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A Comprehensive Management Strategy: Reevaluating Methane Emission Regulations via Integrated Management Systems

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Abstract

One of the most urgent yet poorly controlled causes of climate change is methane, a greenhouse gas with a significantly greater potential to cause global warming than carbon dioxide. Despite their crucial role in hastening global warming, organizational solutions in the oil, gas, and associated industries are still dispersed and frequently limited to technical fixes and policy compliance. Such strategies ignore the structural and cultural changes necessary for long-term emission reductions. In this research, the idea of a specialized Methane Management System (MMS) is presented, based on the integrated and iterative logic of ISO 14001 (environmental management systems) and ISO 50001 (energy management systems). Using qualitative methods design, this research explores how management systems might be modified to incorporate methane mitigation into everyday operations and corporate governance.

The suggested MMS structure, which goes beyond production wells to cover the entire value chain, emphasizes senior leadership, cross-departmental integration, and value chain oversight of methane sources. The results show that companies using integrated approaches obtain quantifiable methane emission reductions, as well as increased operational effectiveness, better risk management, increased stakeholder confidence, and long-term resilience. The MMS offers a revolutionary strategy to integrate sustainability into company practices and further global climate goals by institutionalizing accountability and continuous improvement.

1. Introduction

Carbon dioxide has long been the focus of public discussion on climate change, pushing methane to the periphery.[1] However, its impact on global warming is much more severe. One of the most powerful greenhouse gases disrupting climate systems is methane, which traps more heat than carbon dioxide over shorter time spans. Its shorter atmospheric duration, however, balances this potency, allowing for quick climatic benefits from successful interventions. Despite this, industry-wide methane emission control remains inconsistent, dispersed, and frequently limited to compliance activities rather than long-term, systematic solutions.

The most well-known sources of methane are waste management, livestock agriculture, and the oil and gas industry.[2] These businesses contribute in different ways, such as through the decomposition of organic waste in landfills, enteric fermentation in cattle, and fugitive emissions from pipelines and wells. These regions are frequently identified as the main perpetrators in global emission inventories. Leaks and flaring are nevertheless common, especially in the oil and gas sector, where reporting and monitoring procedures differ greatly between companies and jurisdictions.[3] The continued existence of these pollutants highlights a significant disconnect between corporate will and technical competence.

There are significant ecological stakes. The warming potential of methane intensifies climatic feedback loops, increasing the likelihood of abrupt system shifts, accelerating glacier melt, and worsening weather extremes.[4] These environmental hazards have far-reaching economic repercussions that extend beyond fines or compliance expenses.[5] Businesses that ignore methane risk face increased investor scrutiny, increased regulatory pressure, and reputational damage in markets that are becoming increasingly concerned with sustainability. At the operational level, methane leaks signify wasted resources and inefficiency, eroding profitability while simultaneously harming the environment.[6] Therefore, what emerges is a wider test of organizational resilience and strategic foresight rather than a specific environmental obstacle.

This gap in sustained methane control remains a challenge for the global policy community as it sharpens its focus on the issue. International commitments, such as the Global Methane Pledge (GMP) signed by over 150 countries to cut methane emissions by 30% by 2030, signal rising regulatory expectations for drastic emission reductions. Likewise, multilateral frameworks under the Paris Agreement urge nations to include methane in their climate targets. In other words, industries must rapidly move beyond minimal compliance to meet ambitious standards emerging worldwide. This international momentum further underscores the need for a more systematic and integrated approach for methane mitigation, as proposed in this research[7].

Conventional methods of controlling methane have mostly relied on laws that specify technical specifications or documentation needs.[8] Even while these steps are essential, they frequently fall short of implementing the organizational and cultural shifts needed for sustained success. Instead of encouraging innovation, compliance-driven approaches often establish minimal criteria, which results in an atmosphere where businesses concentrate only on "checking the box" rather than integrating sustainability into the very fabric of their operations. Methane reduction is still a technical chore rather than a shared duty if there are no procedures in place to involve frontline staff, middle management, and senior leadership.[9]

Management systems provide an alternative route to fill this gap. Management systems are designed to offer organized methods for performance evaluation, accountability, and ongoing development. Standards, such as ISO 50001 for energy management[10] and ISO 14001[11] for environmental management, show how formal systems may inspire entire organizations to focus on sustainability goals. They change the focus of the discussion from compliance to integration, where environmental objectives are integrated into corporate governance, daily operations, and decision-making procedures. Through this lens, methane reduction is seen as a shared obligation backed by systemic structures rather than an isolated task.

While this research acknowledges the broader utility of integrated management systems (IMS), it purposefully narrows its focus to the development of a specialized methane management system (MMS). The MMS is not proposed as a generic management tool but as a technical framework derived specifically from the high-level structures of ISO 14001 (Environmental) and ISO 50001 (Energy). By extracting the technical planning requirements of energy management and applying them to methane emissions, this research provides a pragmatic mechanism for mitigation that goes beyond general organizational integration.

Investigating how these ideas might be applied to methane is the aim of this research. The goal is to create a novel approach that transforms emission control into an integrated management system-guided procedure. This framework's scope encompasses the entire value chain, from extraction and

processing to transportation, storage, and end-use, rather than just producing wells or technological interventions. This paper makes the case for a more thorough and long-lasting approach by suggesting an MMS that is adapted to the specifics of methane emissions while drawing inspiration from current standards.[12] To demonstrate how businesses can go beyond compliance and create enduring systems of accountability, efficiency, and sustainability, the following sections will draw on case examples, industry expertise, and theoretical insights.

2. Methodology

This research employs qualitative meta-synthesis and secondary data analysis methodology. It does not involve new field experiments or multi-departmental interventions. Instead, it systematically assesses and triangulates published case studies, industry performance reports (including OGMP 2.0 and UNECE disclosures), and peer-reviewed research on organizations that have implemented ISO 14001 and ISO 50001. This approach allows for the distillation of lessons learned from real-world implementations to build a theoretically sound and pragmatically grounded MMS model.

A key component of this methodology is the decision to place organizational activities in their context. Although emissions occur in technical environments, such as compressors, pipelines, and wells, organizational frameworks influence how they are managed. The degree to which technical solutions are implemented successfully is influenced by policies, leadership choices, resource allocation, and workforce involvement. While the involvement of various departments and senior management is a qualitative organizational shift, it is a technical requirement under ISO 50001 Clause 5.1 (Leadership and Commitment). This research argues that the qualitative 'culture of accountability' is the necessary delivery mechanism for the quantitative 'MRV data integrity.' Without the qualitative governance structure, the quantitative data collection remains fragmented and legally unverifiable. This research supports the systems-based reasoning that underpins ISO standards by examining methane emissions as both environmental outputs and the results of organizational culture. It acknowledges that a management system is a dynamic framework that adapts to a company's internal dynamics as well as the external demands of its operational environment.

Consequently, the systematic review of secondary data was organized around three distinct approaches. First, case studies from published organizational reports offer a basis for understanding the documented implementation of integrated management systems. Based on the publicly available sustainability and energy disclosures of 12 representative companies from the oil, gas, and energy industries, these case studies demonstrate both achievements and weaknesses by enabling a detailed analysis of organizational structures, implementation tactics, and performance results.

Based on the mixed-methods approach outlined above, it should be clarified that this research does not contain new field experiments or multi-department interventions. Instead, it systematically assesses and triangulates published case studies and quantitative industry performance reports (including OGMP 2.0 and UNECE disclosures). The quantitative basis for this research includes: (i) reported year-on-year methane intensity reductions; (ii) documented leak detection and repair (LDAR) response times; and (iii) energy efficiency performance data. By analyzing these metrics alongside the reported organizational structures of the certified organizations, the research distills a pragmatic blueprint for a specialized MMS.[13]

In addition, to these core secondary data sources, document analysis was conducted on relevant methane-related policies, standards, and reports. This step ensured that insights into management systems could be benchmarked against prevailing regulatory requirements and the respective literature view. By triangulating the primary data with policy documents, the research's conclusions were grounded in a wider governance landscape.

Data analysis involved several stages. Thematic analysis and coding were applied to the qualitative data from the case studies. The first step in this approach is the identification of recurrent concepts, difficulties, and behaviors. These were then categorized into more general groups that represented the underlying dynamics of the organization. To create a framework that is both conceptually sound and supported by evidence, this research iteratively switched between data and theory.

Subsequently, a comparative analysis was conducted among the firms under investigation. In addition to highlighting variations related to firm size, sectoral position, or degree of managerial engagement, this phase allowed for the identification of similarities in effective methane management approaches.[14] By evaluating the suitability of the emergent framework for use in a variety of organizational contexts, these comparisons assisted in its improvement.

Triangulation was used several times during the research to guarantee the validity and dependability of the results. While the involvement of various departments and senior management is analyzed as a qualitative governance shift, this approach is mandated by the technical requirements of ISO 50001 Clause 5.1 (Leadership and Commitment). The research analyzes how the documented presence (or absence) of these technical leadership protocols correlates with the quantitative emissions performance of the firms under investigation. Survey data were utilized to confirm more general tendencies indicated by qualitative observations, and case research insights were cross-checked against the theoretical framework provided by the literature review. Cross-verification increased the credibility of the conclusions and decreased the possibility of bias. Additionally, triangulation ensured that the suggested methane management strategy was based on consistent patterns found in a variety of evidence sources rather than on isolated occurrences.[15]

While the qualitative dimension of this research captures organizational behavior and cultural dynamics, the quantitative component is grounded in secondary data from industry reports, emissions disclosures, and survey results. These data sources provide measurable indicators of performance outcomes, allowing the research to validate qualitative insights with empirical evidence and support the proposed MMS framework with documented results[16][17].The survey data referenced in this research were drawn from published industry assessments and methane disclosure reports, including datasets from the Oil and Gas Methane Partnership (OGMP) and UNECE guidance documents. The case study sample included 12 firms across the oil, gas, and energy sectors, selected based on their documented implementation of ISO 14001 or ISO 50001 frameworks and availability of emissions performance data.[18]

To provide the quantitative justification for an integrated approach, this research draws on secondary performance metrics from twelve representative energy firms. These metrics include: (i) year-on-year methane intensity reductions; (ii) leak detection and repair (LDAR) response times; and (iii) the correlation between ISO 50001 certification and energy efficiency gains as reported in corporate sustainability disclosures. By analyzing these quantitative outcomes alongside qualitative organizational behaviors, the research identifies the technical requirements necessary for an effective MRV protocol within the MMS framework. It should be noted that references to the KPIs introduced in the theoretical section are intended to provide pragmatic grounding. However, these are explicitly signposted as conceptual illustrations, with full operationalization and governance treatment deferred to section 5. This sequencing reflects the MMS logic where metrics are derived from theory but implemented through management-system design.

To ensure methodological rigor and consistency, the research employs a structured analytical instrument, referred to as a Methane Management Analytical Framework (MMAF). This researcher tool guides the systematic extraction and coding of data across sources by defining key research dimensions (organizational, technical/MRV, performance, and regulatory), their respective data sources, and the analytical objectives associated with each.

By applying this framework, heterogeneous data from case studies, regulatory reports, and corporate disclosures were analysed consistently, enabling comparability and reducing subjectivity. Table 1 presents the operationalisation of this framework.

Table 1: Methodology Matrix and Data Sources

Research Dimension	Data Source (Secondary)	Goal of Analysis
Organizational	Academic Case Studies (ASQ, Stark)	Identify barriers to cross-departmental communication.
Technical/MRV	UNECE & OGMP 2.0 Best Practices	Extract specific methane quantification protocols.
Performance	12 Corporate Sustainability Reports	Validate the LDAR and efficiency gains of certified firms.
Regulatory	EU/US Methane Regulations	Ensure the MMS model meets emerging legal standards.

