FROM EMISSIONS REPORTING TO OPERATIONAL GOVERNANCE

Carlos Ruiz, Nicolás Carrara, and Michelle Wicmandy, KBC (A Yokogawa Company),
outline the importance of aligning real-time operations, auditability, and regulatory disclosure in the refining sector.

The question is no longer whether refiners report emissions, but whether those numbers can be defended under operational and financial scrutiny.

What was once an annual compliance exercise is now a continuous operational responsibility. Regulatory frameworks governing emissions and sustainability reporting are expanding worldwide. These frameworks place greater emphasis on timely, auditable, activity-based greenhouse gas (GHG) emissions data rather than annual, factor-based estimates. In response, refiners must be able to show how emissions evolve under real operating conditions and produce reporting that stands up to internal and external audits.

Environmental and sustainability-related disclosures are increasingly treated as decision-making inputs for capital allocation, risk management, and corporate oversight. As a result, disclosure must do more than summarise past performance.

In this context, traditional emissions reporting functions like a rear-view mirror. It is accurate but only shows opportunities that have passed. If the refinery utilities system is not operated properly, it drives emissions as well as inefficient use of resources and capital. Integrated energy and emissions management systems act more like an instrument panel, proactively detecting and responding to deviations.

If emissions data cannot be traced, reconciled, and explained at an operational level, how defensible is the resulting disclosure? And, how actionable is it for management?

From an operational and financial perspective, emissions and energy system performance can create associated material costs, as shown in Table 1.

Yet, many refiners still run their environmental, social, and governance (ESG) and emissions programmes on manual or fragmented data workflows. A recent KPMG study of 550 large companies found that 47% still rely on spreadsheets as their primary ESG data management system, even though 83% believe they outperform their peers.[1] Such tools introduce inconsistent data structures, limited auditability, and siloed practices.

Table 1. Operational conditions and cost drivers influencing emissions performance

Operational conditions	Examples
Sub-optimal utilities operations	Steam venting, inefficient operation of letdowns and wrong selection of turbine/motor drivers, improper internal power production; suboptimal fuel mixes; low condensate recovery
Operational disruptions and asset impacts	Severe weather affecting facilities and supply chains; power grid instability, fuel supply interruptions; load shedding
Operational and infrastructure adaptations to fluctuations	Unit revamps to increase throughput, storage tanks capacity increase
Capital and operating expenses for GHG emissions reduction	High-efficiency or electrified heaters and boilers; advanced process control, energy optimisation; real-time performance monitoring systems; lower-carbon fuel alternatives (e.g., hydrogen, biofuels); renewable power, green hydrogen, investments in CCUS
Compliance and market-related exposure	Emissions trading systems; variable electricity pricing

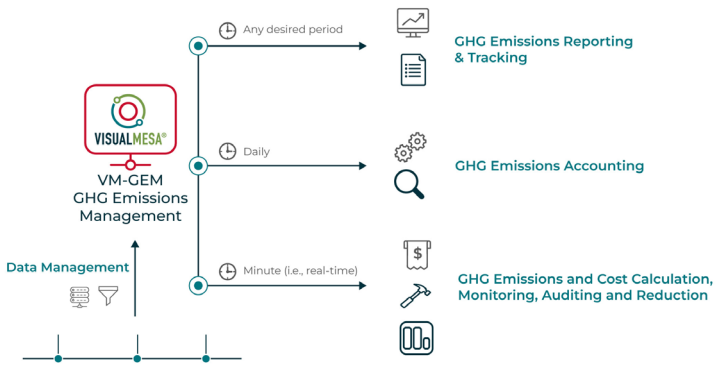

Figure 1. An integrated emissions management workflow supports emissions, costs calculations, and governance across minute, daily, and longer timelines.

These pressures are particularly acute in refining, where emissions arise from diverse, interdependent sources, including fuel combustion, flaring, venting, electrical imports, and hydrogen production. A 2025 review of carbon accounting practices in petroleum refining highlights the complexity and uncertainty inherent in refinery emissions reporting.[2] Static approaches fail to capture real-time variability in operations, fuel mixes, and process configurations. The authors conclude that near-real-time, model-driven accounting and optimisation are increasingly necessary to support transparency, governance, and more defensible reporting.

As a result, many refiners are shifting toward integrated digital emissions management systems that combine real-time monitoring, energy modelling, optimisation, emissions accounting, reconciliation, auditing, and reporting in a single workflow. Figure 1 illustrates this integrated workflow across operational and reporting time horizons.

This shift changes the role of emissions data. So, what changes when emissions are treated not as a year-end output, but as an operational variable that can be monitored and optimised?

