

A Review of Energy and Emission Management Standards, Implementation and Integration Approaches

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The global push for sustainable development and decarbonization has increased the urgency of managing energy and greenhouse gas (GHG) emissions across sectors. Industrial facilities and institutions, including universities, are under growing pressure to meet regulatory standards while improving efficiency and sustainability performance. However, most energy and emissions management systems have developed in isolation, resulting in fragmented implementation, duplicated audits, and inefficient data management. This highlights the need for integrated systems that jointly address energy and GHGs within a unified framework to enhance compliance and impact. This review aims to benchmark globally implemented energy and emissions management systems, with a focus on frameworks that offer unified or complementary approaches in terms of scope, integration potential, governance structure, and sectoral relevance. Through a critical examination of academic literature and national policy documents, the review identifies both the strengths and limitations of current frameworks, emphasizing the need for harmonized standards that bridge the energy and emissions domains. The findings propose a unified framework for energy and emission management systems to support organizational sustainability efforts and align with broader climate and energy transition goals.

1. Introduction

Energy systems are among the most significant contributors to global greenhouse gas (GHG) emissions, particularly in industrial and institutional sectors, due to the usage of fossil-based fuels (Addo et al., 2023). As the global climate crisis intensifies, organizations across sectors face increasing pressure to reduce GHG emissions while improving energy efficiency (Nepal et al., 2021). The International Energy Agency (IEA) reported that energy efficiency measures could contribute up to 40 % of the emissions reductions needed by 2040 to meet the climate goal (IEA, 2021). On the other hand, industrial facilities and institutional sectors, including universities, are increasingly subject to evolving regulatory requirements and societal expectations in the pursuit of sustainable development. Thus, there is a significant need for the organization to measure and manage its energy and emissions simultaneously (Jasim et al., 2025). Despite the inherent link between energy consumption and emissions, most existing management systems have evolved independently, resulting in fragmented implementation, redundant audits, and inefficient data processes (Körner et al., 2024). These inefficiencies not only strain organizational resources but also create misaligned incentives, where energy efficiency improvements may not directly translate to measurable emission reductions under disparate frameworks.

While a broad range of frameworks has emerged, such as ISO 50001 for energy management and ISO 14064 for GHG accounting and emissions tracking, there is a limited synthesis of how these systems operate in tandem or could be harmonized to support integrated sustainability objectives. This gap is particularly critical considering global net-zero commitments, such as the Paris Agreement, which demand cohesive strategies to bridge energy and emission targets.

This review aims to benchmark existing energy and emission management systems implemented globally with a particular focus on management systems that address both elements in a unified or complementary manner

in terms of scope, integration capabilities, governance structures, and sectoral relevance. Key systems analyzed include ISO 50001 (Energy Management), ISO 14064 (GHG Accounting), the EU's EMAS, the U.S. EPA's ENERGY STAR program, and the chemical sector's Together for Sustainability (TfS) initiative. Drawing on international standards, policy documents, and peer-reviewed literature, this review focuses on globally recognized systems with relevance across industrial and non-industrial contexts. The findings aim to inform policy, organizational practice, and future research, guiding a more coherent model for energy and emissions governance.

2. Key Concepts and Systemic Challenges in Energy and GHG Emission Management

Managing energy consumption and greenhouse gas (GHG) emissions has become a critical priority for organizations seeking to align with sustainability goals, regulatory mandates, and stakeholder expectations. However, despite the close interdependence between energy use and emissions generation, most organizations continue to address these two areas through separate management systems. This section outlines the foundational concepts of energy and emissions management, highlighting the structural and operational challenges that hinder their integration.

2.1 Energy Management

Energy management encompasses the strategies, practices, and technologies that organizations implement to monitor, control, and optimize energy use, aiming to enhance energy efficiency, reduce costs, and minimize environmental impact (Kanneganti et al., 2017). It is a critical aspect of sustainable development and corporate social responsibility, influencing various sectors, including manufacturing, commercial buildings, and public facilities (Hasan et al., 2021). Globally, several standards have been developed to support energy management, ISO 50001:2018 (Energy Management Systems), ISO 50002:2014 (Energy Audits), AS/NZS 3598:2014 (Energy Audits - Australia and New Zealand), and EN 16001:2009 (Energy Management Systems - Europe) (Kanneganti et al., 2017). However, the scope of this review is limited to ISO 50001, the European Union's EMAS, and the U.S. EPA's ENERGY STAR program due to their widespread adoption, cross-sector applicability, and distinct governance models. ISO 50001 is recognized globally as a leading standard for energy management systems, aiming to influence up to 60 % of the world's energy use (Marimon and Casadesús, 2017). Energy management plays a critical role in reducing greenhouse gas (GHG) emissions and promoting renewable energy by identifying inefficiencies in energy use and enabling targeted interventions (Monjurul Hasan and Trianni, 2020), thereby reinforcing the need to integrate energy management practices with GHG emissions strategies.