3. Review of Literature

Understanding how established management standards have been applied to instill accountability, sustainability, and efficiency principles within firms forms the basis of this research. These standards include organizational ideologies that direct decision-making and cultural change, in addition to technical frameworks. ISO 9001,[19] ISO 14001,[20] and ISO 50001[21] are among the most important, each demonstrating a different but connected aspect of systemic management. ISO 9001 places strong emphasis on quality control and the development of organizational accountability.[22] This illustrates how a standard can serve as the structural foundation for organizational dependability by mandating that businesses create written procedures, track performance, and strive for continual improvement.[23]

For the purposes of this research, 'Integration' refers to the procedural alignment of methane-specific tasks within an organization's existing energy-planning cycle. The MMS is defined as the technical core of this alignment, prioritizing emissions quantification and reduction over general administrative management.

Across the literature, a consistent conclusion emerges: the effectiveness of management standards depends less on their formal adoption than on the depth of their operational embedding. Numerous studies distinguish between symbolic implementation, where certification serves reputational or compliance purposes, and substantive implementation, in which management systems reshape decision-making, incentives, and routine operational practices. Evidence from ISO 14001 and ISO 50001 adoption demonstrates that environmental and emissions-related performance improvements materialize only when systems are integrated across organizational levels and linked to executive accountability. This distinction is directly relevant for methane governance[24].

An MMS confined to documentation or disclosure risks reproducing the limitations of existing compliance-led frameworks, reinforcing the case for a methane-specific management architecture that connects technical quantification to organisational responsibility and continuous improvement.

The literature also emphasizes that the primary barrier to successful management systems is rarely technical, but rather a lack of executive-level commitment. Research into Malaysian manufacturing firms identifies that even affordable technical solutions remain unimplemented if there is a disconnect between technical staff and senior leadership.[25] As highlighted in recent sustainability research, leadership responsibility acts as the fundamental driver for transforming environmental goals from aspirational values into 'way-of-life' daily briefing and reporting routines.[26] This evidence reinforces the rationale for the proposed MMS: it must function as a bridge that compels leadership to treat methane quantification with the same strategic priority as financial risk.

Moreover, a synthesis of the literature reveals that the effectiveness of management standards depends less on formal adoption than on the depth of their operational embedding. Numerous studies distinguish between symbolic implementation, where certification serves reputational or compliance purposes, and substantive implementation, in which management systems reshape decision-making, incentives, and daily operational routines. Evidence from ISO 14001 and ISO 50001 adoption shows that environmental performance improvements materialize only when systems are integrated across organizational levels and aligned with executive accountability. This distinction is particularly relevant for methane governance: an MMS confined to documentation or disclosure risks replicating the limitations observed in existing policy-driven approaches.

Accordingly, the literature supports the need for a methane-specific management architecture that links technical quantification directly to organizational responsibility and continuous improvement, providing the foundation for the framework developed in the following sections.

4. Theoretical Framework

The creation of a specialized MMS necessitates a thorough explanation of the theoretical underpinnings that support and influence the system, in addition to a list of actionable activities. As seen above, methane emissions are caused by organizational decision-making, resource allocation, and value embedding processes, in addition to technical issues, such as leaks, flaring, or inefficient equipment.[27] A management strategy must therefore be grounded in theories that explain how large, complex companies evolve and maintain their resilience in the face of changing market, regulatory, and environmental conditions if it is to transition from band-aid solutions to long-term reductions.

This section lays out the theoretical foundations of this research. The literature on organizational transformation, which emphasizes the social and cultural aspects of change, is first examined. Long-lasting change requires leadership commitment, clear purpose communication, and the gradual integration of new norms into daily routines, as scholars from Lewin to Kotter have shown.[28] When these insights are applied to methane, they indicate that technical controls alone cannot achieve significant reductions; instead, front-line operators, middle managers, and executives must all acknowledge methane as a strategic issue and share accountability for its management.

Systems thinking is the second pillar of the framework. Systems theory interprets emissions as the result of linked technical processes, human behaviors, and external linkages rather than discrete occurrences. From this perspective, a pipeline leak is not just the result of poor maintenance; it is also the result of decisions made throughout the procurement process, incentive programs, and regulatory requirements that affect every step of the value chain. Therefore, by highlighting feedback loops, cross-departmental connections, and the larger sociotechnical network in which a single organization operates, system thinking enhances transformation theory.

The reasoning underpinning the MMS is derived from these viewpoints taken together. They clarify the need for methane management to be incorporated into corporate governance, linked with risk management and strategic planning, and modified on a regular basis as laws and technology change. These concepts are translated into a tangible design in the following subsections, which first provide a detailed description of the conceptual underpinnings, then describe the MMS's structure, and finally examine integration principles and the real-world applications of systems thinking. This groundwork creates a theoretical foundation for the rest of the research by shifting the conversation from descriptive and empirical to analytical.

To operationalize this analytical shift, the MMS is structured around the two thematic clusters identified as essential for long-term control. The first cluster addresses the corporate integration aspect, focusing on the policy frameworks and governance structures required to promote methane reduction as a strategic priority. The second cluster addresses the technical planning and control mechanisms—derived from the rigorous energy-planning requirements of ISO 50001—which provide the pragmatic tools for baseline establishment, quantification, and continuous emissions monitoring. This dual-pillar structure directly translates corporate ambition into verifiable technical performance.

4.1 Conceptual Foundations

The (MMS) framework proposed in this research is conceptually grounded in three interdependent pillars that bridge the gap between corporate will and technical competence:

1. Organizational Transformation: which addresses the cultural and governance shifts required for corporate integration and policy leadership;
2. Systems Thinking: which frames emissions as outcomes of complex socio-technical networks, requiring ongoing cross-functional control; and
3. Technical Energy-Planning Logic: which provides the specific planning and monitoring mechanisms (derived from ISO 50001) necessary for quantification, baseline establishment, and the continuous improvement of emissions reduction.[29]

These pillars ensure that methane management is not an isolated environmental project, but a technically integrated governance function.

The suggested MMS is intended to provide a framework for long-term organizational change rather than merely serving as a technological methodology for leak detection and repair. Systems thinking and organizational transformation are two interconnected theoretical strands necessary to ground that framework. Each offers a unique perspective on why methane reduction initiatives are successful or unsuccessful and, when combined, clarifies why a management system needs to go beyond engineering to include governance, culture, and stakeholder interactions.

4.1.1 Organizational Transformation: From Technical Fix to Cultural Shift

The research of organizational transitions examines how intricate institutions change in reaction to both internal and external forces. A few recurring themes in the literature, which range from early field studies of industrial transformation to more recent analyses of sustainability transitions, have a direct bearing on methane management.[30]

The three stages of Kurt Lewin's model, unfreezing, altering, and refreezing, remain a benchmark.[31] According to Lewin, to bring about lasting change, routines must be purposefully loosened, followed by the introduction of new behaviors and, lastly, stabilized within daily practice.[32] This straightforward yet effective design emphasizes a key point: organizational habits cannot be changed by technical instructions alone. Employees at all levels will lose their initial enthusiasm and revert to old behavior unless they understand the importance of methane control and feel empowered to act.

John Kotter built on Lewin’s work by articulating an eight-step process that has become standard in management literature: creating a vision, communicating that vision, empowering broad-based action, generating short-term wins, consolidating gains, anchoring new approaches in the culture, creating urgency, and building a guiding coalition.[33] Every step is directly related to lowering methane.[34] For example, to have high-level leaders view methane as a strategic priority rather than a minor compliance concern, "establishing urgency" necessitates converting atmospheric science and regulatory risk into tangible

business language— lost goods, safety issues, and reputational damage. "Generating short-term wins" could entail early leak-detection campaigns that create internal enthusiasm and demonstrate quantifiable savings. Long-term promises to reduce emissions may stagnate in the absence of such observable outcomes.

Executive sponsorship is required but insufficient, according to numerous studies on environmental management. Initiatives will stall if middle managers interpret high-level objectives and distribute daily resources in a way that is disruptive or of low value. In contrast, supervisors convert theoretical sustainability objectives into practical operational realities when they include methane measures in regular performance evaluations or maintenance plans. Therefore, the MMS needs to establish systems — training, rewards, and open reporting — that link boardroom goals to practical applications.

According to organizational academics such as Schein and Argyris, a "learning culture," in which presumptions may be challenged and feedback loops are trusted, is necessary for profound transformation.[35] Uncomfortable realities are frequently revealed by methane management, such as malfunctioning machinery, faulty data, or unbalanced incentives that prioritize production speed over leak control.[36] An effective MMS must establish safe spaces where employees can point out such flaws without fear of retaliation, enabling them to view issues as opportunities for growth rather than places of blame.

These lessons are reinforced by experience from related disciplines. The spread of ISO 50001 energy-management systems demonstrates that companies can only save a substantial amount of money[37] when senior management incorporates energy goals into the main plan and when employees at all levels receive focused training.[38] The implementation of safety-management systems in the aviation sector also serves as an example of how cultural commitment — daily briefings, candid reporting of near-misses — converts a legal mandate into a way of life. Despite being technically different, methane management requires an equivalent level of organizational involvement.

Finally, it should be acknowledged that organizational change is driven not only by internal initiatives but also by external institutional pressures. As institutional theory suggests, companies respond to evolving norms and demands from their environment, including regulations, market forces, and stakeholder expectations, to maintain legitimacy.

In the context of methane, rising investor scrutiny and new policy commitments (for example, over 150 countries joining a GMP to cut emissions) create an additional sense of urgency. These external drivers amplify the need for the cultural and procedural shifts outlined above, essentially pulling organizations towards methane innovation from the outside. This means that the MMS is not just a voluntary improvement but a strategic response to the changing landscape in which companies operate.

4.1.2 Systems Thinking: Methane in the Socio-Technical Web

Systems thinking expands the framework to include the interconnected networks in which emissions occur, whereas organizational change concentrates on internal dynamics. Systems theory, with its roots in the writings of Ludwig von Bertalanffy and further developed by academics such as Donella Meadows, views organizations as open systems with feedback loops between their constituents: people, technology, processes, and external actors.[39]

Feedback Loops and Interdependencies: One of the most prominent examples of systemic behavior pertains to methane releases. Decisions made years ago during the procurement process, incentive schemes that prioritize high throughput over maintenance, or market forces delaying capital improvements, could all be the cause of a leak found at a pipeline junction.[40] Equally obvious are feedback loops: inadequate monitoring results in erroneous inventories, which erode regulatory oversight and lessen the motivation to invest in detection technologies, thereby sustaining emissions. Systems thinking urges managers to address these reinforcing loops and go beyond immediate causes.

To convert these theoretical loops into an effective management mechanism, the MMS borrows the technical architecture of ISO 50001 Clause 6.3 (Energy Review). In this context, systems thinking is operationalized as a 'Methane Emission Review,' requiring the organization to analyze historical and current methane usage/leaks and identify areas of significant emissions. By applying the ISO 50001 logic, methane control is no longer a series of behavioral interventions but a structured process of establishing Methane Emission Performance Indicators (MEPIs) and Methane Emission Baselines (MEBs). This ensures that the socio-technical web is monitored through precise, auditable data points that track the effectiveness of technical interventions across the value chain.

Socio-Technical Perspectives: Here, the notion of the "socio-technical system" is particularly important, which was popularized by the Tavistock Institute and later by innovation academics.[41] In addition to hardware — such as valves, compressors, and detection sensors — methane management also entails social structures, such as contractor relationships, staff training, legal frameworks, and community expectations.[42] One domain's changes have an impact on other domains. For instance, implementing cutting-edge continuous monitoring technologies would necessitate renegotiated supplier contracts, updated maintenance schedules, and new data-analysis abilities. These cascading effects are easily missed in the absence of a systems perspective.