This article explores how integrated systems strengthen environmental key performance indicators (KPIs) – carbon emissions, energy consumption, and renewable energy contribution. These KPIs support governance, optimal operational decision-making, and regulatory disclosure.

Emissions/cost-based operations decisions

Emissions are no longer merely a reporting outcome; they function as a leading indicator of operational and energy risk. The IFRS Sustainability Disclosure Standards (ISSB) emphasise the need for clear, comparable, and consistent climate-related financial information that enables investors and stakeholders to understand how climate risks and opportunities are embedded in an organisation's governance, strategy, risk management processes, and metrics and targets.[3] The ISSB standards require that transition and energy-related risks must be identified, assessed, and managed within core business and operational processes – not isolated within annual reporting cycles.

In refining, emissions performance is closely linked to operational factors such as fuel switching, energy system constraints, equipment reliability, and process upsets. These factors directly map policy and regulatory, technology, market, and physical operating risks affecting asset reliability and continuity. Embedding emissions and cost visibility within day-to-day operations allows refiners to detect emerging asset-level risks as they develop. This visibility supports early intervention and more resilient, cost-effective operations.

From energy cost to emissions performance

For decades, energy management focused almost entirely on reducing costs. Emissions and

environmental outcomes were treated as secondary effects. Few sites maintained structured workflows for tracking hydrocarbon losses or emissions intensity. Operational decisions were driven based exclusively on cost.

The shift toward multi-objective optimisation – managing both energy cost and emissions performance – requires an innovative approach, including new KPIs, models, and closer cross-functional collaboration. Industry experience and research show that emissions intensity is highly sensitive to process and utilities system operating conditions. Historically, those conditions were not monitored or optimised with emissions visibility in mind.

This gap becomes problematic given the dynamic nature of refinery operations. Emissions and costs can change minute by minute as operating conditions and prices shift. When emissions are calculated retrospectively, operators miss opportunities to identify deviations, correct abnormal conditions, or optimise high-emitting equipment.

As a result, effective emissions management must operate across multiple time horizons, from real-time operational decisions to periodic reporting and assurance. Advanced systems must calculate accurately at high frequency while aggregating consistently into daily, monthly, and annual views. Figure 2 shows this multi-frequency requirement that underpins emissions management as an ongoing operational discipline rather than a periodic reporting exercise. The recalculation feature is essential for emissions reporting systems. Emissions factors or faulty measurements need to be retrospectively adjusted for certain periods to more precisely reflect actual operating conditions, with all changes captured in an auditable way.

An integrated framework for emissions and cost management

Fragmented emissions tools cannot support modern governance, auditability, or optimal operational decision-making. Advanced GHG emissions management systems instead integrate monitoring, optimisation, accounting, auditing, and reporting within a single operational framework. This design aligns day-to-day execution with governance and disclosure requirements via four independent pillars:

Real-time monitoring

Real-time monitoring continuously calculates emissions using actual fuel compositions, firing rates, equipment loads, flaring and venting behaviour, and electric power factors. This monitoring provides a dynamic emissions view reflecting current operating conditions.

Daily accounting and reconciliation

This pillar aligns operational data with fuel balances, meter corrections, and validated inputs. It supports consistent aggregation into weekly, monthly, and annual reporting. Post-period corrections trigger controlled bulk recalculation while preserving full audit history. Figure 3 shows how an emissions dashboard looks after a recalculation was performed.

Automated auditability and data governance

Automated auditability and date governance track the full lifecycle of every calculation, adjustment, and data input. Figure 4 presents an example of emissions reporting with audit trail visibility by user, asset, emissions source, and reporting period.

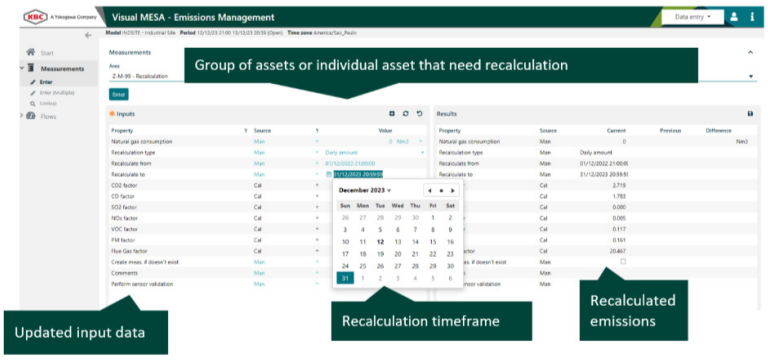

Figure 2. Greenhouse gas (GHG) emissions recalculation in an auditable environment.

