this data will enable utilities to identify potential issues with infrastructure before they cause outages, leading to proactive maintenance and reduced downtime.
- **Personalized feedback:** Costumers will have access to their energy consumption data, allowing them to understand their usage patterns and make informed decisions about energy conservation.
- **Proactive communication:** Industries can use MDMS data to proactively communicate with customers about potential issues, energy-saving tips, and other relevant information.





## Excavator Proximity Detection System (GEOFENCE)

AGP City Gas Pvt. Ltd. (THINK Gas)  
Shri Abhilesh Gupta  
MD & CEO

Operational Efficiency-  
Digitalization & Automation

THINK Gas's Excavator Proximity Detection System integrates QCM, GIS, GPS, SCADA and VTS data to create 5 m virtual geofences along pipelines in 19 areas. GPS-tagged excavation equipment is tracked live; unauthorized or prolonged presence triggers instant alerts to control rooms and O&M teams, speeding responses, preventing third-party pipeline damage, ensuring regulatory compliance and enhancing coordination with external stakeholders.

### BACKGROUND & CONTEXT

Prior to the implementation of the GEOFENCE system, management and protection of the gas pipeline network faced several operational challenges. Data from critical monitoring systems such as QCM, GIS, GPS, SCADA, and Vehicle Tracking (VTS) existed in silos, making it difficult to achieve real-time, centralized situational awareness. Coordination between departments was often reactive rather than proactive, increasing the likelihood of delays in identifying and responding to potential threats.

### Key Challenges:

- **Fragmented Data Sources:** Information related to pipeline integrity, construction activities, patrolling, and third-party interference was scattered across multiple platforms with limited integration.
- **Delayed Threat Detection:** Without centralized data fusion, potential third-party intrusions or excavation activities near pipelines were not always identified in time to prevent damage.

- **Limited Visibility:** Field teams and control rooms lacked a unified operational view, which led to inefficiencies in resource deployment and slower incident response.
- **High Risk of TPD (Third-Party Damage):** Growing urbanization and infrastructure development near pipelines increased the risk of accidental damage, posing serious safety and financial implications.

#### Drivers for Change:

- **Need for Proactive Risk Mitigation:** Rising incidents of third-party damage underscored the urgency for a system that could detect and alert stakeholders in real-time.
- **Desire for Integrated Monitoring:** There was a clear need to bring together diverse datasets into a cohesive monitoring platform for improved decision-making.
- **Regulatory and Safety Compliance:** Enhanced safety regulations and internal safety targets demanded a more robust, technology-driven approach to pipeline protection.

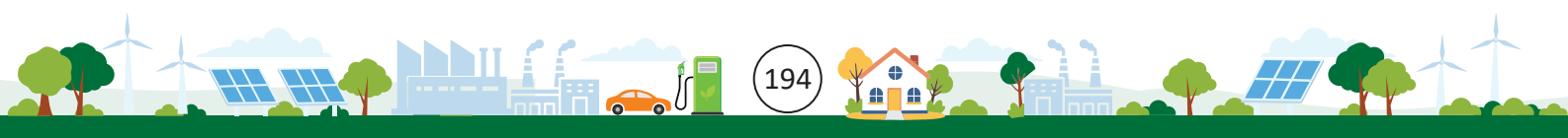
**Operational Efficiency:** Management aimed to streamline coordination among departments and automate alerts and reporting, reducing manual effort and response time.

#### Objectives

- **Enhance Pipeline and Public Safety:** To proactively monitor and protect the gas pipeline network by identifying and mitigating risks of third-party damage (TPD) in real time by monitoring the third-party vehicles proximity to pipeline.
- **Integrate Critical Monitoring Systems:** To create a unified platform by integrating data from existing live systems—QCM, GIS, GPS, SCADA, and Vehicle Tracking

System (VTS)—for centralized visibility and coordination.

- **Enable Real-Time Alerts and Notifications:** To generate automated alerts for unauthorized/uninformed activities, excavation, or intrusions near pipeline corridors using geospatial and telemetry data.
- **Improve Situational Awareness:** To provide a single operational dashboard that gives control room operators and field teams a comprehensive, real-time view of pipeline status and potential threats.
- **Reduce Incident Response Time:** To accelerate detection, assessment, and response to abnormal activities or alarms through faster information flow and automated workflows.
- **Support Proactive Risk Mitigation:** To move from reactive incident handling to predictive and preventive monitoring strategies using historical and live data analytics.
- **Strengthen Regulatory and Safety Compliance:** To support adherence to safety standards and reporting requirements by ensuring timely documentation, tracking, and auditing of pipeline security measures.
- **Optimize Field Resource Deployment:** To improve patrolling efficiency and response logistics by tracking the real-time location and movement of field vehicles and personnel.
- **Facilitate Data-Driven Decision-Making:** To empower operational teams with actionable insights through integrated data visualization, trend analysis, and geospatial intelligence.



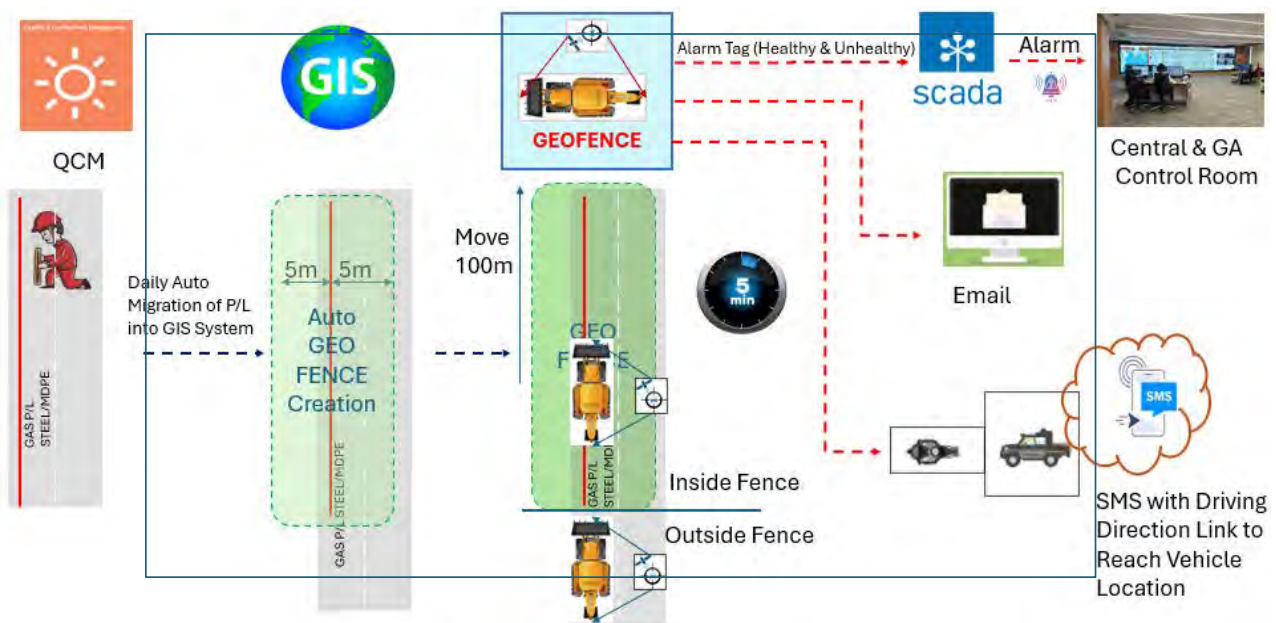
- **Enhance Coordination Across Departments:** To improve collaboration between pipeline operations and maintenance, safety, and GIS teams through shared, real-time access to critical information.

## METHODOLOGY

The GEOFENCE System is a proactive monitoring solution designed to safeguard underground gas pipelines by detecting and managing potential third-party intrusions near critical infrastructure. It operates through real-time tracking and alert mechanisms, integrated into AG&P’s safety and operations workflows.

## METHODOLOGY

The system employs a proactive, preventive safety approach by establishing virtual geofences—5-meter digital perimeters—around the pipeline’s Right-of-Use (RoU) areas. When an earth-moving vehicle equipped with a GPS tracking device enters a geofenced zone and remains stationary for over 5 minutes, the system automatically triggers alarms, along with SMS and email alerts with driving direction link to reach the potential threat location coordinates, to the Control Room, O&M team, and other relevant stakeholders. This helps prevent unauthorized excavation or construction activities that could damage the pipeline. The methodology focuses on early detection,



Utilization of **QCM+GIS+GPS+SCADA+VTS** systems & technology to enhance the pipeline safety

real-time alerts, and a structured incident response.

## APPROACH

Think GAS approach centers on automation, accountability, and integration. The system is integrated with GPS-based tracking devices on third-party vehicles and company fleet assets. Alerts generated through geofence breaches are classified, acted upon, and recorded in a centralized control room. This ensures transparent monitoring, timely

action, and effective coordination between control room operators and O&M field teams.

## Technologies Utilized

- **GIS Mapping Tools & Technology**— Used to create automated geofence zones over pipeline layouts with precise buffer zones.
- **GPS/VTS Devices** – Installed on tracked vehicles to provide real-time location data.

- **Geofence Alert Engine** – Software backend that detects geofence breaches and sends instant alerts.
- **Web-Based Dashboard** – Allows operators to monitor live alerts, update statuses, and access event history.
- **Communication Systems** – Integrated alerts via SMS, email, or in-app notifications ensure timely information flow.
- GPS devices for location tracking, Mobile Application for JCB owners to monitor their vehicle whereabouts.
- Web-based dashboard accessible to multiple user levels
- Cloud Servers for data storage, integration and alert processing

#### Human Resources:

#### Processes Implemented

- QCM Team– To Capture the pipeline asset digitally
  - GIS Team –Manage overall GIS system Infrastructure
  - SCADA & Control Room Operators – Manage alerts and interface with field teams
  - O&M Teams – Respond to escalated cases and conduct physical inspections
  - GIS System Administrators – Maintain geofence accuracy, user access, and data backups
  - Trainers and Analysts – Ensure user competence and process improvement
- Geofence Setup – GIS-based creation of geofence zones around the pipeline corridors based on sensitivity and risk.
  - Alert Generation – Automated alerts triggered when GPS-tracked vehicles enters geofenced areas and ignores when exit.
  - Verification and Categorization – Control room engineers review alerts and classify them (e.g., Authorized Entry, Unauthorized, O&M Verification).
  - Escalation Protocols – Alerts requiring field verification are routed to the O&M team based on predefined escalation levels.
  - Closure and Logging – All alerts are resolved with updated status and remarks for audit and reporting.
  - Data Review – Regular audits are conducted to correct inaccurate status entries and identify patterns for system optimization.

By combining technology with disciplined process control and trained personnel, ThinkGAS Geofence System offers a robust mechanism for pipeline safety, operational transparency, and regulatory compliance.

## CHALLENGES

### Planning Stage Bottlenecks

The implementation of this system for pipeline safety encountered several bottlenecks across the Proof of Concept, planning and execution stages, each requiring strategic intervention to ensure smooth deployment and long-term operational reliability.

- **Low GPS Data Frequency:** During initial POC, the Vehicle Tracking System (VTS) devices reported data at low intervals (greater than 5 minutes), causing delayed location updates and unreliable geofence

## RESOURCES UTILIZED

### Technical Infrastructure:

- QCM – Web, Mobile and High Accuracy Arrow 100 GPS devices and Radiography Scanners
- GIS –Desktop, Web & Mobile GIS applications for mapping and publishing



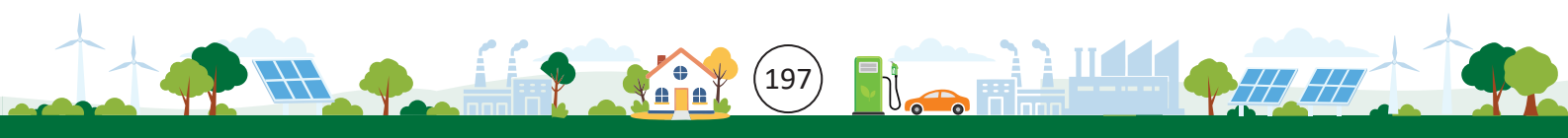
alerts. This delay weakened the system's effectiveness in real-time monitoring. To overcome this, GPS devices were reconfigured for higher-frequency data transmission (10–20 seconds), improving responsiveness and enabling timely alerts.

- **Signal Conversion to Physical Alarms:** Translating digital geofence alerts into audible and visual alarms in the control room posed integration and hardware compatibility challenges. A middleware layer was developed to bridge this gap, converting GPS-triggered alerts into SCADA-compatible formats and triggering physical alarms. This ensured immediate operator's attention to JCB presence.
- **False Alarms and Alert Overload:** The system initially generated numerous false positives due to parking, break down, and GPS drift. These frequent alarms led to desensitization of the control room staff. To address this, alert generation logics were fine-tuned with buffer margins, and multi-parameter logic (such as time spent inside a zone, Vehicle Ignition status) was introduced to filter out false alarms.
- **Absence of SOPs:** Initially established protocols for alert acknowledgment, escalation, or closure were not available. This created inconsistency in response and gaps in accountability. SOPs were developed and formally rolled out, defining alert categorization, response timelines, responsibilities, and escalation matrices.
- **System Integration Challenges:** Integrating the QCM, GIS, SCADA, GPS and VTS platforms was technically

complex. Differences in data formats, lack of APIs, and security protocols slowed the process. A modular integration strategy was adopted, with limited-scope pilot zones. API-based connectors and secure communication protocols were established for data synchronization.

- **Alert Status Entry Errors:** Field and control room staff frequently made incorrect entries in the alert status log (e.g., marking genuine alerts as false or vice versa). These errors impacted reporting and analysis. To mitigate this, dropdown-based status selection was introduced in the interface, reducing manual entry errors. User performance reports were also generated to identify frequent mistakes and provide targeted coaching.
- **Resistance from Vehicle Owners:** Private Third-party vehicle owners initially resisted the installation of VTS devices on their vehicles, privacy, and technical concerns. Engagement sessions were held to explain the safety imperatives and benefits. Mobile applications were developed and given to all owners to view their vehicle whereabouts. Non-compliant owners gradually understood the effectiveness of the system.
- **Scepticism from O&M Field Teams:** Operational teams were skeptical about the system's reliability and its implications on their work. Hands-on training, pilot demonstrations, and inclusion of field feedback in system tuning helped build trust. Champions from the O&M team were identified to support and act as peer trainers.

By systematically addressing these bottlenecks with a balanced mix of



technical fixes, process improvements, and stakeholder engagement, THINK Gas successfully operationalized the Geofence System as a core safety monitoring tool.

## IMPLEMENTATION

The GEOFENCE System was implemented through a structured, phased approach to ensure technical stability, user adoption, and measurable impact. The initiative progressed from proof-of-concept to full-scale deployment over a 12-month period.