2.2 Greenhouse Gas Emissions Management (GHGMS)

Greenhouse Gas Management Systems, on the other hand, are designed to help organizations measure, report, and verify their emissions, which are governed by standards such as ISO 14064 (ISO, 2018a). GHGMS are increasingly essential for organizations participating in emissions trading schemes, carbon disclosure platforms such as the Carbon Disclosure Project (CDP), and corporate ESG reporting. However, most GHGMS are not operationally linked to energy management systems, although energy-related emissions, particularly from fuel combustion and electricity use, account for the largest share of reported GHGs. This lack of integration leads to redundancies in data collection, disjointed audit procedures, and misalignment between energy savings initiatives and emissions targets.

3. Review of Major Frameworks and Standards

To evaluate current energy and greenhouse gas emissions management strategies, this section critically examines five globally recognized frameworks. The European Union EMAS, the U.S. EPA's ENERGY STAR program, ISO 50001, ISO 14064, and the Together for Sustainability (TfS) project are among the standards that represent a range of institutional and industrial approaches. Each is reviewed according to its operational focus, scope, sectoral application, and possibility for integration into a single system for managing GHGs and energy.

3.1 ISO 50001 – Energy Management System (EnMS)

ISO 50001:2018 is a globally recognized standard developed by the International Organization for Standardization (ISO) that provides a structured framework for establishing, implementing, maintaining, and improving an energy management system (EnMS). The standard follows the Plan-Do-Check-Act (PDCA) cycle, ensuring continuous improvement in energy performance (Damasceno et al., 2024). It requires organizations to develop an energy policy, conduct energy reviews, establish energy performance indicators (EnPIs), and implement an energy action plan (Damasceno et al., 2024). ISO 50001 is designed to integrate seamlessly with other ISO standards, including ISO 9001 (Quality Management) and ISO 14001 (Environmental Management)

(Kohl, 2020). The standard is certifiable, allowing organizations to demonstrate compliance with energy efficiency regulations and best practices on a global scale (ISO, 2018b).

3.2 ISO 14064 – GHG Accounting and Verification

ISO 14064 provides a strong framework for measuring, disclosing, and confirming greenhouse gas emissions at the project and organizational levels (ISO, 2018a). It enhances the credibility and transparency of GHG accounting and is divided into three components, which are emissions reporting, project-based reductions, and verification. The standard is intended to enhance transparency, consistency, and reliability in GHG accounting processes across various sectors (Wang et al., 2023). Implementing ISO 14064 enables organizations to develop a credible GHG inventory, which forms the basis for evaluating emissions management strategies and compliance with regulatory requirements. Its principles help organizations to report an accurate and fair account of their emissions, thus facilitating participation in both voluntary and mandatory carbon markets (Wang et al., 2023). Various studies have confirmed that ISO 14064 is widely recognized and employed globally, offering detailed requirements that organizations must meet for effective GHG management (Oblitas-Romero et al., 2023).

3.3 European Union EMAS

The European Union's Eco-Management and Audit Scheme (EMAS), established in 1993, supports organizations in evaluating and improving environmental performance through a verified environmental management system. A foundational aspect of EMAS is its emphasis on a credible and transparent public disclosure of an organization's environmental performance, which is validated by independent auditors to ensure reliability and credibility (García-Álvarez and de Junguitu, 2023). EMAS incorporates GHG emissions and energy use into a more comprehensive environmental framework, necessitating externally validated reporting that contains these indicators (Ociepa-Kubicka et al., 2021). However, most of its adoption is still EU-centric, and its strict criteria make it difficult for SMEs to implement globally. Furthermore, its restricted compatibility with ISO 14064 makes a harmonized application more difficult (Laskurain et al., 2017).

3.4 US EPA's ENERGY STAR Program

ENERGY STAR is a voluntary program introduced by the U.S. Environmental Protection Agency (EPA) in 1992, promoting energy efficiency in both the commercial and residential sectors. It is a top certification in the US, assisting in the reduction of emissions and offering trustworthy data on energy-saving solutions (Houde, 2022). ENERGY STAR is effective at promoting energy awareness and operational improvements, particularly in the building sector. For instance, buildings achieving ENERGY STAR certification typically use 25 % less energy than their peers (Barbosa et al., 2024). The program's simplicity and cost-effectiveness make it highly scalable, especially in the public sector and educational institutions. However, the program lacks formal GHG emissions tracking or verification despite helping in the energy management strategy (Barbosa et al., 2024). While it contributes indirectly to emissions reductions through improved energy performance, it does not provide tools or guidance for GHG accounting. As such, ENERGY STAR is best viewed as a supporting framework that complements more comprehensive systems, such as ISO 14064.

