The Hidden Majority: Addressing Scope 3 Emissions in Refining - ESG Expectations and Practical Pathways to Quantify and Reduce Value Chain Emissions

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Abstract

As the refining and petrochemical industries face growing pressure to decarbonize, Scope 3 emissions — primarily from the use of products — emerge as the dominant share of their carbon footprint. With up to 85% of lifecycle emissions tied to downstream usage, especially in MENA where refining capacity is expanding, managing these emissions is both a regulatory and strategic imperative. The article explores how refiners can move beyond fence-line emissions to quantify, manage, and reduce Scope 3 emissions using an integrated approach. By combining tools like KBC's IP3EM™, the GREET® model, and the BT Index, refiners can create detailed, data-driven decarbonization roadmaps. A case study demonstrates how one refinery modeled a 50% reduction in lifecycle emissions, proving that Scope 3 strategies, when aligned with operational, market, and infrastructure realities, can unlock competitive advantages while meeting emerging ESG expectations.

Introduction

For oil and petrochemical producers, the biggest emissions risk doesn't stay behind the fence line. Rather, it travels through the tailpipe, rises from the smokestack, and runs along the entire value chain.

In refining and petrochemicals, this risk is especially concentrated in Scope 3 emissions – mainly the CO_2 released when fuels and products are used – which vastly outweigh operational emissions. For example, the World Economic Forum estimates that Scope 3 accounts for 75–80% of lifecycle emissions from oil and gas products. Carbon Tracker, however, places that figure closer to 85%. For MENA producers, this means the lion's share of their carbon footprint lies not in what units they operate – but in what they sell. Taming this impact requires refiners to look far beyond the refinery gate, as shown in Fig 1.

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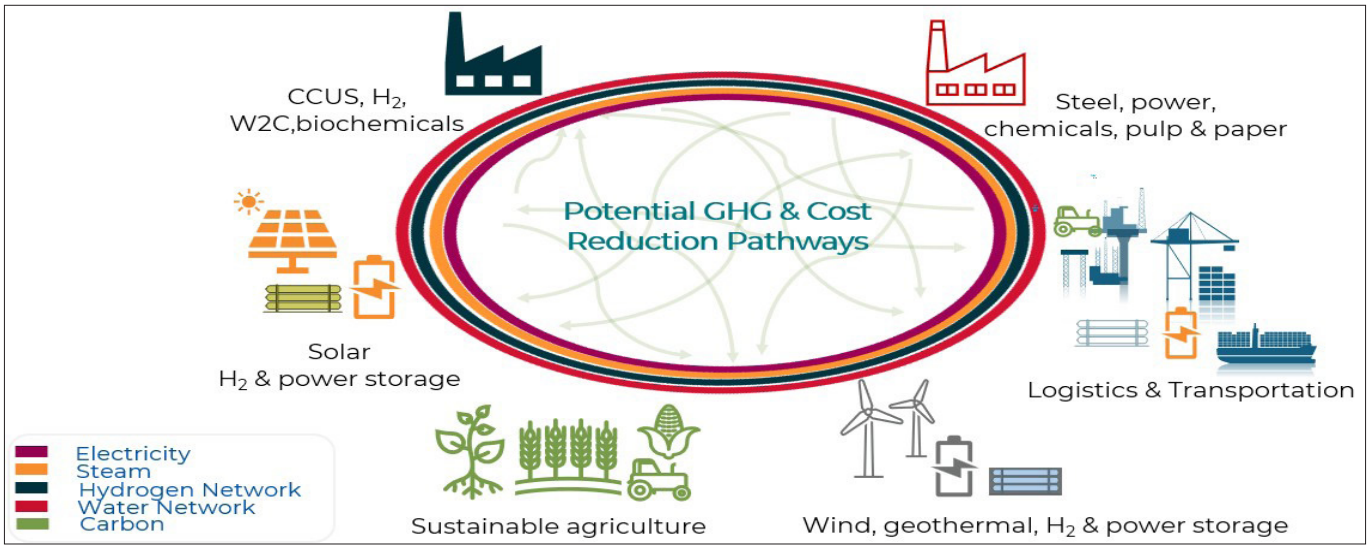

Fig 1. Scope 3 emissions span energy, transport, materials, agriculture, and downstream consumption

According to OPEC's World Oil Outlook 2023, the Middle East alone is expected to add 1.2 million barrels per day of refining capacity between 2024 and 2029. This growth means more hydrocarbons will be combusted as fuels or feedstocks, adding to global Scope 3 emissions unless offset by low-carbon fuels, carbon capture, or non-combustion alternatives. These emissions are the shadow cast by every barrel—trailing each product long after it leaves the refinery.