### Timeline & Key Milestones

- **Month 1–2 – Proof of Concept (POC):** Conducted in a high-risk pipeline corridor to validate geofence logic, GPS/VTS device accuracy, and alert integration with the control room. Identified technical gaps such as low GPS refresh rates and integration with SCADA alarms.
- **Month 3–5 – System Integration:** Developed API-based connectors to integrate QCM, GIS, GPS, SCADA, and VTS. Configured GPS/VTS devices for 10–20 second update intervals. Created middleware to convert geofence alerts into SCADA-compatible signals.
- **Month 6–8 – Pilot Roll-Out:** Expanded coverage to priority zones with high third-party interference risks. Developed Standard Operating Procedures (SOPs) for alert handling, categorization, and escalation. Conducted hands-on training for O&M teams and control room operators.
- **Month 9–10 – Full-Scale Deployment:** Rolled out across the entire pipeline Right-of-Use (RoU) network. Installed GPS devices on third-party vehicles and provided mobile app access to vehicle owners.

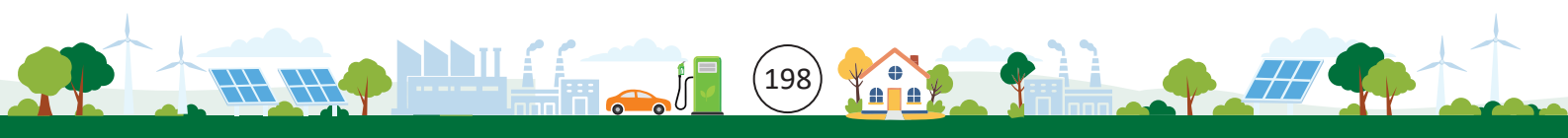
- **Month 11–12 – Optimization:** Fine-tuned alert logic to reduce false alarms, introduced monthly audits, and used trend analysis to optimize patrolling efficiency.

### Stakeholders Involved

- **QCM Team:** Digital mapping of pipeline assets and data accuracy.
- **GIS Team:** Geofence creation, maintenance, and publishing of geospatial data.
- **SCADA & Control Room Operators:** Real-time alert monitoring and escalation.
- **O&M Field Teams:** On-ground verification and rapid incident response.
- **Vehicle Owners:** Participation through GPS-enabled tracking of their equipment.
- **Management & Safety Teams:** Oversight, compliance tracking, and performance review.

### Challenges Encountered & Mitigation

- **Low GPS Data Frequency:** Initial GPS refresh intervals exceeded 5 minutes, delaying detection. Resolved by reconfiguring devices for 10–20 second updates.
- **Integration Complexity:** Different data formats and lack of APIs slowed integration. Adopted modular integration and developed secure API connectors.
- **False Alarms:** Parking, breakdowns, and GPS drift caused frequent false positives. Introduced multi-parameter logic (e.g., stationary time, ignition status) to filter alerts.
- **Absence of SOPs:** Early operations lacked standardized procedures. Developed and rolled out SOPs covering alert categorization, response timelines, and escalation protocols.



- **Resistance from Vehicle Owners:** Privacy concerns hindered GPS installation. Conducted awareness sessions and provided a tracking app to increase acceptance.
- **Operator Skepticism:** Field teams doubted system reliability. Addressed through pilot demonstrations, hands-on training, and assigning O&M “champions” to promote adoption.

The phased rollout ensured that technical issues were addressed before full deployment. The integration of five live systems (QCM, GIS, GPS, SCADA, and VTS)

provided centralized, real-time situational awareness. Comprehensive training, SOP standardization, and stakeholder engagement ensured operational readiness and long-term sustainability. The final system delivered faster detection, reduced response times, and improved pipeline safety across the network.

## INVESTMENTS

Cost Component	Amount (₹ in Lakhs)
Capital Expenditure	27 Lakhs
Operational Expenditure (annual – paper rolls)	8.5 Lakhs for 490 GPS device
<b>Total Investment</b>	<b>35.5 Lakhs</b>

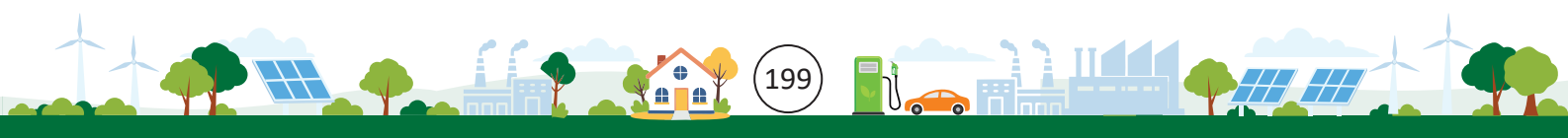
## QUANTITATIVE OUTCOMES

Parameter	Before Neuron	After Neuron	Improvement (%)
Others (please specify) Third-Party Damage (TPD) risks, such as the presence of JCB vehicles within geofenced areas engaged in uninformed activities—including plot levelling, road cleaning, and digging—were detected and notified through the GEOFENCE system, as these activities pose a serious threat to pipeline safety	0 Instances	4513 Instances (From Sep-24 to till 31st-Jul-2025) and ongoing	Out of 4513 Instances JCB Excavation at Site: 947 alerts (21%) – JCB identified by team engaged in uninformed activities like, plot levelling, road cleaning, digging etc. JCB, No Excavation: 3566 alerts (79%) - JCB entered and moved out of pipeline Geofence for parking, stop-over, break down etc.
Integration coverage	Partial integration between systems	100% integration of QCM, GIS, SCADA and GPS	Full Integration Achieved

## QUALITATIVE OUTCOMES

In addition to measurable safety and efficiency improvements, the implementation of the GEOFENCE system has delivered a range of non-quantifiable benefits that have strengthened THINK Gas’s operational culture, stakeholder relationships, and long-term pipeline integrity.

**Enhanced Safety Culture:** The initiative has reinforced a culture of proactive safety within the organization. By providing real-time visibility of potential threats, both control room operators and O&M teams have shifted from reactive incident handling to preventive intervention, fostering greater accountability and vigilance.



**Improved Interdepartmental Collaboration:** Integration of QCM, GIS, SCADA, GPS, and VTS into a single platform has broken down information silos, enabling seamless coordination between operations, maintenance, GIS, and safety teams. This shared visibility has improved decision-making, reduced duplication of effort, and built mutual trust among departments.

**Strengthened Stakeholder Engagement:** Through direct involvement of third-party vehicle owners, the initiative has enhanced trust and cooperation with external stakeholders. Providing mobile app access to equipment location data has increased transparency, reduced resistance to GPS device installation, and encouraged responsible equipment usage near pipeline corridors.

**Regulatory and Brand Reputation Gains:** Demonstrating advanced safety technology and robust monitoring processes has strengthened THINK Gas's position with regulatory bodies and improved its reputation as a safety-focused operator. This proactive approach has positioned the company as an industry leader in pipeline protection.

**Operational Learning & Adaptability:** The phased roll-out, pilot testing, and continuous improvement cycles have created an adaptable operational model. Lessons learned during implementation—such as fine-tuning alert logic and SOP standardization—are now embedded in future project planning, making the organization more agile in adopting new safety technologies.

Together, these qualitative benefits have contributed to a safer operating environment, stronger stakeholder relationships, and a more resilient organizational framework for pipeline safety.

### **Innovation & Uniqueness**

The **GEOFENCE** system represents a first-of-its-kind integration of multiple live operational systems—**QCM, GIS, GPS, SCADA, and VTS**—into a unified platform dedicated to pipeline safety. This initiative

stands out for its ability to detect and mitigate third-party damage risks in real time through a combination of advanced geospatial technology, automation, and stakeholder engagement.

### **Key Innovative Aspects**

- **Virtual Safety Perimeter:** Establishment of 5-meter geofences along the Right-of-Use (RoU) pipeline corridor to detect unauthorized excavation equipment before damage occurs.
- **Real-Time, Multi-Parameter Alerts:** Alerts are triggered not just by geofence entry but also by time spent within the zone and ignition status, significantly reducing false positives.
- **Seamless System Integration:** A modular, API-driven integration framework synchronizes data from disparate systems, enabling a single operational view without replacing existing infrastructure.
- **SCADA-Compatible Alarm Conversion:** Middleware converts GPS alerts into SCADA-readable formats, ensuring instant visual and audible alarms in the control room.
- **Mobile App for External Stakeholders:** Third-party vehicle owners can track their own equipment in real time, creating transparency and reducing resistance to monitoring.

### **Unique Features**

- **Full Asset-to-Alert Workflow:** From GPS-enabled excavation equipment to a unified web dashboard, every stage—from detection to resolutions tracked and logged for audit readiness.
- **Stakeholder-Centric Adoption Model:** The inclusion of external vehicle owners, along with O&M “champions” in the field, ensures buy-in across internal and external parties.



- **Data-Driven Continuous Improvement:** Monthly MIS and trend analysis are built into the process, allowing for ongoing optimization of alert logic, SOP compliance, and patrol efficiency.

This combination of technological integration, real-time prevention, and multi-stakeholder engagement positions THINK Gas’s GEOFENCE system as a benchmark innovation in industrial pipeline safety.

## SCALABILITY & REPLICABILITY

The **GEOFENCE** System has been designed with scalability and adaptability at its core, making it suitable for expansion within THINK Gas’s operational network and replication across other industries with underground infrastructure.

**Scalability within THINK Gas:** The modular, API-based integration framework allows the system to accommodate additional geographical areas without major changes to the core architecture. New pipeline corridors can be quickly geofenced using existing GIS tools, and GPS/VTS devices can be configured for real-time monitoring within hours. Standard Operating Procedures (SOPs) and training materials are already developed, reducing the learning curve for new teams. The centralized dashboard supports multiple user levels, enabling easy onboarding of additional control rooms or regional offices.

**Replicability in Other Contexts:** Beyond gas distribution, the system’s core design—geofencing combined with GPS tracking and multi-system integration—can be applied to safeguard other critical underground assets such as water pipelines, fiber optic cables, and power transmission networks. The methodology is adaptable to varying operational environments, from dense urban areas to remote rural settings.

### Key Enablers for Replication

- **Technology Agnostic Design:** Works with different GPS devices, GIS platforms, and SCADA systems.

- **Customizable Alert Logic:** Can be tailored to local threat profiles, such as construction zones or seasonal agricultural activity.
- **Stakeholder Engagement Model:** Proven approach for involving external contractors and equipment owners, reducing adoption barriers.

With its demonstrated success across 19 Geographical Areas, the **GEOFENCE** system provides a ready-to-deploy blueprint for enhancing underground asset protection. Its combination of real-time monitoring, process discipline, and stakeholder collaboration ensures it can be scaled rapidly within THINK Gas and replicated across other industries or geographies facing similar third-party damage risks.

## KEY LEARNINGS

The implementation of the **GEOFENCE** system provided valuable insights that will guide future safety and technology initiatives within THINK Gas.

### Key Successes

- **Proactive Threat Prevention:** Transitioning from reactive to preventive monitoring significantly reduced third-party damage incidents and improved overall pipeline safety.
- **Effective System Integration:** The successful linking of QCM, GIS, GPS, SCADA, and VTS demonstrated the feasibility and benefits of a centralized monitoring platform without replacing existing infrastructure.
- **Stakeholder Collaboration:** Early engagement with vehicle owners and active involvement of O&M “champions” ensured higher adoption rates and sustained system use.
- **Operational Efficiency Gains:** Automation of alerts, clear SOPs, and integrated communication channels reduced detection and



response times while improving compliance.

## Challenges & Resolutions

- **Technical Limitations in Early Stages:** Initial GPS data refresh delays and integration complexities required reconfiguration of devices and modular API-based integration.
- **High False Alarm Rate:** Initial false positives caused operator fatigue; fine-tuning alert logic and adding multi-parameter triggers significantly improved accuracy.
- **User Adoption Barriers:** Skepticism from O&M teams and resistance from third-party equipment owners were mitigated through training, demonstrations, and transparency tools like the mobile tracking app.

## Strategic Takeaways

- Early-stage **pilot deployments** are critical for identifying technical and process gaps before full-scale implementation.
- **Standardization through SOPs** ensures consistency in response, accountability, and reporting.
- Continuous **system tuning and audits** are essential to maintain accuracy and stakeholder confidence.
- A **people-first approach**—combining technology with user engagement—ensures long-term adoption and maximizes safety benefits.

Overall, the initiative reinforced the value of combining advanced technology, disciplined processes, and strong stakeholder collaboration to deliver sustainable safety and operational excellence.

## Future Plans

Building on the success of the **Excavator Proximity Detection System (GEOFENCE)**, THINK Gas plans to enhance the system's capabilities and extend its application scope.

## Planned Improvements

- **AI-Driven Threat Prediction:** Integrate machine learning models to analyze historical alerts and environmental data, enabling predictive identification of high-risk zones.
- **Enhanced Mobile Application Features:** Provide O&M teams with field-level access to real-time alerts, GIS maps, and incident reporting tools via mobile devices.
- **Video Verification Integration:** Link CCTV or drone-based surveillance to the geofence system for live visual confirmation of alerts before dispatching field teams.
- **Expanded Alert Channels:** Introduce in-app push notifications and instant messaging integration for faster communication with relevant stakeholders.

## Extensions & Scaling

- **Broader Stakeholder Coverage:** Extend GPS/VTS integration to contractors engaged in maintenance, construction, and utility work near pipelines.
- **Cross-Industry Application:** Explore replication of the solution for protecting other underground assets such as water pipelines, fiber optic cables, and power infrastructure.
- **National Integration:** Position the GEOFENCE system as a model safety standard for adoption across the wider gas distribution sector in India.

These enhancements aim to make the system more intelligent, versatile, and widely applicable, ensuring THINK Gas remains at the forefront of pipeline safety innovation.



# Clean Energy



# Enabling LNG for Long-Haul Trucking in India with BOG Management

AGP City Gas Pvt. Ltd. (THINK Gas)  
Shri Abhilesh Gupta  
MD & CEO

Clean Energy

THINK Gas launched a strategic initiative to develop LNG fueling ecosystem for long-haul trucking across India. This included comparative fuel efficiency analysis, technology integration for Boil-Off Gas (BOG) management. The project has demonstrated that LNG trucks provide up to 30% operational savings and reduce CO<sub>2</sub> emissions, establishing LNG as a viable clean fuel for India's heavy transport sector.

## BACKGROUND & CONTEXT

India's commercial vehicle segment which primarily includes long haul trucks and intercity busses accounts for a significant share of fuel consumption and carbon emissions. These vehicles are powered by diesel which faces challenges such as rising fuel cost, increasing regulatory scrutiny over emissions and limited alternatives.

Additionally, the ecommerce logistics and fleet operators highlighted the need for clean, scalable alternatives, to which THINK Gas has identified LNG as a promising fuel

that combines high energy density, lower emissions, and potential cost savings — making it well-suited for heavy-duty, long-haul applications.

However, the shift to LNG was constrained by technical, commercial and regulatory challenges which required immediate intervention. The issues of Boil-Off Gas (BOG) losses, high fuelling temperatures, and lack of familiarity among operators posed significant adoption barriers. Moreover, there was limited awareness of how these factors impact fuel density, efficiency, and safety.



