Swaniti Global

February 2025

Methane Emissions in India's Energy Sector

Current Landscape and Future Prospects

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THE GLOBAL CLIMATE AND DEVELOPMENT INSTITUTE

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Note: This is not a complete list of outreach for this report, and should be considered an illustrative sample of total outreach conducted for this report.

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List of Abbreviations and Acronyms

AI	Artificial Intelligence
AMM	Abandoned Mine Methane
AR5	Fifth Assessment Report
ATF	Aviation Turbine Fuel
BCCL	Bharat Coking Coal Limited
BPCL	Bharat Petroleum Corporation Limited
BRSR	Business Responsibility and Sustainability Reporting
BUR	Biennial Update Report
CBM	Coalbed Methane
CCUS	Carbon Capture, Utilization, and Storage
CH_4	Methane
CHP	Combined Heat and Power
CIL	Coal India Limited
CMM	Coal Mine Methane
CMPDI	Central Mine Planning and Design Institute
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
COPD	Chronic Obstructive Pulmonary Disease
CSOs	Civil Society Organizations
DGH	Directorate General of Hydrocarbons
E&P	Exploration and Production
EDF	Environmental Defense Fund
ESG	Environmental, Social, and Governance
F.Y.	Financial Year
GAIL	Gas Authority of India Limited
GEF	Global Environment Facility
GEM	Global Energy Monitor
Gg	Gigagram
GHG	Greenhouse Gas

GoI	Government of India
GW	Giga Watts
GWP	Global Warming Potential
HMPL	HPCL-Mittal Pipelines Limited
HPCL	Hindustan Petroleum Corporation Limited
IEA	International Energy Agency
IFG	Imported Flare Gas
IGOs	Intergovernmental Organizations
IOCL	Indian Oil Corporation Limited
IPCC	Intergovernmental Panel on Climate Change
kT	kilo tons
LDAR	Leak Detection and Repair
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MFIs	Multilateral Financial Institutions
ML	Machine Learning
MMCM	Million Cubic Meters
MMSCMD	Million Metric Standard Cubic Meters per Day
MMT	Million Metric Tons
MMTPA	Million Metric Tons Per Annum
MoEFCC	Ministry of Environment, Forests, and Climate Change
MoPNG	Ministry of Petroleum and Natural Gas
MRV	Monitoring, Reporting, And Verification
$MTCO_2e$	Metric Tons of Carbon Dioxide Equivalent
NDC	Nationally Determined Contributions
OGDC	Oil and Gas Decarbonization Charter
OGMP	Oil and Gas Methane Partnership
OIL	Oil India Limited
OISD	Oil Industry Safety Directorate
ONGC	Oil and Natural Gas Corporation Limited
PEPL	Prabha Energy Private Limited

PNGRB	Petroleum and Natural Gas Regulatory Board
POL	Petroleum, Oil, And Lubricants
RGPL	Reliance Gas Pipelines Limited
RIL	Reliance Industries Limited
SEBI	Securities and Exchange Board of India
SoEs	State-owned Enterprises
TMTPA	Thousand Metric Tons Per Annum
TNC	Third National Communication
U.S. EPA	United States Environmental Protection Agency
UNDP	United Nations Development Program
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UTs	Union Territories
VOCs	Volatile Organic Compounds

Executive Summary

Global climate models indicate that reducing methane emissions is one of the quickest and most effective strategies to slow global warming. To limit warming to 1.5°C, experts estimate that global methane emissions must decrease by at least 30% by 2030 from 2020 levels. Globally, some policies, regulations, and pledges hold promise in achieving this goal; however, substantial action is required by all major nations to address methane emissions originating from the energy sector.

As India's economy grows, the nation will experience rapid increases in energy demand. The growth in energy demand will be fueled by low-carbon and fossil fuel sources. This presents India with substantial opportunities to address methane emissions originating from the energy sector. It is imperative that stakeholders act now to pursue mitigative measures, which will not only boost climate action but will also bring several co-benefits.

To explore the challenges and opportunities for India to strategically manage methane emissions in its energy sector, we conducted a systematic review study of the Indian coal and oil and gas sectors. This involved a comprehensive review of academic and policy literature, including reports from government bodies, national and international organizations and institutions, along with articles from newspapers and journals. To further explore the diverse perspectives of stakeholders, and validate potential mitigation pathways, the team organized two expert workshops and conducted over a dozen interviews.

For the coal sector, we make the following key findings:

1. Certain coal mines emit significantly more methane than others in India. While every mine in India emits some methane, the East Bokaro and Jharia coalfields in Jharkhand and the Raniganj coalfield spread over West Bengal and Jharkhand, are particularly gassy.

2. There is a major gap in India's current estimates of methane emissions from coal mines. While the Government of India has consistently reported methane emissions for its active mining operations to the United Nations Framework Convention on Climate Change (UNFCCC), these do not account for abandoned and other non-producing mines.

3. The Indian government's plan to increase India's domestic coal production to 1.5 billion metric tons and potentially triple underground mining output to 100 million metric tons may further increase methane emissions. Under this scenario, proactive drainage and utilization of coalbed methane from virgin seams can serve as a first line of defense against increasing fugitive coal mine methane emissions. Capture and utilization of methane from active and inactive mines should also be pursued.

4. Capture and utilization of coalbed methane from virgin seams and of methane originating from active and inactive mines provides substantial co-benefits beyond curbing greenhouse gas emissions and mitigating climate change. These include occupational safety, public health and economic ben-

efits. More work is needed to quantify these benefits under specific methane mitigation scenarios.

For the oil and gas sector, we make the following key findings:

1. Estimates of methane emissions in India's oil and gas sector rely primarily on aggregated default emission factors, are prone to uncertainty, and have potential for significant errors. Although officially reported emissions are based on outdated methodologies, recent efforts by oil and gas companies to curb leaks and reduce flaring, as highlighted in their annual reports, along with the evolution of emissions standards over time, suggest that actual emissions may in fact be lower than official estimates. At the same time, satellite-based flaring estimates from the World Bank's Global Gas Flaring Tracker suggest the potential for substantial underreporting of methane emissions under the default emission factors-based approach. These discrepancies highlight the urgent need for transparent, verifiable, and source-specific emissions reporting across the sector.

2. Beyond data reliability challenges, effective monitoring and mitigation of methane emissions demand substantial financial investments, elevating operational costs and potentially diminishing companies' competitiveness in a market that already favors imported oil and gas. The absence of a sector-wide methane-focused policy and regulatory framework also complicates mitigation efforts. Moreover, the lack of a coherent narrative on methane emissions in the oil and gas sector leads to a range of challenges, including limited public awareness and support, underinvestment in monitoring and mitigation technologies, and weakened regulatory action.

3. While all major oil and gas companies in India have announced their net zero targets, detailed methane mitigation targets and comprehensive plans integral to their net zero strategies are not publicly accessible for all companies.

4. Despite these challenges, India's oil and gas sector presents numerous opportunities to advance methane mitigation. Sector-wide methane-focused policy and regulatory frameworks, improved transparency in emissions reporting, and partnerships with international initiatives and technology providers offer pathways for impactful change. Collaborations with research organizations, access to external funding for innovation, capacity building and training can further support sector-wide methane mitigation efforts.

5. Methane mitigation not only contributes to global warming mitigation but also offers notable co-benefits. These include improved public health for communities near oil and gas facilities, new high-quality employment opportunities, and additional revenue streams for companies through captured gas. Mitigating methane emissions also strengthens companies' environmental stewardship, builds goodwill within local communities, and enhances social capital.

Based on our findings, we make the following recommendations for action by relevant stakeholders to move forward on mitigating methane within the energy sector over the coming years:

Government and regulators can lead by embracing frameworks for transparent methane emissions reporting and aligning it with India's overall decarbonization goals. For example, one option is to amend Business Responsibility and Sustainability Reporting (BRSR) regulations to include methane-specific disclosures. This could also be a critical first step. Introducing performance-based regulations, integrating methane targets into Nationally Determined Contributions (NDCs), and setting up a 'methane fund' to support research and innovation can accelerate progress.

Investors can influence methane reduction by embedding methane-specific targets into Environmental, Social, and Governance (ESG) criteria. They can also provide favorable financing, such as lower interest rates or better equity terms, to companies adopting cleaner practices concerning methane emissions. Furthermore, supporting methane-based carbon credits and using shareholder influence to push for robust methane management policies are key opportunities for investors to drive change.

Energy companies could focus on improving methane emissions reporting by transitioning to empirically-based reporting systems. They could also join global initiatives to improve access to advanced technologies that enhance methane emissions detection and operational efficiency. Lastly, collaboration with stakeholders is crucial for mitigating emissions across value chains.

Technology providers could support stakeholders by offering integrated platforms that combine satellite and ground-based data for better emissions monitoring. Artificial intelligence and machine learning tools for predictive maintenance and improved operational efficiency, along with training programs on latest advancements in measurement and mitigation technologies, could help energy companies adopt advanced methane mitigation technologies effectively.

Multilateral financial institutions could offer concessional financing to modernize aging infrastructure and support with establishing methane-focused carbon credit systems.

Intergovernmental organizations could assist with developing robust policies and programs, such as for commercialization of flare gas, to promote methane mitigation.

Philanthropies could support methane mitigation by funding research on its economic, health, and environmental impacts.

Civil Society Organizations (CSOs) could lead public awareness campaigns to highlight the benefits of methane emissions reduction. CSOs could also work on mapping funding opportunities and foster collaboration between stakeholders to further strengthen India's methane mitigation efforts.

Together, these coordinated actions can enable the Indian energy sector to reduce methane emissions effectively, achieve its climate commitments, and unlock significant co-benefits for its economy, environment, and public health.

1.0 Introduction

Methane (CH_4) is a potent short-lived climate pollutant that has a global warming potential more than 80 times that of carbon dioxide over a 20-year period [1]. Global climate models indicate that reducing methane emissions is one of the quickest and most effective strategies to slow global warming [2]. To limit global warming to 1.5°C, experts estimate that global methane emissions must decrease by at least 30% from 2020 levels by 2030[3].

According to the International Energy Agency (IEA), the energy sector is the second-largest source of anthropogenic methane emissions, following agriculture[4]. In 2023, combined emissions from coal, oil, and gas operations made up approximately 92% of methane emissions within the energy sector. Specifically, oil and gas operations released about 80 million tons of methane, while coal mining contributed nearly 40 million tons[5]. Research suggests that a 75% reduction in methane emissions from fossil fuel sectors—coal, oil, and gas—is essential to keeping the rise in average global temperatures under 1.5°C[6]. Fortunately, this level of methane reduction from global fossil fuel operations is achievable with existing technologies, with around half of these emissions reducible at no net cost.[3]

1.1 Methane emissions in the Indian energy sector

While most of India's methane emissions originate from agriculture and waste, the energy sector still contributes substantially to the country's overall emissions[7]. As a major producer and consumer of fossil fuels, India has substantial opportunities to address methane emissions originating from the energy sector. As India's economy grows, the nation will experience rapid increases in energy demand, which will largely be met by fossil fuels. Coal production is projected to reach 1.5 billion metric tons by 2030[8]. Likewise, by 2030, oil demand is expected to grow by 50%, natural gas demand by 100%, and refining capacity by 30%, relative to 2019 levels[9]. This anticipated growth underlies the urgency of action and offers India vast potential to address both current and future methane emissions within its energy sector.

However, there is currently no national policy or regulatory framework in India that specifically targets methane emissions from the energy sector through a climate change lens. Further, a considerable gap exists in the systematic understanding of the challenges and opportunities related to methane mitigation within this sector. Despite this, some energy companies have taken proactive steps, working to identify methane emission sources and implement mitigation strategies. These efforts, often supported by national and international organizations, are driven by short-term goals to reduce carbon intensity and long-term ambitions to achieve net-zero emissions. Addressing methane emissions also provides several co-benefits, including enhanced energy security, improved energy efficiency, job creation, revenue generation, and public health improvements.

Nevertheless, methane mitigation in India's energy sector remains fragmented, lacking a unified national strategy and clear policy direction. This challenge is further compounded by persistent issues with transparency in methane emissions monitoring and reporting, which creates significant uncertainties about these emissions' contribution to global warming.

In this context, the authors of this report conducted the first systematic study of its kind to examine methane mitigation challenges and opportunities in India's energy sector. This study involved a comprehensive review of academic and policy literature, including reports from government bodies, national and international organizations, and institutions, along with articles from newspapers and journals. To further explore the diverse perspectives of stakeholders and validate our findings, the team organized two expert workshops and conducted over a dozen interviews. The insights and recommendations from these experts are thoroughly integrated into this report.

This report examines the challenges and opportunities for India to strategically manage its energy sector's methane emissions in alignment with its socio-economic and climate goals in the years ahead. The following section (2.0) outlines the objectives, research questions, and methodology for this study. The report then provides a detailed analysis of the coal sector (section 3.0), followed by an in-depth look at the oil and gas sector in India (section 4.0). For each sector, the report presents a sectoral overview, identifies sources of methane emissions, provides emissions data, and discusses methane mitigation's co-benefits, challenges and opportunities, in that order. It concludes with sector-specific recommendations for potential actions by relevant stakeholders (section 5.0).

2.0 Objectives, Research Questions, and Methodology

This study was conducted with the following objectives:

- Identifying techno-economic, socio-economic, and political challenges and opportunities for mitigating methane emissions in India's coal, oil, and gas sectors;
- Exploring co-benefits associated with methane mitigation in these sectors;
- Providing recommendations to key stakeholders, including government, energy companies, and philanthropies, to expedite methane mitigation actions.

In line with these objectives, we addressed the following research questions:

- What are the techno-economic, socio-economic, and political challenges and opportunities for mitigating methane emissions in India's coal, oil, and natural gas sectors?
- What are the co-benefits, beyond addressing global warming, associated with methane mitigation in these sectors?
- What actions can key stakeholders take to accelerate methane mitigation in the coal, oil, and gas sectors?

2.1 Methodology

To address the above research questions, we conducted a thorough systematic literature review and stakeholder engagement process. Our literature review encompassed a wide range of sources, including National Communication and Biennial Update Reports from the Ministry of Environment, Forests, and Climate Change (MoEFCC), Government of India, as well as relevant Intergovernmental Panel on Climate Change (IPCC) reports and recommendations related to methane emissions in the energy sector. Additional sources included reports and datasets from international organizations such as the International Energy Agency (IEA), United Nations Environment Programme (UNEP), World Bank, and Global Energy Monitor (GEM), which provide insights into global and sector-specific methane mitigation challenges and opportunities, alongside policy and regulatory documents from various countries focused on methane abatement.

Further, we reviewed recent reports and articles detailing advancements in methane monitoring and measurement technologies, as well as global standards, agreements, charters, and partnerships aimed at addressing methane emissions. We also examined India's regulatory framework and standards governing hydrocarbon gas emissions in the energy sector. Peer-reviewed research papers and reports were analyzed for insights on mitigation opportunities and the associated co-benefits, such as employment generation and public health improvements.

Beyond the literature review, two in-person expert workshops were conducted, each with over 20 participants, to explore the unique challenges and opportunities in methane mitigation within India's energy sector. Additionally, interviews were held with experts and key stakeholders, including representatives from government agencies, energy sector companies, and academia. These discussions provided valuable perspectives and allowed for validation of preliminary findings. Key insights and recommendations from these workshops and interviews have been integrated into relevant sections of the report.