Specifically, applying the 'Energy Planning' structure of ISO 50001 allows the organization to differentiate between 'static factors' and 'relevant variables' which contributes to methane emissions from different sources, such as fixed infrastructure and operational venting/flaring. Effective management mechanisms are thus derived from the ISO-standardized requirement to identify 'Significant Methane Sources' (SMS) - those facilities or processes where the warming potential is highest—allowing for the targeted allocation of resources. This technical mapping transforms the sociotechnical system from a descriptive map into a pragmatic hierarchy of intervention priorities.

Value-Chain Approaches: A value chain view is also required by systems thinking. Exploration sites, processing, and transportation facilities, and even end-use distribution networks emit methane.[43] If storage facilities vent during maintenance or if downstream pipelines leak, reducing flaring at the wellhead is useless. As a result, a strong MMS charts the entire value chain, pinpointing the leverage points where actions have the greatest overall impact.

Network Governance and External Stakeholders: No company operates in a vacuum. Emission results are influenced by local communities, suppliers, contractors, investors, and regulators. Systems theorists emphasize the significance of "border-spanning" management — structures that coordinate behavior across organizational boundaries.[44] In practice, this may take the shape of transparent reporting in line with investor climate-risk frameworks, cooperative leak-detection programs with pipeline operators, or supplier agreements of conduct containing methane performance clauses. Instead of limiting accountability to the plant gate, the MMS needs to institutionalize these interactions with the outside world.

Resilience and Adaptation: Resilience is also discussed in systems thinking. Rapid technological advancements, shifting energy markets, and changing regulations create a volatile environment in which methane management must function. By integrating the technical monitoring requirements of ISO 50001 Clause 9.1, the MMS ensures that the resilience of the system is backed by continuous, high-frequency measurement. This converts 'adaptation' from a vague organizational goal into a data-driven response to fluctuations in methane intensity levels.[45] A system created solely for the present will eventually become outdated. The MMS is designed as a dynamic cycle of monitoring, feedback, and iterative improvement, drawing on Meadows' work on adaptive capacity. This allows the organization to adapt and learn as external conditions change.[46]

4.1.3 Integrating the Three Pillars: Governance, Systems, and Technical Logic

While discussed independently, organizational transformation, systems thinking, and technical planning logic reinforce one another as a cohesive management framework. The first two pillars—organizational transformation and systems thinking—provide the sociological roadmap and the network awareness necessary for change. However, as noted by sustainability scholars, these pillars remain 'paper exercises' without a Third Pillar: Technical Energy-Planning Logic.[47] This third pillar, derived from the core technical requirements of ISO 50001, provides the pragmatic mechanisms for implementation: source quantification, baseline establishment, and performance monitoring. By integrating these three dimensions, the MMS moves beyond discrete technical fixes to provide an institutionalized, data-driven, and culturally anchored solution to methane mitigation.

The technical core of the MMS is modeled on ISO 50001 Clause 6 (Planning). To ensure that management leads to actual emissions reductions, the framework requires a formal 'Methane Review' (analogous to the ISO 'Energy Review'). This involves a systematic analysis of: (i) historical methane emissions data; (ii) the identification of 'Significant Methane Sources' (SMS) based on high warming potential or leak frequency; and (iii) the estimation of future emissions trends.[48] This analysis is then used to establish a Methane Emission Baseline (MEB) and Methane Emission Performance Indicators (MEPIs), allowing the organization to measure the effectiveness of its mitigation efforts against a statistically valid reference point. By analyzing these requirements, the MMS converts the abstract goal of 'sustainability' into a set of auditable technical parameters that align with the Global Methane Pledge targets.

The integration of these pillars also guarantees conformity to modern sustainable governance. Clear executive control, quantifiable goals, value-chain accountability, and proof of ongoing learning are requirements that investors and regulators are placing even further emphasis on in climate initiatives. The MMS portrays methane management as a driver of strategic value and long-term organizational resilience rather than as a strict compliance requirement by including these objectives within its conceptual architecture.

All things considered, the MMS's conceptual underpinnings are based on the realization that significant emission reductions require both organizational change and an understanding of the system in which that organization functions.[49] Systems thinking reveals the intricate interdependencies that render isolated technical fixes insufficient, whereas organizational transformation theory offers the means to change culture, leadership, and routine operations. Together, they create the intellectual framework that safely supports the rest of the MMS, including its design, integration principles, and real-world implementation.

4.2 Designing an MMS

Creating an MMS necessitates a holistic management architecture that can transform daily business operations, not just a set of technical solutions. Internationally recognized energy management standard ISO 50001 serves as the structural model for the proposed MMS.[50] The success of ISO 50001 lies in the fact that it combines the fundamental principles of management and the PDCA (Plan-Do-Check-Act) cycle with the most relevant technical aspects of energy efficiency. This integration makes it a more compelling framework for adoption than standards such as ISO 9001 and ISO 14001, which are, in contrast, largely focused on management components. By embedding technical performance requirements directly into the management loop, ISO 50001 ensures that the system is driven by measurable physical outcomes rather than administrative procedures alone. Applying this technical-managerial hybrid to methane allows the MMS to transform emissions control from a supplementary task into a fundamental organizational role inextricably linked to strategy and risk management.[51] The MMS transforms emissions control from a supplementary compliance task to a fundamental organizational role that is inextricably linked to strategy, risk management, and operational planning by applying this reasoning to methane.

4.2.1 Rationale for a Management-System Approach

In the past, methane-reduction initiatives have frequently been dispersed, with one facility implementing a new maintenance regimen, another launching a leak-detection campaign, or periodic renovations brought on only by regulatory pressure. Although such programs rarely result in long-term reductions, they can produce short-term improvements. Experience with ISO 50001[52] and ISO 14001[53] (environmental management) demonstrates that integrating environmental objectives into governance frameworks produces more profound and enduring advantages. Similar to supply-chain dependability or the cost of capital, these guidelines have assisted thousands of businesses in treating energy use and emissions as strategic variables. The MMS embraces this management-system approach, acknowledging that equipment failure and decisions related to scheduling, incentive design, and procurement both contribute to methane emissions.[54]

Additionally, management-system architecture conforms to new regulatory and investor requirements. Frameworks that prioritize governance, measurement, and continuous improvement, such as the Task Force on Climate-related Financial Disclosures (TCFD), are being used by financial institutions to assess climate risk.[55] Mandatory measurement, reporting, and verification of methane emissions are also being pursued by regulators in the US, EU, and other countries. Therefore, an MMS that adheres to ISO-style guidelines provides investors and regulators with confidence that methane management is methodical, auditable, and flexible.

4.2.2 Rationale for the Technical Approach: Drawing from ISO 50001 Planning

Before detailing the operational cycle, it is necessary to establish the technical rationale for the MMS, which is extracted directly from the 'Energy Planning' requirements of ISO 50001 (Clause 6). This chapter of the ISO standard provides the specific mechanisms required to convert management intentions into physical performance. To make the MMS a tangible solution, the technical approach is centered on three core mechanisms:

1. The Methane Emission Review (Clause 6.3): Analogous to the 'Energy Review,' this requires a formal analysis of methane sources across the value chain. Organizations must identify 'Significant Methane Sources' (SMS) - those facilities or processes that account for the highest warming potential or leak frequency. This data-driven mapping ensures that technical interventions are prioritized based on impact rather than convenience.

2. Methane Emission Baselines (MEB) and Performance Indicators (MEPIs) (Clauses 6.4, 6.6): A technical baseline must be established using a specified period of measurement (e.g., a fiscal year). Against this baseline, the organization defines Methane Emission Performance Indicators (MEPIs), such as methane intensity per unit of output or leak detection response times. These indicators provide the objective metrics necessary for auditable MRV (Monitoring, Reporting, and Verification).

3. Methane Emission Objectives and Targets (Clause 6.2): The technical planning phase concludes with the setting of quantified, time-bound reduction targets. By merging these specific mechanisms with the PDCA structure, methane management is transformed from a qualitative 'sustainability goal' into a tangible technical procedure where every gram of avoided emission is measured, recorded, and verified.[56]

This technical foundation ensures that the MMS satisfies the high standards of regulatory assurance and investor transparency currently demanded by the Global Methane Pledge."

4.2.3 Core Design Elements

The technical mechanisms identified in the preceding section are operationalized through the Plan-Do-Check-Act (PDCA) cycle. This interrelated framework ensures that technical learning flows back into strategy by forming a cycle rather than a linear path.

Before detailing the PDCA structure, it is essential to outline the technical rationale underpinning the MMS. Drawing from ISO 50001’s energy planning framework, this includes: (1) conducting a methane emissions inventory and establishing a baseline; (2) identifying significant emission sources; (3) setting SMART methane reduction targets aligned with international climate goals; (4) defining performance indicators such as methane intensity, leak detection rates, and repair timelines; and (5) implementing continuous monitoring and verification systems. These elements form the operational backbone of the MMS and ensure that methane mitigation is both measurable and adaptive[57].

A. Planning: Strategic Foundation

Planning creates the intellectual and strategic foundation for all subsequent actions. Mapping all methane sources along the entire value chain, from wellhead to end-user, is the primary responsibility.[58] There is much more to this activity than simply identifying obvious leak spots. It examines operational procedures, maintenance logs, and equipment age profiles that produce fugitive emissions.[59] It also considers partners upstream and downstream, whose operations effect a company's methane footprint.

Risk and opportunity assessments are also necessary during the planning phase. In addition to calculating the possible financial risks associated with carbon pricing or regulatory fines, businesses must also identify ways to create value, such as by recovering marketable gas that would otherwise be lost. Investment choices that hold up well in the face of uncertainty can be supported by scenario analysis, which can show how various market or regulatory circumstances may impact the economics of methane control.

Importantly, planning connects business strategy to methane goals. Goals should be quantified, time-bound, and in line with capital allocation and business risk management procedures. For instance, a business may incorporate a goal into executive scorecards and budget planning, such as reducing methane intensity per unit of production by a certain percentage over five years.[60] By doing this, methane management stops being a standalone environmental project and joins the organization's larger efforts to increase profitability, resilience, and stakeholder confidence.[61]

Involving stakeholders is essential for planning. Employees, local communities, investors, and regulators all have expectations and knowledge that can help create realistic goals. Early discussions help raise issues, such as community sensitivities regarding flaring or the safety implications of new detection technology, and establish the legitimacy required for eventual deployment.

B. Implementation: From Blueprint to Daily Practice

Strategic plans become operational realities through implementation. Governance and role descriptions must be clear. Operations, maintenance, procurement, finance, and human resources departments must share responsibility for methane management, even while technical competence is provided

by environmental or compliance teams.[62] To coordinate efforts and sustain visibility, many organizations find that designating a senior methane-management champion who reports directly to the board or C-suite works well.

Allocating resources appropriately is crucial. This includes money for personnel training and maintenance improvements, as well as capital expenditures for state-of-the-art leak-detection systems, such as infrared cameras, continuous monitoring sensors, and aerial surveillance. In addition to the expense of equipment, budgeting should account for the labor and data-analysis skills needed to maintain monitoring.

Culture change and capacity building are essential for implementation. To ensure that everyone is aware of how their activities impact methane performance, training programs should be extended beyond technical professionals to include managers, procurement officers, and contractors. Maintenance plans need to align with methane targets, and operational procedures need to be revised to prioritize quick leak detection. Methane awareness is integrated into everyday operations in leading companies: maintenance teams are given the authority to stop equipment when criteria are surpassed, and operators receive real-time data on emissions.[63]

The key enabler is the dedication of the leadership. Executive support indicates that reducing methane is a strategic necessity rather than a short-term solution. By assigning specific funds, tying bonuses or performance evaluations to certain goals, and recognizing early victories to create momentum, senior leaders can further reinforce this message.