In response, THINK Gas undertook a detailed analysis of LNG as a transport fuel, aiming to bridge the knowledge gap. The goal was to support industry stakeholders with performance comparisons, economic models, and practical strategies to optimize LNG usage in Indian operating conditions — especially for logistics and fleet operators with high daily running and emissions impact.

## OBJECTIVES

The primary objectives of the initiative were:

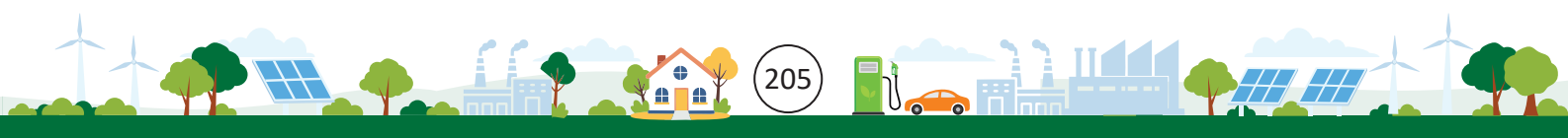
- **Promote LNG as a viable, cleaner alternative** to diesel in the heavy-duty trucking and intercity transport sector, particularly for long-haul applications.
- **Quantify and showcase the economic advantages** of LNG, such as lower fuel costs and reduced maintenance needs, through comparative analysis with diesel.
- **Reduce greenhouse gas (GHG) emissions** and improve overall air quality by transitioning to a low-emission, cleaner-burning fuel.
- **Support logistics operators and fleet owners** with technical performance comparisons, lifecycle cost analysis, and payback calculations to enable informed decision-making.
- **Highlight and mitigate operational challenges**, such as Boil-Off Gas (BOG) losses and temperature-induced fuel inefficiencies, by identifying best practices in fuelling techniques and storage management.
- **Encourage development of LNG refuelling infrastructure** that ensures desired pressure and temperature control, enabling optimal fuel density and minimizing gas losses.

## METHODOLOGY

THINK Gas has adopted a data driven approach integrating technical, commercial and regulatory challenges to compute the feasibility and advantages of using LNG as a clean transportation fuel.

The approach started with a comparative lifecycle assessment between diesel and LNG trucks focussing on critical parameters such as calorific value, fuel efficiency, running cost, maintenance cost, total cost of ownership, emissions, environmental impacts, truck lifespans and overall safety. **As per the comparative lifecycle assessment, THINK Gas concluded that LNG segment delivered up to 30% operational savings over the Diesel counterpart along with significant reduction in carbon emissions.** In the next phase, THINK Gas undertook a technical evaluation of truck models from major OEMs like Tata Motors, Ashok Leyland, Volvo, Eicher and Blue energy, through publicly available technical specifications. The overall insights helped to develop a comparative framework for existing truck user including ecommerce logistics and fleet operators, to consider LNG adoption in the coming future.

Next critical study which was conducted to understand how LNG Fuelling temperature and Boil Off Gas (BOG) impact operational efficiency. THINK Gas highlighted that LNG fuelling requires precise temperature control (in cryogenic tanks to maintain liquid state) to prevent evaporation and pressure build-up. Temperature fluctuations during fuelling can lead to inconsistent fuel quality and safety risks. The Boil Off Gas which is natural gas vapor formed due to heat ingress into LNG tanks during storage or transport, often leads to other economic losses such as reduced payload, more frequent refueling, LNG Venting which is basically fuel lost leading to economic losses and raising environment concerns. Therefore, as per study, maintaining BOG is very important, otherwise it leads to economic and environment impact.



To overcome the commercial challenge, THINK Gas developed financial models for both LNG and Diesel segment and simulated the parameters in real world operating conditions. The study showed that LNG Vehicles offered 40% higher upfront cost than their diesel counterparts, but the overall savings based on daily running, payload and other parameters offered 30% savings along with a payback period of 1.5 to 2 years for logistics and fleet operators. The delta on LNG conversion vis-à-vis buying a new LNG truck is considered as Rs 20 Lakhs.

The regulatory challenge study involved policy and stakeholder engagement, referencing provisions under 2017 Motor Vehicles Rules Amendment which highlighted to legalize LNG as auto fuel, 2018 Gas Cylinder Rules which regulated LNG storage and transport and other proposed incentives such as toll tax waivers, GST reduction up to 5% from MoPNG.

Throughout the process, THINK Gas covered all aspects related to technical, commercial and regulatory challenges which enabled informed decisions to adopt LNG as a fuel.

## CHALLENGES

THINK Gas encountered several operational, financial and regulatory challenges that impacted both planning and execution.

The most critical challenge was management of Boil Off Gas, because LNG stored in cryogenic tanks often experiences pressure buildup due to vaporisation considering India's high ambient temperature and long refuelling cycles. Mismanagement of BOG often leads to fuel losses (0.3-5.3 vol.% at refuelling stations), safety reasons (risk of flammable gasses) and environmental challenges (direct BOG venting releases potent greenhouse gas).

Another challenge was the limited awareness among the logistics and fleet operators regarding the LNG's advantages and operational savings and ultimately the reduced emissions. The major uptakes

were the lack of knowledge about fuelling temperature, tank pressure control and BOG mitigation strategies.

The other challenge was the higher upfront cost for LNG Vehicles (40% more than diesel counterparts) which provided a financial hurdle for existing logistics and fleet operators to transition over LNG Trucks. Additionally, the lack of adequate LNG refuelling infrastructure, proved to be another bottleneck in adoption of LNG Trucks as means of transportation.

The regulatory challenges included the ambiguity around incentives including toll tax waivers, GST Reduction and other fiscal benefits for LNG Trucks. The absence of such support and fiscal policy creates uncertainty for all major stakeholders.

To address these challenges, THINK Gas developed comparative analysis, financial modelling and addressed the regulatory bottlenecks which are necessary for adoption of LNG in transport sector.

## IMPLEMENTATION

THINK Gas implemented a structured phase approach by initiating the pilot deployment in Bhopal, where THINK Gas facilitated the installation of LNG Dispensers at selected company operated fuelling station, ensuring the availability of sub cooled LNG to improve fuel density, reduce flash losses and optimise energy efficiency. THINK Gas also took special emphasis on maintaining proper dispensing temperatures to mitigate BOG losses. To standardise the BOG management, SOPs were also developed and implemented throughout the fuelling and refuelling process. THINK Gas also conducted driver training sessions focusing on handling, fuelling techniques, and safety protocols.

On the regulatory front, THINK gas supported a policy push for VAT inclusion and broader recognition of LNG as a clean commercial fuel, engaging with local authorities and regulatory bodies.



## QUANTITATIVE OUTCOMES

Parameter	Before (Diesel Trucks)	After (LNG Trucks)	Improvement / Benefit
CO <sub>2</sub> Emissions	~64 tonnes/year per truck	~46 tonnes/year per truck	~18 tonnes/year reduction (~28%)
Fuel Cost per km	~₹ 55–58/km	~₹ 38–42/km	Up to 30% savings
Annual Fuel Cost	~₹ 45–48 lakhs/year	~₹ 32–34 lakhs/year	₹ 13–15 lakhs/year savings
Mileage	2.75 km/litre (diesel)	Equivalent of ~3.2–3.4 km/litre	~15–20% better fuel economy
Boil-Off Gas Losses	~5–6% during storage/dispensing	<1% with sub-cooled LNG & SOPs	~5% reduction in losses
Operating Cost per km	₹ 55–58	₹ 38–42	Up to 30% lower
Vehicle Maintenance Cost	Baseline (diesel engine wear)	~15–20% lower (cleaner combustion)	Lower O&M cost
Payback Period	Not applicable	1.5–2 years (through fuel savings)	Faster ROI



## QUALITATIVE OUTCOMES

THINK Gas has successfully demonstrated the operational viability of LNG as a clean fuel for India's growing long haul trucking demand and focus on decarbonising transport sector. The key learnings along with technical, commercial and regulatory studies have helped key stakeholders who were previously sceptical about LNG's practicality in real world logistics operations. The initiative also created awareness among policymakers, ecommerce logistics and fleet operators, and OEMs about the strategic and environmental advantages of adopting LNG. Additionally, the focus on driver awareness and BOG management protocols has led to improve handling process, thereby enhancing safety and regulatory compliances.

## INNOVATION & UNIQUENESS

THINK gas took the development of India's first BOG focused fuelling optimisation framework for LNG Trucks by implementing operational strategies to reduce vapor losses during storage and dispensing.

THINK Gas uses a net-metering-based billing system at its LNG stations. This system ensures that any natural gas vapor called boil-off gas is not wasted or released into the air during LNG fuelling. Instead, it is captured and returned to THINK Gas's gas distribution network. Customers get an appropriate net off discount reflecting the value of this recovered gas.

This makes billing more accurate and transparent, THINK Gas supplies LNG at a sub-cooled temperature that helps reduce boil-off gas, reduce flash losses during dispensing & improving fuel efficiency for customers.

Another unique initiative includes incentive based retrofitting models supported by calculated payback projections (1.5 - 2 years) making transition to LNG easy and economical for logistics and fleet operators.

Together, these features showcase THINK Gas's unique approach to building a sustainable, efficient, and transparent LNG fuelling ecosystem.

## SCALABILITY & REPLICABILITY

THINK Gas has implemented a structured phase wise approach which is designed with scalability and replicability at its core, ensuring that this approach can be expanded across India's growing clean fuel corridor network.

With successful deployment of Bhopal Pilot, THINK Gas is preparing to rollout LNG dispensing Infrastructure at three upcoming locations: Wallam, Raptadu and Nellore. The same approach and practice will be followed covering all technical, commercial and regulatory challenges. THINK gas also plan to replicate this model across 18 additional LNG Stations very soon with the same framework for BOG management, transparent billing, safety protocols and making deployment standardised and operationally efficient.

## KEY LEARNINGS

THINK Gas learned critical insights which can shape the future of clean fuel adoption in long haul transport.

- **Fuelling Temperature significantly impacts LNG Economics:** THINK gas approach to fuelling sub cooled LNG ensures better fill density and reduces flash losses.
- **BOG Management:** THINK Gas focus on implementing SOPS, effective insulation, pressure regulation and venting control such that it leads to least economical and environmental concerns.
- **Training and Awareness Programs:** THINK Gas also conducted driver training sessions focusing on handling, fuelling techniques, and safety protocols.



- **Cross Sector collaboration:** Engagement between all CGD entities, OEMs, and govt stakeholders, can enable a holistic approach in adoption of LNG Trucks and fuel in transport sector.

THINK Gas concludes that with right blend of infrastructure, knowledge and policy support, LNG can be a scalable, safe and cost-effective solution for India's Transportation decarbonisation goals.

## FUTURE PLANS

Based on the key learnings, THINK Gas has planned other provisions which includes

- THINK Gas plans to scale LNG Dispensing infrastructure to 20 new locations with upcoming stations at Wallam, Raptadu and Nellore.
- All the stations will be equipped with subcooled LNG capabilities,

net metering systems, standardised BOG system, forming part of broader strategy to develop India's LNG corridor for long haul freight transport.

- THINK Gas also plans to explore the retro fitment of existing diesel tankers into LNG compatible trucks and tankers.
- THINK Gas also intends to continue policy advocacy and stakeholder engagement to secure incentives such as toll tax waivers, reduced GST, and simplified permitting for LNG infrastructure.

THINK Gas continues to envision building a fully integrated LNG ecosystem, combining supply chain reliability, vehicle compatibility, operational efficiency and environmental compliance- contributing to India's transportation decarbonisation goals.





# Renewable Energy Integration

Megha City Gas Distribution Pvt Ltd  
Shri Shoan P Umathe  
Manager – PMC

Clean Energy

Megha City Gas implemented solar in its mother station to reduce the operational costs. The initiative integrates 45 kw solar capacity to power administrative offices. This transition enhances energy efficiency by 71.25%, cuts carbon emissions and aligns with India's renewable energy targets. The project demonstrates scalable clean energy adoption in CGD operations.

## BACKGROUND & CONTEXT

Prior to the solar initiative, **Megha City Gas** faced escalating operational challenges driven by heavy reliance on grid electricity. The CGD network's critical infrastructure consumed over 96000 kWh/year of grid power, accounting for 4% of operational costs other than forcing dependency on backups that Intensified GHG emissions (~78.72 t CO<sub>2</sub>e annually).

### India's Grid Emission Factor:

- **0.82 kg CO<sub>2</sub>e/kWh** (Source: Central Electricity Authority (CEA), 2023)

Note: This accounts for India's coal-dominated grid mix.

- **Convert kWh to kg CO<sub>2</sub>e:**  
 $96,000 \text{ kWh} \times 0.82 \text{ kg CO}_2\text{e/kWh} = 78,720 \text{ kg CO}_2\text{e}$
- **Convert kg to tonnes (tCO<sub>2</sub>e):**  
 $78,720 \text{ kg CO}_2\text{e} \div 1,000 = 78.72 \text{ tCO}_2\text{e/year}$

### Key challenges included:

- **Rising energy costs:** AP's industrial electricity tariffs increased by 20.4% over three years.



## AP Industrial Tariff Hike (HT Category)

Financial Year	Tariff (₹/kWh)	YoY Increase
2021-22	₹6.85	Baseline
2022-23	₹7.40	+8.0%
2023-24	₹8.25	+11.5%

### Drivers for change emerged from:

- **Regulatory push:** PNGRB urging CGDs to adopt renewables.
- **Economic urgency:** Solar LCOE (Levelized Cost of Electricity) dropping below grid tariffs (₹3.5/kWh vs. ₹8.2/kWh).
- **Strategic opportunity:** Abundant solar potential in Agiripalli (300+ sunny days/year).

The combination of operational challenges, unpredictable costs, and regulatory requirements made it necessary to switch to renewable energy for sustainable and reliable operations.

## OBJECTIVES

- Achieve renewable energy penetration across core operations within 3 years.
- Improve energy efficiency by replacing grid with solar systems.
- Reduce operational GHG emissions through fossil-fuel displacement.
- Develop a scalable clean energy model for replication across AP's CGD network by 2026.

## METHODOLOGY

### Approach:

Megha City Gas adopted a **phased solar integration strategy** targeting high-energy-load facilities. The initiative prioritized:

- **Technical Feasibility:** Site assessments for solar potential and

grid connectivity.

- **OPEX Minimization:** Capitalizing on CAPEX to avoid upfront costs.

### Technologies Deployed:

- **Solar PV Systems:**
  - **Capacity:** 45 kWp rooftop (540 Wp MonoPerc Modules)
  - **Inverters:** Grid-tied string inverters with smart metering for real-time monitoring.
- **IoT Integration:**
  - WIFI-enabled energy management system for load optimization and fault detection.

### Key Processes:

- **Site Selection:**
  - Mapped energy consumption patterns (using historical data) to prioritize the location.
- **System Design:**
  - Customized tilt angles (45°) and orientation (south-facing) for max yield.
- **Installation:**
  - Partnered with **IREDA-empaneled EPC vendor** for turnkey deployment.
- **Grid Synchronization:**
  - Net metering under APCPDCL.
- **Performance Tracking:**
  - Cloud-based dashboards for generation vs. consumption analytics.