3.5 Together for Sustainability

Together for Sustainability (TfS) is an industry-led initiative launched by leading chemical companies to enhance sustainability performance across global supply chains. One of TfS's key contributions is the development of a Product Carbon Footprint (PCF) Guideline, which provides a harmonized approach for calculating and reporting carbon footprints at the product level. This guideline supports alignment with ISO standards and broader frameworks such as the UN Global Compact and aims to improve consistency, transparency, and comparability of PCF data among suppliers (TfS, 2024a). By incorporating sustainability, especially GHG-related measures, into procurement procedures, TfS encourages integration and influence of the upstream and downstream supply chain partners. By 2024, the program will have expanded to over 54 member businesses and evaluated over 20,000 suppliers (TfS, 2024b). Although TfS is not a standalone energy or emissions management system, its PCF guideline represents a practical step toward operationalizing carbon accounting at the product and supply chain level. This makes TfS a promising model for integrating emissions management into procurement policies, particularly in complex, globalized industries such as the chemicals and manufacturing sectors.

4. Comparative Analysis and Synthesis

This section synthesizes findings from the five frameworks discussed in Section 3, focusing on their comparative strengths, limitations, and potential for integration between energy and GHG emissions management. The analysis reveals key operational patterns and structural inconsistencies that hinder the development of coherent,

cross-functional sustainability systems. Table 1 summarizes the core characteristics of ISO 50001, ISO 14064, EMAS, ENERGY STAR, and Together for Sustainability (TfS). It assesses each framework's emphasis on energy and GHG emissions, its integration capability, governance model, and sectoral relevance.

Table 1: Comparison of Major Energy and Emissions Management Frameworks

| Framework | Energy Focus | GHG Focus | Integration Capability | Governance Model | Sectoral Applicability |
|-----------------------------------|--|---|---|--|--|
| ISO 50001 | Strong, structured approach to improving energy efficiency | Indirect; emissions reductions are an outcome of energy savings, but not explicitly tracked | Limited; does not include emissions monitoring or reporting mechanisms | Voluntary, certifiable by third-party auditors | Widely used across industrial, institutional, and public sectors |
| ISO 14064 | Limited; includes some energy-related data, but not focused on energy use efficiency | Strong; primary standard for emissions quantification and verification | Limited; not operationally integrated with energy management practices | Voluntary, with optional third-party verification | Broad applicability in corporate, governmental, and non-profit sectors |
| EU EMAS | Moderate; incorporates energy performance indicators into broader environmental reporting | Moderate; includes GHG emissions in verified public statements | High; combines environmental, energy, and emissions metrics in one framework | EU-regulated voluntary scheme requiring public disclosure | Mostly adopted within the EU, with some international uptake |
| ENERGY STAR | Strong focus on energy benchmarking and performance improvement in buildings and equipment | None; does not include emissions accounting or reporting | Low; no structural mechanisms to align energy metrics with carbon tracking | Government-administered (U.S. EPA) | Primarily used in the building, commercial, and institutional sectors |
| Together for Sustainability (TfS) | Moderate; energy use is part of supplier sustainability assessments | Moderate; emissions performance is evaluated in supply chain audits | Moderate; encourages combined reporting through procurement criteria, but not a formal system | Industry-led, collaborative governance by member companies | Chemical sector and industrial supply chains worldwide |

This comparative table highlights the varied scope and functionality of five primary energy and GHG management frameworks. ISO 50001 and ISO 14064 are complementary but were designed to serve different purposes. ISO 50001 focuses on operational energy efficiency but lacks provisions for emissions accounting, whereas ISO 14064 emphasizes emissions tracking without providing tools for energy performance. Their parallel implementation often leads to fragmented practices. The capacity to integrate makes EMAS unique. Although its complexity and regional concentration have hindered its global acceptance, it integrates energy, emissions, and other environmental indicators into a single, publicly certified system. Widely used in institutional settings, ENERGY STAR is an excellent tool for evaluating energy performance. However, it falls short as a stand-alone sustainability tool because it does not include information related to emissions. Together for Sustainability (TfS) provides an industry-driven concept of procurement-based embedded sustainability. Although it does not serve as a formal management system, it encourages supply chain strategies to incorporate energy and carbon issues. Overall, Table 1 illustrates that while some frameworks offer partial alignment between energy and emissions management, none provides complete integration. This reinforces the paper's core argument, which is the need for a unified system that addresses both domains under a shared framework.