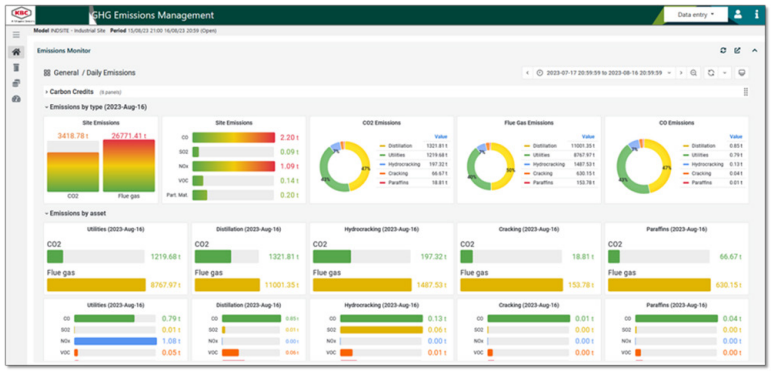

Figure 3. GHG emissions management dashboards.

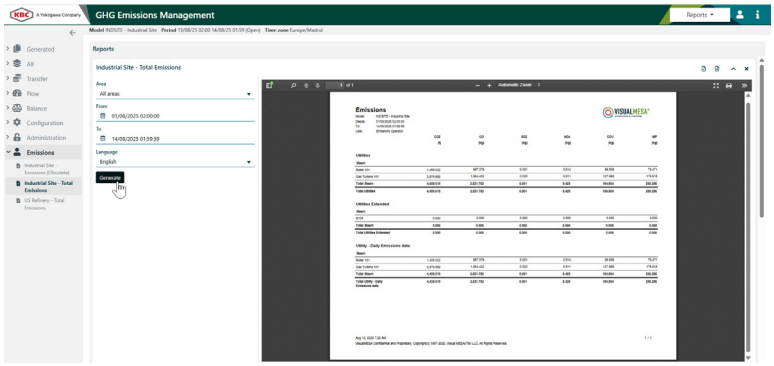

Figure 4. GHG emissions management reporting.

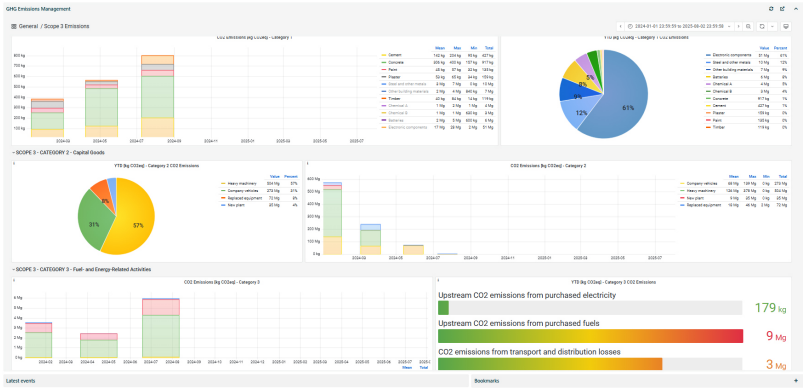

Figure 5. Accounting and reporting for all the 15 Scope 3 categories.

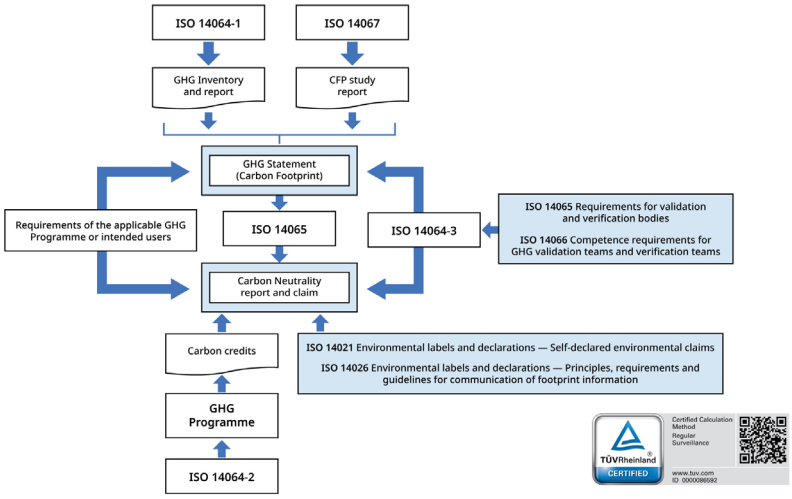

Figure 6. ISO 14068 in relation to other ISO 14060 series standards, illustrating the governance chain linking emissions quantification, reporting, validation, verification, and carbon-related claims.