## CHALLENGES

### Planning Phase Bottlenecks

- **Liaison Issues**
  - Issue: Amending the existing CEIG approval to accommodate the solar.
  - Strategy: consulted the Third-



Party vendors to get the approvals done.

- **Land/Rooftop Constraints**

- Issue: Limited space restricted solar capacity.
- Strategy: Utilized the full rooftop.

Execution Phase Bottlenecks

- **Grid Synchronization Failures**

- **Issue:** Voltage fluctuations triggered inverter strings (DC) and drives failure.

- **Strategy:** Developed a **transformer tap-changing solution** to stabilize voltage fluctuations preventing inverter failures during grid instability.

- **Supply Chain Delays**

- Issue: the materials delivered to us 1.4 years after the release of PO.

- **Net Metering Issues**

- Issue: APCPDCL delayed 2 months for providing Net Metering.

## IMPLEMENTATION

Phase	Timeline	Key Activities
<b>Pre-Installation</b>	Q1 2022	<ul style="list-style-type: none"> <li>• PO Released to Interactive Data Systems Limited</li> </ul>
<b>Installation</b>	Q2 2023 – Q2 2024	<ul style="list-style-type: none"> <li>• Deployment of 540 Wp mono panels + 50 kw grid inverter</li> <li>• Civil works.</li> <li>• Net Metering</li> </ul>
<b>Commissioning</b>	Q3 2024	<ul style="list-style-type: none"> <li>• Grid synchronization</li> <li>• Performance testing (97.3% efficiency)</li> <li>• Operator training</li> </ul>
<b>Operations</b>	Q3 2024– Ongoing	<ul style="list-style-type: none"> <li>• Real-time monitoring</li> </ul>

## INVESTMENTS

Cost Component	Amount (₹ in Lakhs)
Capital Expenditure	21.75
Operational Expenditure (annual)	0.25

## QUANTITATIVE OUTCOMES

Parameter	Before Implementation	After Implementation	Improvement (%)
GHG Emissions (tCO <sub>2</sub> e)	78.72	22.63	71.25%
Energy Consumption (units)	96000	27600	71.25%
Cost Savings (₹ in Lakhs)	11.4	6.24	45.26%



## QUALITATIVE OUTCOMES

The solar initiative delivered transformative **non-quantifiable benefits** across four key areas:

- **Workforce Empowerment**
  - Upskilled technicians in renewable energy management through **training**, fostering a culture of innovation and reducing external dependency.
- **Strategic Positioning**
  - Recognized as a **CGD** sector pioneer in AP's renewable transition, influencing PNGRB's 2024 solar integration guidelines. Vendor partnerships strengthened through demonstrated tech reliability.

## INNOVATION & UNIQUENESS

The initiative stands out for its strategic fusion of renewable energy with CGD operations—an area traditionally reliant on grid power. Key innovations include:

- **Smart Solar Architecture:** Integration of WIFI-enabled solar PV systems with real-time analytics, enabling predictive maintenance and load balancing.
- **Customized Engineering:** South-facing 45° tilt design optimized for Agiripalli's solar profile, maximizing yield despite rooftop constraints.
- **Regulatory Trailblazing:** First CGD site in AP to secure CEIG amendments for solar-grid synchronization, setting a precedent for future installations.
- **Financial Innovation:** CAPEX-based deployment with minimal upfront OPEX, leveraging vendor partnerships and net metering to reduce payback.

This initiative redefines how CGD networks can adopt clean energy without

compromising operational reliability, making it a benchmark for sector-wide transformation.

## SCALABILITY & REPLICABILITY

The success at Agiripalli CGS cum MS demonstrates high replicability across similar CGD stations.

### Scalability Pathways:

- **Geographical Expansion:**
  - *Phase 1 (2024–2026):* Scale solar capacity to 65KWH for the upcoming mother station at vedurupavuluru.
- **Operational Integration:**
  - Embed solar into Compressors Operations to reduce auxiliary power loads.

## KEY LEARNINGS

### Successes:

- Achieved 71.25% energy efficiency improvement and 45.26% cost savings.
- Strengthened internal capabilities in solar operations and vendor management.
- Enhanced brand positioning as a clean energy leader in CGD.

### Challenges:

- Grid synchronization failures required technical interventions like transformer TAP adjustments.
- Supply chain delays highlighted the need for tighter vendor selections and buffer planning.
- Net metering approvals demanded persistent regulatory follow-up.

### Insights:

- Early stakeholder engagement and technical feasibility studies are critical.
- Real-time monitoring tools



significantly improve system uptime.

- Solar adoption is not just feasible—it's strategically advantageous.]

### FUTURE PLANS

- Integrate SCADA into it for multi-site solar performance analytics.
- Canopy-Based Solar Architecture: Installation of MonoPerc modules on the station canopy—an

underutilized structural asset—maximizing solar exposure without compromising ground operations.

- Collaborate with PNGRB to co-develop sector-wide solar adoption guidelines.

These steps will further decarbonize operations, enhance energy resilience, and position Megha Gas as a national leader in sustainable CGD infrastructure.





# Sectionalization Valve (SV) Station Powered by Hybrid Renewable Architecture

Petronet MHB Limited  
Shri Prasanna Kumar R  
Head-Procurement

Clean Energy

PMHBL has established India's first SV station that is fully powered by solar PV technology and a Lithium Iron Phosphate (LiFePO<sub>4</sub> or LFP) battery energy storage system (BESS). The setup is managed through hybrid inverters and an integrated SCADA.

This deployment fully retires Diesel Generators (DGs), legacy lead-acid batteries, and conventional battery chargers. It facilitates round-the-clock autonomous management of cathodic protection (CP), SCADA, and telecom functions, delivering a substantial reduction in carbon emissions and operating expenditure.

## BACKGROUND & CONTEXT

Traditionally, SV stations have been manned 24x7 and powered by State Electricity Board with Diesel Generator (DG) backup. Diesel use posed fire risk, environmental concerns, and high maintenance. Manual operation reduced system uptime and responsiveness. In pursuit of safety, sustainability, and reliability, Petronet MHB Limited (PMHBL)

undertook the initiative to eliminate fossil-fuel-based power at SV stations and implement intelligent, remotely operated, renewable-powered infrastructure.

## OBJECTIVES

- Achieve 100% automated SV station operations.
- Eliminate DG dependency to reduce emissions and fire risk.



- Improve reliability and automate CP/SCADA/telecom operations.
- Initiative towards company's aspiration towards sustainability.
- Ensuring solar generation meets 24x7 critical load demand.
- Fine-tuning LFP BMS alerts for autonomous switching.

## METHODOLOGY

The power system design uses:

- **Solar PV** as the primary source of power
- **Lithium Iron Phosphate BESS** as backup during night hours (charged only via solar PV system)
- **The hybrid inverter** delivers 3-phase, single-phase AC, and 48V DC output, enabling the complete replacement of legacy infrastructure—including diesel generator (DG) sets, CP & Telecom charger panels & lead-acid battery arrays.
- All subsystems are energized via a unified 48V DC bus architecture, streamlining power distribution across components. The integrated SCADA Remote Terminal Unit (RTU) facilitates real-time control, diagnostics, and performance monitoring. Intelligent switching mechanisms, coupled with advanced power factor correction, mitigate harmonic distortion and minimize power losses.

## CHALLENGES

- Integration of multi-output inverters (single, three phase AC Power supply and 48V DC) across legacy infrastructure.

## IMPLEMENTATION

The project was scoped in Dec 2024, implemented from Feb 2025. The scope included:

- Solar installation
- Lithium Iron Phosphate BESS System Installation
- Hybrid inverter deployment
- Full migration of CP, SCADA, telecom to unified DC
- Remote monitoring system implemented for this site (Solar generation, Load, Battery SOC)
- SCADA telemetry integration from Inverter to Petronet SCADA

The project was completed without disruption to live operations in May 2025.

## INVESTMENTS

Cost Component	Amount (₹ in Lakhs)
Capital Expenditure	16
Operational Expenditure	-
Human Resources	-
R&D and Innovation	(Same as Capex)
<b>Total Investment</b>	16 lakhs

## QUANTITATIVE OUTCOMES

Parameter	Before Implementation	After Implementation	Improvement (%)
GHG Emissions (tCO <sub>2</sub> e)	19.68	0	100
Energy Consumption (units)	24000	7320	70
Water Consumption (KL)	Not Applicable	Not Applicable	

Parameter	Before Implementation	After Implementation	Improvement (%)
Water Generation (tonnes)	Not Applicable	Not Applicable	-
Resource Utilization	Diesel for DG and power from Grid	Power generated through Solar backed up by BESS.	-
Operational Efficiency	60%	100%	40%
Cost Savings (₹ Lakhs)	2.65	0.58	2.07

### QUALITATIVE OUTCOMES

- Enhanced safety through DG elimination (fire, fuel storage, spill risk)
- Demonstrated proof of concept for fully automated pipeline nodes
- Increased uptime, reduced manual errors, remote troubleshooting
- Positive environmental and sustainability branding impact

### INNOVATION & UNIQUENESS

This is India’s first implementation of a fully unmanned SV station powered by solar with BESS, with integrated SCADA and no fossil fuel dependency. Hybrid inverters enable multiple voltage outputs in a unified cabinet, simplifying power delivery to CP, SCADA, and telecom equipment. Real-time power optimization, zero-DG design, and system modularity make this a scalable and forward-looking model.

### SCALABILITY & REPLICABILITY

India has over 20,000 km of cross-country petroleum pipelines with dozens of SV stations. This model can be replicated across the entire network with minimal changes. All SVs with moderate to low loads can switch to this setup, cutting emissions and maintenance while improving safety and reliability.

### KEY LEARNINGS

- Battery sizing must consider surge loads from CP systems
- Decommissioning DG infrastructure creates space, reduces pollution and simplifies operations

### FUTURE PLANS

- Deploy this model to 9 more SV stations during 2025-2026
- Integrate real-time weather forecasting for solar prediction and BESS optimization
- Explore AI-driven SCADA analytics.

### SUPPORTING MATERIALS



Solar PV Modules on SV Station Roof Top



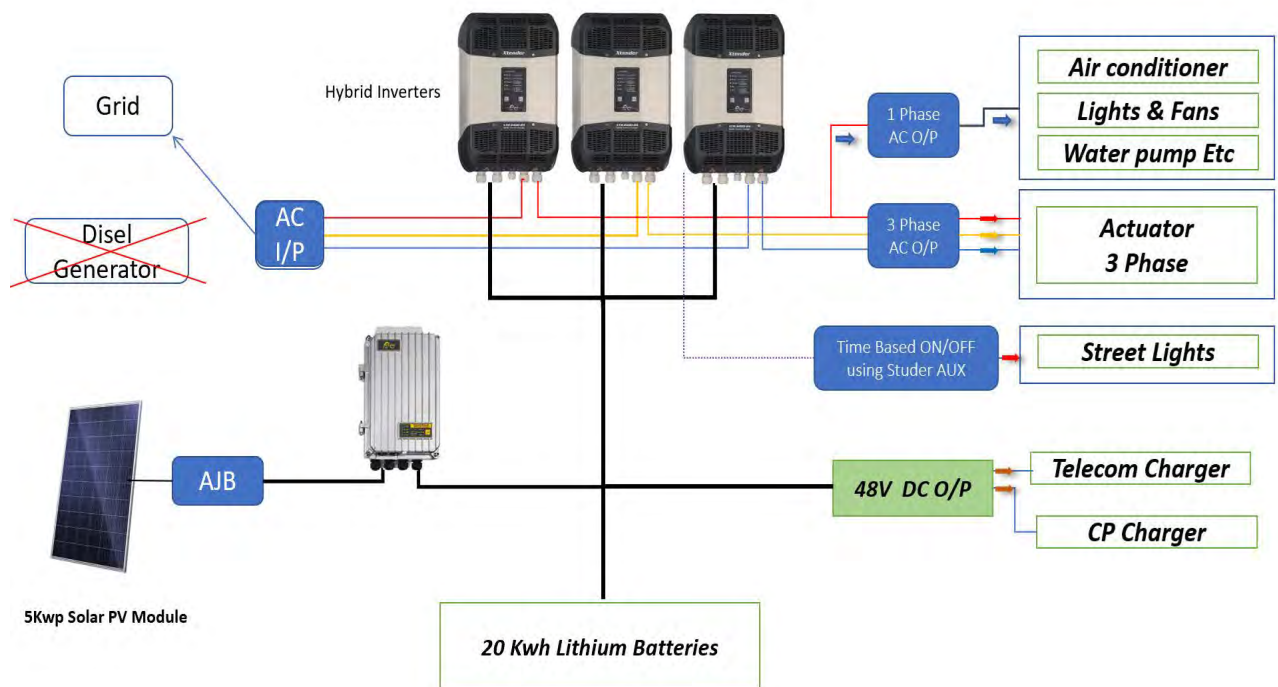


Hybrid Inverter, Charge controller & Protections

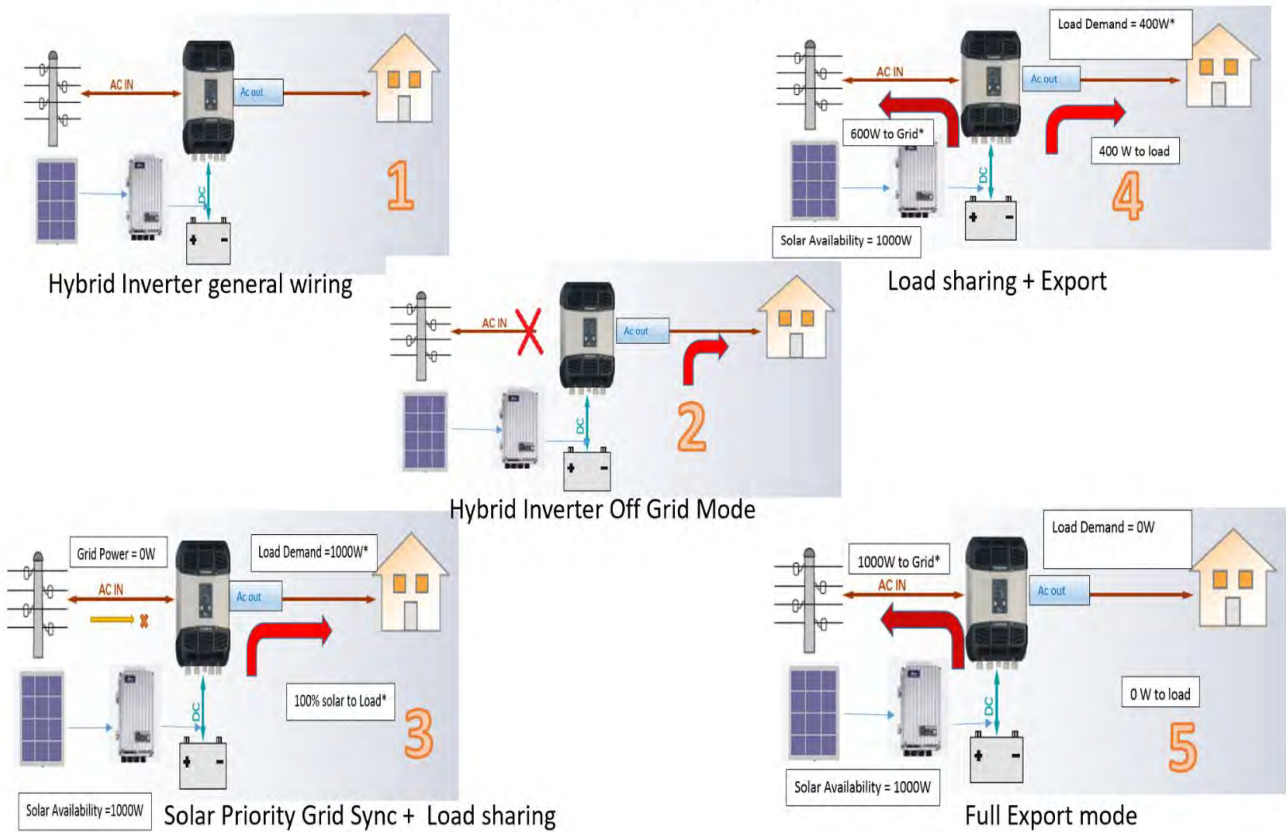


Lithium Iron phosphate (Lifepo4) Batteries

## SV 10 Yelahanka Site Photos & Map



## Working principle of Studer Hybrid System



## Hybrid System Working Methodology- real time monitoring



- Hybrid Solar System universal system connected with Solar, Grid, Battery storage.
- Hybrid System will give : 1 Phase, 3 Phase O/P , 48V DC O/P.