2.2 Limitations

While this study involved an extensive literature review, expert workshops, and stakeholder interviews, the following limitations should be considered when interpreting the findings and planning subsequent actions:

- **Data gaps in methane sources and mitigation measures:** Although workshops and interviews enriched the findings, the limited availability of primary data on methane emission sources, their scale and mitigation measures may affect the study's comprehensiveness.
- **Stakeholder biases:** Stakeholder perspectives may introduce biases, as government representatives, industry professionals, and researchers could each prioritize different aspects of methane mitigation, potentially influencing the recommendations.
- **Generalized emission factors:** Officially reported data on methane emissions in India's energy sector rely on emission factors that are not independently verifiable, and thus may not accurately represent the exact sources and scales of emissions.
- **Rapidly evolving methane measurement and mitigation landscape:** The findings may not fully reflect recent advancements or innovations in methane mitigation, particularly given the rapidly evolving technological and regulatory landscape.

3.0 Coal Mining Sector

Coal has been mined commercially in India since 1774 when the East India Company established mines in the Raniganj Coalfield, along the Damodar River in West Bengal[10]. Today, India is the second largest producer of coal. The International Energy Agency (IEA) projects India will produce nearly 1.2 billion metric tons, or around 12% of the world's coal, by 2026—about four times the anticipated production of the United States[11].

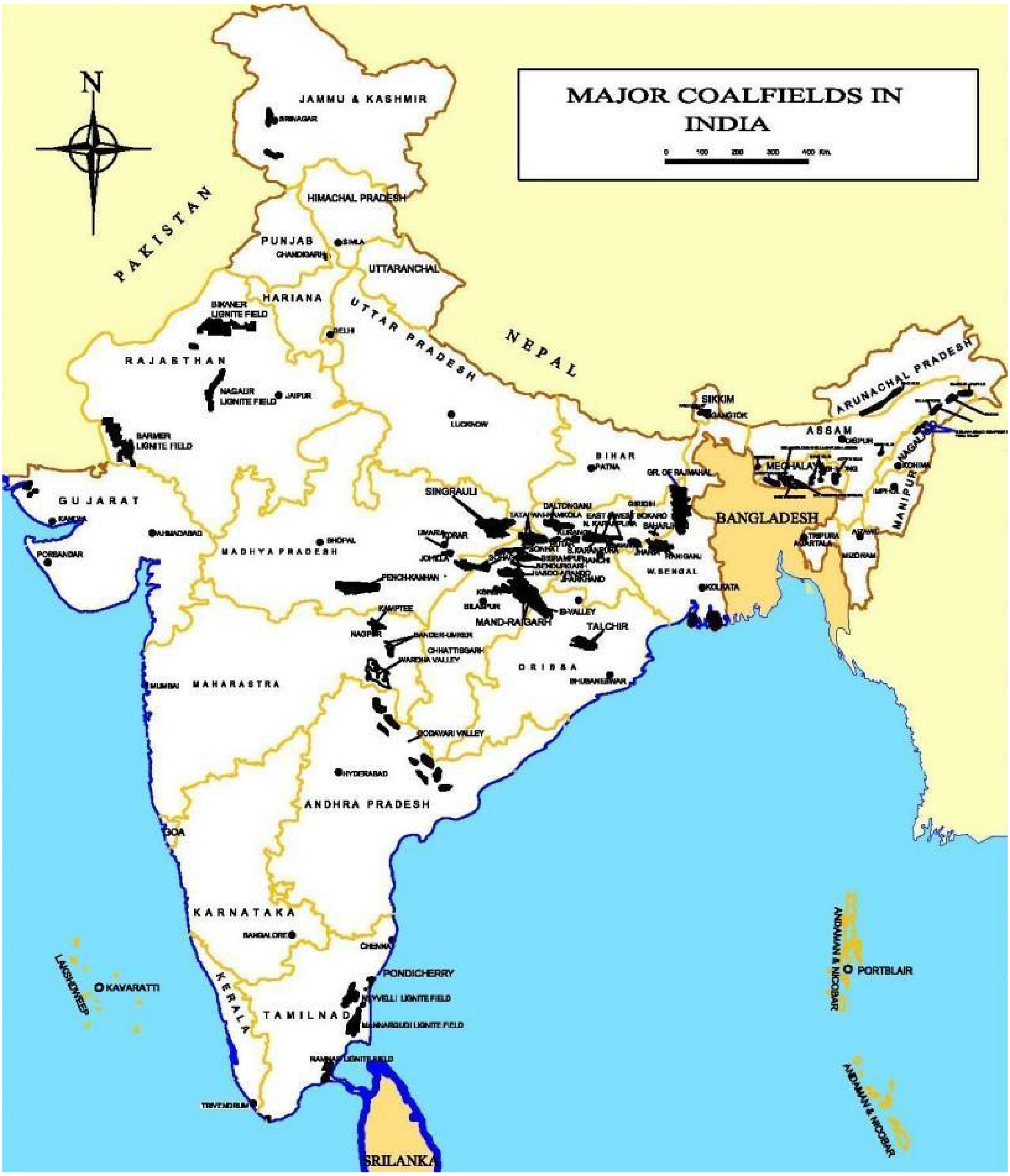
Above, coal pickers collect coal from a pile of overburden in the Jharia Coalfield. Smoke from underground mine fires can be seen rising in the distance. Photo credit: Rishi Kishore.

Coal production in India is dominated by a network of state-owned enterprises. In the 2023-24 production year, India produced just over 997 million metric tons of coal—approximately 85% of which was mined by state-owned companies under the ownership of the Ministry of Coal. Notably, Coal India Limited (CIL) and its subsidiaries were responsible for 78% of total production.[12] One CIL subsidiary, the Central Mine Planning and Design Institute (CMPDI), provides critical technical consulting services to CIL and its other subsidiaries to inform efficient mineral exploration and mining operations.

3.1 Methane emissions

Coal mining is a major source of global methane emissions. In 2022, the world's active and inactive mines released more than 40 million metric tons of methane into the atmosphere—about 10% of all methane emissions from human activity for that year[13]. Generally, methane originating from coal can be categorized three different ways: coalbed methane (CBM), coal mine methane (CMM), and abandoned mine methane (AMM).

Map 1: Major coalfields of India



Source: Geological Survey of India[14]

(Above) Major coalfields are found throughout India with particular concentration in the eastern part of the country.

- **CBM** refers to methane gas trapped or produced in an unmined coal seam. Typically, CBM can be recovered using surface boreholes.
- **CMM** refers to methane gas that originates from a working mine site. CMM either escapes as fugitive emissions or is captured utilizing underground drainage techniques before or during mining operations.
- **AMM** refers to methane emitted from previously active and currently abandoned mines.

The presence of CBM in underground geology does not necessarily pose an emissions liability until it is intentionally or unintentionally brought to the surface. When it is brought to the surface through the drilling of boreholes or other oil and natural gas extraction methods, its related emissions are attributed to the oil and natural gas industry. However, if methane is brought to the surface through coal mining, it is considered CMM or AMM.

Table 1: Coalbed methane resources by state

State	CBM resources* (billion cubic meters)
Jharkhand	722
Rajasthan	360
Gujarat	351
Odisha	244
Chhattisgarh	241
Madhya Pradesh	218
West Bengal	218
Tamil Nadu	105
Telangana and Andhra Pradesh	99
Maharashtra	35
Other northeastern states	8

Source: Ministry of Petroleum and Natural Gas (MoPNG) (2022)[15].

*Note: CBM reserves above are estimated. Usable reserves may be significantly less.

(Above) CBM reserves are present in more than 10 Indian states.

CMM and AMM are substantial sources of methane emissions in India. The quantity of CMM and AMM is largely determined by the rank of coal being produced, method of mining, and seam depth. Most methane is released at the mine site; however, coal continues to release stored methane for a short time post-mining, so some methane emissions can be attributed to post-mine coal handling[16]. Globally, around 70% of mining-related methane emissions can be attributed to underground mining operations[17]. While approximately 95% of Indian coal is currently extracted from opencast mines, production from underground mines is expected to triple by 2028[18]. This could potentially create a substantial increase in methane emissions if not properly planned.

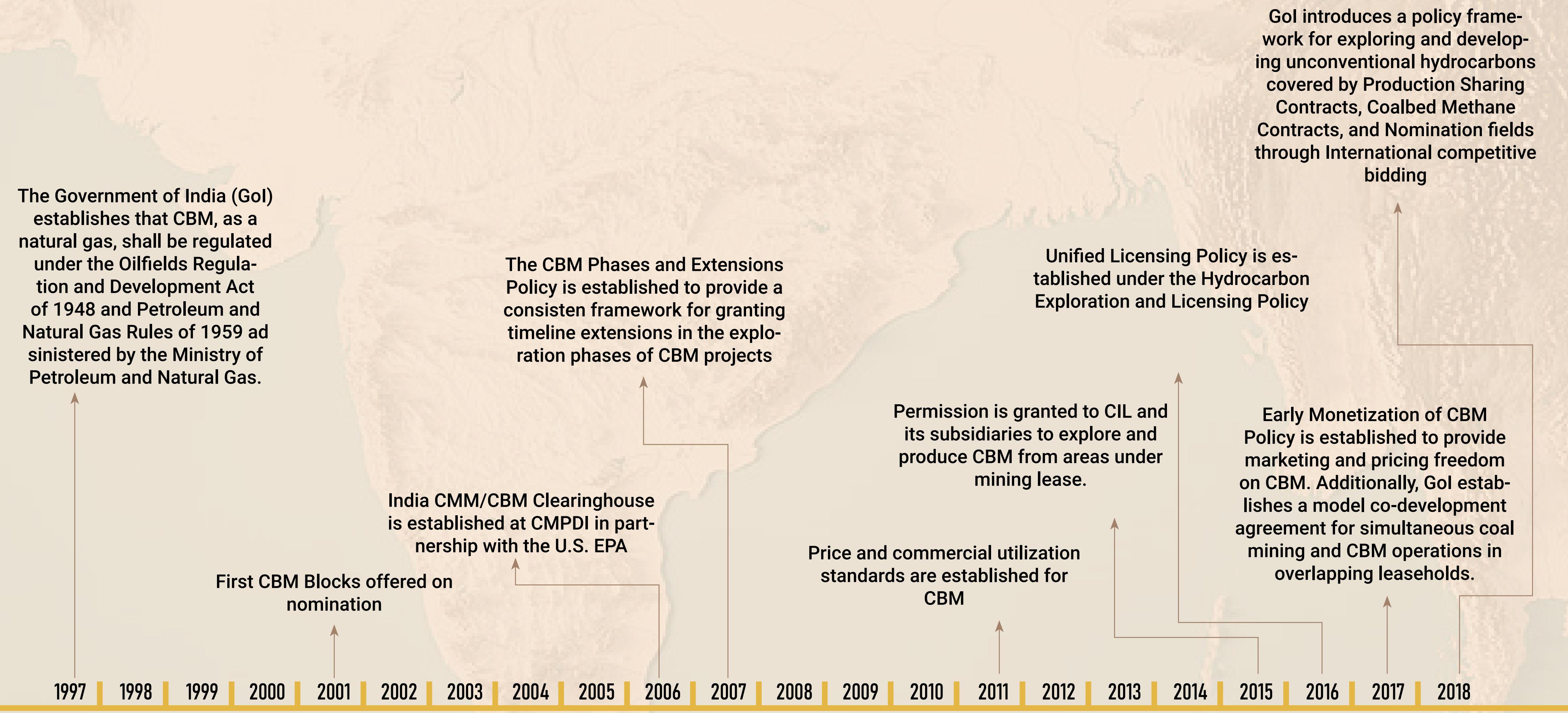
The regulation of methane extraction in the coal mining sector started in 1997 when the Government of India established that coalbed methane, as a natural gas, will be regulated under the Oilfields Regulation and Development Act of 1948 and the

Petroleum and Natural Gas Rules of 1959, which are administered by the Ministry of Petroleum and Natural Gas. Over the subsequent two decades, the government spearheaded several policies and actions to facilitate the efficient extraction and utilization of CBM and CMM. The first CBM contracts were awarded in 2001, and to date, 40 individual contracts have been awarded. Notably, in 2015, to increase coalbed methane exploration and accelerate the production of natural gas, Coal India Limited and its subsidiaries were granted permission to explore and produce coalbed methane from areas it has under mining lease, waiving any previous licensing requirements from the Ministry of Petroleum and Natural Gas for areas under leasehold by the companies[15].

Also of note, in 2008 with support from the United States Environmental Protection Agency (U.S. EPA) and the United States Trade and Development Agency, the Ministry of Coal established the India CMM/CBM Clearinghouse at CMPDI. Among its many accomplishments, the CMM/CBM Clearinghouse produced a technical guide on CBM opportunities, partnered on feasibility studies of CMM and CBM projects in different Indian coalfields, and hosted several workshops aimed at increasing the awareness and uptake of CMM abatement projects. Critically, the Clearinghouse also served as an initial point of contact for foreign and domestic investors, and shaped public discourse on CMM/CBM in India[19].

Journey of coalbed methane extraction in India

Regulation of methane extraction in the coal-mining sector started in 1997 when the Government of India established that coalbed methane (CBM), as a natural gas, will be regulated under the Oilfields Regulation and Development Act of 1948 and the Petroleum and Natural Gas Rules of 1959, which are administered by the Ministry of Petroleum and Natural Gas. Over the subsequent two decades, the government spearheaded several policies and actions to facilitate the efficient extraction and utilization of CBM and coal mine methane (CMM).

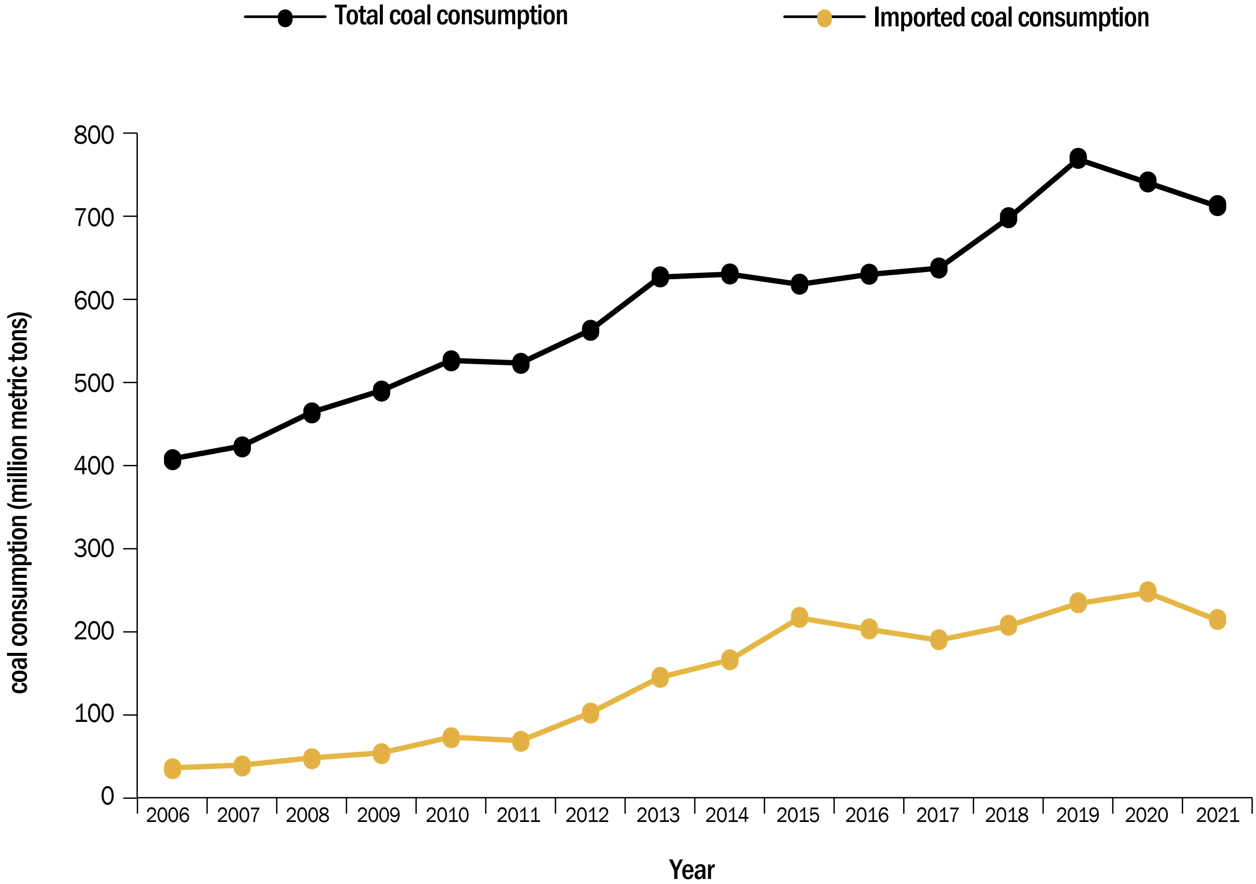


Source: Directorate General of Hydrocarbons [15]

3.1.1 Industries driving CMM emissions

The steel, cement, and power industries are India's primary industrial consumers of coal. While these industries have limited direct methane emissions, they indirectly drive substantial CMM emissions globally through their consumption of coal. Decarbonization efforts that reduce the sectors' reliance on coal will also reduce methane emissions associated with the industry.