Scope 3 has 15 categories — but only a few tip the scales. Focus on the emissions that matter most.

Responding to Rising MENA Regulations

Amid this growth, the Gulf Cooperation Council and regional regulators have established ESG guidelines that encourage full greenhouse gas (GHG) emissions disclosure across the value chain. Issued in 2020, the UAE's Securities and Commodities Authority requires listed firms in Abu Dhabi and Dubai to publish sustainability reports aligned with GRI standards, which includes Scope 1, 2, and relevant Scope 3 disclosures. Oman's stock exchange mandates ESG reporting by 2025, with Scope 3 emissions reporting encouraged if applicable. While Scope 3 targets remain voluntary, these moves signal a growing push for full-value-chain transparency. Investor expectations are also rising for Scope 3 disclosure, especially among carbon-intensive sectors such as oil and gas.

In response, Scope 3 accounting is no longer optional – it's essential. The article explores how refiners can calculate, manage, and reduce Scope 3 emissions using an integrated approach that combines the IP3EM , GREET and Best Practices (BT) Index. The IP3EM is an advanced tool that links process, energy emissions and economics data to support lifecycle analysis, including Scope 3 assessments and decarbonization roadmap development. A case study covered in the latter part of article shows how this approach helped one refinery target a 50% reduction in lifecycle emissions. In doing so, the article demonstrates how refiners can turn emissions goals into operational strategies while Bringing Decarbonization to Life® across the entire value chain.

Understanding Scope 3 Emissions

What does Scope 3 really look like across a refinery's full value chain? Figure 2 illustrates the three scopes defined by the GHG Protocol and shows where Scope 3 stretches beyond the refinery's fence line – capturing upstream, midstream, and downstream emissions.

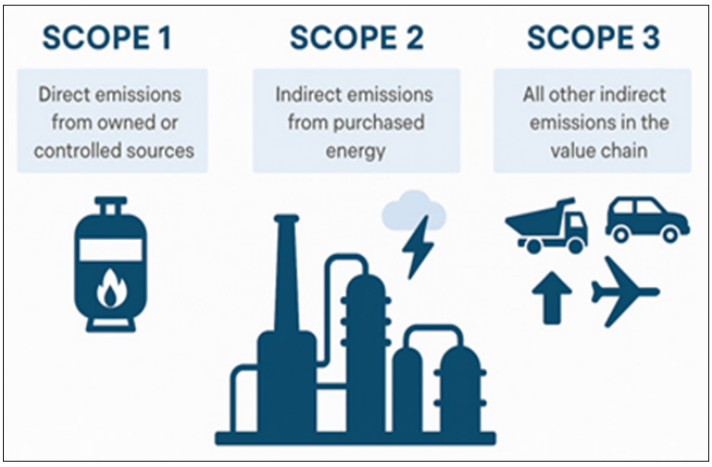

Fig. 2. Overview of Scopes 1, 2, and 3

Scope 3 emissions – already the largest share of a refinery's carbon footprint - also represent the broadest and most elusive layer to quantify and tame. Unlike Scope 1 or 2, Scope 3 emissions span the entire product lifecycle. For refiners, managing Scope 3 emissions means tracing the carbon trail far beyond the refinery border. In fact, key Scope 3 emissions reduction efforts must be taken at the refinery level.

To bring consistency across industries, the GHG Protocol's Corporate Value Chain Standard (2011) defines 15 categories of Scope 3 emissions, which remains the most widely adopted framework across sectors. It splits these emissions into upstream and downstream sources and urges companies to prioritize the categories which are materially important for their operations. In refining, five categories typically dominate, as summarized in Table 1.

According to KBC modeling, these five categories collectively can contribute up to 99% of a refinery's Scope 3 emissions.

Category	Description	Example Activities
1	Purchase goods and services for consistency	Crude oil exploration and production Farming/sourcing bio-feeds
4	Upstream transportation and distribution (purchased)	Shipping crude oil from terminal and subsequent transport to refinery gate
9	Downstream transportation and distribution (purchased)	Distributing gasoline from refinery gate to gas station
10	Processing sold products	Processing naphtha sold to a petrochemical site from a 3rd party
11	Using sold products	Combusting gasoline from automobiles

Table 1. Major contributors of Scope 3 emissions for refineries

Exploring Solutions That Deliver

Understanding where emissions originate is only half the challenge. Reducing Scope 3 emissions calls for systemic thinking and coordinated effort across the value chain that triggers measurable impact. Globally, a range of practical initiatives are considered:

- Shifting from fuel to non-combustible products (e.g., redirect naphtha into polymers).
- Blending biofuels (e.g., ethanol, biodiesel, renewable diesel, SAF) into products.
- Co-processing biogenic or waste-based feedstocks (e.g., used cooking oil, animal fats, biomass, pyrolysis oil).
- Investing in biorefining, feedstock flexibility, and logistics infrastructure.