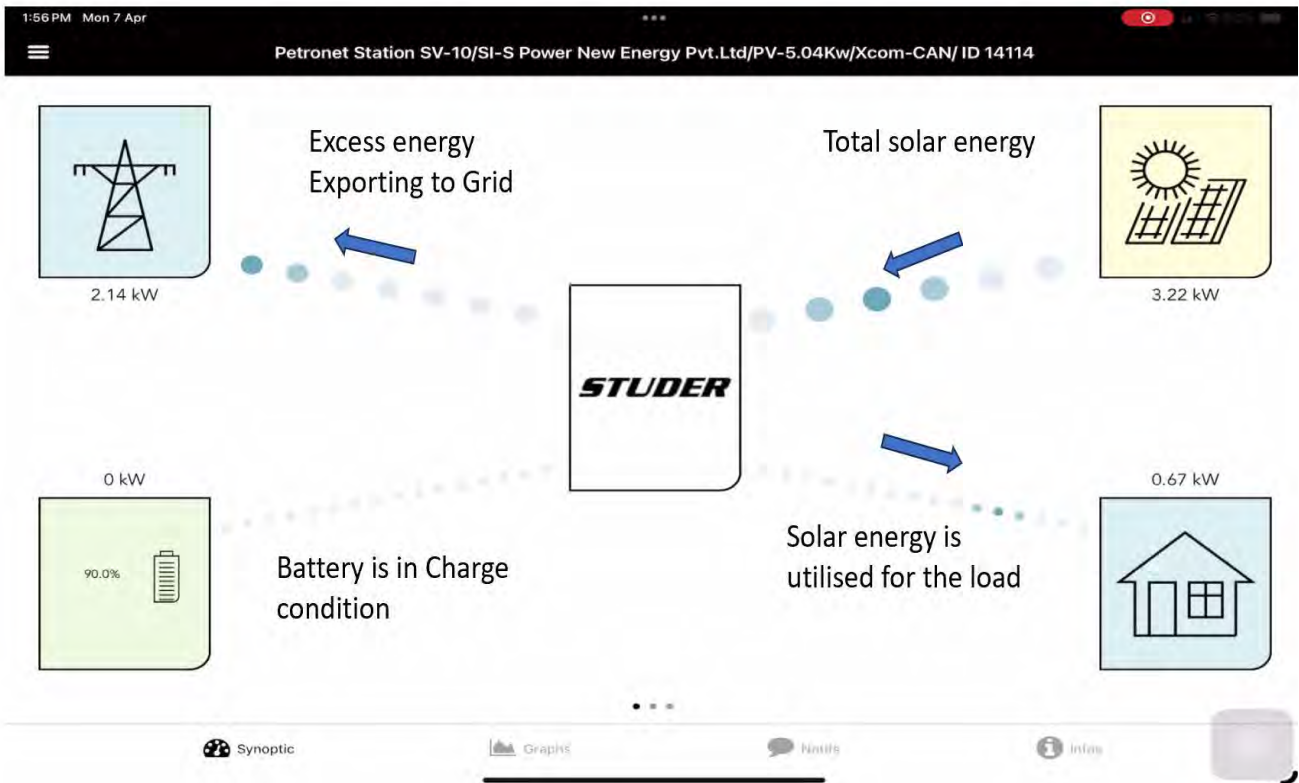
### Hybrid Inverter will work all loads through below priority

- 1st priority : Solar
- 2nd Priority : Grid/ Battery ( Programmable)
- 3rd Priority : Battery / Grid ( Programmable)

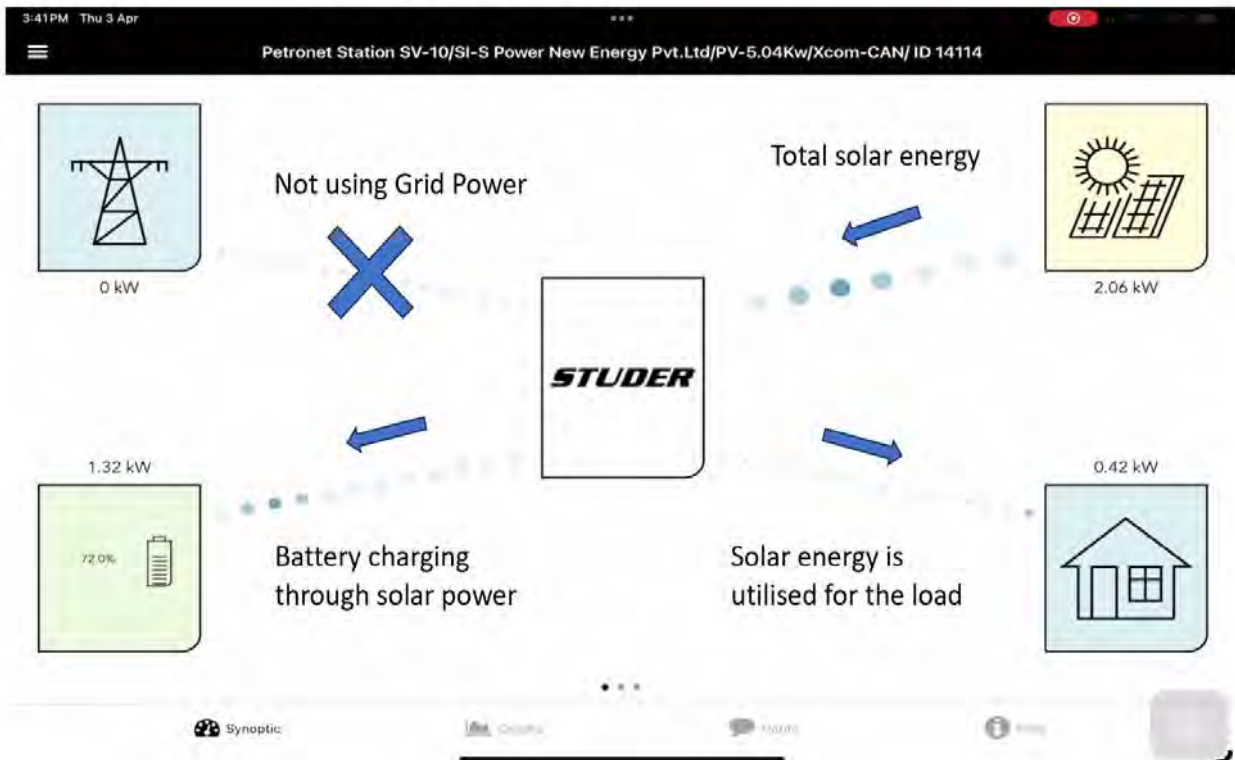
Battery based operation : Programmable if loads are running through Battery we can set the cutoff, Grid charging Etc

Excess Energy : Solar generation is more than the requirement. Excess energy will be exported to Grid. In case of power cuts. Solar generation will be limited to load.

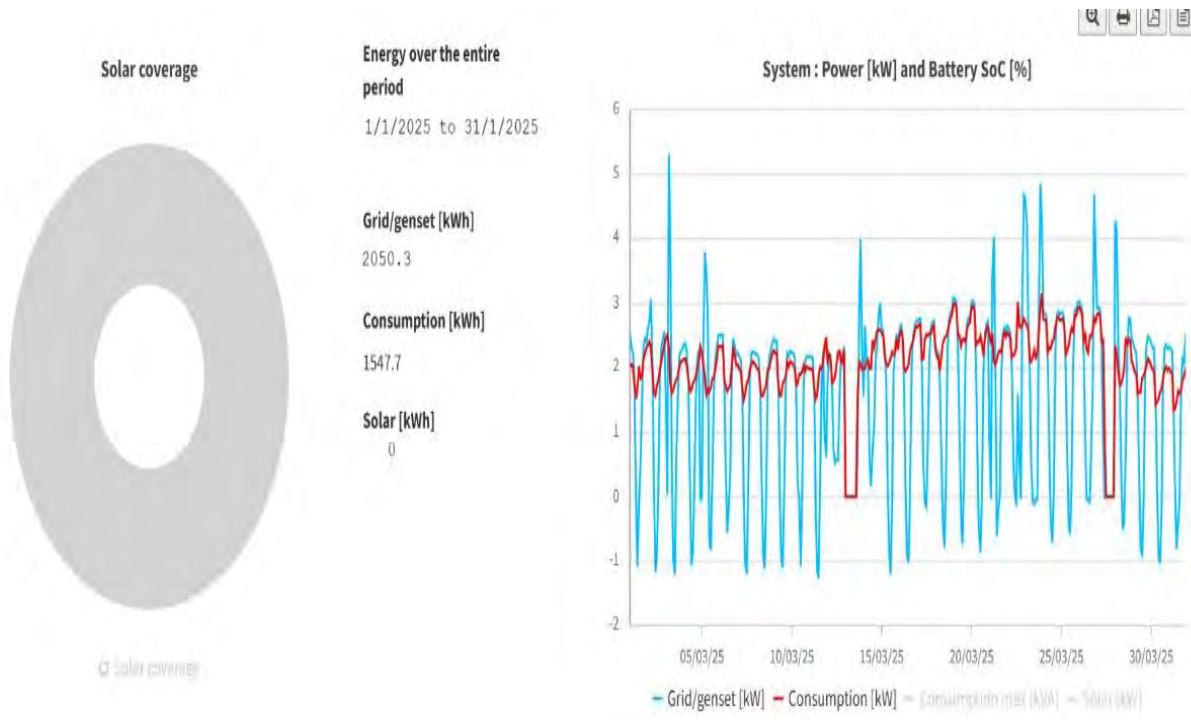
## Energy Flow : With Grid Export Operation



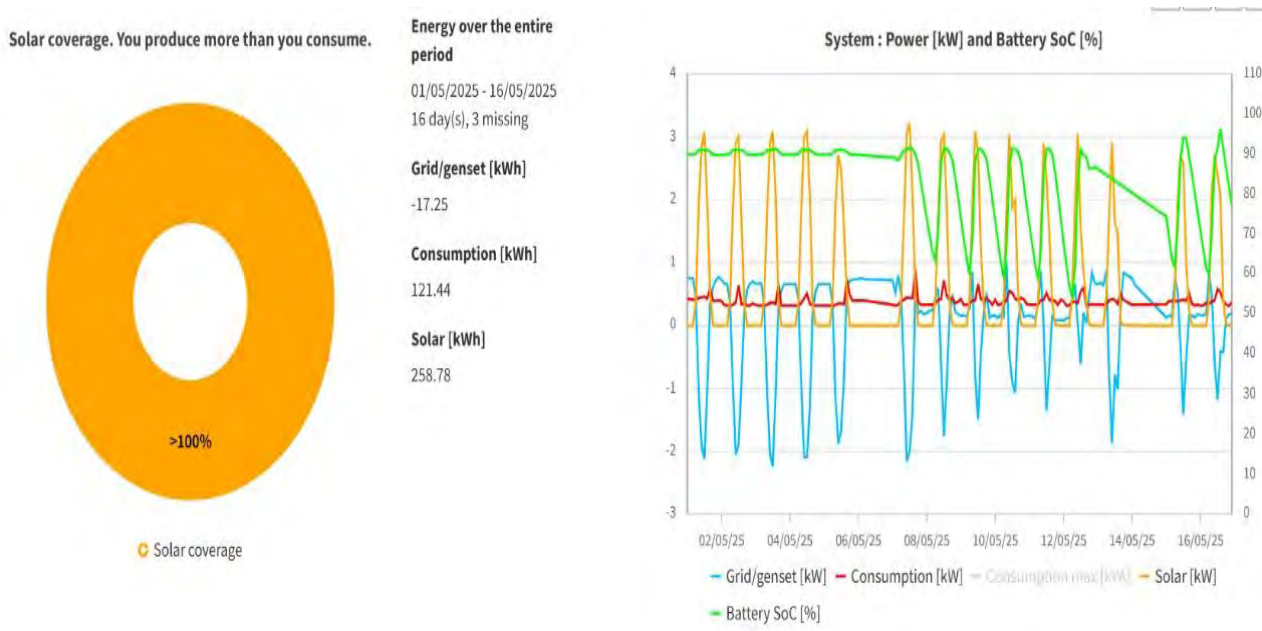
## Energy Flow : Without Grid Operation



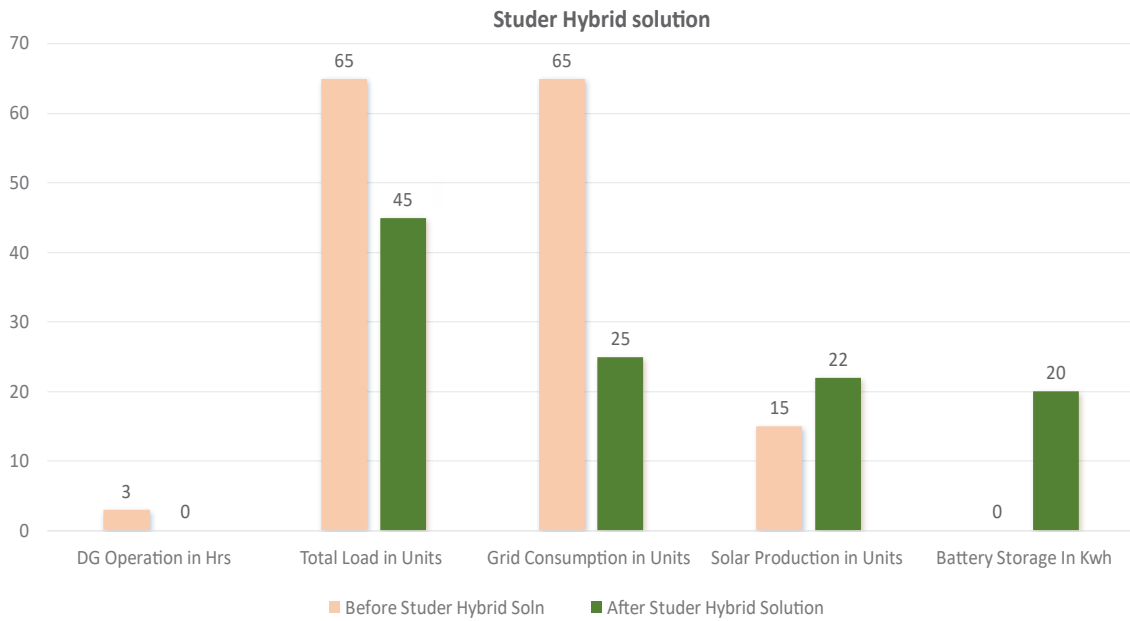
### Before Installation of Solar Hybrid System