Figure 1: Coal consumption in the Indian steel, cement, and power industries, 2006-2021



Source: NITI Aayog (2024)[20]

(Above) Between 2006 and 2021, the Indian steel, cement, and power industries consumed nearly 9.5 billion metric tons of coal. Around 76% of the coal sourced to these industries in this time was from Indian mines, while 24% was imported—primarily from Australia, Russia, and the United States.

i) Steel industry

Between 2006 and 2021, the steel industry witnessed an average year-over-year coal consumption growth rate of more than 3%, driving increases in methane emissions at mines upstream of the steel manufacturing process. This growth in coal consumption coincided with unprecedented growth of the industry and record-breaking levels of crude steel production[21]. The Government of India (GoI) is making substantial efforts to decarbonize the steel industry, primarily through energy efficiency measures and fuel switching, which will indirectly reduce methane emissions from Indian mines. Between 2005 and 2023, average total greenhouse gas (GHG) emissions per metric ton of Indian crude steel were reduced from 3.1 $MTCO_2e$ (metric tons of carbon dioxide equivalent) to 2.5 $MTCO_2e$. These decarbonization efforts are likely to continue in the future[22].

In parallel with India's net zero by 2070 target, strategies in the short, medium and long terms have been developed to reduce and eliminate the industry's reliance on coal. In the short-term, between now and 2030, the Ministry of Steel is focused on the promotion of measures for energy and resource efficiency at India's steel plants and increased use of renewable energy. In the medium-term, between 2030 and 2047, focus will shift to implementing green hydrogen-based steel manufacture, and carbon capture, utilization, and storage (CCUS) at steel plants throughout the country. In the long term, between 2047 and 2070, the Ministry of Steel has its sights on disruptive alternative technologies like molten oxide electrolysis to take the industry to net zero[23].

ii) Power industry

Between 2006 and 2021, the power sector witnessed an average year-over-year coal consumption growth rate of more than 4.3%. Due in large part to India's recent period of sustained economic growth and the rise in electrification rate, energy demand has more than doubled in the last 25 years, during which time just less than one billion citizens have gained an electrical connection[24]. Approximately 49% of India's existing electricity generation capacity—a little more than 200 gigawatts (GW)—comes from coal-fired power plants. While the existing fleet of coal-fired power plants has been recognized for its technical inefficiency, it is anticipated to remain in operation for at least the next few decades, due in part to high capital costs of replacement technologies and a scarcity of capital[25]. Furthermore, the Ministry of Power plans to add a minimum of 80 GW of additional coal capacity by 2032[26].

iii) Cement industry

Unlike the steel and power industries, coal consumption by the cement industry has fallen off in recent years. This, at least in part, is due to increased use of imported petroleum coke and other alternative fuels over coal in the country's cement kilns[27]. If nothing substantial changes, CO_2 emissions from the Indian cement industry are anticipated to almost double between 2020 and 2030[28]. Like the steel industry, efforts to decarbonize the cement industry will inevitably reduce its reliance on coal. Current efforts to decarbonize the cement industry largely focus on energy efficiency and integration of alternative fuels, like renewable energy, biomass, and refuse-derived fuels[29].

3.2 Emissions sources

The GoI reported its CMM emissions in its Third National Communication and Fourth Biennial Update Report to the United Nations Framework Convention on Climate Change (UNFCCC) in December 2023 and December 2024 respectively. Both reports utilize country-specific emissions factors for mining and post-mining coal handling activities from surface and underground mines. Underground mines are categorized based on their level of gassiness—Degree 1 being the lowest level of gassiness and Degree 3 being the highest. Degree 3 mines are generally found in the East Bokaro and Jharia coalfields in Jharkhand, and the Raniganj coalfield in Jharkhand and West Bengal[30]. Utilizing these emission factors and mine-specific coal production estimates from the Ministry of Coal, GoI reported CMM emissions of approximately 810 kilo tonnes (kT) in 2019 and just less than 800 kT in 2020. This is roughly equivalent to the emissions of approximately 60 (800 MW) natural gas-fired power plants operating for one year[31]. Citing a limited number of abandoned mines, which had low production during historic operations, the GoI reported AMM emissions as negligible and did not provide AMM emissions estimates in the Third National Communication or Fourth Biennial Update Report.

Table 2: Coal mining and handling emission factors

Operation	Methane emission factors (m^3 of CH_4 per metric ton of coal)			
	Surface mining	Underground mining		
		Degree 1	Degree 2	Degree 3
Mining	1.18	2.91	13.08	23.64
Post-mine handling	0.15	0.98	2.15	3.12
Total	**1.33**	**3.89**	**15.23**	**26.76**

Source: MoEFCC[32]

(Above) Official CMM emission estimates provided to the UNFCCC in India's Third National Communication and Fourth Biennial Update Report utilize country-specific emission factors for mining and post-mine coal handling activities from surface and underground mines. The emissions factor for surface mining is the lowest. Underground mines are categorized based on their level of gassiness—Degree 1 being the lowest and Degree 3 the highest.

Efforts have been made to update the emissions factors India uses for its underground mining operations. A recent study found that Degree 1 underground mines likely have a rate of nominal emission at less than $1m^3$/metric ton of coal produced. Furthermore, the study finds that Degree 2 mines have an emission rate between 1 and $10m^3$/metric ton of coal produced, and Degree 3 mines always have an emission rate greater than $10m^3$.[33] Notably, all of these are significantly less than the emissions factors utilized for underground mining in the Third National Communication.

Conversely, several studies have found that methane emissions may be significantly higher than the estimates provided in the Third National Communication. A recent study from the IEA, for example, utilized satellite data to show that India's coal-related methane emissions may be as high as 2,770 kT per year—more than triple the number reported in GoI's reports to the UNFCCC[34]. Notably, this study's top-down approach to estimating methane emissions considers emissions originating from both producing and non-producing coal mines. The Third National Communication does not account for or mention methane emissions from non-producing coal mines.

The IEA estimates that approximately 50% of global CMM emissions could be abated utilizing existing technologies[17]. The first line of defense against CMM emissions is pre-mine drainage of CBM. High concentrations of methane can be captured prior to mining operations and utilized for different purposes. Different types of methane utilization projects are explained in Section 3.3.2. After mining operations begin, CMM can be captured and utilized from underground mines, and in some cases, from opencast mines. Where utilization of CMM is not possible or practical, mining companies may employ high efficiency flaring or thermal oxidation processes to destroy the captured gas and reduce methane emissions. Utilizing similar processes, AMM can be captured and utilized from abandoned mines.

Table 3: Options for CMM mitigation by mine status [17]

Mine status	Technological option for abatement
Pre-mining	Drainage and utilization of CBM from unworked seams utilizing degasification wells and drainage boreholes.
	In cases where utilization is not practical or feasible, destruction of methane through high efficiency flaring or thermal oxidation.
Mining	Capture of CMM from ventilation systems
	Implementation of technological and process efficiency improvements to decrease fugitive methane emissions
	In cases where utilization is not practical or feasible, destruction of methane through high efficiency flaring or thermal oxidation.
Post-mining	Capture of AMM and utilization of AMM from underground abandoned mine voids.
	In cases where utilization is not practical or feasible, destruction of methane through high efficiency flaring or thermal oxidation.

(Above) There are opportunities to mitigate methane emissions at every stage of mine development. Pre-mining abatement options focus on drainage and utilization or destruction of methane. Abatement options during active mining operations or post-mining include capture of methane from the mine and destruction of methane through flaring or other means.

3.3 Co-benefits of addressing coal-mine methane emissions

The planned increase of India's domestic coal production to 1.5 billion metric tons[8] and potential tripling of underground mining output to 100 million metric tons[18] may substantially increase methane emissions. Effectively managing methane emissions from India's active and inactive coal mines doesn't just curb greenhouse gas emissions and mitigate climate change; it can also reduce occupational and public health risks, avoid substantial social costs, and provide direct and indirect economic benefits by supplying an alternative energy source to different sectors of the economy. Furthermore, coal mine methane could play a role in local and national decarbonization strategies.

3.3.1 Occupational and public health benefits

Controlling mine methane is critical for maintaining occupational health, safety, and productivity of underground mining operations. In addition to being highly flammable and potentially explosive, methane can displace oxygen and cause asphyxia if breathed. Ventilation systems have been deployed for hundreds of years to move methane-contaminated air away from active mining areas and towards the surface.[35,36]

Ventilation air methane is considered a subcategory of CMM. While the actual methane content of mine ventilation air is quite low when it reaches the surface, it is released in huge quantities into the atmosphere[37]. The release of this methane into the atmosphere directly leads to increased concentrations of tropospheric ozone through methane oxidation[38,39]. Exposure to heightened concentrations of tropospheric ozone can cause shortness of breath and coughing. It can also exacerbate asthma and bron-

> "We must pursue solutions that are best suited to our socio-economic situation."
>
> Workshop on Methane Mitigation in India's Energy Sector, August 2024: Comment on the need to address methane emissions while considering India's unique socio-economic situation and energy needs.

chitis symptoms and lead to irritation and damage of airways [40]. Approximately 374,000 premature deaths are caused by long-term tropospheric ozone exposure in India each year, and if nothing significant changes, this is expected to rise to 1,126,000 deaths per year by 2050[41].

The methane-ozone mechanism is attributable to 760 respiratory-related deaths per million metric tons of methane emissions[42]. As methane persists in the atmosphere for a period of time, emissions today will influence tropospheric ozone levels and subsequent disease burdens in the future. Proactive draining of CBM and capture and utilization of CMM and AMM would provide a proportional reduction in tropospheric ozone and prevent a number of future premature deaths. Additional deaths accrue each year these emissions go unabated.

3.3.2 Avoided social cost and economic benefits

Social cost is the economic damage borne by society as the result of a specific action. While the social cost of methane emissions originating from Indian livestock has been studied extensively[43], the cost of Indian CMM and AMM emissions and other energy sector-related methane emissions has been limited. A recent study examined the social cost of methane emissions across countries and regions of varying socio-economic status, and determined the global average social cost of methane as $922 per metric ton[44]. Applying this value to India's recent CMM estimates, we estimate that Indian citizens are bearing about $747 million in externalized costs related to unabated emissions each year.

The primary economic benefits of mitigating CMM emissions from active mining areas are related to the utilization of a previously discarded energy resource and potential mine productivity improvements related to more active management of methane. For coal seams that have yet to be mined, the primary benefits also include substantial oil and gas sector job creation opportunities posed by potential CBM extraction operations.

As of 2024, there are 248 operational CMM projects worldwide. Of these projects, 82 capture methane from abandoned underground mines, 153 capture methane from active underground mines, a single project captures methane from a surface mine, and 12 projects—mostly in China—occur on mines of unknown type or status[45].

Despite the global popularity of CMM capture and utilization projects, India has only implemented one such project, a 500 kW power generation pilot project at Bharat Coking Coal Limited (BCCL)'s Moonidih Underground Mine in Jharkhand. This project was conceptualized in 1996 and subsequently funded for implementation by the Global Environment Facility (GEF) Council, United Nations Development Program (UNDP), and India's Ministry of Science and Technology. The project captured CMM, which fed into a local pipeline that led into two 250 kW gas generators producing electricity. Ownership of the project was officially turned over to BCCL in 2010[46]. The project is no longer active.

Table 4: Global CMM and AMM projects by end use

End use	Number of projects
Combined Heat and Power (CHP)	72
Direct thermal	15
Flaring or other destruction	56
Gas sales to pipeline	16
Power generation	75
Town gas	9
Other end use	5

Source: Global Methane Initiative [45]

(Above) More than half of global CMM/AMM utilization projects use captured methane for combined heat and power (CHP) applications or for power generation. Direct thermal applications for coal drying and industrial boiler firing, town gas, and gas sales to pipelines are also popular end-use options. On some projects where end uses are not economic or available, the destruction of methane through flaring is used to reduce GHG emissions.

While some other projects have been conceptualized and studied, none have been fully operationalized. Notably, an additional feasibility study was completed for the capture and utilization of ventilation air methane at Moonidih in 2015. As a Degree 3 underground mine, Moonidih has a higher quality and quantity of methane gas. The study found that heat produced from the combustion of ventilation air methane could produce just less than 74 GWh of electricity per year [30], which is equivalent to producing electricity for nearly 56,000 Indian residents—from a single underground mine.

Methane drainage projects can also boost mine productivity levels by cost effectively reducing the amount of downtime a mine experiences due to high methane levels[47,48]. In international case studies, pre-mine methane drainage has been shown to increase mine productivity to as much as 40 tons per man hour and reduce mining costs by as much as 25% and similar benefits can be achieved in India[49].

Finally, for areas that have yet to be mined, additional economic activity can be supported through pre-mine drainage of CBM. In its maiden CBM project within a BCCL leasehold area covering nearly 27 square kilometers, CIL and its partners are exploring CBM production and monetization of the Jharia coalfield. Currently in the exploration phase of the project, Prabha Energy Private Limited (PEPL) has been contracted to develop the block. While exploration is still underway, it is estimated that the production phase of this single coalfield could involve more than 100 CBM wells. Depending on the coal seam's thickness and spacing, project partners estimate each well will support between 6 and 10 jobs. As a result, CBM production of this single coalfield could support between 480 and 1,200 direct jobs[50]. As of 2023, there were 11 other CBM projects in similar phases of development regulated by the Directorate General of Hydrocarbons.

3.3.3 Potential role in decarbonization strategies

Mine methane mitigation can play a strategic role in decarbonizing the coal sector as India charts its path towards net zero by 2070. Globally, CMM and AMM capture and utilization projects have demonstrated the ability to generate substantial offset credits in both voluntary and compliance carbon markets[51,52]. For example, the McElroy Mine Ventilation Air Methane Abatement Project in West Virginia, USA commenced operation in 2012 and over the subsequent 5-year period, registered over one million tons of carbon dioxide equivalent emission reductions—about 200,000 tons per year[51]. With global voluntary carbon market prices currently hovering right around $7 per ton[52] this project would produce $1.4 million in revenue per year from carbon offsets. In addition to generating in-demand carbon offsets, revenue generated through offset sales could be reinvested into additional decarbonization or just transition efforts undertaken by the coal industry. Similar benefits could be achieved in India.