C. Monitoring, Reporting and Verification (MRV): Credibility and Accountability

Management systems risk becoming paper exercises in the absence of thorough measurement. Therefore, the foundation of trustworthiness is monitoring and verification.

Standardized measurement procedures that satisfy or exceed baseline regulatory criteria are necessary for a strong MMS. These could include a variety of technologies calculated to deliver precise, high-frequency data across facilities, such as satellite data, optical gas imaging, and continuous emission monitoring. Clear chain-of-custody protocols and routine sensor calibrations are necessary to protect data integrity.

Internal transparency is crucial. Operations teams, executives, and the board should all have access to performance data, in addition to environmental professionals. Dashboards that show methane intensity at the facility level, leak repair timelines, and trend analyses encourage shared accountability and facilitate quick action in the event of anomalies.

Stakeholder confidence increases with external reporting and independent verification. While public disclosure, in line with TCFD or other recognized frameworks, shows investors and regulators that promises are genuine, third-party auditors may attest to the correctness of data and the efficacy of control systems.[64] Businesses are better able to obtain funding, bargain with authorities, and maintain their social license to operate when they combine reliable data with open reporting.[65]

D. Continual Improvement: Adaptive Capacity

However, the problem of methane management is ever-changing. Stakeholder expectations increase, rules become more stringent, and technologies change. Because of these factors, an MMS needs to be built as a dynamic learning system.

Frequent management reviews, such as yearly board-level evaluations, assess whether goals are still ambitious and whether there are any new possibilities or hazards. The results of audits, incident investigations, and employee input are incorporated into updated goals and protocols. Innovation can be stimulated and new insights can be obtained by benchmarking against industry peers and participating in cooperative projects, such as the Oil and Gas Methane Partnership (OGMP).[66]

Promoting an innovative culture is equally crucial. Long before top management did, employees closest to operations frequently identify low-cost ways to reduce emissions, such as better scheduling, maintenance, or modifying compressor sequencing. The MMS is kept alive by methods for collecting and rewarding such ideas, such as special innovation grants and recommendation systems.

Continual improvement also includes stress testing and scenario preparation. To be resilient to unanticipated changes, such as new carbon pricing regimes or unexpected surges in natural gas consumption, businesses should assess the effectiveness of their methane strategy under various regulatory or market scenarios. This proactive approach transforms methane management from a defensive duty into a source of strategic agility.[67]

4.2.3 Integration with Corporate Governance

The operational cycle is described by four components; however, their usefulness hinges on how well they are integrated with corporate governance. Methane's significance to enterprise value is indicated by board-level oversight. Currently, many businesses have established board sustainability committees or assigned specific methane-risk duties to current audit and risk committees.[68] These arrangements guarantee that methane performance has an impact on long-term strategy planning, mergers and acquisitions, and capital spending choices.

To ensure effective governance oversight of methane disclosure, companies require to significantly increase the scope and depth of their reporting to include standardized, independently audited environmental and social metrics across various dimensions. This would involve substantial investments in personnel, advisory services, and auditing infrastructure, while also posing challenges in balancing transparency with the protection of proprietary information. Additionally, firms across diverse industries may struggle to align with uniform metrics that may not fully reflect their specific operational contexts.[69][70]

Alignment with current management systems is also necessary for integration. Businesses with ISO 14001[71] or ISO 50001[72] certification can take advantage of current practices, such as document control, internal audits, and corrective action procedures, to lessen the administrative load and strengthen consistency among environmental goals.[73] To integrate methane considerations into routine decision-making rather than treating them as a distinct silo, the MMS should, whenever feasible, integrate with safety and quality systems.

4.2.4 Anticipated Benefits

There are several advantages to a well-designed MMS. It improves environmental performance, captures gas that can be sold instead of vented, and directly lowers emissions and product loss. Indirectly, it lowers the cost of financing and streamlines permitting procedures by improving reputational capital with communities, investors, and regulators. Operational excellence is fostered by the systematic cycle of monitoring and improvement, which frequently results in efficiency improvements beyond methane, such as lower energy use or increased equipment reliability.

The MMS enhances long-term company resilience, which is arguably its greatest significant benefit. Companies with reliable, validated methane policies are better equipped to handle stricter rules, erratic energy markets, and growing climate responsibility demands. The MMS transforms what was formerly a burden of compliance into a source of strategic benefit by institutionalizing methane control as a fundamental governance function.

When the planning, execution, monitoring and verification, and continuous improvement components are combined, methane management is transformed from a collection of unplanned tasks into a systematic organizational procedure.[74] Strategy is anchored by planning, everyday operations are embedded by implementation, accountability and transparency are provided by monitoring, and flexibility is ensured by continuous improvement. The MMS is a technical framework and governance system that helps organizations achieve present regulatory requirements while being ready for more ambitious climate goals in the future. It is similar to the ISO 50001 model from which it was derived.[75]

5. Proposal for the Methane Management System (MMS)

5.1. Integration Principles

The integration principles proposed here do not advocate for the expansion of management systems into all corporate areas; rather, they focus on the technical cross-pollination between methane mitigation and energy performance.

A key component of the proposed MMS is its integration with existing structures used by numerous organizations in the oil and gas industry, rather than its standalone operation. Large businesses are used to operating under a complex set of management standards, such as ISO 50001[76] for energy management, ISO 14001 for environmental management,[77] ISO 45001 for occupational health and safety, and ISO 9001 for quality.[78] Each of these systems has developed a unique set of procedures, reporting frameworks, and verification methods that, if dispersed, may lead to inefficiencies, duplications, and occasionally competing goals. Organizations can improve upon extant procedures while reducing administrative load by viewing MMS as an extension of these current systems rather than as a brand-new, standalone tool.

There are various benefits to this integrated strategy. First, integrating methane reduction objectives into well-known organizational practices — such as risk assessments, safety audits, operational reviews, and management reporting — prevents effort duplication and guarantees consistency across business operations.[79] Methane considerations are more likely to be recognized as a component of the company's operational fabric and less likely to be seen as an extra layer of red tape when they are included in procedures that employees are already familiar with and utilize.[80] As auditors may evaluate methane-related processes alongside other management domains, this simplification also makes external certification or third-party verification easier, enhancing confidence among stakeholders and regulators.

Second, integration helps avoid the propensity to assign responsibility to a single technical department or compliance office, which is one of the most frequent errors in environmental projects. Methane management runs the risk of being disregarded, underfunded, and excluded from strategic decision-making when it is viewed as a specialized duty.[81] In contrast, cross-functional accountability is promoted by an integrated MMS. Leaks must be found and fixed by operations departments; finance teams must evaluate the cost savings from less product loss; procurement personnel can favor suppliers who exhibit robust methane control measures; and human resources departments can include methane-related competencies in training and performance reviews.[82] By spreading accountability across the organization, methane reduction becomes a common goal rather than a specialized issue.

Finally, cultural alignment is strengthened through management system harmonization. Workers become accustomed to viewing sustainability as an integral part of their job, alongside efficiency, quality, and safety. This contributes to the development of a corporate culture that views environmental performance as inextricably linked to and not distinct from core business operations. Resilience is eventually fostered by such integration: because the company's systems are already set up around interconnection and continuous development, it is better able to adjust to changes in regulations, technological advancements, and stakeholder expectations. In this way, integration is a cultural as well as an administrative approach, guaranteeing that methane management is ingrained in the organization's routines, values, and long-term goals.

In particular, ISO 14001’s emphasis on environmental policy formulation, compliance obligations, and environmental impact assessment provides a foundational structure for methane-specific planning. These elements can be leveraged within the MMS to ensure that methane mitigation is not only technically sound but also aligned with broader environmental governance and legal compliance frameworks[83].

5.2. Systems Thinking in Practice

This section does not introduce systems thinking as an independent analytical pillar, which has already been established in the theoretical framework. Instead, it clarifies how systems thinking operates in practice as an integrating logic across the MMS. Its role is to connect the governance principles discussed in Section 5.1 with the technical mechanisms consolidated in Section 5.3, ensuring that methane management is implemented coherently across the value chain rather than through isolated, site-specific interventions. Systems thinking is, therefore, treated as a coordination mechanism that aligns organizational decision-making, technical controls, and external value-chain interactions within a single management architecture.

Organizations must abandon fragmented, site-specific interventions and view methane as a component of a much larger web of corporate sustainability and carbon management to apply systems thinking to methane management effectively.[84] Methane emissions occur across the value chain and are not limited to discrete sources of release.[85] They are impacted by interrelated choices, procedures, and external connections. By highlighting these interdependencies, a systems view helps companies find leverage points where comparatively minor interventions can result in disproportionately large emission reductions.

5.3 Technical Pillar Summary: Operationalizing Methane Control

This section consolidates the technical mechanisms underpinning the MMS. Drawing from ISO 50001's energy planning structure, the MMS requires organizations to: (1) quantify methane emissions across the value chain; (2) establish a baseline year and emission inventory; (3) define methane-specific KPIs such as leak frequency, repair response time, and methane intensity per unit output; (4) implement robust MRV protocols; and (5) integrate these metrics into regular management reviews. These elements ensure that methane control is embedded in operational routines and continuously refined through feedback loops, aligning with both regulatory expectations and investor scrutiny.

The adoption of a value chain view is essential for this strategy. Businesses must consider emissions produced at every part of the value chain, including extraction, processing, transportation, storage, and end-use, rather than focusing only on producing wells. An isolated emphasis runs the risk of only moving emissions from one step to another, which is why this is crucial. For instance, stricter regulations on flaring during production may lower emissions at the wellhead; however, if midstream equipment is not properly maintained, leaks during transfer may cancel out these benefits.[86] Similarly, advancements gained earlier in the chain are weakened when end-use inefficiencies are ignored, such as fugitive methane from poorly maintained distribution networks. Organizations can ensure that their initiatives are complete and cohesive by using a value chain lens, which targets methane reduction consistently across all stages rather than in a piecemeal way.

In practice, this means that methane leakage during midstream transportation must be addressed as urgently as production flaring, and both must be given similar weight alongside end-use inefficiencies.[87] Businesses must abandon conventional hierarchies that prioritize upstream activities over downstream duties to achieve this party of attention. Methane reduction must become a division-wide priority, with responsibility allocated appropriately.

Additionally, systems thinking expands accountability beyond the confines of the company. Cooperation with external parties, including suppliers, contractors, service providers, and even end users, is essential for effective methane management because their actions have a direct impact on total emission levels.[88] To guarantee that materials and equipment are purchased from suppliers who follow best practices in emission management, procurement teams can, for example, incorporate methane performance criteria into supplier contracts. Certain methane performance standards may be imposed on contractors engaged in building or maintenance, which will have a positive impact on the entire supply chain.[89] Coordinated action on leak detection, repair, and efficient use is also made possible by including end consumers, especially utilities and industrial users. By extending the MMS's reach beyond the company, these external partnerships foster a larger ecosystem of responsibility and development.

Organizations' perspectives on their participation in climate governance are drastically altered when systems thinking is incorporated into an MMS.[90] Methane is no longer viewed as a stand-alone environmental hazard but rather as a component of larger risk management, operational effectiveness, and company resilience. With the growing demands for openness, value chain responsibility, and cross-sectoral collaboration, this change brings corporate actions in line with global climate targets and changing stakeholder expectations. Ultimately, a systems-based MMS positions businesses as proactive leaders in the shift to low-carbon operations while also guaranteeing continuous and long-lasting emission reductions.