### After Installation of Solar Hybrid System

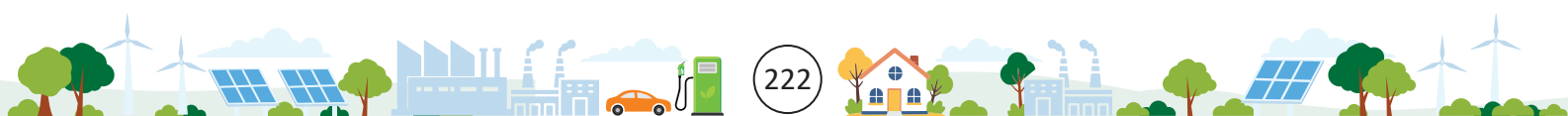
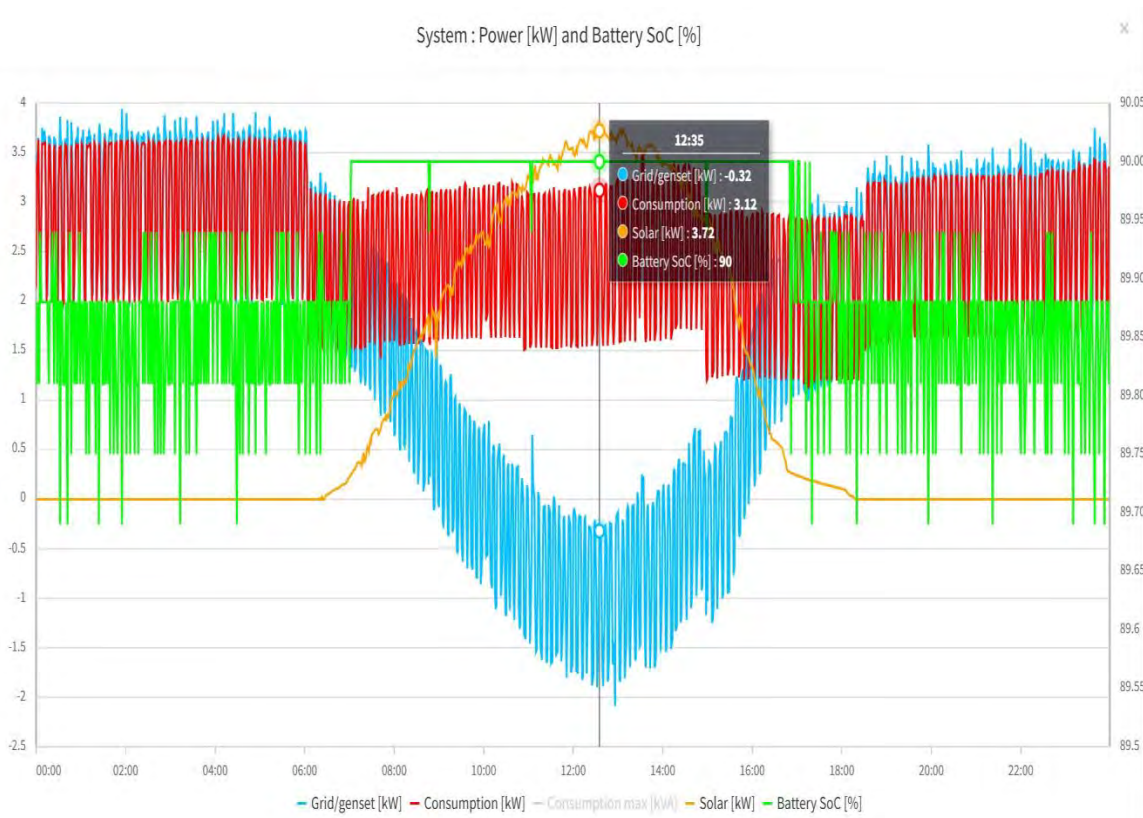


## Energy Details Before & After Hybrid System



### Data Sheets/Charts

## SV 10- Solar Generation, Load, Grid Usage for 1 day min to min



## Impact Assessment Reports

- Diesel Generator Elimination
- Un-manned SV Station
- Clean Power without voltage fluctuations
- Hybrid System gives **230V 1 Phase, 415V, 3 Phase, DC 48V Loads at 0.1 to 1 load PF** (Unity PF), 2X Aux Contacts program contact for Export excess energy & using another Aux you can program street lights time based operation.
- Telecom and Cathode protection external chargers Elimination
- Elimination of Capacitor banks which is used for PF correction. having Input APF correction.
- Auto power factor correction (PFC EN 61000-3-2) available in Hybrid Inverter, Automated Street lights ON/OFF time based operation built in
- Hybrid inverter can handle inrush current up to 3 times the nominal power ( Surge handling up to 31.5 KW up to 5 Sec )
- Hybrid Inverters Syncs with Solar, Battery, Grid automatically controls the load priorities which is programmable.
- This hybrid system is capable to export excess solar power to ESCOM (Grid), Utilizing 100% solar completely.

## Key Reasons for Unmanned SV Station :

- Power Supply and Redundancy: Since these stations are unmanned, they are designed to operate continuously without human intervention. As such, reliable Hybrid solar systems Installed with Battery backup .
- Street Light Auto ON /OFF control by Studer : inverter is managing Time based operations of Street lights .
- Since these stations are unmanned, they are designed to operate continuously without human intervention. As such, reliable power systems (e.g., solar panels, batteries, or backup generators) and redundancy are critical to ensure that the station remains operational in remote or harsh environments
- These stations are designed to operate without human intervention on-site. All actions such as opening, closing, or monitoring the valves are performed remotely via automated systems.
- Automation & Remote Monitoring:
- Sensors and actuators connected to the sectionalizing valves allow for automated control based on predetermined conditions (e.g., pressure, flow, temperature).
- Media Coverage: NIL
- Testimonials

### Elimination of Cathode protection, Telecom Chargers & Lead-acid Battery Banks



Lead-acid Battery Bank

Cathode Protection & Telecom Battery Chargers are having 2 to 3 kW self-consumption.

#### **Integrated Solar /Grid Charging Systems:**

This remote stations are equipped with Hybrid solutions using solar panels that supply direct power to the equipment, bypassing the need for battery chargers altogether. The system is designed to ensure continuous operation by adjusting to different energy demand profiles throughout the day.



## Floating Solar Power Plant at Rainwater Harvesting Pond

Bhart Petroleum Corporation Limited  
Shri GopalaKrishnan M  
General Manager I/C (E&C -E/I & New Projects)

Clean Energy

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

### BACKGROUND & CONTEXT

Kochi Refinery has nearly 18 acres of rainwater harvesting pond and mainly connected to fire water network inside refinery. This water body is well exposed to solar irradiation and found the feasibility to setup floating solar plant of capacity 4.6 MW DC/ 3.2 MW AC. Floating solar is the smart combination of floats (for supporting solar panels, cables and inverters) and solar panels, the whole system being anchored at the bottom and to the bank with the help of concrete blocks.

➤ Advantages of floating solar compared to ground mounted system:

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



- Reduced Algae Growth
- Reduced Installation Costs

## OBJECTIVES

- To generate green solar power.
- Water Conservation
- Reduce SCOPE-2 emissions

## METHODOLOGY

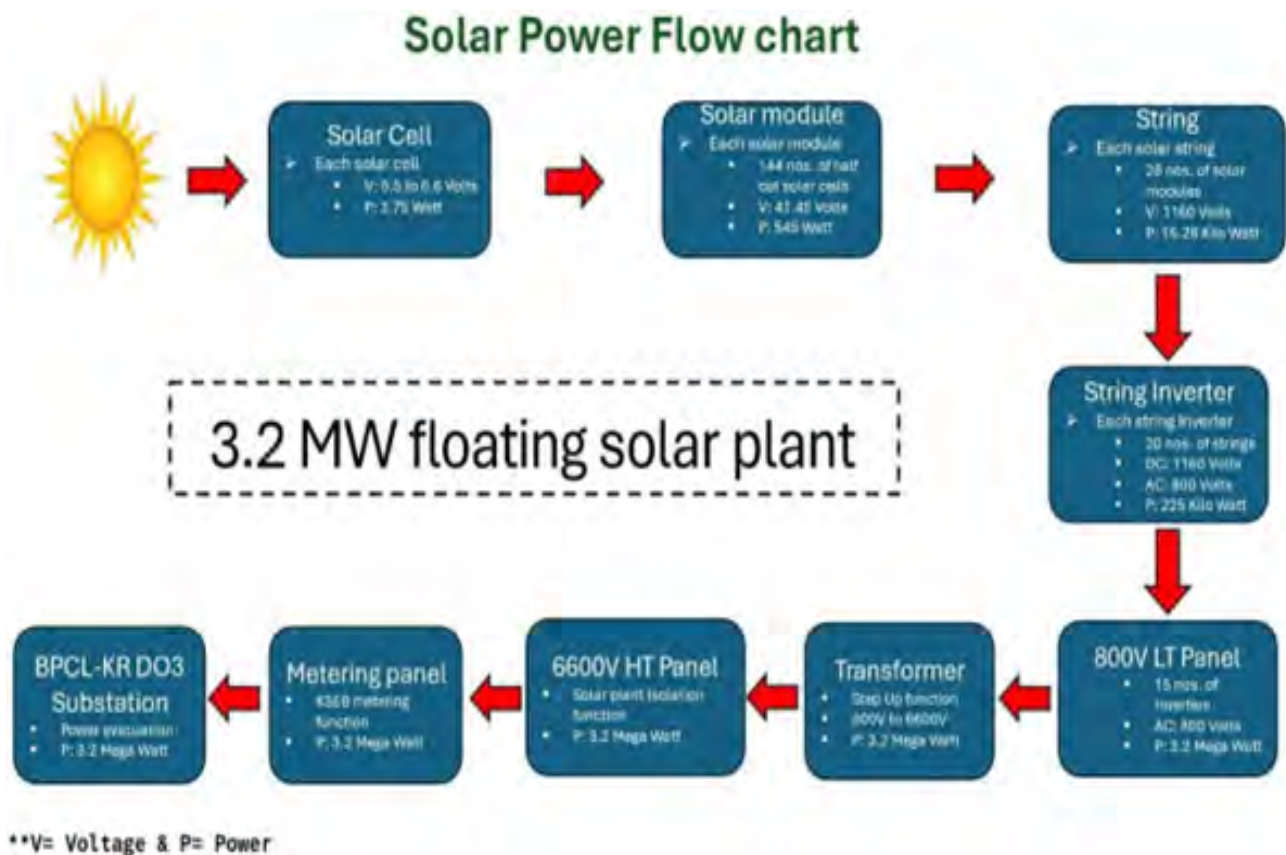
Being first floating solar plant in BPCL organization, we have appointed a consultant to guide on technical parameters and for site supervision. Basic technologies involved in this job are:

- **Solar Panels:** These are central to floating solar farms, which house multiple PV solar cells capable of transforming sunlight into direct current (DC) electricity via the photovoltaic effect.
- **Floating Platforms:** These floating platforms constructed from buoyant materials such as high-density polyethylene (HDPE) to

accommodate the solar panels, cables etc. ensuring to remain afloat on the water's surface.

- **Anchoring System:** This is required to secure the floating platforms, averting any drifting instigated by wind or water currents, thereby guaranteeing the stability and precise positioning of the solar arrays upon the water body.
- **Inverter:** The DC electricity engendered by the solar panels necessitates conversion into alternating current (AC) to facilitate utilization in electrical systems.
- **Electrical Infrastructure:** This includes High tension, Low tension electrical panels, Transformer to step-up the voltage, SCADA system for control and monitoring of complete solar plant, RO plant for cleaning of modules, Metering system for accounting the guaranteed generation.

### Solar power generation process:

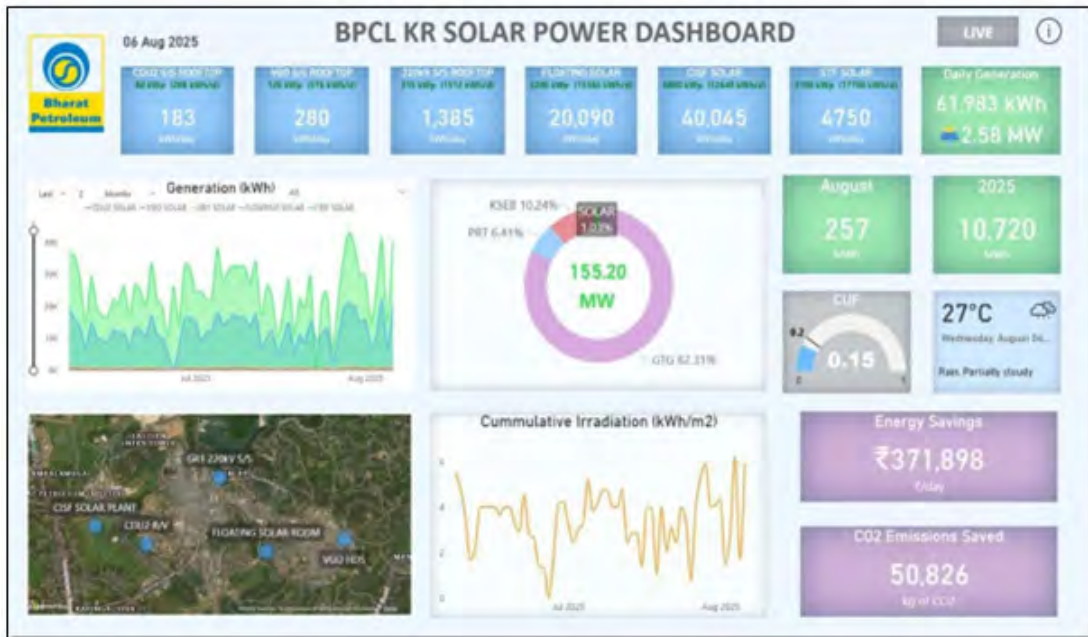


This job involves effective utilization of free space on water body.