3.4 Challenges in methane mitigation in the coal-mining sector

The following challenges pose major hurdles for methane mitigation within the coal mining sector in India.

3.4.1 Need for improved data

As highlighted previously, there are obvious gaps in India's official estimates of CMM and AMM emissions, which likely result in the underestimation of emissions. Source monitoring methodologies, especially top-down approaches, are rapidly evolving. Within the GHG monitoring-community of practice, there is a growing recognition that India must pursue a mixture of bottom-up and top-down approaches in order to improve the accuracy of its coal mine methane emissions estimates. Nevertheless, implementing new approaches to monitoring methane emissions across India's expanding network of mines poses at least some additional cost for the coal industry. Without curtailing these potential costs, and in the absence of regulation, the industry is unlikely to adopt more rigorous, proactive measures for quantifying methane emissions from active and inactive mines.

3.4.2 No commercial CMM or AMM capture and utilization projects

At this time, India has only implemented one operational CMM project, a 500 kW power generation pilot project at BCCL's Moonidih Underground Mine in Jharkhand. This project was conceptualized in 1996 and subsequently funded for implementation by the GEF Council, UNDP, and the Government of India Ministry of Science and Technology. The project captured CMM, which was fed into a local pipeline leading to two 250 kW gas generators to produce electricity for local consumption. Ownership of the project was officially turned over to BCCL in 2010[46]. While some other projects have been conceptualized and studied, none have been fully operationalized.

3.4.3. Time-consuming nature of CBM drainage and near-relinquished status of most contracts

Given the imminent increase in coal production, proactive CBM drainage and utilization projects are India's first line of defense against multiplying methane emissions. CBM drainage projects take at least a couple of years to reach steady gas production, and once gas is produced, it can take a few to many years to fully drain a reservoir[53].

This prolonged timeline is not compatible with India's ambitious coal production targets and plans.

As of mid-2024, 40 CBM contracts had been awarded across six individual rounds of bidding. Of these 40, eight contracts have reached the development and production phase. Most contracts are either under relinquishment or have been completely relinquished due to technical or financial complications[15].

3.5 Opportunities for collaboration

A variety of stakeholders would benefit from advancing methane mitigation opportunities in the coal-mining sector and could all play important roles in facilitating this work in India. They include government representatives—both regulators and policymakers—civil society, academia, mining companies, philanthropy, financial institutions, and intergovernmental organizations, among others. These stakeholders could be involved in advancing specific projects or broad policies. An alliance of diverse stakeholders working together would make it possible for more methane mitigation to occur in the mining sector, and quicker. Below, we describe opportunities for collaboration among stakeholders to move forward on mitigating methane within the mining sector over the coming years. Additional stakeholder-specific recommendations and possible action steps are provided in the final section of this report.

3.5.1 Improving efficiency and collaboration on CBM

Developing an interdisciplinary task force can be a strategic approach to tackling complex environmental challenges. A task force helps capitalize on diverse expertise within a group of stakeholders to efficiently direct action toward achieving ambitious goals. We propose the creation of a task force for improving efficiency and collaboration on CBM.

As mentioned previously, proactive CBM drainage and utilization projects are India's first line of defense against multiplying methane emissions considering the imminent rise in coal production. The government has taken actions to facilitate the expedited development of India's CBM resources; however, many CBM projects have been plagued by unforeseen technical and economic complications that increase project timelines or lead to project cancellation. A multisectoral task force to explore opportunities for improving efficiency and interministerial and public-private collaboration on CBM extraction projects would serve to inform the next generation of government actions to further assist the burgeoning industry.

The initial objectives of this task force could include:

1. Examining the causes of CBM project delays and cancellations, and assessing remedial actions to prevent similar incidents in future.
2. Exploring intragovernmental and public-private collaboration opportunities to improve efficiency and success rate of CBM extraction projects.
3. Drafting a short-term (5-year) CBM extraction and utilization plan that:
    i. locates specific areas for focused CBM prospecting.
    ii. provides updates on awarded CBM contracts and projections of po-

> There is rising awareness of methane emissions in India, and there is a need for further collaboration."
>
> Workshop on Methane Mitigation in India's Energy Sector, March 2024: Comment on the need for collaboration and improved awareness for enhanced methane mitigation efforts

tential CBM extraction.

iii. identifies key technologies and equipment to be popularized and applied.

iv. pinpoints opportunities to strengthen supervision and management of CBM contracts.

v. determines potential policy interventions for better development of CBM.

vi. identifies opportunities for enhanced coordination between the coal and gas industry.

3.5.2 Improving emissions estimates

There is broad consensus among interested stakeholders that India must pursue a mixture of bottom-up and top-down approaches to improving the accuracy of its coal mine methane emissions estimates. Researchers from civil society and academia have produced several alternative coal-mine methane emissions estimates that employ methodologies that vary from those employed by India in its most recent communications to the UNFCCC.

An additional task force for improved coal-mine methane estimations could be set up to examine evolving methodologies to establish and employ an improved methodology in future UNFCCC communications. This task force may also examine national coal-mine methane emissions data availability.

Ideally, this task force would be championed by a representative from the MoEFCC, which oversees India's communications to the UNFCCC. Additional participants could be from civil society organizations working on coal-mine methane, Indian academic institutions, the Ministry of Coal, and CMPDI.

Initial objectives of this task force could be to:

1. Examine evolving methodologies of coal mine methane emission estimations to establish and deploy an improved methodology that closes existing data gaps (abandoned and non-producing mines) and more accurately estimates the country's coal-mine methane emissions.

2. Explore making higher-resolution coal-mine methane emissions data available publicly.

3.5.3 Relaunch the CMM/CBM Clearinghouse

With support from the U.S. EPA, the Ministry of Coal established the India CMM/CBM Clearinghouse in 2008. Between 2008 and 2023, the Clearinghouse served to develop capacity in needed areas to expedite the commercial development of CMM/CBM in India. Approximately 75% of its funding came from CIL and 25% from the U.S. EPA. Among its many accomplishments, the CMM/CBM Clearinghouse produced a technical guide on CBM opportunities, partnered on feasibility studies of CMM and CBM projects in different Indian coalfields, served as an initial point of contact for foreign and domestic investors, and shaped public discourse on CMM/CBM in India[19].

Unfortunately, the CMM/CBM Clearinghouse website has not been active since 2021[19]. This is particularly problematic considering multilateral development banks, large philanthropic organizations, and the private sector are increasingly interested in funding methane mitigation projects to meet climate objectives. The watershed moment for methane mitigation finance may be imminent, and India's gassy mines could be a huge opportunity. At a minimum, stakeholders should develop and regularly update a pipeline of investable CMM and AMM projects in anticipation of future funding opportunities.

In this time of evolving methane capture and utilization technologies and finance opportunities, a relaunch of the CMM/CBM Clearinghouse is necessary to continue the vital work the first-generation clearinghouse carried out. Ideally this would be an effort led by CIL, given its integral involvement in the first-generation clearinghouse. However, civil society could also step up to the plate to assist in this effort.

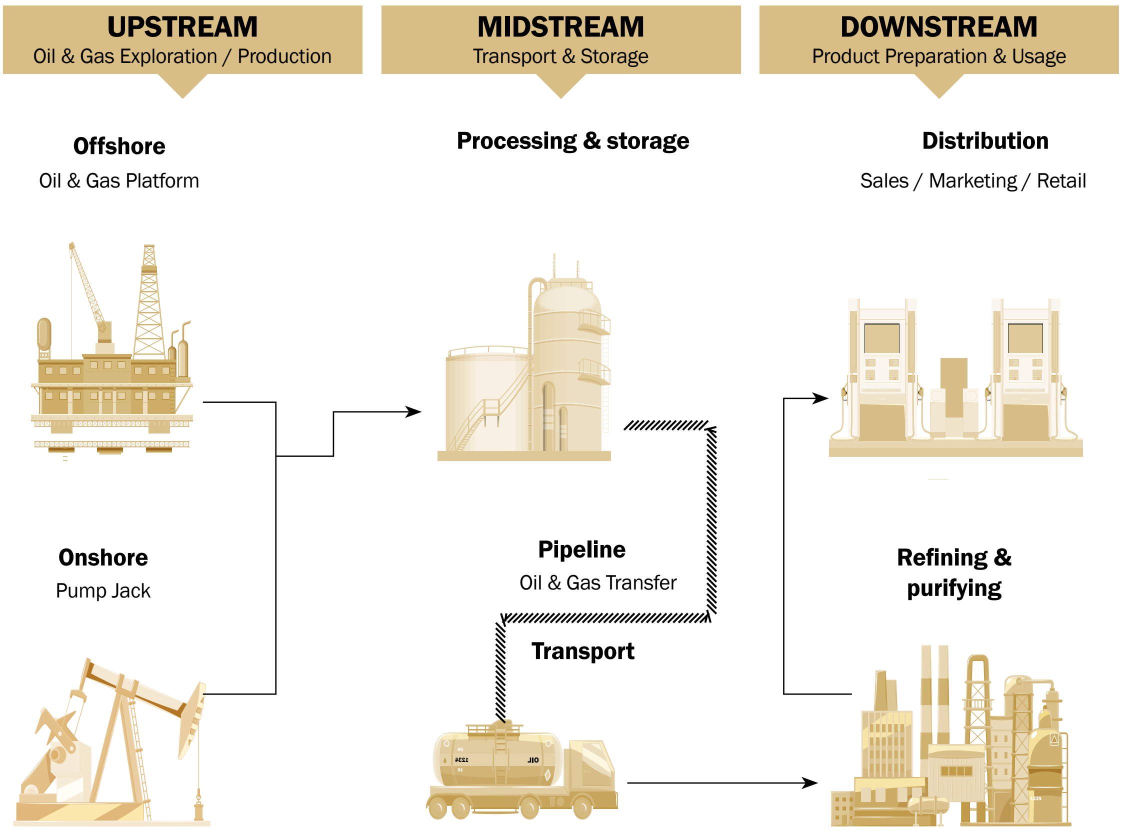
4.0 Oil and Gas Sector

The petroleum industry in India dates back to 1889 when the first oil deposits in the country were discovered in Digboi in Assam. In 1899, the Assam Oil Company Ltd. was established to manage the oil business in the region. Subsequently, the first oil refinery was set up at Digboi in 1901. The Digboi refinery is the oldest oil refinery not only in India but in the whole of Asia. Although the oil industry in India is more than a century old, the natural gas industry began only in the 1960s with the discovery of gas fields in different parts of the country[54].

The oil and gas sector is crucial in India's energy landscape, contributing significantly to its overall energy provision. In 2021, this sector accounted for nearly 30% of India's total energy supply[55]. India currently ranks 3rd in crude oil consumption and imports, 4th in oil refinery capacity, 7th in exports of petroleum products, and 15th in natural gas consumption globally, highlighting the sector's importance in meeting the country's energy needs[56]. As India's energy demand continues to surge, projections indicate a substantial increase by 2030, with a 50% rise in oil demand, a doubling of natural gas demand, and a 30% expansion in refining capacity compared to 2019 levels[9].

In traditional terms, the oil and gas sector is typically categorized into 3 segments: upstream, midstream and downstream.

Figure 2: Segments of the oil and gas sector [57,58, 59]



(Above) The upstream segment of the oil and gas sector focuses on exploration, field development, and production operations. The midstream segment focuses on transportation, processing, trading, and storage of oil and gas. The downstream segment focuses on product preparation and use by industry.

Upstream segment

Also known as the exploration and production (E&P) segment, the upstream segment focuses on discovering potential oil and gas reserves, both onshore and offshore, as well as subsequent drilling to extract these resources and bringing them to the surface[57].

In India, the production of oil and gas is carried out by state-owned enterprises (SoEs), namely, Oil and Natural Gas Corporation (ONGC) and Oil India Limited (OIL), as well as private sector players such as Cairn, Reliance Industries Limited (RIL), and through joint ventures. ONGC and OIL also have a sizable overseas E&P portfolio spread across many countries globally[56].

Although India produces crude oil and natural gas in substantial quantities domestically, it heavily relies on imports to meet its crude oil and natural gas requirements. In the Financial Year (F.Y.) 2022-23, India's import dependence on crude oil and natural gas stood at 87.4% and 43.86% respectively. In 2022-23, the share of SoEs and private/joint-venture companies in imports (crude oil and petroleum products) in terms of volume was 58% and 42% respectively[56]. The top countries exporting crude oil to India in 2022 were Russia, Iraq, Saudi Arabia, the UAE, the United States, Kuwait, and Nigeria[60], while the top petroleum gas-exporting countries for the same year were Qatar, the UAE, Saudi Arabia, Kuwait, the United States, and Oman[61].

Midstream segment

This segment is responsible for the intermediate stages of the oil and gas journey. The midstream segment oversees activities such as gathering, processing, storing, and transporting the extracted oil and gas resources[58].

As of 31st March 2023, India has 6 operational Liquefied Natural Gas (LNG) terminals with a combined capacity of 42.7 million metric tons per annum (MMTPA) and 6 planned/under-construction LNG terminals with a total capacity of 22 MMTPA. These LNG terminals are promoted by both SoEs and private companies. Additionally, as of the same date, India has 30 major crude oil pipelines spanning a total of 10,420 kilometers with a capacity of 147.9 million metric tons (MMT). These pipelines are owned by various SoEs, joint ventures, and private companies such as Indian Oil Corporation Limited (IOCL), ONGC, HPCL-Mittal Pipelines Limited (HMPL), and Cairn India Limited. Moreover, there are over 28 major natural gas pipelines with a total authorized length spanning 33,592 kilometers and a capacity of 717 million metric standard cubic meters per day (MMSCMD). These natural gas pipelines are owned by different SoEs and private enterprises including Gas Authority of India Limited (GAIL), IOCL, and Reliance Gas Pipelines Limited (RGPL)[56].

Downstream segment

Serving as the final link in the value chain, the downstream segment specializes in refining crude petroleum, processing and purifying natural gas, and distributing oil and gas products to customers. Its primary objective is to transform these raw materials into a diverse range of consumer products, including gasoline, jet fuel, asphalt, and various everyday items derived from oil and gas[59].

India currently operates 23 crude oil refineries spread across the country. Among these, 19 are managed by SoEs such as IOCL, Bharat Petroleum Corporation Limited (BPCL), and Hindustan Petroleum Corporation Limited (HPCL), 3 refineries are under the private sector companies Nayara Energy Limited and RIL, while one operates as a joint venture between HPCL and Mittal Energy Limited. These refineries produce a wide range of products including LPG, motor spirit, naphtha, aviation turbine fuel (ATF), kerosene, and fuel oils[62].

As of 31 March 2023, India has 56 major Liquefied Petroleum Gas (LPG) and petroleum product pipelines, spanning 22,494 kilometers with a capacity of 161.6 MMT. Most of these pipelines are owned by SOEs such as GAIL, HPCL, BPCL, OIL, and IOCL. Additionally, the country has 86,855 retail outlets for petroleum products, operating across 36 states and union territories (UTs). India also maintains 309 operational petroleum, oil, and lubricants (POL) depots/terminals and 208 LPG bottling plants with a combined capacity of 22,225 thousand metric tons per annum (TMTPA), distributed across all 36 states and UTs as of April 2023[56].

Together, these three segments form the backbone of the oil and gas industry. Their collective actions play a pivotal role in shaping the dynamics of the global energy market.