4.1 The Need for a Unified Framework

The division between energy management and greenhouse gas (GHG) emissions management systems has led to considerable inefficiencies, including overlapping data collection, inconsistent performance metrics, and disorganized strategic planning. This fractured structure resulted in operational silos, which impede a comprehensive approach to sustainability performance and prevent organizations from synchronizing efficiency

enhancements with decarbonization objectives. To address these issues, a proposed Unified Energy and Emissions Management System Framework has been created, as depicted in Figure 1. The framework was formulated from an extensive review of five major international standards, which are ISO 50001, ISO 14064, EMAS, ENERGY STAR, and the TfS guideline, and supplemented by findings from a gap analysis derived from industrial case studies and qualitative feedback gathered from stakeholder interviews with facility managers and sustainability officers. The analysis revealed significant differences in energy and emissions management, including data systems, audit frequency, strategic priorities, organizational accountability, reporting, and performance metrics. These differences have led to several significant integration challenges, including the division of team roles, a lack of data interoperability, duplicate reporting practices, inconsistent key performance indicators, and misaligned planning objectives.

The proposed unified framework, as shown in the bottom part of Figure 1, addresses these issues by promoting integrated data management, synchronized auditing protocols, standard reporting formats, and a shared governance structure that supports both regulatory compliance and strategic decision-making. Specifically, the framework comprises three key components, which are firstly, a unified data templates that harmonize energy and emissions data collection to reduce duplication and enhance interoperability. Secondly, integrated planning enables the joint setting of energy and GHG targets, aligning energy efficiency with decarbonization goals through shared key performance indicators (KPIs), such as energy use per unit of CO₂e. Thirdly, data governance and verification introduce shared audit mechanisms and standardized protocols to support transparent reporting and enable the auto-generation of sustainability reports for both internal and external use. By combining energy efficiency and emissions reduction efforts into a cohesive system, the framework provides a structured pathway for organizations to move beyond fragmented practices and toward a more holistic, efficient, and future-ready sustainability model.

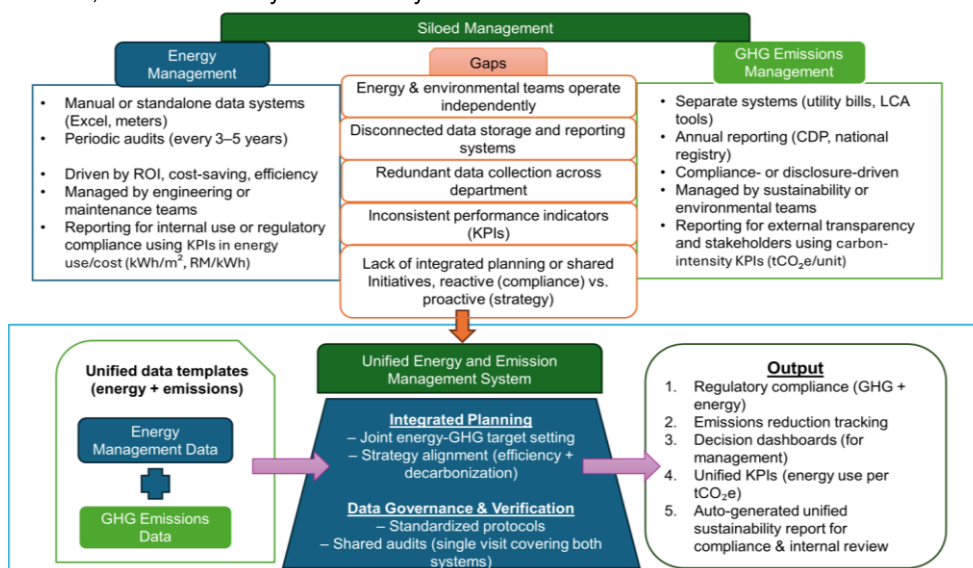


Figure 1: A Proposed Unified Energy and Emission Management System Framework

5. Conclusion

The ongoing fragmentation between energy and greenhouse gas (GHG) emissions management is highlighted in this review. Although frameworks like ISO 50001 and ISO 14064 provide valuable resources for emissions accounting and energy performance, respectively, they are not integrated, resulting in inefficiencies and redundant work, including EMAS, ENERGY STAR, or TfS. Organizations aiming to fulfill their sustainability objectives and adhere to climate policies face difficulties due to this disconnect. Therefore, it is necessary to have a unified framework that is flexible across industries, has shared indications, modular design, and digital interoperability. To ensure that this framework is scalable and effective in furthering decarbonization objectives, future research should focus on applying and evaluating this framework in a real-world setting.

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