For effective monitoring of solar plant generation on continuous basis, an inhouse dashboard has been created using basic

digitalization tools, with this tool we can understand the details like, instantaneous generation, overall generation, weather conditions etc.

**Snaps of Dashboard is given below:**



## CHALLENGES

- **New and Emerging technology:** Floating solar is a new technology that too very less commissioned plants in India for knowledge transfer/sharing. We visited the floating solar plant that got recently commissioned to understand the difficulties faced, design of

float system including buoyancy calculations and anchoring and mooring system

- **Limited vendors in market that can manufacture floats:** Very few float manufactures are available in market. With in-depth market analysis 3 float manufacturers were shortlisted.



- **Availability of Skilled manpower:** This job involves requirement of skilled manpower in multiple stages like launching of floats with modules, earthing of solar modules by going inside pond, working on water body for cabling and termination works. Skilled/experience contract workforce for working on floating solar project was limited and we have put great effort in mobilizing skilled manpower from various execution agencies
- **First containerized substation in BPCL-KR:** Since this is a fast-track project with good IRR, to cut short the time for constructing civil substation, we had opted for containerized substation that houses LT, HT and metering panels.

## IMPLEMENTATION

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

## INVESTMENTS

Cost Component	Amount (₹ in Lakhs)
Capital Expenditure	2642
Operational Expenditure (annual)	12
<b>Total Investment</b>	<b>2654</b>

## QUANTITATIVE OUTCOMES:

Parameter	Before Implementation	After Implementation
GHG Emissions (tCO <sub>2</sub> e)	-	5604000
Energy Consumption (units)	-	6809756
Operational Efficiency	-	80%
Cost Savings (₹ in Lakhs)	-	406

## QUALITATIVE OUTCOMES

- Space Efficiency
- Enhanced Efficiency i.e. due to cooling effect from water
- Albedo Effect i.e. Due to reflection of irradiation from water surface
- Reduced Algae Growth

## INNOVATION & UNIQUENESS

Floating solar plant by itself and its buoyancy floating system with thousands of floating and its anchoring & mooring system with 150 Nos. of 2.8MT concrete blocks and its containerised substation altogether forms very innovative and attractive with-it unique features.

## SCALABILITY & REPLICABILITY

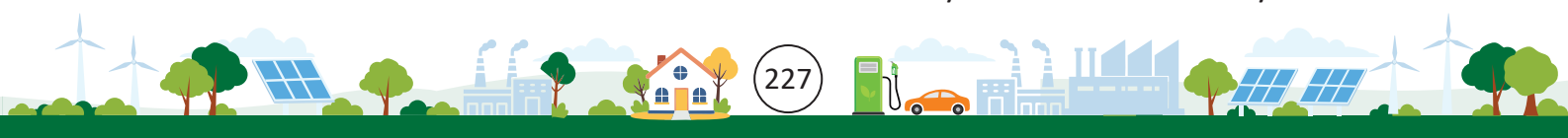
We have replicated the similar kind of floating solar plant in another installation called Shore Tank Farm Puthuvypin with a capacity of 5.2MW DC /3.7MW AC.

## KEY LEARNINGS

Leant about new technology evolving in the market for effective utilisation of surface area above water bodies.

## FUTURE PLANS

Will plan to replicate similar floating solar power plants wherever water bodies are available with necessary depth and availability of water all over the year.





*Containerised substation, Transformer and SCADA facility:*





*Solar Block: A*



*Solar Block: B*



## Hybrid Thermal Solar Panel Installation at VRV System (HVAC)

Mahanagar Gas Limited  
Shri Kaushik Banerjee  
Manager (Administration)

Clean Energy

The Hybrid Thermal Solar (HTS) Panel is an innovative solar-based technology designed primarily for use in central air-conditioning systems. Installed on building terraces to maximize solar energy capture—the system’s primary resource, it significantly reduces the electricity consumption of air-conditioning units. Since HVAC systems account for a major portion of energy usage in most of the premises, this technology leads to substantial reductions in both monthly electricity bills and carbon emissions, making it a sustainable and eco-friendly solution.

### BACKGROUND & CONTEXT

Our Goal was to have substantial energy efficiency in monthly electricity consumption as well as reduction of Carbon emission using sustainable innovation & technology.

Any Commercial Building having Servers, UPS, Data centers etc., the average distribution of Electrical Load pattern is as follows: -

- HVAC/ Central AC Load: 60-65%
- UPS / Server/Critical Load: 20-25%
- Lighting & other Load: 10%-20%

So, in hindsight, it was proposed to use natural resources & optimize the consumption & make the premise more sustainable which in turn help the environment more viable. Nowadays, there are various technologies available in the market which are commonly used across many buildings like LED based lighting fixtures, sensor-based system, software-based hibernation mode used in Desktops/Laptops etc. but the saving output is not found to be substantial.



In the case of any technology-based sustainable method that can be used in the Central Air-conditioning system, the output becomes much higher considering that it influences the major electricity consumption. In any conventional air-conditioning system, the heating of refrigerant system is commonly used by using thermal energy. If the same can be done by using solar energy, there shall be an enormous amount of saving in terms of electricity consumption as well as carbon emission.

At the time of review of Electrical & HVAC system of MGL House, various probable options were explored but most of the options were not found that viable. The primary intent was to have technology on HVAC system to attain significant amount of energy saving.

## OBJECTIVES

This initiative was undertaken with a focus on energy efficiency and the development of sustainable infrastructure. The goal was to achieve long-term reductions in electricity consumption, resulting in a positive environmental impact. By promoting eco-friendly practices, the initiative contributes to a cleaner, greener environment, ultimately supporting the vision of building a better city for the future. In commercial premises, a significant portion of energy consumption is attributed to HVAC systems. Therefore, the initiative specifically targeted a reduction in air-conditioning usage by leveraging natural resources, aligning energy savings with

environmental responsibility.

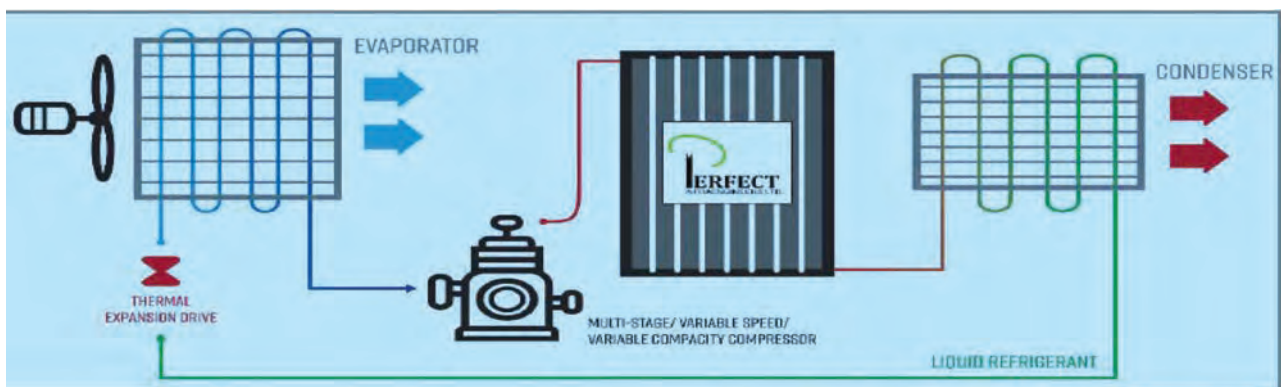
In pursuit of technology-driven innovation, a Hybrid Thermal Solar Panel was identified and integrated into the VRV system. Utilizing the principles of thermodynamics, this solar-powered solution channels thermal energy into the cooling process, significantly reducing electrical consumption.

## METHODOLOGY

### Hybrid Thermal Solar Panels working principle: -

The hotline discharge from the Outdoor Unit (ODU) is connected to the top inlet of the Hybrid Thermal Solar (HTS) Panels installed on the rooftop. These panels utilize smart sun-tracking parabolic heat concentrators to harness solar energy, adding additional heat and pressure to the refrigerant gas. The heated refrigerant is then returned to the ODU condenser. This added thermal energy reduces the load on the compressor, allowing it to operate at a lower speed and thereby cutting its energy consumption by up to approximately 40%.

Functioning entirely on solar energy, the HTS Panel is installed between the compressor and the condenser. The outlet of the compressor is connected to the panel's inlet, and the panel's outlet feeds into the condenser. As the refrigerant gas from the inverter compressor enters the HTS Panel, it absorbs solar heat via six parallel parabolic aluminum reflectors within the panel. This solar-assisted heating allows the panel to



perform part of the compressor's work, effectively lowering the compressor's RPM. The thermal energy contributed by the HTS Panel directly correlates with the energy savings from the reduced compressor speed. This not only maintains or improves cooling performance but also minimizes system wear and tear. Benefits include reduced mechanical faults, lower noise levels, extended system life, and improved overall energy efficiency.

## CHALLENGES

The successful implementation of any solar panel technology—whether conventional, unconventional, or innovative—depends on two key factors: optimal sunlight accessibility throughout the day and sufficient space on the premises' terrace. These elements present both opportunities and challenges in deploying solar solutions.

Hybrid thermal solar panels are particularly effective for Central AC Variable Refrigerant Volume (VRV) systems. The VRV system is inherently energy-efficient, boasting a design that can reduce energy consumption by approximately 20%. By integrating hybrid thermal solar technology, this efficiency can be further enhanced, potentially lowering energy use by an additional 40%. This results in significant savings in energy costs and a reduction in carbon emissions.

To maximize these benefits, it is crucial to monitor and maintain the entire Central AC VRV system alongside the hybrid thermal solar system, ensuring they operate seamlessly together for optimal energy savings.

## IMPLEMENTATION

Provide details of how the initiative was implemented, including timeline, stakeholders involved, and any challenges encountered During implementation (max 500 words)

The Hybrid Thermal Solar (HTS) panel was implemented at our organization following a comprehensive site inspection and data verification. In December 2023, a joint survey was conducted along with representative from M/s Perfect Infraengineers Ltd.(vendor) at the International Agro Export Facility Centre, located at Plot No. 3, Sector-19F, Vashi, Navi Mumbai, under the Maharashtra State Agriculture Marketing Board (MSAMB), which oversees the Agriculture and Processed Food Products Export Authority.

During the inspection, we discovered 11 HTS panels that had been installed for the past seven to eight years. The solar panels were functioning well, and the log sheets and readings indicated satisfactory performance. This case study provided strong evidence that HTS panels are a viable step toward sustainability.

As a result, we decided to initiate the first phase of administrative approval as part of our ongoing Environmental, Social, and Governance (ESG) initiative. The installation was planned for the MGL Corporate Office in BKC to ensure effective implementation and continuous monitoring.

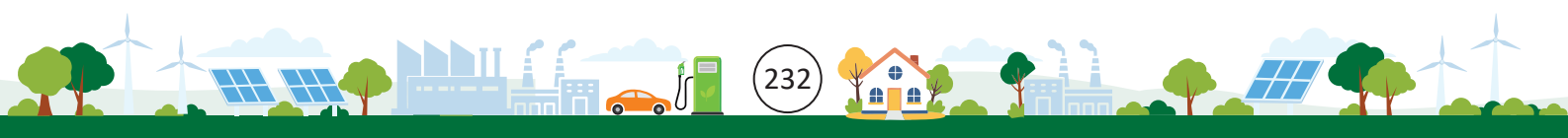
The approval process began in February 2024, followed by a series of internal approvals, financial assessments, and ultimately, the issuance of a purchase order. The first phase included an order for three solar panels to evaluate their performance at an initial stage. After installation in May 2024, we received the performance analysis report in June 2024, which revealed outstanding results and demonstrated the panels' significant potential.

The consumption analysis summary is as below:-

Phase-I:

For a period of 9 days, without solar panel consumption per day :- 68.8 KWH

For a period of 9 days, with Solar Panel Electrical consumption per day : 28.1 KWH



Average saving : 40.7 KWH (unit)

Savings in percentage = Decrease in consumption due to HTS Panel / Consumption without Panel = 40.7 / 68.8 = 59.1 %

The initiative was highlighted immediately to the management & it was well-appreciated. Simultaneously, it was instructed to initiate the second phase immediately & followed by a survey of other site offices to check the feasibility of the same initiative.

This was the initial stage of implementation of HTS panel initiative. Accordingly, the second phase of the work was initiated in the month of August 2024 & it was completed in February 2025.

## INVESTMENTS

Cost Component	Amount (₹ in Lakhs)
Capital Expenditure	44 lakh
Others (please specify)	16 lakh (Installation + Labor)
<b>Total Investment</b>	<b>60 lakh</b>

## QUALITATIVE OUTCOMES

### Impact on Distribution Company (DISCOM):

The biggest issue DISCOMS face in India is the peak power demand in summer. This occurs solely due to the usage of air conditioning. By saving up to 40% or so, these HTS panels significantly ease pressure on DISCOM.

### Stop Derating the Air-conditioning system:

All AC systems are designed as per AHRI guidelines. These conditions are 35 deg C dry bulb & 24 deg C wet bulb. In summer during high-ambience, air-cooled HVAC system doesn't cool the area as per required temperature. As HTS panels are doing part-load of compressors, hence the compressor always runs on partial load, hence during capacity demand, compressor can run up to full capacity. This helps to avoid derating of the complete AC system.

**Reduction of Compressor Failure:** During high ambient the condenser IN goes as high as 48 to 49 Deg. C, add 10 Deg. C, the condensing temp rises to 58 to 59 deg. C. During such high condensing temp, the refrigerant entering the compressor is also at higher temp (10 to 12 Deg. F super heat differential.) If system runs for long time, in such high super heat temp. There is a possibility of Scroll Compressor failure. Since the HTS Panel is doing part load of compressor, compressor always runs on partial load. It helps to keep Super Heat in required band which helps to avoid compressor failure.

## INNOVATION & UNIQUENESS

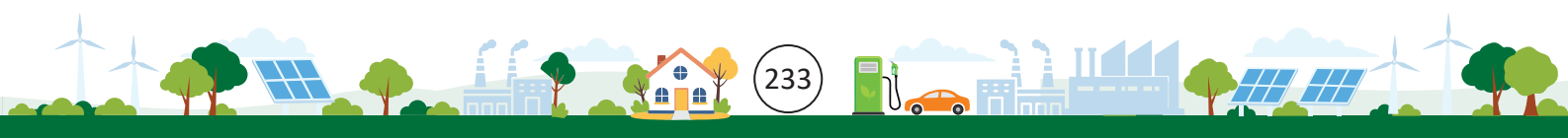
Air conditioning accounts for 60% of any commercial building's monthly electricity cost. In this age of energy conscious building designs & renewable solutions, no technology is addressing the primary issue i.e. Air- conditioning system. The Hybrid Thermal Solar panel based air-conditioning system uses solar thermal energy to reduce the monthly electricity consumption which is produced by AC system up to 40%. This HTS panel-based system does not generate any electricity. It is integrated with VRV system to make it more energy efficient.