In India, the Ministry of Petroleum and Natural Gas (MoPNG) is responsible for the overall regulation and development of the oil and gas industry across upstream, midstream and downstream segments. Specialized organizations under the MoPNG manage various aspects across the industry such as operations and skill enhancement, regulatory development, formulation and implementation of safety standards, etc.

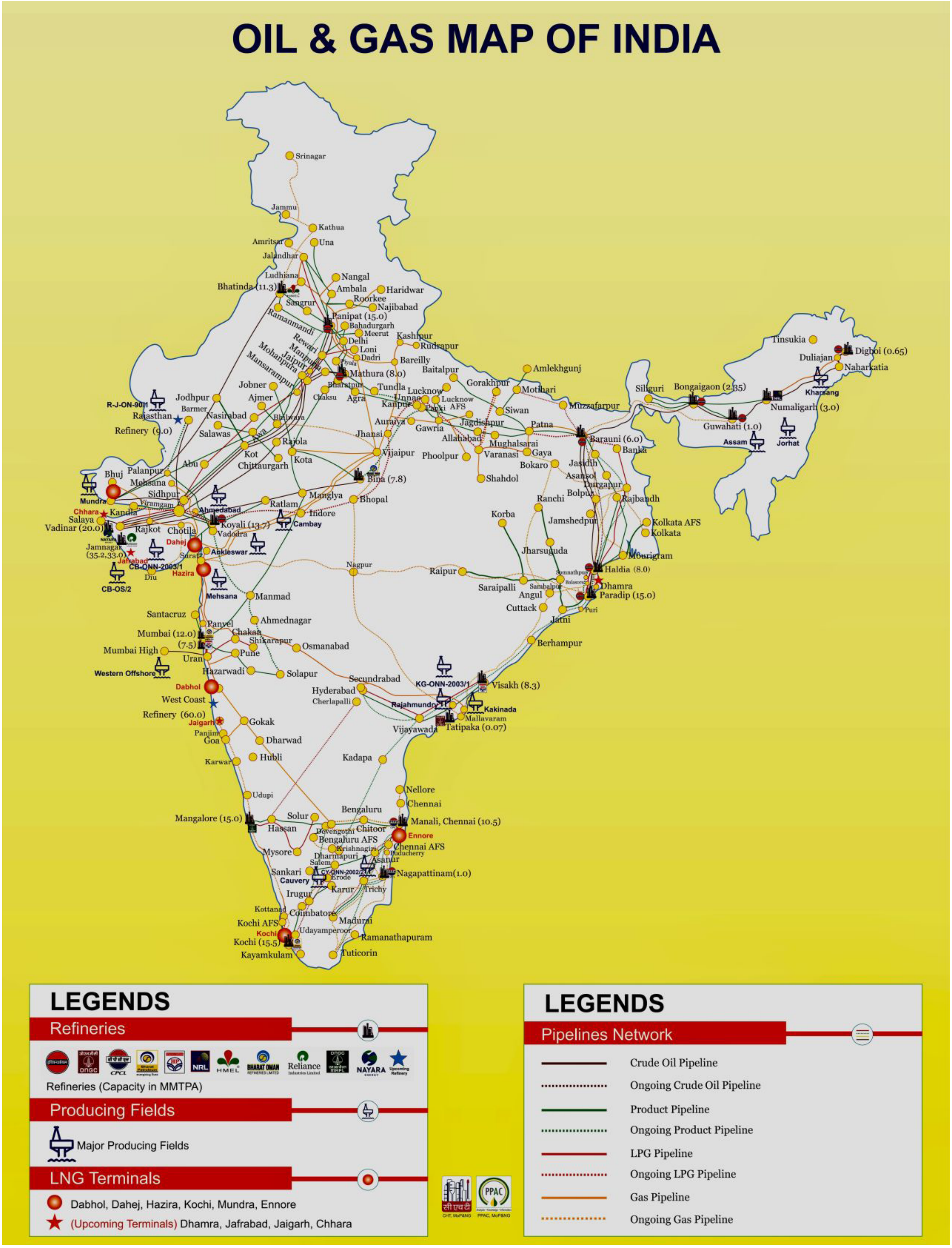
Figure 3: Oil and gas sector regime in India [63,64,65,66]

MINISTRY OF PETROLEUM & NATURAL GAS (MoPNG) oversees oil and gas sector in India, including exploration and production, refining, distribution, marketing, import, export, and conservation of petroleum products

- **OIL INDUSTRY DEVELOPMENT BOARD (OIDB)** provides financial assistance, grants, and loans to oil industrial concerns and overseeing strategic initiatives such as establishing petroleum reserves and skill development efforts
- **OIL INDUSTRY SAFETY DIRECTORATE (OISD)** focuses on enhancing safety standards within the industry by formulating and coordinating the implementation of self-regulatory measures
- **DIRECTORATE GENERAL OF HYDROCARBONS (DGH)** regulates the upstream segment, including implementing the Hydrocarbon Exploration Licensing Policy (HELP), promoting investment within the segment, and monitoring E&P activities
- **PETROLEUM AND NATURAL GAS REGULATORY BOARD (PNGRB)** regulates the midstream and downstream segments, ensuring the smooth functioning of refining, processing, storage, transportation, and distribution of petroleum and natural gas across the country

(Above) Various specialized organizations within the MoPNG oversee various aspects within the industry such as operations and skill development, policy and regulatory development, safety standards etc.

Map 2: Oil and gas infrastructure map of India



Source: Ministry of Petroleum and Natural Gas, Government of India

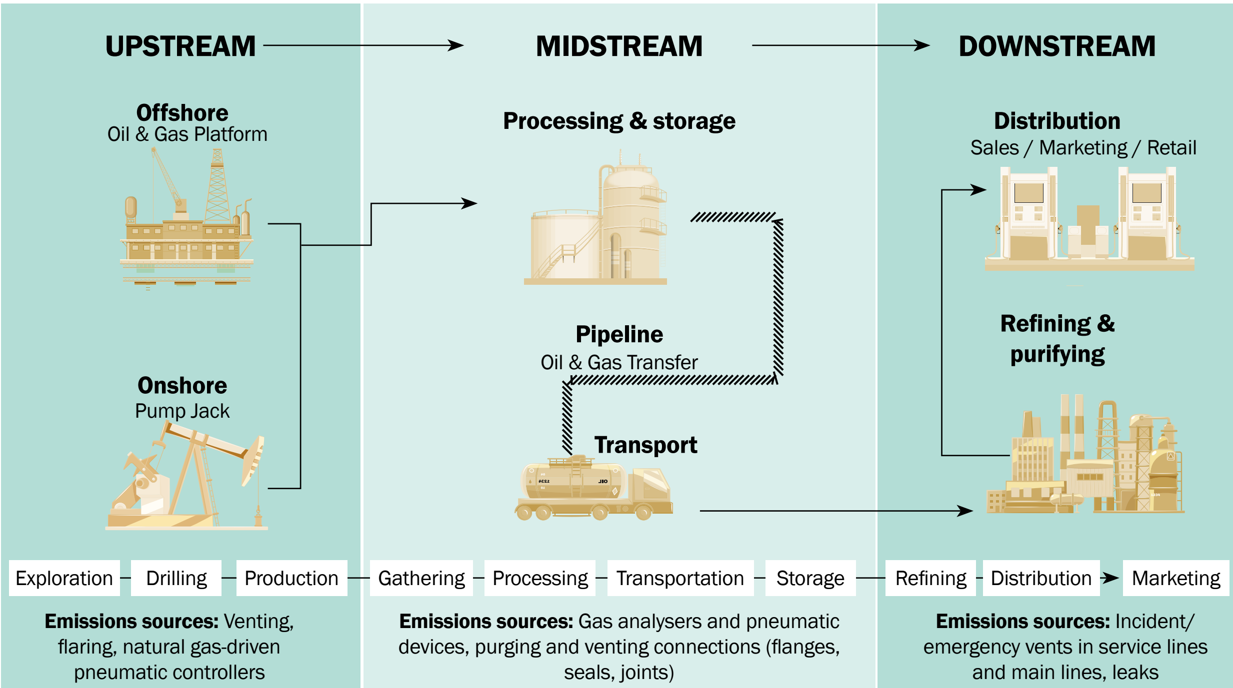
(Above) India's oil and gas infrastructure, including refineries, major producing fields, LNG terminals, and the network of crude oil, product, LPG, and natural gas pipelines, is well distributed across the country.

4.1 Methane emissions sources

While the oil and gas sector is crucial to meeting primary energy demands, it is also responsible for significant quantities of methane emissions. Methane, being the main component of natural gas, is emitted from various sources across the entire oil and gas value chain. While in oil production and processing upstream of refineries methane can be emitted due to the presence of natural gas alongside oil deposits, these emissions occur during natural gas production, processing, transmission, and distribution. Additionally, methane emissions may occur in oil refineries from equipment leaks, process vents, and flare systems[67].

Some of these emissions are deliberate or engineered, such as flare systems and process vents, while others are unintentional, like gas release due to leakages, equipment failure, or other unplanned events. This unintentional release of gasses from oil and gas equipment, facilities, or processes is termed fugitive emissions. Fugitive emissions are considered challenging to manage as they can occur from diverse sources throughout the oil and gas value chain and are less predictable. However, at a global level, more than 75% of current oil and gas sector methane emissions can be averted using existing technologies. And around 40% of these emissions could be cut at no net cost[68].

Figure 4: Processes and emission sources across the oil and gas value chain



Source: IMEO (2022)[69]

(Above) As shown above, the emission sources are diverse, encompassing venting[a] and flaring[b] at oil and gas facilities, leakages during drilling and well completion activities, transportation of crude oil, refining processes, gas transportation systems, and gas distribution to end users [67].

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a. Venting refers to direct release of unburned gas into the atmosphere without being combusted.

b. Flaring refers to controlled combustion of unwanted gas at the end of a flare stack. Flaring is used to burn off unwanted or excess gases, converting them into carbon dioxide and water vapor. As flare combustion efficiency varies, some amount of unburnt gas is also released to the atmosphere during the flaring.

As shown below, there are diverse technological options for methane abatement depending on the specific source of emissions.

Table 5: Methane emissions sources and technological options for abatement*

Methane emissions source	Technological option for methane abatement
Gas-driven pneumatic devices (to operate and control valves and pumps with changes in pressure; used across production and compression facilities)	Replacing high-bleed with low-bleed devices or with instrument air system
Pneumatic pumps using pressurized natural gas as a power source	Replacement with electrical pump
Periodic venting from storage tanks	Installing vapor recovery unit
Gas blowdown (for equipment depressurization)	Blowdown capture
Excess gas produced during well workover or completion	Installing efficient and portable flares; local utilization of excess gas
Fugitive leaks during upstream and downstream activities	Leak detection and repair; better equipment and process performance standards

Source: Global Methane Tracker[14]

*Note: The listed emission sources are indicative, not exhaustive.

4.2 Methane emissions data

The Third National Communication (TNC) report by the MoEFCC submitted to the UNFCCC in December 2023, provides a detailed overview of India's greenhouse gas inventory for 2019. The report highlights that 4.61% of the country's total methane emissions are fugitive emissions[c] from oil and gas systems[32]. The table below provides detailed estimates of fugitive methane emissions and emission factors used for oil and gas systems in India for 2019:

Table 6: Fugitive methane emissions from oil and gas systems in India, 2019

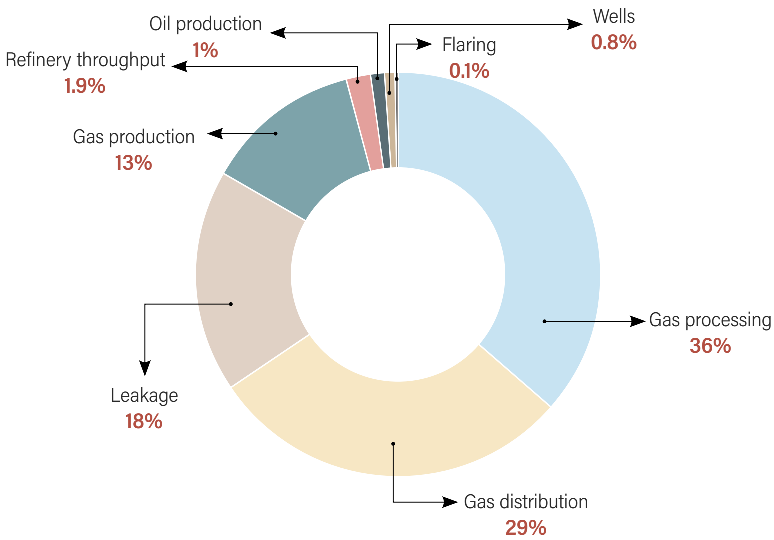
Source	Amount in Gigagram (Gg)	Emission factor used / unit of activity
Wells	7	0.003 Gg/well
Oil production	10	0.000334 Gg/kiloton
Refinery throughput	17	6.75904×10^{-5} Gg/million tons
Gas production	114	0.003556 Gg/million cubic meters (MMCM)
Gas processing	328	0.010667 Gg/MMCM
Gas distribution	263	0.010667 Gg/MMCM
Leakage	160	0.006482 Gg/MMCM
Flaring	0.5	0.000641 Gg/MMCM
Total	**899.5**	

Source: MoEFCC [32], Ministry of Environment and Forests[70]

c. It is to be noted that these numbers don't include methane emissions that occurred beyond India's national borders (associated with the production of crude oil and natural gas imported to India). Also, all of methane emissions from oil and gas systems in India are termed fugitive (unintentional release of gas to the atmosphere) as the oil and gas sector regulations don't allow direct release of hydrocarbon gasses to the atmosphere except in emergency situations.

According to official estimates, in 2019 gas processing was the biggest contributor to fugitive methane emissions from India's oil and gas sector, accounting for 36% of such emissions. Gas distribution and leakages followed at 29% and 18%, respectively. Gas production contributed 13% to methane emissions, while oil production accounted for just 1%. Notably, flaring contributed a minimal 0.1% to methane emissions.

Figure 5: Distribution of fugitive methane emissions from oil and gas systems in India, 2019



Source: MoEFCC [32]

(Above) As per official estimates using the aggregated default emissions factor approach, in 2019, fugitive methane emissions from India's oil and gas systems were led by gas processing (36%), followed by gas distribution (29%), leakages (18%), gas production (13%), oil production (1%), and flaring (0.1%).

It is important to highlight that the above estimation of fugitive methane emissions from oil and gas systems utilizes aggregate default emission factors. The IPCC refers to this approach as a Tier 1 methodology for estimating methane emissions, cautioning against its use due to significant uncertainties. This approach is considered a last-resort option, as it carries a high risk of errors, potentially reaching magnitudes of an order or more [63].

India recently submitted its Fourth Biennial Update Report (BUR) to UNFCCC, which includes the country's GHG inventory for 2020. According to the report, total fugitive methane emissions from India's oil and gas systems decreased by 46.04% between 2019 and 2020, a reduction primarily attributed to the nationwide economic slowdown caused by the COVID-19 pandemic. The emissions estimates in the report continue to rely on the default methane emission factors[71].