Economic justifications of these initiatives depend on the refiner's ability to accurately estimate Scope 3 emissions and reinforce the need for integrated modeling tools to steer decision-making. Before strategies can be prioritized and evaluated for technical readiness, carbon emissions impact, and economic viability, refiners need a clear line of sight into where Scope 3 emissions originate and how they flow across the value chain.

Visualizing Scope 3 Emissions Across the Value Chain

How can refiners uncover emissions they can't directly measure or see at operating units? Making Scope 3 visible is the first step toward making it actionable. When working with well-established suppliers and off-takers, refiners can engage them to share emissions data to improve data transparency. However, new decarbonization efforts—like introducing biogenic feedstocks—require modeling tools that combine sound assumptions with full data coverage. Without structured accounting, these emissions remain blind spots – unseen, unmanaged, and underestimated. To tame this complexity and trace emissions from barrel to tailpipe, refiners must move beyond estimates and siloed solutions, as shown in Figure 3. Instead, they need integrated tools that can quantify emissions, simulate performance, and harness data to power better decision making across the full value chain.

One integrated approach combines the following technologies:

- **IP3EM** Built within the Petro-SIM process simulator, the IP3EM models operations, mass balances, and energy use to calculate Scope 3 lifecycle emissions. By linking process, utility, and economic models, the IP3EM evaluates

Decarbonization goes beyond the checkbox. The real journey starts with tracing the carbon trail and taming Scope 3 through integrated modeling and supplier collaboration.

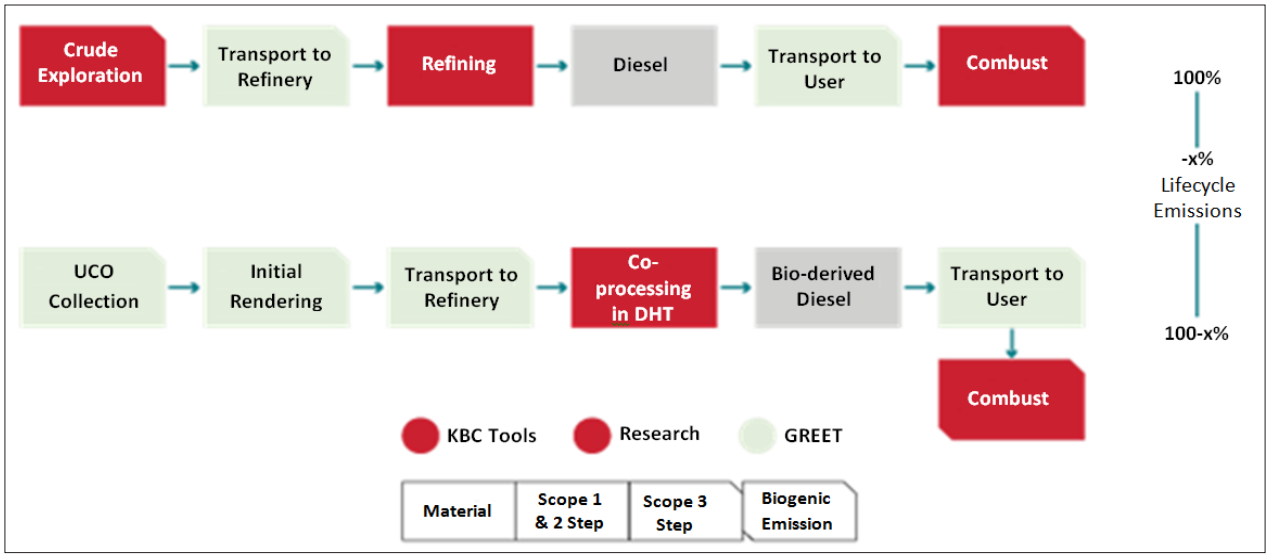

Fig. 3. Single solutions in silos fall short of delivering full value chain insights

multi-scenarios to align emissions tracking with asset-wide strategy, as shown in Figure 4.

- **GREET** Developed by Argonne National Laboratory, this open-source lifecycle analysis tool models emissions across fuel and energy systems.
- **BT Index and client specific research** Calculates site-specific energy pricing structures and constraints, providing insight into potential energy improvement and emissions reduction while filling key data missing in the GREET model.

Together, these tools help refiners strengthen evidence, allowing them to measure, model, and mitigate Scope 1, 2 and 3 emissions. For instance, these tools can model how switching from fossil to renewable diesel alters a product's or an entire asset's carbon intensity. This includes evaluating feedstocks such as used cooking oil, soy, forest residues, and ethanol as well as non-fuels like naphtha and bitumen.