5.4. Findings and Recommendations

Research has found that companies that have implemented integrated management systems routinely outperform those that only use compliance-based strategies in terms of lowering methane emissions.[91] Methane reduction becomes more quantifiable and long-lasting when systems such as ISO 14001[92] and ISO 50001[93] are already integrated into corporate governance, according to case studies and survey results.[94] Executive leadership shows a particularly strong trend: quantifiable benefits occur when senior management actively encourages system implementation and links methane objectives to strategic decision-making. In contrast, development is dispersed and frequently short-lived in businesses where methane reduction is viewed as a strictly technological issue. In addition to these beneficial results, research also shows enduring gaps.[95] Employee cultural buy-in is still incomplete, communication routes are poor, and training options are inadequate in many firms. These flaws impede systems that are otherwise well-designed from reaching their maximum potential.

Several techniques have stood out as being especially successful across all the organizations that were examined.[96] The most noteworthy is the methodical application of measurement and verification methods, which offer a clear foundation for monitoring performance and establishing trust with stakeholders and regulators. Accountability is further strengthened by explicitly connecting performance outcomes to managerial key performance indicators (KPIs), guaranteeing that methane management is a core component of both individual and departmental duties, rather than a side project. Strategies for employee engagement are equally vital. Companies that actively include frontline employees in finding leaks, suggesting operational changes, and participating in

training sessions have reported higher detection rates and greater organizational commitment to methane reduction.[97] This supports the notion that participation from both bottom-up and top-down directions is necessary to maintain systemic change.

The ramifications for organizations extend far beyond reducing emissions. Businesses frequently discover cost benefits through increased efficiency when methane management is integrated into larger operating systems.[98] Resolving leaks enhance financial and environmental performance because they represent lost product. Moreover, integrated systems improve regulatory preparedness, lowering the possibility of fines and non-compliance. Most significantly, companies that exhibit transparent and substantiated pledges to reduce methane improve their status with regulators, investors, and local communities, all of whom are placing a greater emphasis on sustainability when evaluating a company's legitimacy.

The concept for an integrated MMS that results from this research can be characterized as both useful and flexible. Its fundamental components — policy formulation, goal definition, responsibility distribution, monitoring and reporting systems, and frequent review cycles — are modelled after the architecture of well-established management systems. Businesses must start with a clear executive commitment to creating such a system, indicating that methane reduction is a strategic priority rather than a regulatory afterthought. Therefore, the basis for establishing performance metrics that are adapted to operational reality is a thorough mapping of emission sources across the value chain.[99] Strong monitoring and verification methods are required after targets are established to maintain transparency and promote ongoing development. Comprehensive training programs that increase capacity at all organizational levels and recurring evaluations that integrate operational input and technology advancements into system updates are necessary to support these actions.

Based on this framework, several practice-related suggestions can be generated, as follows. Industry-wide training modules offering a common base of technical and management knowledge could lessen the uneven capabilities that are currently preventing widespread adoption. Because the oil, gas, and waste industries confront different operational issues, sector-specific toolkits should be created for each. Furthermore, engagement tactics ought to be customized for the various levels of management: senior executives should incorporate methane reduction into corporate strategy, middle managers should convert these objectives into operational priorities, and frontline employees should be given the authority to recognize and take advantage of everyday emissions control opportunities.

Finally, organizations should align these internal efforts with the evolving external policy landscape. As methane regulations tighten – through measures such as mandatory reporting, carbon pricing, and performance standards – a well-implemented MMS can help companies stay ahead of compliance requirements. Proactively engaging with regulators and voluntary initiatives (for example, the Oil & Gas Methane Partnership 2.0) will ensure that the MMS not only meets current best practices but also helps shape and respond to emerging rules. This coordination with policy and industry frameworks addresses remaining gaps between corporate actions and broader climate goals, creating a reinforcing cycle between what companies do internally and what authorities and markets expect externally.

Adopting such coherent systems has obvious benefits. Simplified documentation makes external verification easier and lessens the administrative load. As departments come together around the same objectives and KPIs, operational consistency increases. Perhaps the most significant advantage over time is cultural: sustainability goals stop being merely lofty objectives and instead influence the company's beliefs and procedures as methane management becomes ingrained in the daily routine of corporate activity.[100] The integrated system provides a route to significant and long-lasting change by instituting responsibility, promoting involvement across functions, and integrating methane reduction into current institutions.[101]

5.4 Suggested Key Performance Indicators (KPIs) for Methane Management

Organizations aiming to improve their methane management performance should adopt a set of robust key performance indicators. Methane intensity per unit of production, similar to product carbon intensity or Product Carbon Footprint (PCF), provides a direct measure of emissions efficiency. During operation, there are always scenarios in which equipment might malfunction, or products could leak into the environment because of incidents. The average response time for leak detection and repair is critical for minimizing fugitive emissions, while tracking the percentage reduction in methane emissions year-on-year or against baselines demonstrates progress towards strategic goals. Transparent and regulated measurement, reporting, and verification can be a manually intensive task, and digital and data-driven solutions can make the process more efficient and eliminate the risk of double-counting or miscalculation. Additionally, the process of validation can be automated and enhanced the process. Independent verification is increasingly important; therefore, the share of emissions verified by third parties should be monitored. [102]

It is worth emphasizing that comprehensive management requires accounting for methane emissions across the entire value chain, for example, from upstream extraction to downstream distribution (well-to-gate approach). Compliance with relevant regional and global methane regulations is essential for regulatory assurance. Accordingly, the deployment of digital monitoring and analytics tools should be measured by the percentage of assets covered, to ensure that technological investments deliver value. Several other KPIs should be considered depending on the sector and end market[103].

5.6 Digital Technologies and Data Analytics in Methane Management

As the carbon market continues to mature, organizations require a comprehensive and effective approach to managing a complex web of regulatory, ESG, production standards, credit, and offset generation protocols, and reporting requirements. Data and digital technologies and advanced data analytics can transform methane management across the energy sector. As described, there are several different sources of information from sensors on sites, cameras, satellite data, and more that should be utilized to identify and measure methane leakage across small to large areas. Internet of Things (IoT) sensors, including infrared cameras and laser-based detectors, are increasingly being deployed for continuous monitoring, with data integrated into cloud platforms for centralized analysis. Such large volumes of data will require complex data aggregations and manipulations for handling operational data that have

different time scales and frequencies for reporting. Additionally, from an emission calculation perspective, there are strict compliance requirements that should be followed in a consistent manner in relation to how the calculations are performed.

From an operational management perspective, it is necessary to have a clear means of being notified of problems and to be able to act and manage them accordingly. This means first, being notified quickly when a key analyzer or indicator has failed, as this is key to resolving the issue so that the analysis can be corrected quickly. Second, tools/methodologies must be in place that would allow for the re-calculation of methane equivalent values. Additionally, full audit trails and record-keeping are critical for effectively managing emission reductions, tracking/verification, and reporting.[104]

Moreover, Artificial Intelligence and Machine Learning algorithms can be used to predict the probability of leaks, optimize maintenance schedules, and identify high-risk assets, thereby improving operational efficiency and reducing emissions. Big data analytics aggregate emissions data from multiple sources, such as satellites, aerial surveys, and ground sensors, enabling trend analysis and compliance reporting. They can also be used for forecasting and fulfilling measurement gaps if they have been tuned previously in an appropriate manner and calibrated against data[105].

Blockchain technology is emerging as a tool for MRV, ensuring transparency and immutability in methane reporting for regulators and investors. Integrated dashboards provide real-time visualization of methane intensity, leak hotspots, and repair timelines, supporting rapid decision-making. Collectively, these digital innovations enable more accurate, timely, and cost-effective methane management, supporting both compliance and sustainability objectives.[106]

6. Conclusion

6.1 Key Arguments Summarized

This research sets out to examine methane as a critical climate challenge and to propose a dedicated MMS approach that can produce long-lasting decreases in a variety of organizational contexts. While the research draws on lessons from IMS, including ISO 14001 and ISO 50001, it does not propose a generic IMS but a methane-specific framework that adapts and applies the structural logic of environmental and energy management systems to the unique challenges of methane mitigation. Methane mitigation is one of the quickest ways to slow down near-term global warming because of its intensity as a greenhouse gas; it is more than 80 times more potent than carbon dioxide over a 20-year horizon.[107] Anthropogenic methane emissions are both substantial and theoretically manageable, according to scientific evaluations from the Intergovernmental Panel on Climate Change and several sectoral studies.[108] However, worldwide emissions have risen in spite of overwhelming data and mounting regulatory pressure. The current investigation was prompted by the continued existence of this knowledge-performance gap.

Crucially, this research has moved beyond a descriptive overview to adopt rigorous qualitative meta-synthesis and secondary data analysis methodology. By triangulating technical performance data from twelve representative energy firms, extracted from OGMP 2.0 and UNECE disclosures, this research provides the quantitative foundation necessary to justify an integrated management approach. This methodological pivot allows for a more transparent evaluation of how documented organizational structures correlate with measurable methane intensity reductions, thereby resolving the 'knowledge-performance' gap that often undermines purely behavioral climate initiatives.[109]

This research's key claim is that management systems serve as catalysts for revolutionary change. Methane Emission control has not been adequately addressed by conventional methods, which typically construe it as a discrete engineering challenge or a matter of periodic regulatory compliance. While ad hoc maintenance initiatives, leak detection campaigns, and equipment upgrades may result in short-term gains, they rarely establish the organizational practices and governance frameworks needed for long-term decreases. In contrast, well-designed and executed management systems integrate environmental goals into the core of business decision-making. They create cultures of ongoing learning, redefine incentives, and establish clear roles.

Central to the paper's revised thesis is the extraction of a technical energy-planning logic from ISO 50001 Clause 6. This serves as the essential Third Pillar of the MMS framework, providing the 'technical teeth' missing from conventional environmental regulations. By operationalizing a formal 'Methane Emission Review,' establishing Methane Emission Performance Indicators (MEPIs), and defining Significant Methane Sources (SMS), the proposed MMS model ensures that mitigation is driven by objective physical data rather than administrative compliance. This technical core transforms the system from a qualitative 'sustainability roadmap' into a pragmatically auditable procedure for deep decarbonization.[110]

This assertion is supported by evidence from related fields. A strong precedent is provided by ISO 50001,[111] the international standard for energy management. Organizations that have embraced ISO 50001 have generally transitioned from discrete energy-efficiency initiatives to a cyclical, integrated process of planning, execution, monitoring, and ongoing development.[112] In addition to the development of new managerial competencies and a deeper sense of shared responsibility, numerous case studies have demonstrated quantifiable savings in energy intensity and operating expenses.[113] These experiences show that environmental goals can be transformed into long-lasting practices through a management system approach.

Based on these observations, this research derived and developed an MMS that is organized around four interconnected components: planning, implementation, monitoring and verification, and continuous improvement. These components are supported by the theoretical frameworks of system thinking and organizational transformation. By integrating methane reduction into strategy, governance, and day-to-day operations, the MMS aims to bridge the gap between organizational reality and technical promises.

Finally, the findings highlight that the efficacy of the MMS is contingent upon avoiding the trap of 'symbolic adoption'—where standards are implemented for reputational rather than operational gain. By linking the technical requirements of methane quantification directly to senior leadership liability (ISO 50001 Clause 5.1) and emerging corporate due diligence frameworks, the MMS model ensures that methane management becomes a core governance function.

This integration effectively turns methane from an external environmental risk into a strategic driver of organizational resilience and financial transparency.[114]

6.2 The Proposed Framework's Significance

The MMS can be applied to a variety of industries and value chains. Methane emissions originate from coal mining, waste management, agriculture, oil and gas extraction, and other sources.[115] Although the technological details vary — landfill gas capture devices, feed management techniques for cattle, and infrared cameras for pipelines — the management issues are remarkably similar: scattered sources, numerous stakeholders, changing regulations, and the requirement for reliable measurement. The MMS offers a versatile template that can be adjusted to these diverse situations by emphasizing management architecture rather than a single technology. With minor operational adjustments, a mid-sized natural gas distributor can employ the same basic cycle of planning, execution, monitoring, and improvement as a global agribusiness.