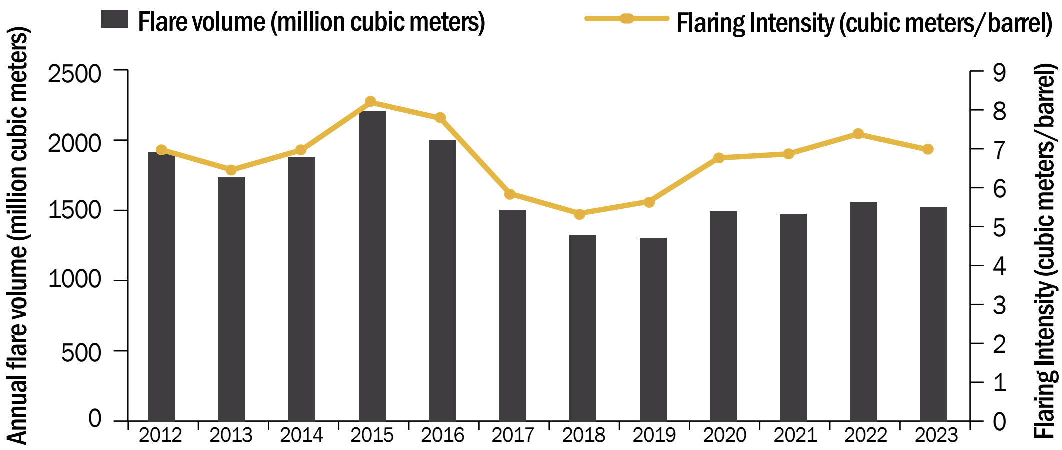
Both the TNC report and the Fourth BUR submitted to the UNFCCC lack comprehensive data on emissions from flaring activities. These reports acknowledge the need for further refinement of data on flaring activities in the oil and gas sector to improve future GHG emissions estimates[32, 71]. However, for the purposes of this report, the authors have utilized datasets from the World Bank's Global Gas Flaring Tracker to estimate and analyze GHG emissions from flaring activities attributed to India, as detailed below.

4.2.1 Greenhouse gas emissions from flaring

Upstream oil and gas production facilities destroy unwanted gas generated during the extraction process through combustion at the flare stack. Traditionally, methane destruction efficiency[d] during flaring is assumed to be 98%, provided the flares are continuously lit[72]. However, this efficiency can decrease if flares operate improperly or remain unlit, allowing methane to be vented directly into the atmosphere. As a result, flaring practices at upstream oil and gas facilities contribute to greenhouse gas emissions in the form of methane and carbon dioxide.

According to the World Bank's Global Gas Flaring Tracker, the volume of flare gas in India has decreased over the last decade—from 1.9 billion cubic meters in 2012 to 1.5 billion cubic meters in 2023—primarily due to a reduction in oil production. However, during the same period, flaring intensity[e] has increased slightly, from 6.7 cubic meters per barrel to 6.9 cubic meters per barrel (see Figure 6)[73].

Figure 6: Flare volume and flaring intensity in India, 2012-2023



Source: World Bank's Global Gas Flaring Tracker [73]

(Above) Between 2012 and 2023, the volume of flare gas in India decreased from 1.9 billion cubic meters to 1.5 billion cubic meters due to reduced oil production, while flaring intensity slightly increased from 6.7 to 6.9 cubic meters per barrel of oil produced during the same period.

Flaring associated with oil imports

Since India imports more than 85% of its crude oil demand, the majority of its greenhouse gas emissions from flaring—primarily methane and carbon dioxide—are also imported. In 2023, the volume of flare gas associated with India's oil imports was approximately 10.3 billion cubic meters, nearly seven times higher than the estimated 1.5 billion cubic meters of domestically flared gas. In total, India accounted for roughly 8% of global flaring volumes from both domestic and imported sources in 2023[73].

In terms of flaring intensity, India's domestic flaring stood at 6.9 cubic meters per barrel of oil produced, higher than the flaring intensity of its imported oil, which was 5.8 cubic meters per barrel. Both figures exceed the global average flaring intensity of

d. Methane destruction efficiency refers to the percentage of methane that is successfully burned or eliminated during processes like flaring, with the goal of preventing it from being released into the atmosphere.

e. Flaring intensity refers to volume of gas flared per unit crude oil produced.

5 cubic meters per barrel[73].

Methane emissions from flaring over different time scales

Assuming a flare methane destruction efficiency of 98 percent[72] and a methane composition of 81 percent[74] in the flared gas, India's total methane emissions from flaring at oil and gas production facilities—both domestic and imported—were estimated at 3.9 million tons of CO_2 equivalent over a 100-year horizon, and 11.6 million tons on a 20-year basis (Table 7 and Figure 7).

Table 7: GHG emissions from flaring in 2023: India compared to global emissions

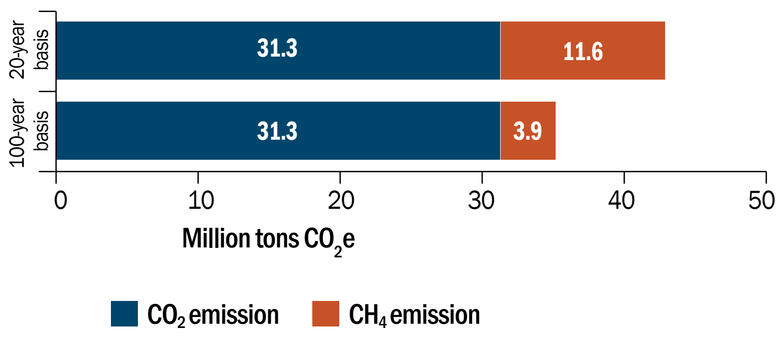
Source	Emissions type		
	CO_2 (million tons)	CH_4 (million tons CO_2e)	
	100-year basis	100-year basis	20-year basis
India (domestic and imported)	31.3	3.9	11.6
Global totals	333	45	136
India's share (%)	**9.4**	**8.7**	**8.5**

Source: Authors' calculations based on World Bank's Global Gas Flaring Tracker data [73]

(Above) In 2023, flaring emissions from India's domestic and imported oil production contributed nearly 9% to global greenhouse gas emissions from oil production-related flaring.

India's combined domestic and imported CO_2-equivalent emissions from flaring in upstream oil and gas facilities in 2023 is equivalent to nearly 60 percent of India's total greenhouse gas emissions from the waste sector in 2019.

Figure 7: India's GHG emissions from oil production related flaring in 2023 (domestic and imported combined)



Note: Calculations assume a flare gas methane content of 81 percent and a methane global warming potential of 28 over a 100-year period and 84 over a 20-year period, consistent with the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5).

(Above) In 2023, India's greenhouse gas emissions on a 20-year basis from flaring related to domestic and imported oil production amounted to nearly 43 million tons of CO_2e.

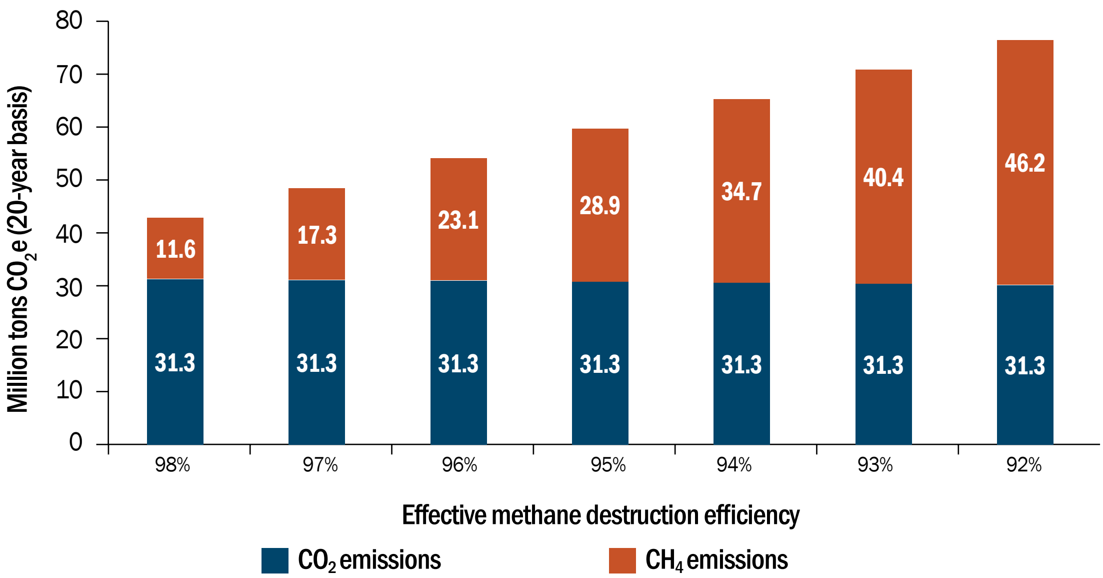
Effective flare destruction efficiency and methane emissions

Assuming a 98 percent flare destruction efficiency, India's contribution to global flaring—both domestically and through imports—resulted in 42.9 million tons of CO_2 equivalent (CO_2e) emissions. This comprised 31.3 million tons of carbon dioxide and 11.6 million tons of CO_2e from unburned methane, based on methane's global warming potential on a 20-year basis.

However, due to operational inefficiencies and instances where flares remain unlit, allowing gas to vent directly into the atmosphere, actual destruction efficiency can decrease. A reduction in flare efficiency from 98 percent to 97 percent can increase methane emissions by 50 percent. A further drop to 94 percent would result in a 200 percent rise in methane emissions.

The IEA estimates the global average flare destruction efficiency at around 92 percent[f,5]. If flare combustion efficiency drops from 98 percent to 92 percent, methane emissions would increase by nearly 300 percent. These figures underscore the importance of deeper research and stronger efforts to understand and mitigate emissions from flaring.

Figure 8: India's GHG emissions from flaring: Comparing the 98% conventional assumption with varying effective destruction efficiency scenarios for both domestic and imported contributions (20-year basis)



(Above) If effective methane destruction efficiency drops from 98 percent to 92 percent, methane emissions would increase by nearly 300 percent (on a 20-year basis).

Discrepancies in methane emissions data: Satellite data vs. default emission factors

Methane emissions from flaring in India were estimated at 0.5 gigagrams (Gg) using the default emission factor for 2019[32]. However, data from the World Bank's Global Gas Flaring Tracker, which utilizes satellite technology to estimate gas flared from oil and gas facilities, placed methane emissions at 14.95 Gg—nearly 30 times higher

f. Based on a detailed bottom-up assessment of production types; facility and flare design practices; operators; changes in produced volumes over field lifetime; local crosswind variability; and the strength of regulation, oversight and enforcement in flaring sites around the world.

than estimates based on default factors. This stark difference corroborates the limitations of default emission factors in accurately assessing methane emissions and underscores the need to employ both top-down and bottom-up approaches for a more comprehensive understanding of methane emissions from flaring.

4.3 Co-benefits of addressing methane emissions in the oil and gas sector

Reducing methane emissions from India's oil and gas sector serves as a vital step toward meeting global temperature rise goals to combat climate change along with bringing about a range of additional benefits, as outlined below:

4.3.1 Public health benefits

Incomplete combustion of unwanted gasses during flaring causes emissions from the oil and gas sector that extend beyond methane, encompassing various volatile organic compounds (VOCs) and harmful chemicals, not only contributing to air pollution but also posing substantial health risks to communities. While India-specific data is currently unavailable, an Iraqi study found the potentially carcinogenic substance 2-Naphthol in communities living near oil fields, and linked benzene exposure to leukemia and other blood disorders, highlighting health concerns for communities residing near oil fields[75]. Additionally, as previously noted, methane serves as a precursor to tropospheric (ground-level) ozone and contributes almost 35% of the total tropospheric ozone burden[76]. Tropospheric ozone is a secondary pollutant that poses significant health risks to humans including asthma and chronic obstructive pulmonary disease (COPD).

Therefore, addressing methane emissions also mitigates harmful gas releases, and thus offers substantial public health benefits by reducing hospital visits and mortality rates. According to the Global Methane Assessment (2021), methane mitigation from fossil fuels, aligned with limiting global warming to 1.5 degrees Celsius, could avoid 250,000 asthma-related emergency room visits and 80,000 ozone-related premature deaths per year by 2030[77].

4.3.2. Improved community trust and environmental stewardship

Public health benefits for communities near oil and gas facilities, achieved through methane mitigation efforts, can also help build community trust in the industry and foster positive corporate-community relationships that are often marked by suspicion. Furthermore, in today's investment climate, where environmental, social, and governance (ESG) factors significantly influence capital flows, a proactive approach to methane reduction not only helps attract investment but also reinforces long-term operational resilience and safeguards corporate reputation. Recognizing the need to uphold their social license to operate, major oil and gas companies in India are now committed to decarbonizing their value chains and have set ambitious targets for net-zero emissions in scope 1 and scope 2 by 2046 or sooner. Achieving these goals will require addressing fugitive methane emissions, also presenting an opportunity to enhance companies' environmental stewardship, strengthen goodwill among local communities, and build social capital.

Table 8: Net zero targets and methane mitigation initiatives of major oil and gas companies in India

Company	Net zero target year	Methane/flaring specific initiatives
Cairn Oil & Gas	2030	▪ Reducing flare gas through utilization or process optimisation ▪ Conducting periodic Leak Detection and Repair (LDAR) studies to control fugitive emissions ▪ Joined Oil and Gas Methane Partnership (OGMP) 2.0
Reliance Industries Limited	2035	▪ Flare gas capturing/process optimization
Gas Authority of India Limited	2035	▪ Addressing leakage during gas transmission ▪ Initiatives for flare minimization
Oil and Natural Gas Corporation Limited	2038	▪ Signed the Oil and Gas Decarbonization Charter (OGDC) and pledged to eliminate routine flaring by 2030 and achieve near zero upstream methane emissions by 2030 ▪ Standard operating procedures in place to arrest pipeline leakages
Oil India Limited	2040	▪ Signed the OGDC, plans to eliminate routine flaring by 2030 and aims to achieve near zero upstream methane emissions by 2030
Bharat Petroleum Corporation Limited	2040	▪ Conducting LDAR procedures on various lines to prevent leaks ▪ Continuous monitoring of excess oxygen concentration in the stacks
Hindustan Petro-leum Corporation LImited	2040	▪ Minimising losses in natural gas storage and transport, LDAR, use of double sealed tanks, vapour recovery systems to reduce hydrocarbon and related methane emissions
Indian Oil Corpora-tion Limited	2046	▪ Minimising losses in natural gas storage and transport, LDAR, use of double sealed tanks, vapour recovery systems to reduce hydrocarbon and related methane emissions

Source: Companies' websites and annual sustainability reports

(Above) While all major oil and gas companies in India have announced their net zero targets, detailed methane mitigation targets and comprehensive plans, integral to their net zero strategies, are not publicly accessible for all companies.

4.3.3. Promoting job creation and economic opportunities

Implementing a mandated framework for methane monitoring and reporting within the oil and gas sector can drive the creation of high-quality jobs across various segments. These include methane measurement equipment manufacturing and assembly, equipment maintenance, services and sales, data analytics, mitigation technologies, and strategic advisory roles in the methane mitigation industry. A study by Datu Research highlights the growth potential in this sector, with the U.S. experiencing a 33% increase in methane mitigation manufacturing since 2014 and a doubling of the service sector since 2017[78].