The benefits of this system are: -

- Monetary saving: 40% reduction on AC electricity bill. COP of AC becomes 6+
- Judicious use of Roof top space: This system is much more space efficient than conventional solar (PV) panels
- Life cycle of AC system increases due to partial load on compressor as HTS panels take the additional load
- Auxiliary benefits include accelerated depreciation & beneficial ROI (up to 3 -3.5 yrs)

## SCALABILITY & REPLICABILITY

HTS Panels are modular, compact, and



designed to integrate with existing commercial air conditioning systems without the need for major redesign or additional infrastructure. Manufacturing can be scaled easily using standard industrial fabrication processes. As demand increases, production and deployment can be ramped up quickly due to its standardized design and minimal on-site customization needs.

The HTS Panel solution is highly replicable across smart cities as it can retrofit into any air-cooled HVAC system—common across urban commercial buildings, government facilities, hospitals, and malls. It does not require location-specific environmental conditions or water availability, unlike water-cooled systems, making it suitable for diverse climates and city infrastructures.

**Energy Savings:** Reduces compressor energy consumption by up to 40%, cutting down electricity usage significantly.

**GHG Emission Reduction:** Lower power usage translates into reduced carbon emissions, especially in coal-heavy power grids like India's.

**Water Conservation:** Unlike water-cooled chillers, HTS Panels require no water, helping conserve a critical resource, particularly in water-stressed cities.

**Air Quality Improvement:** By lowering energy demand, HTS Panels indirectly reduce the pollution associated with thermal power generation.

**Supports Net-Zero Goals:** Helps urban infrastructure move toward carbon neutrality without requiring full system overhauls.

## KEY LEARNINGS

The pre-requisite of any solar based panels (conventional, unconventional or innovative) is the accessibility of sunlight at an optimum level throughout the entire day time. Also, space on terrace area of any premise is essential. These are the two primary learning & challenges to execute any solar-based technology.

These Hybrid thermal solar panels are applicable for the Central AC VRV system. VRV system itself has energy efficiency by its design up to 20% or so. This technology helps to further minimize energy consumption up to 40% which induces immense saving in terms of energy efficiency & carbon emission.

The entire Central AC VRV system & Hybrid Thermal solar system functions in tandem hence the entire system needs to be monitored & maintained very precisely to get the utmost saving

## FUTURE PLANS

### 2nd Project- Hybrid Thermal Solar Panel at Mahape Admin Building (Navi Mumbai)

Following the significant savings observed at the BKC Corporate Office, a similar survey was conducted at the Mahape Admin Building, Navi Mumbai, where a Variable Refrigerant Volume (VRV) system is installed for the central air-conditioning. The project is currently underway, with an expected **completion date of October 2025.**

The estimated capital investment for this initiative is approximately ₹28 lakh.

Energy conservation Impact: -

**Average Electricity saving per month: Rs. 1.15 Lakh**

Average Electricity saving per annum : Rs. 13.8 Lakh (approx.)

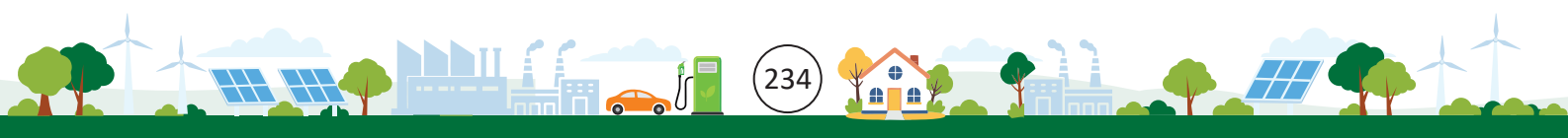
Environmental impact: -

Average Electricity unit saving per month: Rs. 1,15,907/22 (unit price) = 5268.5 unit (KWh)

Average Co2 saving per month = 5268.5 x 0.82 kg = 4320.17 Kg

**Average Co2 saving per annum = 4320.17 x 12 = 51842 Kg i.e. 52 tons (approx.)**

Cumulative Carbon emission saving (incl. 1st & 2nd Project) : 74 tons + 52 tons = 126 tons per annum



## Recognition/Awards Received:

- This ESG Project has been recognized amongst Top 5 nominations under “Green Building Category” at FICCI Urban Innovation Awards 2025 held on 24th July, 2025 at FICCI Federation House, New Delhi.
- This project is received “Best-3 Solar Energy Initiative of the year 2025” at an event “Global CSR & ESG Award” organized at Hyatt Centric, New Delhi on 25th April 2025.
- This project is received “Gold” award in ESG category at Workplace Excellence Conference & Awards 2025 at Nesco, Goregaon, Mumbai on 14th February 2025.

## Data Sheets/Charts:

Total saving in May 2025: 8530 KWH

Total saving in June 2025: 7675 KWH

Total saving in July 2025: 7626 KWH

Consumption during the period		8 HP- BM 313				8 HP- BM 314				6 HP- BM 290			
		Starting Reading (kWh)	Ending Reading( Kwh)	Consumption in kWh	Deamed saving in kWh	Starting Reading (kWh)	Ending Reading( Kwh)	Consumption in kWh	Deamed saving in kWh	Starting Reading (kWh)	Ending Reading( Kwh)	Consumption in kWh	Deamed saving in kWh
01-07-2025	31-07-2025	5471.3	6765.7	1294.4	1008.8	3815.1	4631.8	816.7	636.5	8697.5	10800.4	2103.0	1639.0

12 HP- BM 315				12 HP- BM 305				12 HP- BM 296			
Starting Reading (kWh)	Ending Reading( Kwh)	Consumption in kWh	Deamed saving in kWh	Starting Reading (kWh)	Ending Reading( Kwh)	Consumption in kWh	Deamed saving in kWh	Starting Reading (kWh)	Ending Reading( Kwh)	Consumption in kWh	Deamed saving in kWh
5471.3	6765.7	1294.4	1008.8	1309.4	1689.9	380.5	296.5	5778.8	6994.7	1216.0	947.7

14 HP- BM 304				16 HP- BM 289				Total Metered consumption	Total Deamed saving in kWh of MGL, BKC
Starting Reading (kWh)	Ending Reading( Kwh)	Consumption in kWh	Deamed saving in kWh	Starting Reading (kWh)	Ending Reading( Kwh)	Consumption in kWh	Deamed saving in kWh		
6231.0	7645.3	1414.3	1102.3	2933.2	4199.3	1266.1	986.7	9785.2	7626.2



## Solarisation Across all ATGL Locations

Adani Total Gas Limited  
Shri Pranab Ghosh  
Vice President

Clean Energy

India's commitment to addressing climate change is reflected in its enhanced Nationally Determined Contributions (NDCs) under the Paris Agreement, incorporating the five elements outlined at COP26 in Glasgow.

As a part of the updated NDC submitted to the UNFCCC (United Nations Framework Convention on Climate Change) India has committed to reducing its emissions intensity by 45% by 2030, achieving 50% of cumulative electric power capacity from non-fossil fuel sources by 2030, and promoting a sustainable way of living through the 'LIFE' (Lifestyle for Environment) movement. These targets also contribute to India's long-term goal of reaching net-zero emissions by 2070, supported by the 'Long-term Low Carbon Development Strategy'.

In accordance with the above commitment We are in the process of installing captive roof top solar plants under Solarisation initiative across all our CGS, CNG stations, LCGN stations etc. to integrate renewable energy into our operational framework which would reduce our electricity consumption from Grid.

### BACKGROUND & CONTEXT

To transition from non-renewable to renewable energy sources, we have initiated solar panel installations across ATGL sites, wherever feasible. As of March 31, 2025, the installation of solar rooftop panels

was successfully completed at 54 sites, encompassing both Company Owned Dealer Operated (CODO) and Dealer Owned Dealer Operated (DODO) CNG stations, City Gate stations and offices.

We have installed close to 1 MW of solar



panel so far which averted 800Mt CO2 equivalent and we have the target to reach 1.5 MW by the end of 2025.

The Solaraman tool is employed to closely monitor the solar power generation process, providing real time data updates every five minutes. In order to maintain optimal performance, automated cleaning devices are being incorporated to keep the panels free of dust and ensure maximum generation efficiency. Direct grid connectivity for the generated power has led to a downward trend in our energy bills.

### OBJECTIVE

- To enhance renewable energy share in operation.
- To reduce Grid electricity and Scope 2 GHG emissions

### METHODOLOGY

- Preliminary site survey conducted of all our GA locations having City gate station, CNG stations, for identification of feasible sites. As per feasibility report and solar intensity, the roof top solar installation has been designed and installed.
- After installation commissioning activity has performed to check the operational parameters in line with safety features & monitor real time data base for recording of actual generation thru Solarman app.

### CHALLENGES

- Availability of more number sites is one of the big challenges because some sites are under COLO model basis.
- Currently as per PESO requirement the installation of solar panel is not approved on top of the front court canopy structure which would provide us more space for

the solarization across all our CNG station in all GAs

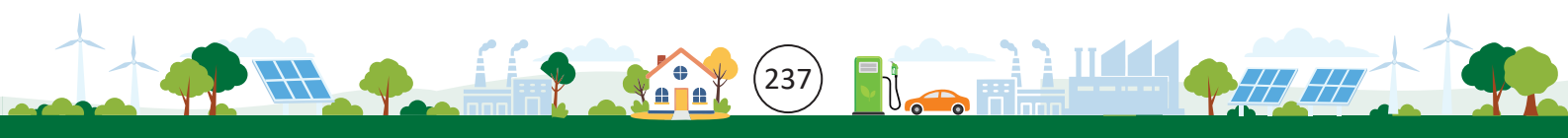
- Being spread across distributed site, maintenance and cleaning on regular frequency is a challenge.
- Some of GAs have been facing issues with power cut, and during power cut solar electricity is not available due on-grid connection.

### IMPLIMENTATION

- Based on preliminary site survey, the sites to be identified for execution the project of installation of roof top solar system.
- High efficiency solar panel has been used on all the location
- The solar panel has been connected thru SOLARMAN app for real time monitoring
- During commissioning activity, we check the performance & operational parameters in line with safety features along with monitoring real time data base for recording of actual generation.

### INVESTMENT

Cost Component	Amount (₹ in Lakhs)
Capital Expenditure	39
Operation Expenditure	00
<b>Total Investment</b>	<b>39</b>



## QUANTITATIVE OUTCOMES

Parameter	Before Implementation	After Implementation	Improvement (%)
GHG Emission (Tco2)	800 MtCO <sub>2</sub> eq. due to use of 1101666.67 Kwh units generated from grid electricity before 943.16KW solarization installed at 54 sites.	00 Mt. CO <sub>2</sub> eq. in FY 24-25 due to use of units generated from rooftop solar of 54 sites.	800 MtCO <sub>2</sub> eq./ year averted due to solar energy consumption from rooftop solar system
Energy Consumption (Units)*	28553611 Kwh (NRE) in FY 21-22	62172946 Kwh (NRE+RE) & 1101666.67 Kwh (RE) in FY 24-25	Around renewable energy share is close to 1.77% of total energy mix.
Cost Saving (In Rs.)	00	77,66,000	Savings of 77.66 Lakh rupees in electricity bills.

We have installed 943.16KW rooftop solarization across stations which generate 1101666.67 Kwh units per year which are consumed in our operation & considering emission factor 0.727 Mt CO<sub>2</sub>/ Mwh so around 800 MtCO<sub>2</sub> is avoided.

Renewable energy share 1.77% estimated based on solar unit generated from rooftop solar system per total energy mix consumption means (1101666.67 (RE)/ 62172946 (RE+NRE))

## QUALITATIVE OUTCOMES

- Our renewable energy share is close to 2% of total energy mix.

## INNOVATION & UNIQUENESS

- Free space on the roof top which is unutilised has been getting used in productive purpose to enhance sustainability

## SCALABILITY & REPLICABILITY

- Yes. This can be replicated to all our installations wherever feasible

## KEY LEARNING

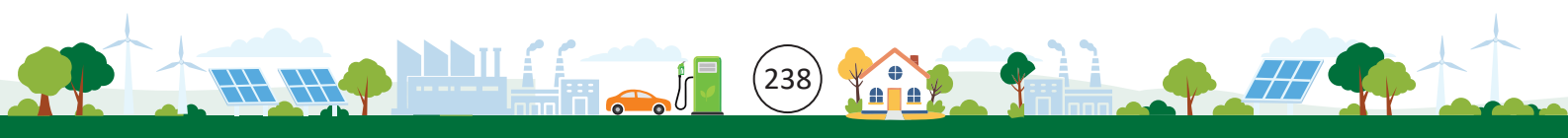
- Cleaning & regular maintenance play an important role for unit generation so defined frequency must be required.

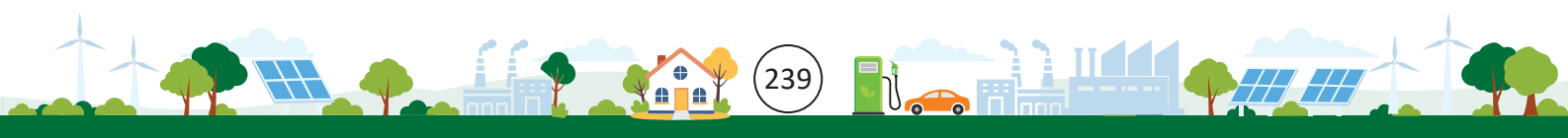
## FUTURE PLAN

- We are going to execute open access 7.3 Mw capacity solar project – what is this... should be saying this to authorities right now. is it contingent / aspirational figure.

## SUPPORTING DOCUMENTS

- [https://www.adanigas.com/-/media/Project/AdaniGas/Investors/Financials/Annual-Report/AT-GL-IR-2025\\_For-Website.pdf](https://www.adanigas.com/-/media/Project/AdaniGas/Investors/Financials/Annual-Report/AT-GL-IR-2025_For-Website.pdf)







## CONCLUDING REMARKS

### Let's walk together on the journey towards Sustainability

This compendium affirms that India's oil and gas fraternity is not observing the energy transition from the sidelines; it is actively scripting it. Case studies collected herein illuminate a sector that has moved beyond compliance-embedding sustainability into core strategy, capital allocation, and culture.



Few imperatives emerge: decarbonize core assets with measurable targets; embed circularity across supply chains; and cultivate alliances in pursuit of shared climate objectives.

Guided by PNGRB's sustainable vision for the sector, these exemplars furnish a replicable blueprint for the decade ahead. The narratives collected herein are therefore not a culmination, but a call to accelerate the transition from pioneering projects to systemic transformation.

*Let this compendium serve as both mirror and compass: a mirror that reflects hard-won progress, and a compass that orients policymakers, investors, and practitioners toward a low-carbon, resilient, and inclusive energy future.*





## **SUSTAINABILITY CELL**

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- **Shri Madhoop Sah, Deputy Director**

## **SUPPORTED BY**

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- **Shri Mayank Parihar, Data Entry Operator**
- **Shri Dipin Jindal, ICF**

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