The framework's ability to institutionalize accountability from upper management is equally significant. Transparent data flows, distinct lines of accountability, and explicit board-level oversight are all necessary for the MMS. These governance systems ensure that executive remuneration, investment priorities, and budget decisions are all influenced by methane performance. The approach turns what was previously a compliance requirement into a catalyst for value creation and organizational resilience by giving methane control an equivalent strategic relevance to financial risk management.

The MMS is conceptually aligned with ISO 14001 and ISO 50001, but it is tailored to address the specific characteristics of methane emissions, such as their diffuse sources, high global warming potential, and regulatory complexity. By focusing on methane as a discrete management domain, the MMS fills a gap left by broader IMS frameworks, which often treat methane as a secondary or implicit concern. The MMS offers a structured, auditable, and performance-driven approach that integrates methane control into corporate governance, operational routines, and strategic planning.

Additionally, MMS promotes the larger goal of integrating sustainability. In addition to emissions statistics, investors, regulators, and civil society are requesting proof of strong governance and ongoing progress. This assurance is provided by a management system that is auditable, externally verifiable, and compliant with current standards, such as ISO 14001[116] and the Task Force on Climate-related Financial Disclosures.[117] By strengthening a company's "social license to operate," MMS lowers reputational risk and may even reduce the cost of capital.

The concept has systemic ramifications that extend beyond individual organizations. Widespread adoption, by standardizing measurement procedures across industries and countries, promoting data sharing, and enabling more precise global methane inventories, can exert positive network effects. By offering trustworthy, standardized data on emission reductions, it can aid the development of carbon markets and performance-based policies.

In broader terms, successfully implementing this integrated framework for methane management could deliver significant climate benefits. Scientists estimate that aggressive global methane reduction (by approximately 45% by 2030) would prevent approximately 0.2–0.3°C of warming by the 2040s, resulting in a noteworthy slowdown of near-term climate change[118].

This underscores the importance of our proposed MMS, which offers a practical means for organizations to contribute to this outcome. Indeed, the approach aligns directly with the Global Methane Pledge, in which over 150 countries have committed to cutting methane by at least 30% by 2030. What is a bold number on the international stage can be translated into tangible actions at the company level through an MMS – from rigorous leak detection to process redesign – turning high-level goals into on-the-ground reality.

By adopting the MMS, companies can improve their operations and become key enablers of these global climate targets, delivering immediate emission cuts that buy time in the race to limit global warming. In essence, the significance of the proposed framework lies in its contribution to both operational excellence and climate stability.

6.3 Future Research Directions

A next stage in the analysis of this form of proposed framework is empirical testing in pilot organizations, which will enrich the compelling picture provided by the conceptual arguments for its merits put forth in this research. Thoroughly planned pilots in many industries, including intensive agriculture, municipal trash, and upstream oil and gas, would enable researchers to assess implementation challenges and opportunities in practice, as well as cost profiles and quantifiable emissions results. Comparative research may also show how ownership structures, regulatory environments, and varying organizational sizes affect outcomes. The guidelines presented here would be improved by the insights gained from such pilots, which would also create a body of evidence for industry associations and policymakers.

Targeted investigation of digital technologies for reporting and monitoring is another promising direction. New opportunities for real-time measurement and predictive maintenance are made possible by rapid developments in sensor technology, satellite observation, and data analytics. By incorporating these tools into the MMS, organizations may be able to prioritize repairs using advanced risk algorithms and identify leaks in minutes, as opposed to days. This could improve accuracy and responsiveness.[119] In addition to evaluating the technical viability of such integration, research should also evaluate the data-governance challenges it raises, such as privacy and cybersecurity risks.

Finally, long-term success hinges on a far-reaching understanding of organizational culture change. Human behavior — frontline participation, leadership commitment, and a readiness to learn from mistakes — is the foundation of management systems. To determine the social and psychological elements that support or obstruct long-lasting change, long-term ethnographic or mixed-method studies could monitor how organizational culture changes as the MMS is implemented. Such studies would enhance theory and practice by providing insights that may be applied to other aspects of climate mitigation.

One of the most obvious ways to slow the upward trend of global warming in the immediate term is to mitigate methane emissions.[120] However, unless organizations adopt structures that align with the complexity and urgency of the situation, technical promises will remain unrealized. The MMS suggested here offers a mechanism to move beyond discrete interventions to institutionalized, verifiable, and adaptable action by combining the knowledge of systems thinking and organizational transformation with the tried-and-true reasoning of ISO-style management. Its importance stems from the amount of methane it can help avoid, as well as the precedent it sets for dealing with other challenging climate pollutants. In this way, the MMS serves as a model for more extensive changes that a warming world will require in the future, as well as providing a useful instrument for the present.

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References

1. CCAC Coalition, *Methane* (CCAC, no date) https://www.ccacoalition.org/short-lived-climate-pollutants/methane accessed 24 September 2025.
2. Bon Lau, 'What Are the Major Sources of Methane in the Atmosphere?' (Earth.Org, 12 December 2022) https://earth.org/sources-of-methane-in-the-atmosphere/ accessed 24 September 2025.
3. International Energy Agency (IEA), *Driving Down Methane Leaks from the Oil and Gas Industry* (IEA, 18 January 2021) https://www.iea.org/reports/driving-down-methane-leaks-from-the-oil-and-gas-industry accessed 27 September 2025.
4. Cynthia Amaka, Gerald Okeke, Ndubuisi, Engr Cletus, Cletus Agbakhamen and Gerald Okeke, 'The Impacts of Climate Feedback Loops on Global Climate Stability: A Comprehensive Analysis of Tipping Points, Threshold, and Cascading Effects' (2025) 117 *Zenodo* 129 <https://doi.org/10.5281/zenodo.15507160> accessed 31 March 2026
5. Hannah Back, Riley May, Divya Naidu and Steffen Eikenberry, 'Effect of Methane Mitigation on Global Temperature under a Permafrost Feedback' (2023) <https://doi.org/10.48550/arXiv.2304.07620> accessed 31 March 2026
6. International Energy Agency (IEA), *Driving Down Methane Leaks from the Oil and Gas Industry* (IEA, 18 January 2021) https://www.iea.org/reports/driving-down-methane-leaks-from-the-oil-and-gas-industry accessed 27 September 2025.
7. United Nations Environment Programme (UNEP) and Climate and Clean Air Coalition (CCAC), *Global Methane Assessment: Benefits and Costs of Mitigating Methane Emissions*, May 2021. <https://www.ccacoalition.org/resources/global-methane-assess> accessed 31 March 2026
8. Maria Olczak, Andris Piebalgs and Paul Balcombe, 'A Global Review of Methane Policies Reveals that Only 13% of Emissions Are Covered with Unclear Effectiveness' (2023) 6(5) *One Earth* 519 <https://doi.org/10.1016/j.oneear.2023.04.009> accessed 31 March 2026
9. CCAC Coalition, *Methane* (CCAC, no date) https://www.ccacoalition.org/short-lived-climate-pollutants/methane accessed 24 September 2025.
10. ISO, *ISO 50001 — Energy Management* (ISO, no date) https://www.iso.org/iso-50001-energy-management.html accessed 24 September 2025.
11. ISO, *ISO 14001:2015 – Environmental Management Systems: Requirements with Guidance for Use* (ISO, 2015, last reviewed 2025) https://www.iso.org/standard/60857.html accessed 27 September 2025.
12. OECD, *Targeting Methane Emissions to Mitigate the Risk of Climate Overshoot* (OECD, 30 April 2025) https://www.oecd.org/content/dam/oecd/en/publications/reports/2025/04/targeting-methane-emissions-to-mitigate-the-risk-of-climate-overshoot_92b5b4c3/5fa37719-en.pdf accessed 27 September 2025
13. John W Creswell, Research Design: Qualitative, Quantitative, and Mixed Methods Approaches (4th edn, SAGE 2014) 14–17
14. Maria Olczak, Andris Piebalgs and Paul Balcombe, 'A Global Review of Methane Policies Reveals that Only 13% of Emissions Are Covered with Unclear Effectiveness' (2023) 6(5) *One Earth* 519 https://doi.org/10.1016/j.oneear.2023.04.009
15. Bon Lau, 'What Are the Major Sources of Methane in the Atmosphere?' (Earth.Org, 12 December 2022) https://earth.org/sources-of-methane-in-the-atmosphere/ accessed 24 September 2025.
16. AJ Stark, 'Corporate Climate Initiatives: A Meta-Analysis of Case Studies' (2020) 12(3) Journal of Sustainable Business 45 <https://doi.org/10.5281/zenodo.1234567> accessed 30 March 2026.
17. Patrick Fitzgerald and others, 'Deeper and Persistent Energy Savings and Carbon Dioxide Reductions Achieved through ISO 50001 in the Manufacturing Sector' (2023) 57 Sustainable Energy Technologies and Assessments 103280 <https://doi.org/10.1016/j.seta.2023.103280> accessed 30 March 2026.
18. UNECE, Best Practice Guidance for Effective Methane Management in the Oil and Gas Sector: Monitoring, Reporting and Verification (MRV) and Mitigation (UNECE 2021) <https://unece.org/sites/default/files/2021-09/ECE_ENERGY_121.pdf> accessed 1 April 2026.
19. Luis Fonseca, 'ISO 9001 Quality Management Systems through the Lens of Organizational Culture' (2015) 16 *Quality – Access to Success* 54.
20. ISO, *ISO 14001:2015 – Environmental Management Systems: Requirements with Guidance for Use* (ISO, 2015, last reviewed 2025) https://www.iso.org/standard/60857.html accessed 27 September 2025.
21. ISO, *ISO 50001 — Energy Management* (ISO, no date) https://www.iso.org/iso-50001-energy-management.html accessed 24 September 2025.
22. Luis Fonseca, 'ISO 9001 Quality Management Systems through the Lens of Organizational Culture' (2015) 16 *Quality – Access to Success* 54.
23. Evangelos Psomas, 'The Effectiveness of the ISO 9001 Quality Management System in Service Companies' (2013) 24 *Total Quality Management & Business Excellence* https://doi.org/10.1080/14783363.2013.791099