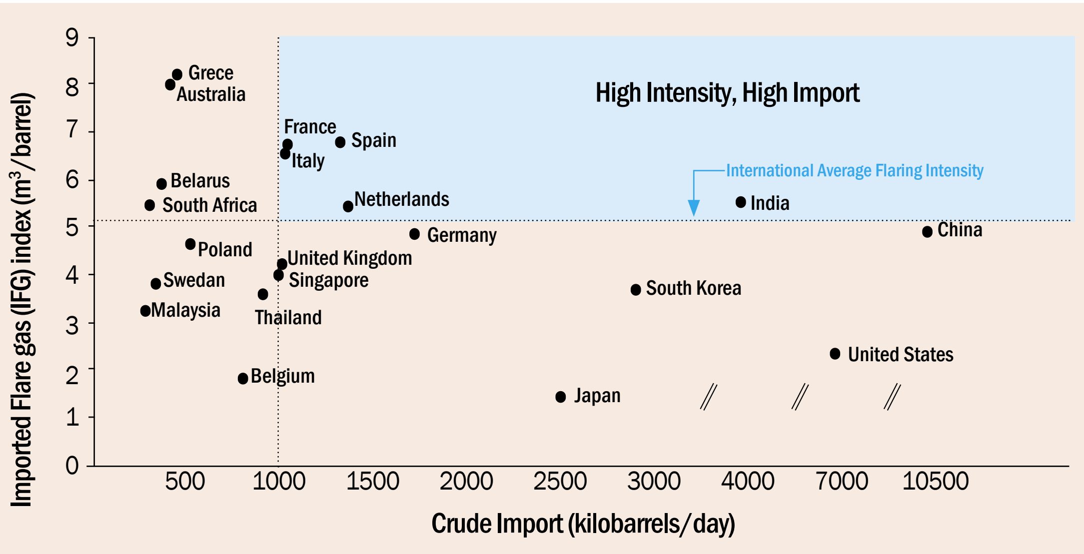
Recent U.S. studies indicate that the adoption of the latest U.S. Environmental Protection Agency (EPA) methane emission rules could generate thousands of jobs. Specifically, comprehensive methane reduction efforts within the oil and gas sector could generate 35,006 new jobs in Texas, 15,530 in the Appalachian region, and 2,600 in Louisiana[79,80,81].

Similarly, India, where no methane-specific national standards currently exist for the oil and gas sector, stands to benefit significantly as the industry expands to meet the nation's growing energy demands. As Indian oil and gas companies work toward achieving their net zero targets, methane mitigation provides opportunities to assess overall and region-specific job requirements and training needs, and could create long-term, high-quality employment opportunities for individuals with the appropriate training.

4.3.4 Addressing methane emissions beyond national borders

With over 85% of its oil needs and approximately half of its natural gas requirements being met through imports, India faces a significant challenge in mitigating methane emissions, extending beyond its borders. The Imported Flare Gas (IFG) Index, a tool developed by the World Bank's Global Gas Flaring Reduction (GGFR) Partnership , offers a quantifiable perspective on this issue. While some experts contest this kind of emissions accounting, the tool highlights that when a country imports crude oil, it also imports the flaring intensity associated with the production of that oil, in proportion to the amount imported. India's substantial reliance on imported crude, coupled with the relatively higher flaring intensities of key supplier nations such as Russia, Nigeria, and Iraq, places it within the 'High Intensity, High Import' quadrant of the IFG Index–Crude Import chart (Figure 9)[82].

Figure 9: Imported Flare Gas Index–Crude Import chart by the World Bank's Global Gas Flaring Reduction Partnership



Source: The World Bank's Global Gas Flaring Reduction Partnership [82]

(Above) India is placed within the 'High Intensity, High Import' quadrant of the IFG Index–Crude Import chart, with its imported flare gas intensity slightly higher than the international average flaring intensity.

Therefore, establishing stringent methane and flaring standards for imported crude oil and gas could prove instrumental in reducing India's imported flaring intensity. Moreover, it could serve as a substantial contribution to global methane emission reduction efforts, transcending geographical boundaries and aligning with India's commitment to environmental sustainability.

4.4 Challenges in methane mitigation in the oil and gas sector

Based on our secondary research and expert insights gained during the workshops and interviews, the following challenges pose major hurdles in addressing methane emissions within the oil and gas sector:

4.4.1 Economic and operational obstacles to methane mitigation

Oil and gas companies working to mitigate methane emissions face significant economic hurdles in the form of high costs for satellite data used in leak detection, according to our literature review and several interviewees. The absence of industry-wide mandates for methane monitoring, reporting, and mitigation means that voluntary efforts by some operators create additional financial burden, discouraging further investment in methane reduction. Moreover, balancing the need for domestic production with efforts to prevent gas leakages presents a considerable challenge, especially since shutting down oil-producing wells in mature fields to address leaks can render them unviable for future production.

> "The industry must communicate its needs so that other stakeholders can provide support."
>
> Workshop on Methane Mitigation in India's Energy Sector, August 2024: Comment the importance of the industry communicating its requirements to other stakeholders to ensure timely and effective mitigation of methane emissions in the energy sector.

On a practical level, operators employing a bottom-up approach for leak detection and methane monitoring encounter logistical issues, as many emission sites and point sources are difficult for ground personnel to access, disrupting regular surveys. Sanctions and security concerns further exacerbate these challenges by restricting access to gas cameras, leading to missed market opportunities and hampering leak detection efforts. Although optical image cameras offer an alternative, their requirement for extended focus time introduces additional operational challenges in effectively identifying leaks.

4.4.2 Unreliable data on sources and scale of methane emissions

India's current approach to estimating the oil and gas sector's methane emissions relies on aggregate default emission factors. However, this approach is least recommended as it is known to be fraught with uncertainties, potentially leading to errors of an order of magnitude or more. Therefore, on the one hand, the absence of source-based methane emissions monitoring, reporting, and verification (MRV) leads to data quality uncertainties. On the other hand, the methane emissions estimation methodology overlooks the updated higher Global Warming Potential (GWP) value of 28, as recommended in the Fifth Assessment Report (AR5) of the IPCC[83]. This neglect results in a significant underestimation of methane's impact. Also, even though methane is a powerful climate pollutant in the short term, using a Global Warming Potential (GWP) value over 100 years doesn't fully reflect its impact. Instead, a 20-year GWP value, which shows methane as 80 times more powerful than CO_2, would better capture its true importance.

The issue of data inaccuracy and unreliability is further underscored by a recent IEA report which reveals that methane emissions from the energy sector are 70% higher than those reported by national governments [44]. This calls for an urgent emphasis on accurate and reliable methane emissions data to guide effective mitigation strategies.

4.4.3 Limited discourse on oil and gas sector methane emissions

In India's public sphere, discussions on the impact of methane emissions from the oil and gas sector—particularly on climate change and public health—are notably absent. This lack of discourse is partly due to official estimates suggesting that the oil and gas sector contributes only about 5 percent to India's overall methane emissions[32]. Additionally, the sector's emissions attract limited attention as oil and gas are critical to meeting India's growing energy demands. The energy security imperative emphasizes domestic production of oil and gas, often placing concerns about methane emissions lower on the priority list.

Moreover, workshop participants and interviewees noted that monitoring and mitigating methane emissions requires substantial investments and increases operational costs, potentially reducing companies' market competitiveness. As a result, many oil and gas companies are disinclined to openly discuss methane emissions, even though they actively work to identify and reduce emissions across their supply chains.

This lack of narrative on methane emissions from the oil and gas sector entails several challenges—such as limited public awareness and support, underinvestment in monitoring and mitigation technologies, policy inaction and weak regulation—which pose significant barriers to advancing methane mitigation efforts in India's oil and gas sector.

4.4.4 Absence of a well-defined policy and regulatory framework

India currently lacks a comprehensive policy and regulatory framework to address fugitive methane emissions from the oil and gas sector in the context of climate change. Oversight in this sector is fragmented: the Directorate General of Hydrocarbons (DGH) oversees the upstream segment, while the Petroleum and Natural Gas Regulatory Board (PNGRB) is responsible for midstream and downstream operations. Additionally, the Oil Industry Safety Directorate (OISD) formulates and coordinates the implementation of safety standards for the industry. Existing regulations governing hydrocarbon gas emissions are largely focused on personnel and property safety related to fire hazards, with limited emphasis on mitigating environmental/climate pollution. Interviewees and workshop participants also noted that the prescriptive nature of these regulations, coupled with weak regulatory enforcement, may be obscuring the true scale of methane emissions.

> “[We must] focus more on policy and regulations to streamline objectives for methane mitigation."
>
> Workshop on Methane Mitigation in India's Energy Sector, August 2024: Comment on the role of methane-specific policies and regulations within the broader climate change context to address methane emissions in the energy sector.

Another key challenge is the absence of regulations mandating comprehensive reporting of methane emissions. In 2021, the Securities and Exchange Board of India (SEBI) introduced Business Responsibility and Sustainability Reporting (BRSR) requirements, which mandate companies to disclose their Scope 1 and Scope 2 greenhouse gas (GHG) emissions[84]. However, detailed reporting of specific GHGs, including methane, remains voluntary rather than compulsory.

These notable gaps in policy and regulation leave oil and gas operators with limited incentives to engage in systematic methane measurement, reporting, and mitigation. Consequently, the industry lacks proactive measures to address methane emissions, thereby hindering progress in combating climate change.

4.5 Opportunities for methane mitigation

Below, the authors provide suggestions for methane mitigation in the oil and gas sector, including opportunities for collaboration among stakeholders over the coming years. Additional stakeholder-specific recommendations and possible action steps are provided in the final section of this report.

4.5.1 Enhancing transparency on emissions data and mitigation efforts

The aggregated default emissions factors currently used to estimate methane emissions from India's oil and gas sector may not accurately reflect the present reality due to their outdated nature. On one hand, substantial efforts by major players like ONGC, Cairn Oil & Gas, and GAIL over the past two decades to reduce leaks and gas flaring suggest that methane emissions could be less than official estimates[85,86,87]. Additionally, regulatory changes in the last decade might have also impacted emission levels. On the other hand, the prescriptive nature of existing regulations for hydrocarbon emissions, coupled with non-stringent enforcement may be underestimating the true scale of emissions. In this context, more transparent reporting of methane emissions is required.

> "Improved compliance with existing regulations and transparent public disclosure can significantly address methane emissions in the oil and gas sector."
>
> Workshop on Methane Mitigation in India's Energy Sector, March 2024: Comment on whether the existing regulatory framework can adequately support the Indian energy sector's efforts to mitigate methane emissions.

The Government of India could push for transparent methane emissions reporting by oil and gas companies, requiring them to disclose emissions data and mitigation plans either through regulations or by mandating adoption of internationally recognized reporting standards and mitigation practices. The Oilfields (Regulation and Development) Amendment Bill, 2024, passed by the Rajya Sabha (upper house of the Indian parliament) in December 2024, empowers the central government to make rules for promoting measures to report and reduce greenhouse gas emissions resulting from mineral oil operations[88]. This is a timely and commendable step in the right direction.

The government could collaborate with the Climate and Clean Air Coalition through its recently launched Fossil Fuels Regulatory Programme, which offers tailored assistance in building capacity, developing regulatory frameworks, and ensuring compliance with existing policies[89]. Additionally, drawing inspiration from recent methane regulations in the United States and European Union, the government can ensure a level playing field for all players by bringing regulations and standards for methane-specific emissions monitoring, measurement, reporting, and verification; leak detection and repair; flaring intensity; and super-emitter events[90,91]. These regulations should emphasize empirically based reporting and be outcome-focused, rather than prescriptive.

The increased transparency in reporting will not only enhance the reliability of methane emissions estimates but will also help researchers identify effective mitigation strategies. Moreover, calibrating source-based emissions data provided by companies with emission data from satellites will offer data validation opportunities. Furthermore, improved reporting transparency could also help in implementing incentive schemes and obtaining external financial support to further enhance methane mitigation efforts in the sector.

4.5.2 Financial support mechanisms to complement mitigation efforts

Monitoring and measuring methane emissions—whether through on-ground methods or satellite technology—can be highly resource-intensive, requiring significant human and financial investments. These efforts also demand continuous investment in research, training, and capacity-building, given varied and widely dispersed sources of emissions throughout the oil and gas value chain, including difficult-to-access sites like offshore platforms and remote terrains. Moreover, when mitigation opportunities are identified, companies are fully responsible for covering implementation costs, which can create a financial burden and reduce their cost competitiveness in a market that already favors imported oil and gas.

Therefore, to support companies' monitoring and mitigation efforts, India could pursue the creation of a government-owned 'methane mitigation fund' to bridge research and training gaps in addressing methane emissions in the oil and gas sector, while providing incentives for innovation and mitigation efforts. Western countries, international financial institutions, and philanthropies could further support the government's efforts by contributing to this fund.

Additionally, given India imports more than 85% of its crude oil needs and nearly half of its natural gas demand, this fund could be used to address Scope 3 emissions beyond India's national borders. The fund could provide research, training and capacity-building support to India's overseas oil and gas trading partners and complement their methane monitoring and mitigation efforts.

4.5.3 Voluntary initiatives for timely reductions in methane emissions

A variety of top-down and bottom-up strategies are required to effectively monitor and mitigate methane emissions in the oil and gas sector. Voluntary commitments from oil and gas sector companies, exemplified by ONGC and OIL joining the Oil and Gas Decarbonization Charter launched at COP 28, Cairn Oil & Gas joining the UNEP-led Oil and Gas Methane Partnership (OGMP) 2.0, and Total Energies' collaboration with ONGC and OIL for methane emissions detection, surpass regulatory requirements

> "Share and collaborate—that is the only way to address this global problem. This is the time to act, and time is running out quickly."
>
> Workshop on Methane Mitigation in India's Energy Sector, August 2024: Comment on the most effective way to address methane emissions in the energy sector.

and drive timely reductions in methane emissions [92,93,94,95]. Drone deployment for methane detection and periodic monitoring for leakages by DLTPL (Adani-Total) is another such example[96].

Going forward, voluntarily leveraging satellite data from sources like MethaneSAT, Carbon Mapper and Copernicus Sentinel 5P, alongside ground-based point-source monitoring, can enhance methane emissions measurement capabilities[97,98,99]. Additionally, these companies can collaborate with expert organizations such as Carbon Limits, leveraging their expertise and knowledge base to enhance methane inventory, reporting accuracy, and align mitigation efforts accordingly[100]. Following the lead of Cairn Oil & Gas, other Indian oil and gas companies could also consider joining the OGMP 2.0, which has established a reporting framework often regarded as the 'gold standard' for methane emissions reporting[101]. Over time, companies could transition to source-based monitoring and reporting of methane emissions across the oil and gas value chain.

While the oil and gas sector's fugitive methane emissions represent almost 20% of global anthropogenic methane emissions, the current market dynamics and the availability of low-cost mitigation options suggest vast potential for cost-effective methane reduction. Research indicates that over 59% of methane emissions in the oil and gas sector can be mitigated at a cost of less than zero dollars per metric ton of CO_2e, presenting an opportunity for substantial net profits[102]. Targeting non-emergency flaring and venting in oil and gas facilities can yield substantial reductions in methane emissions. Strategies such as purge gas recovery, flare gas recovery, and the implementation of a robust safety instrumented system (SIS) are effective measures to mitigate flaring.

Finally, directing attention to super-emitter facilities and events across the entire oil and gas value chain can lead to significant and timely outcomes in methane mitigation. Moreover, experts during the workshops noted that integrating predictive maintenance systems based on Artifical Intelligence (AI) and Machine Learning (ML) into current oil and gas projects in India can proactively identify equipment failures, thereby minimizing flare loads. In the upstream segment, the deployment of AI can significantly improve the prediction of well performance, surpassing the capabilities of human experts[103]. Furthermore, AI can facilitate advanced leak detection, offering the potential for substantial cost savings over time as AI technology becomes more sophisticated[103]. Therefore, voluntary initiatives by the oil and gas sector companies hold immense potential to make significant strides toward achieving timely reductions in methane emissions.