As refinery energy systems incorporate renewable power, alternative fuels, and electrified assets, operational complexity increases significantly. While many studies have examined the economic impact of renewable integration at the design stage, far fewer address operational execution.

Aligning short-term scheduling decisions with real-time operational constraints becomes critical to maintaining feasibility, profitability, and emissions performance. Without integrated optimisation, emissions reductions may be economically unsustainable.

Integrated optimisation

This evaluates operating scenarios to balance energy cost and emissions output. Shifting loads to more efficient equipment can reduce emissions while lowering cost. KBC's optimisation study for a refinery with a relatively standard utility system configuration identified a cost-emissions trade-off, with a 3% reduction and around US$1 million of savings due to improved overall performance.

Carbon emissions: from estimation to insight

Carbon emissions are no longer just the primary environmental KPI for refiners. They are a real-time operational signal that must be calculated, explained, and defended with precision. In integrated systems, reported emissions reflect actual process and utilities system behaviour rather than relying on averaged assumptions.

GHG emissions management systems support multi-scope reporting across Scope 1, Scope 2, and Scope 3 emissions. Figure 5 shows configurable Scope 3 reporting across all 15 categories, combining system-generated calculations with structured manual capture where automated data is unavailable.

Perhaps most importantly, integrated platforms provide drill-down visibility that transforms emissions from compliance statistics into diagnostic KPIs. Emissions changes can be traced up to specific assets, operating periods, or input values. That traceability identifies and proactively addresses abnormal conditions, inefficiencies, or high-emitting equipment.

Energy use as an emissions driver

Energy consumption is the dominant operational driver of refinery emissions. Every change in steam generation, fuel mix, process heater duty, power generation, compressor load, or turbine output directly influences GHG emissions.

Modern platforms simulate the full refinery energy network – including boilers, furnaces, gas turbines, steam systems, and fuel gas headers – to consider the energy balance in real time. This simulation capability continuously quantifies system efficiency and supports optimal decision-making.

Because energy consumption is linked directly to emissions, operators can immediately see the environmental and cost implications of operational decisions. This capability supports ISSB-aligned metrics and targets by enabling comparison of actual emissions against plans, budgets, or reduction trajectories.

Quantifying renewable energy contribution

As renewable power and alternative fuels enter refinery energy systems, renewable energy contribution becomes a measurable, auditable performance KPI rather than a static procurement metric.

Integrated systems track emissions factors associated with imported electricity based on grid mix. These systems also quantify internal generation impacts, improving Scope 2 reporting credibility. Systems differentiate hydrogen production pathways, biofuel blending, and

renewable-derived feedstock based on emissions intensity and source characteristics. This traceability supports certification and reporting requirements.

Reporting as governance

In mature emissions programmes, reporting is not just an output: it is a governance system. Advanced emissions management systems generate auditable, multi-frequency reporting from a single, validated data foundation. Integrated platforms ensure consistency across operational, accounting, and compliance views while capturing the cost implications.

This governance role is reinforced by the structure of international emissions standards. The ISO 14060 series explicitly link emissions quantification, reporting, validation, verification, and claims within a single governance chain, connecting operational data to external assurance and disclosure requirements.

A single calculation framework supports real-time operational decisions, daily reconciliation and internal review, periodic performance monitoring, and regulatory and financial disclosures, as shown in Figure 6.

This structure enables clear accountability. Operations, management, and executives can review, challenge, and act on emissions and cost performance with the same rigour applied to financial and safety metrics.

Conclusion

The era of emissions as just a retrospective reporting exercise is ending. The refining industry is moving toward an integrated and operationally grounded model of environmental governance and cost reduction. High-integrity environmental KPIs – carbon emissions, energy consumption, and renewable energy contribution – now require advanced systems capable of real-time calculations, auditability, and multi-scale reporting.

For refiners, investing in a dedicated GHG emissions management system is a core operational decision, not just a compliance add-on. By unifying emissions calculation, data reconciliation, audit trails, optimisation, and reporting, energy and emissions management systems enable compliance while improving operational efficiency.

Aligned with governance expectations outlined by frameworks such as ISSB, this integrated approach provides a forward-looking model for managing emissions, risk, and performance in refining operations. The holistic integration of financial disclosure supports compliance with evolving stakeholder expectations while fostering more efficient capital allocation and risk-adjusted decision-making.

References

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2. XING, Y., LIANG, F., LIU, H., XIA, R., ZHANG, S., ZHAO, D., ZHANG, L., and FANG, W., 'A review of carbon accounting in petroleum refining industry', Chemical Engineering Research and Design, Vol. 222, pp. 191 - 204, (October 2025).
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