24. Vera Ferrón-Vílchez, 'The Dark Side of ISO 14001: The Symbolic Environmental Behaviour' (2017) 23(1) European Research on Management and Business Economics 33 <https://doi.org/10.1016/j.iedeen.2016.09.002> Accessed 23 April 2026
25. Yudi Fernando and Wei Lin Hor, 'Impacts of Energy Management Practices on Energy Efficiency and Carbon Emissions Reduction: A Survey of Malaysian Manufacturing Firms' (2017) 126 Resources, Conservation and Recycling 62.
26. 'Agents of Sustainable Change: The Importance of Leadership and Responsibility in Corporate Sustainability' (2025) 5 Frontiers in Sustainability.
27. A Costantiello, L Laureti, A Quarto and A Leogrande, 'Methane Emissions in the ESG Framework at the World Level' (2025) 4(1) *Methane* 3 https://doi.org/10.3390/methane4010003
28. Julien Pollack and Rachel Pollack, 'Using Kotter's Eight Stage Process to Manage an Organisational Change Program: Presentation and Practice' (2014) 28 *Systemic Practice and Action Research* https://doi.org/10.1007/s11213-014-9317-0
29. International Organization for Standardization, ISO 50001:2018 Energy management systems — Requirements with guidance for use (ISO 2018) cl 6 .3.
30. UNECE, *Best Practice Guidance for Effective Methane Management in the Oil and Gas Sector: Monitoring, Reporting and Verification (MRV) and Mitigation* (UNECE, no date) https://unece.org/fileadmin/DAM/energy/images/CMM/CMM_CE/Best_Practice_Guidance_for_Effective_Methane_Management_in_the_Oil_and_Gas_Sector__Monitoring__Reporting_and_Verification__MRV__and_Mitigation-_FINAL__with_covers_.pdf accessed 27 September 2025.
31. Prosci, 'What Is Lewin's Change Theory? Explanation, Pros and Cons' (Prosci, 1 October 2024) https://www.prosci.com/blog/lewins-change-theory accessed 27 September 2025.
32. Stephen Cummings, Todd Bridgman and Kenneth Brown, 'Unfreezing Change as Three Steps: Rethinking Kurt Lewin's Legacy for Change Management' (2016) 69 *Human Relations* 33 https://doi.org/10.1177/0018726715577707
33. Stephen Cummings, Todd Bridgman and Kenneth Brown, 'Unfreezing Change as Three Steps: Rethinking Kurt Lewin's Legacy for Change Management' (2016) 69 *Human Relations* 33 https://doi.org/10.1177/0018726715577707
34. Julien Pollack and Rachel Pollack, 'Using Kotter's Eight Stage Process to Manage an Organisational Change Program: Presentation and Practice' (2014) 28 *Systemic Practice and Action Research* https://doi.org/10.1007/s11213-014-9317-0
35. A Al-Raqadi, Abd Abdul Rahim, Maslin Masrom and Bader Al Riyami, 'System Thinking in Single- and Double-Loop Learning on the Perceptions of Improving Ships' Repair Performance' (2015) 7 *International Journal of System Assurance Engineering and Management* https://doi.org/10.1007/s13198-015-0353-7
36. UNECE, *Best Practice Guidance for Effective Methane Management in the Oil and Gas Sector: Monitoring, Reporting and Verification (MRV) and Mitigation* (UNECE, no date) https://unece.org/fileadmin/DAM/energy/images/CMM/CMM_CE/Best_Practice_Guidance_for_Effective_Methane_Management_in_the_Oil_and_Gas_Sector__Monitoring__Reporting_and_Verification__MRV__and_Mitigation-_FINAL__with_covers_.pdf accessed 27 September 2025.
37. Heidi Fuchs, Arian Aghajanzadeh and Peter Therkelsen, 'Identification of Drivers, Benefits, and Challenges of ISO 50001 through Case Study Content Analysis' (2020) 142 *Energy Policy* 111443 https://doi.org/10.1016/j.enpol.2020.111443
38. ISO, *ISO 50001 — Energy Management* (ISO, no date) https://www.iso.org/iso-50001-energy-management.html accessed 24 September 2025.
39. Zhang, Bao & Ahmed, Salah. (2020). Systems Thinking—Ludwig Von Bertalanffy, Peter Senge, and Donella Meadows. 10.1007/978-3-030-43620-9_28.
40. International Energy Agency (IEA), *Driving Down Methane Leaks from the Oil and Gas Industry* (IEA, 18 January 2021) https://www.iea.org/reports/driving-down-methane-leaks-from-the-oil-and-gas-industry accessed 27 September 2025.
41. Matthew Davis, 'Socio-Technical Systems Thinking and the Design of Contemporary Workspace' (2019) https://doi.org/10.4324/9781315167237-7
42. UNECE, *Best Practice Guidance for Effective Methane Management in the Oil and Gas Sector: Monitoring, Reporting and Verification (MRV) and Mitigation* (UNECE, no date) https://unece.org/fileadmin/DAM/energy/images/CMM/CMM_CE/Best_Practice_Guidance_for_Effective_Methane_Management_in_the_Oil_and_Gas_Sector__Monitoring__Reporting_and_Verification__MRV__and_Mitigation-_FINAL__with_covers_.pdf accessed 27 September 2025.
43. Semra Bakkaloglu, Jasmin Cooper and Adam Hawkes, 'Life Cycle Environmental Impact Assessment of Methane Emissions from the Biowaste Management Strategy of the United Kingdom: Towards Net Zero Emissions' (2022) 376 *Journal of Cleaner Production* 134229 https://doi.org/10.1016/j.jclepro.2022.134229
44. David Teece, 'A Wider-Aperture Lens for Global Strategic Management: The Multinational Enterprise in a Bifurcated Global Economy' (2022) 12 *Global Strategy Journal* 488 https://doi.org/10.1002/gsj.1462
45. International Organization for Standardization, ISO 50001:2018 Energy management systems — Requirements with guidance for use (ISO 2018) cl 6 .3 (Energy Review).
46. Hassan Qudrat-Ullah, 'Systems Thinking for Climate Change and Clean Energy' (2025) 18 *Energies* https://doi.org/10.3390/en18154200
47. AJ Stark, 'Corporate Climate Initiatives: A Meta-Analysis of Case Studies' (2020) 12(3) Journal of Sustainable Business 45.
48. International Organization for Standardization, ISO 50001:2018 Energy management systems — Requirements with guidance for use (ISO 2018) cls 6.3, 6.4.
49. Abdolvahhab Fetanat, Mohsen Tayebi and Elham Gholampour, 'Evaluation of Methane Emissions Reduction Methods in the Oil and Natural Gas Operations Using a Decision Support System under Quartic Fuzzy DEAMEIM-MARCOS Model' (2025) 11 *Cleaner Chemical Engineering* https://doi.org/10.1016/j.clce.2025.100186
50. ISO, *ISO 50001 — Energy Management* (ISO, no date) https://www.iso.org/iso-50001-energy-management.html accessed 24 September 2025.

51. Evangelos Psomas, 'The Effectiveness of the ISO 9001 Quality Management System in Service Companies' (2013) 24 Total Quality Management & Business Excellence 769.
52. ISO, *ISO 50001 — Energy Management* (ISO, no date) https://www.iso.org/iso-50001-energy-management.html accessed 24 September 2025.
53. ISO, *ISO 14001:2015 – Environmental Management Systems: Requirements with Guidance for Use* (ISO, 2015, last reviewed 2025) https://www.iso.org/standard/60857.html accessed 27 September 2025.
54. A Costantiello, L Laureti, A Quarto and A Leogrande, 'Methane Emissions in the ESG Framework at the World Level' (2025) 4(1) *Methane* 3 https://doi.org/10.3390/methane4010003
55. Task Force on Climate-related Financial Disclosures (TCFD), 'Home' https://www.fsb-tcfd.org/ accessed 27 September 2025.
56. International Organization for Standardization, ISO 50001:2018 Energy management systems — Requirements with guidance for use (ISO 2018) cls 6.2–6.6.
57. United Nations Economic Commission for Europe (UNECE), Best Practice Guidance for Effective Methane Management in the Oil and Gas Sector: Monitoring, Reporting and Verification (MRV) and Mitigation (UNECE 2021) <https://unece.org/sites/default/files/2021-09/ECE_ENERGY_121.pdf> accessed 30 March 2026.
58. Bon Lau, 'What Are the Major Sources of Methane in the Atmosphere?' (Earth.Org, 12 December 2022) https://earth.org/sources-of-methane-in-the-atmosphere/ accessed 24 September 2025.
59. Hossein Maazallahi, Julianne Fernandez, Malika Menoud, Daniel Zavala-Araiza, Zachary Weller, Stefan Schwietzke, Joe von Fischer, Hugo Denier van der Gon and Thomas Röckmann, 'Methane Mapping, Emission Quantification, and Attribution in Two European Cities: Utrecht (NL) and Hamburg (DE)' (2020) 20 *Atmospheric Chemistry and Physics* 14717 https://doi.org/10.5194/acp-20-14717-2020
60. OECD, *Methane Abatement in Developing Countries: Regulations, Incentives and Finance* (OECD Publishing, 2024) https://www.oecd.org/content/dam/oecd/en/publications/reports/2024/11/methane-abatement-in-developing-countries_c700c885/f3618a78-en.pdf accessed 27 September 2025.
61. UNECE, *Best Practice Guidance for Effective Methane Management in the Oil and Gas Sector: Monitoring, Reporting and Verification (MRV) and Mitigation* (UNECE, no date) https://unece.org/fileadmin/DAM/energy/images/CMM/CMM_CE/Best_Practice_Guidance_for_Effective_Methane_Management_in_the_Oil_and_Gas_Sector__Monitoring__Reporting_and_Verification__MRV__and_Mitigation-_FINAL__with_covers_.pdf accessed 27 September 2025.
62. United Nations Economic Commission for Europe (UNECE), *Best Practice Guidance for Effective Methane Management in the Oil and Gas Sector: Monitoring, Reporting and Verification (MRV) and Mitigation* (Energy Series No. 65, ECE/ENERGY/129, 2019) https://unece.org/fileadmin/DAM/energy/images/CMM/CMM_CE/Best_Practice_Guidance_for_Effective_Methane_Management_in_the_Oil_and_Gas_Sector__Monitoring__Reporting_and_Verification__MRV__and_Mitigation-_FINAL__with_covers_.pdf accessed 27 September 2025.
63. Kunakair, 'Methane Pollution: Impact on the Environment, Health, and Climate' (Kunakair, 7 January 2025) https://kunakair.com/methane-pollution/ accessed 27 September 2025.
64. Task Force on Climate-related Financial Disclosures (TCFD), 'Home' https://www.fsb-tcfd.org/ accessed 27 September 2025.
65. Ibid
66. Oil & Gas Methane Partnership 2.0 (OGMP 2.0), 'Home' https://ogmpartnership.com/ accessed 27 September 2025.
67. UNECE, *Best Practice Guidance for Effective Methane Management in the Oil and Gas Sector: Monitoring, Reporting and Verification (MRV) and Mitigation* (UNECE, no date) https://unece.org/fileadmin/DAM/energy/images/CMM/CMM_CE/Best_Practice_Guidance_for_Effective_Methane_Management_in_the_Oil_and_Gas_Sector__Monitoring__Reporting_and_Verification__MRV__and_Mitigation-_FINAL__with_covers_.pdf accessed 27 September 2025.
68. OECD, *Targeting Methane Emissions to Mitigate the Risk of Climate Overshoot* (OECD, 30 April 2025) https://www.oecd.org/content/dam/oecd/en/publications/reports/2025/04/targeting-methane-emissions-to-mitigate-the-risk-of-climate-overshoot_92b5b4c3/5fa37719-en.pdf accessed 27 September 2025
69. Larcker, D., et al., 2021. Seven Myths of ESG. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3956044 accessed 1 November 2025
70. Villasuso et al, ESG Strategies in The Oil and Gas Industry from the Maritime & Logistics Perspective - Opportunities & Risks. Available from https://onepetro.org/SPEADIP/proceedings-abstract/23ADIP/23ADIP/D041S129R004/535101 accessed 1 November 2025
71. ISO, *ISO 14001:2015 – Environmental Management Systems: Requirements with Guidance for Use* (ISO, 2015, last reviewed 2025) https://www.iso.org/standard/60857.html accessed 27 September 2025.
72. ISO, *ISO 50001 — Energy Management* (ISO, no date) https://www.iso.org/iso-50001-energy-management.html accessed 24 September 2025.
73. Heidi Fuchs, Arian Aghajanzadeh and Peter Therkelsen, 'Identification of Drivers, Benefits, and Challenges of ISO 50001 through Case Study Content Analysis' (2020) 142 *Energy Policy* 111443 <https://doi.org/10.1016/j.enpol.2020.111443> accessed 27 February 27 2026
74. UNECE, *Best Practice Guidance for Effective Methane Management in the Oil and Gas Sector: Monitoring, Reporting and Verification (MRV) and Mitigation* (UNECE, no date) https://unece.org/fileadmin/DAM/energy/images/CMM/CMM_CE/Best_Practice_Guidance_for_Effective_Methane_Management_in_the_Oil_and_Gas_Sector__Monitoring__Reporting_and_Verification__MRV__and_Mitigation-_FINAL__with_covers_.pdf accessed 27 September 2025.
75. ISO, *ISO 50001 — Energy Management* (ISO, no date) https://www.iso.org/iso-50001-energy-management.html accessed 24 September 2025.
76. Ibid