4.5.4 Expert committee on methane mitigation within the oil and gas sector

Establishing an expert committee to offer advice and recommendations on methane mitigation in the oil and gas sector can be a prudent step. This committee can provide invaluable input towards the development of both a broad policy and a detailed regulatory framework tailored for methane mitigation within the industry. To ensure effective leadership, the committee could be chaired by a representative from the Ministry of Petroleum and Natural Gas. The other members of the committee can include representatives from the following institutions:

1. The Oil Industry Development Board
2. The Directorate General of Hydrocarbons
3. The Petroleum and Natural Gas Regulatory Board
4. The Oil Industry Safety Directorate
5. MoEFCC
6. State-owned enterprises and private companies operating within upstream, midstream, and downstream segments of the oil and gas sector
7. Indian academic institutions and civil society organizations

The terms of reference for the committee on methane mitigation in the oil and gas sector can include:

- Providing inputs on improving methodology for estimating fugitive methane emissions for oil and gas systems
- Contributing insights on adopting a global standard methane reporting framework or developing India's own reporting framework
- Offering suggestions on adopting methane import performance standards.
- Suggesting a practical timeline for 'phasing down' and ultimately 'phasing out' fugitive methane emissions and flaring from the oil and gas sector
- Exploring the possibility of a methane mitigation incentive structure for the oil and gas sector companies
- Looking into the feasibility and adoption of flare gas commercialization options
- Providing inputs on role of international collaboration with technology providers and multilateral financial institutions for methane monitoring and mitigation

Based on the broad inputs and recommendations of the expert committee, working groups or task forces can be formed to prepare detailed plans on different aspects of methane mitigation in the oil and gas sector. CSOs may serve as secretariats for these working groups/task forces.

5.0 Conclusions and recommendations for stakeholders

Global climate models indicate that reducing methane emissions is one of the quickest and most effective strategies to slow global warming, and global methane emissions must decrease by almost a third by 2030 in order to limit warming to 1.5°C. Globally, some policies, regulations, and pledges hold promise in achieving this goal; however, substantial action is required by all major nations to address methane emissions originating from the energy sector. As a major producer and consumer of fossil fuels, India has significant opportunities to address methane emissions originating from the energy sector. As India's economy grows, the nation will experience rapid increases in energy demand. It is imperative that action is taken now to pursue mitigative measures.

A variety of stakeholders would benefit from advancing methane mitigation opportunities in the energy sector and could all play important roles in facilitating this work in India. These include government and regulators, investors, energy companies, technology partners, multilateral financial institutions, intergovernmental organizations, philanthropies, and other civil society organizations. These stakeholders could be involved in advancing specific projects or broad policies. An alliance of diverse stakeholders working together would make it possible for more methane mitigation to occur in the energy sector, and quicker. Below, we provide recommendations for action by specific stakeholders to move forward on mitigating methane within the energy sector over the coming years.

5.1 Government and regulators

Governments and regulators play an essential role in methane mitigation by establishing and enforcing standards and regulations for the energy sector, setting emissions monitoring and reporting requirements, and incentivizing the adoption of methane mitigation technologies. This stakeholder group includes, but is not limited to, the Government of India; the Ministry of Coal; the Ministry of Petroleum and Natural Gas; the Ministry of Environment, Forest, and Climate Change; the Petroleum and Natural Gas Regulatory Board; the Directorate General of Mines Safety; the Oil Industry Safety Directorate; and the Reserve Bank of India.

Based on the findings of this report, government and regulatory agencies can consider the following options to expedite methane mitigation in India's energy sector:

1. **Mandating transparent and verifiable reporting of methane emissions**

   A reliable baseline methane inventory is essential to create methane mitigation goals in the short, medium and long term. Transparent and verifiable reporting of methane emissions from the energy sector is a crucial first step in this direction. The government could consider amending Business Responsibility and Sustainability Reporting (BRSR) regulations to make methane emissions reporting (with a source-wise detailed break-up) mandatory for the energy sector. Additionally, it could collaborate with the Climate and Clean Air Coalition (CCAC) to develop a transparent and verifiable methane-specific reporting and regulatory framework aligned with the sector's overall decarbonization and net zero targets.

2. **Identifying "low-hanging" opportunities and bringing methane-specific goals under national carbon emissions reduction targets**

   Taking a cue from recent regulations in the United States and the European Union, the government could begin with tried and tested policies for the oil and gas sector to maximize methane mitigation in short-term, such as leak detection and repair (LDAR) programs; standards for equipment, technologies, and procedures; zero tolerance non-emergency flaring and venting. To further help methane mitigation gain momentum, the government could also integrate oil, gas, and coal sector methane abatement goals in the country's Nationally Determined Contributions (NDC) targets.

3. **Ensuring stringent compliance with existing regulations and introducing performance-oriented regulations for methane mitigation from a climate change lens.**

   Regulatory agencies for oil, gas, and coal sectors could ensure strict compliance with the existing regulations on hydrocarbon venting, flaring, and fugitive emissions. Moreover, any new regulations could be designed from a climate change lens and be performance- or outcome-oriented rather than prescriptive.

4. **Setting up a 'methane fund' to support measurement and mitigation research and innovation.**

   The government could set up a Methane Mitigation Fund to support a) methane monitoring and measurement efforts; b) measurement and mitigation research and innovation; c) knowledge exchange, training, and capacity building for companies, overseas fossil fuel trading partners, and researchers. Money for this fund could be raised by levying cess on imported and domestically produced oil, gas, and coal. Additionally, western countries, philanthropies, and oil companies could contribute to this fund.

5. **Easing external commercial borrowing norms to increase foreign investment**

   The Reserve Bank of India allows borrowers to raise no more than $750 million in foreign investment per year. It could ease these external borrowing limits to promote significant foreign investment in methane mitigation measures in the energy sector and broader environmental initiatives.

5.2 Investors

Investors can play an important role in methane mitigation by utilizing their influence to ensure companies that rely on their financial capital are effectively managing their methane emissions. Similarly, investors can exert influence on government institutions to encourage broad policy support for methane mitigation. The stakeholder group includes, but is not limited to, public sector enterprises, public and private sector banks, foreign banks that operate in India, international investment firms and private energy companies, pension and sovereign wealth funds, and private domestic companies.

The investors can support the energy sector methane mitigation in the following ways:

1. **Supporting methane mitigation efforts by offering favorable financing terms**

   Banks and investment firms can incentivize methane mitigation in the energy sector by offering favorable financing, such as interest rate subsidies on loans or more attractive equity terms, encouraging companies to adopt cleaner practices.

2. **Including methane-specific conditions in investing decisions**

   Sovereign wealth funds, pension funds, and investment firms can strengthen methane mitigation by embedding methane reduction targets within their Environmental, Social, and Governance (ESG) criteria for investments in oil, gas, and coal companies. This approach encourages fossil fuel companies to adopt cleaner practices to meet investors' sustainability expectations.

3. **Encouraging the development of methane-based carbon credits**

   Investors can drive the growth of methane-based carbon credits by offering critical technical and administrative support, along with guaranteed purchase commitments. This dual approach fosters both the development and market demand for these credits.

4. **Influencing company policies by utilizing ownership stakes**

   Investors can leverage their influence to shape internal company policies that prioritize methane mitigation, advocating for robust reduction plans and transparent reporting through shareholder resolutions. By using their reputational power, investors can also encourage energy companies to adopt transparent practices in emissions reporting and enhance their overall commitment to methane reduction efforts.

5.3 Energy companies

Energy companies can play a leading role in methane mitigation by ensuring that equipment and operational mitigation techniques are appropriately applied across value chains to reduce emissions. This stakeholder group includes Coal India Limited, CMPDI, ONGC, OIL, GAIL, Cairn Oil and Gas, Indian Oil, Bharat Petroleum, Petronet LNG, Adani Total Gas, and Reliance Industries Limited.

Energy sector companies in India could expedite their methane mitigation efforts in the following manner:

1. **Bringing transparency in methane emissions reporting, mitigation action plans, and their outcomes**

   Indian oil and gas companies could gradually shift from default emissions factor-based reporting to empirically-based reporting. Additionally, Indian oil, gas, and coal companies could publicly disclose their methane-specific detailed mitigation plans and strategies, aligned with their decarbonization and net zero targets.

2. **Joining international collaborative efforts dedicated to methane mitigation**

   Coal India Limited could consider relaunching the India CMM/CBM Clearinghouse in cooperation with the Global Methane Initiative and U.S. EPA. Private-sector oil and gas companies can follow the lead of ONGC and OIL and join the Oil and Gas Decarbonization Charter. Moreover, oil and gas companies can adopt the internationally recognized Oil and Gas Methane Partnership (OGMP) 2.0 reporting framework, often dubbed the 'gold standard' of reporting.

3. **Partnering with diverse stakeholders such as technology providers, research organizations, peer companies, suppliers, and contractors to expedite methane mitigation efforts**

   Indian oil and gas companies can collaborate with expert organizations like Carbon Limits to improve their greenhouse gas inventory management and mitigation strategies. Leading players in the sector like ONGC and Adani-Total Gas can support their peers' methane mitigation efforts by exchanging knowledge and sharing best practices. Additionally, Indian fossil fuel companies can partner with suppliers and contractors to address emissions across the oil, gas and coal value chains and beyond national borders.

   Oil, gas, and coal companies can work on reconciling satellite-based emissions data with ground-based measurement to improve understanding of sources, frequency, and scale of emissions. EDF's MethaneSAT and CarbonMapper's Tanager satellites offer a great opportunity to identify emission sources and rates through dedicated online portals, at minimal cost. Additionally, oil and gas companies can reap 'low-hanging' mitigation opportunities by adopting comprehensive LDAR, utilizing flare gas, and addressing emissions from super-emitter sources.

   Moreover, collaboration with research organizations can provide deeper insights into methane mitigation potential, associated costs, mitigation funding options, employment generation opportunities, etc.

4. **Using Artificial Intelligence/Machine Learning (AI/ML) on in-house inventory to predict methane emissions in advance**

   Integrating AI/ML-based predictive maintenance in India's oil and gas projects can reduce emergency venting and flare loads by proactively identifying equipment failures. In the upstream oil and gas segment, AI can enhance well performance prediction and improve leak detection, leading to substantial long-term cost savings.

5.4 Technology providers

A wide variety of technologies, including advanced emissions monitoring and reporting systems, are available for companies and other stakeholders working to reduce methane emissions. Technology providers play an important role in the adoption of both novel and well-established technological solutions for reducing methane emissions. The stakeholder group includes but is not limited to Google, CarbonLimits, Advanced Resources International, EDF MethaneSAT, and CarbonMapper.

Technology providers can support methane mitigation by:

1. **Providing a multi-source data integration platform or service**

   Satellite-measured emissions data providers like Carbon Mapper and EDF's MethaneSAT and technology providers like Google can collaboratively support methane mitigation efforts by providing an integrated multi-source top-down and bottom-up data platform/service with features such as a) historical emissions trend analyzer tool, b) more granular data to attribute sources of emissions, c) emissions alert system, d) data-to-policy translation tool.

2. **Developing aerial/remote-sensing monitoring technologies, building capacity, and providing comprehensive training**

   Technology providers can support through training and capacity building of diverse stakeholders to make more informed, data-backed decisions. Technology companies can also partner with oil and gas companies to improve emissions detection via ground-based and aerial/remote-sensing technologies.

3. **Supporting energy companies with AI/ML tools and data analytics**

   Technology providers can collaborate with oil and gas companies by deploying data analytics and AI/ML-based tools to proactively identify process inefficiencies and equipment failures, helping to reduce flare loads and emergency gas venting. Additionally, these tools can enhance oil well performance prediction and leak detection, offering critical support in optimizing operations and minimizing emissions.

5.5 Multilateral financial institutions and intergovernmental organizations

Multilateral financial institutions (MFIs) and intergovernmental organizations (IGOs) can play a supporting role in methane mitigation by more intentionally supporting interventions where methane emissions are set to increase, such as the Indian energy sector. Additionally, this stakeholder group can inform national policy-making and intergovernmental engagements through emissions data analytics and provide financing solutions that may not be readily available through traditional investors. The stakeholder group includes, but is not limited to, the World Bank, the Asian Development Bank, UNEP, and the IEA.

MFIs and IGOs can back Indian energy sector methane mitigation in the following ways:

1. **Supporting companies' methane mitigation efforts through concessional financing**

   Supporting energy companies via low-cost financing for methane-focused retrofitting and upgrading of aging oil and gas infrastructure can significantly reduce emissions. Low-cost financing can enable companies to modernize their facilities affordably, making methane mitigation more achievable.

2. **Establishing and supporting methane-based carbon credit mechanism**

Multilateral financial institutions can drive methane reduction by developing transparent and robust carbon credit mechanisms specifically focused on methane emissions. Supporting the growth of this market will incentivize companies to invest in methane mitigation, creating a measurable impact on emissions reduction.

3. **Providing support to develop programs, policies, and regulatory frameworks**

   Intergovernmental organizations like UNEP and IEA can play a vital role in helping the oil and gas sector establish a flare gas commercialization program. Through research and technical assistance, UNEP, World Bank, and IEA can also support the development of effective policy and regulatory frameworks for broader methane mitigation efforts. Their involvement can ensure that these frameworks are grounded in transparent and verifiable data, driving accountability and measurable progress.

5.6 Philanthropies and civil society organizations

Philanthropies and civil society organizations can play a vital stopgap role in supporting and implementing methane mitigation measures. In India, this stakeholder group currently plays a particularly important role in funding and producing research and other products that support the growing community of practice on methane mitigation in India. This stakeholder group includes climate, environmental, energy, and just transition philanthropies and civil society organizations.

Based on the findings of this report we recommend this stakeholder group focus its efforts in the short-term on:

1. Funding and/or conducting research and innovation for efficient methane detection and reduction technologies.
2. Supporting collaborations, capacity building, and policy development.
3. Running education and awareness campaigns, demonstrating the substantial co-benefits of methane mitigation.

Specific actions this stakeholder group may consider pursuing include:

1. **Mapping of financial resources available for methane mitigation**

   India's only CMM capture and utilization project received substantial outside funding from UNDP and GEF, in addition to local funding from the Ministry of Science and Technology. Funding from international development agencies like UNDP and GEF is on an upward trajectory, particularly for developing countries and countries with economies in transition to meet the objectives of international environmental agreements. Substantial new resources may be available for methane mitigation projects in India. These need to be identified and mapped.

   Stakeholder philanthropy and civil society organizations should prioritize the development of a mitigation project leverage guide that identifies prospective funding opportunities—both traditional and non-traditional—and demonstrates how to stack or leverage specific opportunities to implement projects.

2. **Providing financial and technical support to promote research in methane detection and reduction technologies, including supporting studies on the economic, health, and environmental impacts of methane mitigation in India**.

   There remains a need to explore the potential economic, health, and environmental impacts (jobs, wages, government revenues, disease burdens, air quality etc.) of methane mitigation opportunities in India. Better understanding the numbers associated with these impacts may compel the government and other stakeholders to act ambitiously. There are several Indian civil society organizations and other research institutions that are well qualified to complete such an analysis.

3. **Encouraging cross-stakeholder collaboration, developing a community of practice, and informing policy development.**

   As mentioned previously, philanthropies and other civil society organizations are currently playing a particularly important role in funding and producing research and other products that support the growing community of practice on methane mitigation in India. Promoting increased cross-stakeholder collaboration will undoubtedly grow this burgeoning community of practice and inform sound policy development as challenges are assessed and mitigation measures are pursued.

4. **Running education and awareness campaigns to improve public awareness of methane's impact on the climate, environment, and public health and supporting narrative building around energy sector methane mitigation.**

   As mentioned in this report, limited public awareness of methane's impact on the climate, environment, and public health poses a significant barrier to advancing methane mitigation efforts. To a certain extent, this is due to a lack of India-specific data and talking points on the issue. As new resources such as studies on the economic, health, and environmental impacts of methane mitigation, become available, civil society could come to play an important role in improving public awareness.

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