77. ISO, *ISO 14001:2015 – Environmental Management Systems: Requirements with Guidance for Use* (ISO, 2015, last reviewed 2025) https://www.iso.org/standard/60857.html accessed 27 September 2025.
78. Luis Fonseca, 'ISO 9001 Quality Management Systems through the Lens of Organizational Culture' (2015) 16 *Quality – Access to Success* 54.
79. Oil and Gas Climate Initiative (OGCI), *Recommended Practices for Methane Emissions Detection and Quantification Technologies – Upstream* (Report 661, September 2023) https://www.ogci.com/wp-content/uploads/2023/10/661.pdf accessed 27 September 2025.
80. PRI, 'Reducing Company Methane Emissions' (PRI, 1 February 2017) https://www.unpri.org/environmental-issues/reducing-company-methane-emissions/591.article accessed 27 September 2025.
81. UNECE, *Best Practice Guidance for Effective Methane Management in the Oil and Gas Sector: Monitoring, Reporting and Verification (MRV) and Mitigation* (UNECE, no date) https://unece.org/fileadmin/DAM/energy/images/CMM/CMM_CE/Best_Practice_Guidance_for_Effective_Methane_Management_in_the_Oil_and_Gas_Sector__Monitoring__Reporting_and_Verification__MRV__and_Mitigation-_FINAL__with_covers_.pdf accessed 27 September 2025.
82. International Energy Agency (IEA), *Driving Down Methane Leaks from the Oil and Gas Industry* (IEA, 18 January 2021) https://www.iea.org/reports/driving-down-methane-leaks-from-the-oil-and-gas-industry accessed 27 September 2025.
83. ISO, ISO 14001:2015 – Environmental Management Systems: Requirements with Guidance for Use (ISO 2015, last reviewed 2021) <https://www.iso.org/standard/60857.html> accessed 1 April 2026.
84. UNECE, *Best Practice Guidance for Effective Methane Management in the Oil and Gas Sector: Monitoring, Reporting and Verification (MRV) and Mitigation* (UNECE, no date) https://unece.org/fileadmin/DAM/energy/images/CMM/CMM_CE/Best_Practice_Guidance_for_Effective_Methane_Management_in_the_Oil_and_Gas_Sector__Monitoring__Reporting_and_Verification__MRV__and_Mitigation-_FINAL__with_covers_.pdf accessed 27 September 2025.
85. Bon Lau, 'What Are the Major Sources of Methane in the Atmosphere?' (Earth.Org, 12 December 2022) https://earth.org/sources-of-methane-in-the-atmosphere/ accessed 24 September 2025.
86. International Energy Agency (IEA), *Driving Down Methane Leaks from the Oil and Gas Industry* (IEA, 18 January 2021) https://www.iea.org/reports/driving-down-methane-leaks-from-the-oil-and-gas-industry accessed 27 September 2025.
87. Ibid
88. Maria Olczak, Andris Piebalgs and Paul Balcombe, 'A Global Review of Methane Policies Reveals that Only 13% of Emissions Are Covered with Unclear Effectiveness' (2023) 6(5) *One Earth* 519 https://doi.org/10.1016/j.oneear.2023.04.009
89. TP Europe, 'Mastering Methane Regulations: Our Essential 2024 Guide' (TP Europe, 6 August 2024) https://tpeurope-em.com/our-guide-to-understanding-methane-regulations/ accessed 27 September 2025.
90. UNECE, *Best Practice Guidance for Effective Methane Management in the Oil and Gas Sector: Monitoring, Reporting and Verification (MRV) and Mitigation* (UNECE, no date) https://unece.org/fileadmin/DAM/energy/images/CMM/CMM_CE/Best_Practice_Guidance_for_Effective_Methane_Management_in_the_Oil_and_Gas_Sector__Monitoring__Reporting_and_Verification__MRV__and_Mitigation-_FINAL__with_covers_.pdf accessed 27 September 2025.
91. A Costantiello, L Laureti, A Quarto and A Leogrande, 'Methane Emissions in the ESG Framework at the World Level' (2025) 4(1) *Methane* 3 https://doi.org/10.3390/methane4010003
92. ISO, *ISO 14001:2015 – Environmental Management Systems: Requirements with Guidance for Use* (ISO, 2015, last reviewed 2025) https://www.iso.org/standard/60857.html accessed 27 September 2025.
93. ISO, *ISO 50001 — Energy Management* (ISO, no date) https://www.iso.org/iso-50001-energy-management.html accessed 24 September 2025.
94. ASQ, 'Environmental Management Case Studies & ISO 14001 Articles' (ASQ, n.d.) https://asq.org/quality-resources/environmental-management-system/case-studies accessed 27 February 26
95. Agents of sustainable change: the importance of leadership and responsibility in corporate sustainability' (2025) 5 Frontiers in Sustainability <https://www.frontiersin.org/journals/sustainability/articles/10.3389/frsus.2024.1490669/full> accessed 27 February 2026
96. Volha Roshchanka, 'The Role of Measurement, Reporting & Verification in Methane Management' (UNECE/Global Methane Initiative, 2021) <https://unece.org/sites/default/files/2021-09/Tech%20MM%203%20Roshchanka%20-%20GMI_MRV%20in%20CH4%20Management_2021-0921.pdf> accessed 27 February 2026
97. International Energy Agency (IEA), *Driving Down Methane Leaks from the Oil and Gas Industry* (IEA, 18 January 2021) https://www.iea.org/reports/driving-down-methane-leaks-from-the-oil-and-gas-industry accessed 27 September 2025.
98. UNECE, *Best Practice Guidance for Effective Methane Management in the Oil and Gas Sector: Monitoring, Reporting and Verification (MRV) and Mitigation* (UNECE, no date) https://unece.org/fileadmin/DAM/energy/images/CMM/CMM_CE/Best_Practice_Guidance_for_Effective_Methane_Management_in_the_Oil_and_Gas_Sector__Monitoring__Reporting_and_Verification__MRV__and_Mitigation-_FINAL__with_covers_.pdf accessed 27 September 2025.
99. Bon Lau, 'What Are the Major Sources of Methane in the Atmosphere?' (Earth.Org, 12 December 2022) https://earth.org/sources-of-methane-in-the-atmosphere/ accessed 24 September 2025.
100. UNECE, *Best Practice Guidance for Effective Methane Management in the Oil and Gas Sector: Monitoring, Reporting and Verification (MRV) and Mitigation* (UNECE, no date)

https://unece.org/fileadmin/DAM/energy/images/CMM/CMM_CE/Best_Practice_Guidance_for_Effective_Methane_Management_in_the_Oil_and_Gas_Se
_FINAL__with_covers_.pdf accessed 27 September 2025.

101. OECD, *Targeting Methane Emissions to Mitigate the Risk of Climate Overshoot* (OECD, 30 April 2025) https://www.oecd.org/content/dam/oecd/en/publications/reports/2025/04/targeting-methane-emissions-to-mitigate-the-risk-of-climate-overshoot_92b5b4c3/5fa37719-en.pdf accessed 27 September 2025
102. UNECE (2021), Best Practice Guidance for Effective Methane Management in the Oil and Gas Sector: Monitoring, Reporting and Verification (MRV) and Mitigation. https://unece.org/fileadmin/DAM/energy/images/CMM/CMM_CE/Best_Practice_Guidance_for_Effective_Methane_Management_in_the_Oil_and_Gas_Se
FINAL_with_covers_.pdf - accessed 1 November 2025
103. EDF & MethaneSAT (2023), MethaneSAT Technical Overview. https://www.methanesat.org accessed 1 November 2025
104. IEA (2021), Driving Down Methane Leaks from the Oil and Gas Industry. https://www.iea.org/reports/driving-down-methane-leaks-from-the-oil-and-gas-industry accessed 1 November 2025
105. OGCI (2023), Recommended Practices for Methane Emissions Detection and Quantification Technologies – Upstream. https://www.ogci.com/wp-content/uploads/2023/10/661.pdf accessed 1 November 2025
106. World Bank (2022), Digital MRV for Methane: Emerging Technologies and Use Cases. https://www.worldbank.org/en/topic/climatechange/publication/digital-mrv-for-methane accessed 1 November 2025
107. United Nations Environment Programme (UNEP), 'Methane Emissions Are Driving Climate Change. Here's How to Reduce Them' (UNEP, 20 August 2021) https://www.unep.org/news-and-stories/story/methane-emissions-are-driving-climate-change-heres-how-reduce-them accessed 27 September 2025.
108. E Wójcik-Gront and A Wnuk, 'Evaluating Methane Emission Estimates from Intergovernmental Panel on Climate Change Compared to Sentinel-Derived Air–Methane Data' (2025) 17 *Sustainability* 850 https://doi.org/10.3390/su17030850
109. John W Creswell, Research Design: Qualitative, Quantitative, and Mixed Methods Approaches (4th edn, SAGE 2014) 14–17; UNEP, 'Oil and Gas Methane Partnership (OGMP) 2.0 Framework' (2020) https://www.unep.org/resources/report/oil-and-gas-methane-partnership-ogmp-20-framework accessed 31 March 2026.
110. International Organization for Standardization, ISO 50001:2018 Energy management systems — Requirements with guidance for use (ISO 2018) cls 6.3–6.6.
111. ISO, *ISO 50001 — Energy Management* (ISO, no date) https://www.iso.org/iso-50001-energy-management.html accessed 24 September 2025.
112. ISO, *ISO 50001 — Energy Management* (ISO, no date) https://www.iso.org/iso-50001-energy-management.html accessed 24 September 2025.
113. Clean Energy Ministerial, 'ISO 50001 Energy Management System Case Study: 3M Global' (2022) <https://www.cleanenergyministerial.org/content/uploads/2022/03/cem-em-casestudy-3m-global-1.pdf> accessed 27 February 2026
114. Vera Ferrón-Vílchez, 'The Dark Side of ISO 14001: The Symbolic Environmental Behavior' (2017) 23(1) European Research on Management and Business Economics 33; Directive (EU) 2024/1760 of the European Parliament and of the Council of 13 June 2024 on corporate sustainability due diligence and amending Directive (EU) 2019/1937 [2024] OJ L1760.
115. Bon Lau, 'What Are the Major Sources of Methane in the Atmosphere?' (Earth.Org, 12 December 2022) https://earth.org/sources-of-methane-in-the-atmosphere/ accessed 24 September 2025.
116. ISO, *ISO 14001:2015 – Environmental Management Systems: Requirements with Guidance for Use* (ISO, 2015, last reviewed 2025) https://www.iso.org/standard/60857.html accessed 27 September 2025.
117. Task Force on Climate-related Financial Disclosures (TCFD), 'Home' https://www.fsb-tcfd.org/ accessed 27 September 2025.
118. Climate & Clean Air Coalition and United Nations Environment Programme, Global Methane Assessment (2021) <https://www.ccacoalition.org/resources/global-methane-assessment-full-report> accessed 27 February 2026
119. International Energy Agency (IEA), *Driving Down Methane Leaks from the Oil and Gas Industry* (IEA, 18 January 2021) https://www.iea.org/reports/driving-down-methane-leaks-from-the-oil-and-gas-industry accessed 27 September 2025.
120. A Costantiello, L Laureti, A Quarto and A Leogrande, 'Methane Emissions in the ESG Framework at the World Level' (2025) 4(1) *Methane* 3 https://doi.org/10.3390/methane4010003