With this visibility, refineries can begin by setting meaningful Scope 3 targets and aligning them with feasible, high-impact initiatives.

Setting Targets and Timelines

Scope 3 targets typically fall into two categories:

- Intensity-based e.g., -x% tCO_2e per tonne of product.
- Absolute e.g., -x% total tCO_2e reduction.

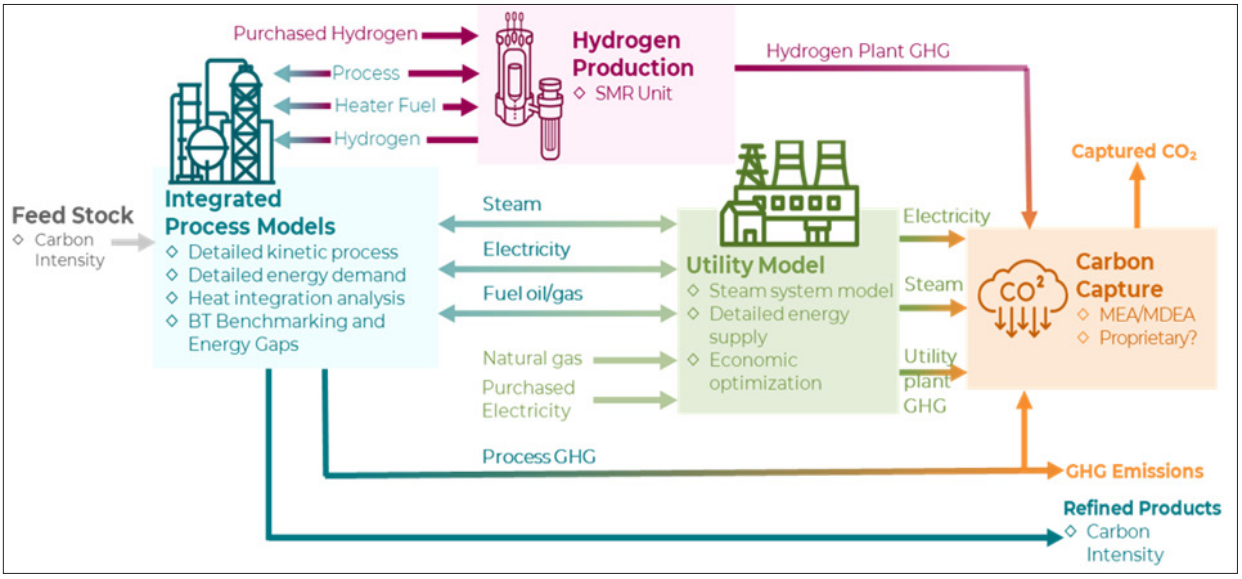

Fig. 4. IP3EM architecture connecting processes, emissions, and economic modeling for full value chain visibility

Absolute targets often challenge refiners, who have two ways to reduce absolute Scope 3 emissions:

- Producing more non-fuel products (e.g. bitumen for roads, naphtha for plastics, etc.), however:
  - Refineries can only produce a limited amount of non-fuel products.
- Reducing crude oil feed rates, which poses issues:
  - It reduces product output which reduces market share and profitability.
  - If demand remains constant, it shifts emissions to another facility.
  - Additionally, product qualities need scrutiny when feed and effective product rates are changed.

Therefore, the most effective means for reducing Scope 3 emissions involves replacing fossil molecules with non-fossil, biogenic alternatives. When sourced responsibly, biogenic emissions do not contribute toward Scope 3 totals, as they form part of the natural carbon cycle.

Another key consideration involves setting practical timelines to balance technology, infrastructure readiness, and evolving stakeholder expectations. These timelines, along with broader emissions goals, must align with operational, logistical, and market realities – including disclosure mandates such as the EU's Corporate Sustainability Reporting Directory if product is flowing to EU.

Aligning Strategy with Market and Infrastructure

Successful Scope 3 reduction strategies should align with four dimensions:

1. **Hotspots and targets:** Prioritize initiatives that address high-impact sources.
2. **Operational factors:** Assess interactions with existing assets and yield structures.
3. **Economics and market:** Evaluate CapEx against NPV, IRR, carbon abatement, cost performance, and market factors such as product premiums and supply chain maturity. For example, used cooking oil has its own sourcing and certificate of origin challenges, and renewable diesel often trades at a premium to fossil diesel in the EU, which offsets high production costs.
4. **Logistics and infrastructure:** Evaluate site space, storage, handling facilities, and transport flexibility.

When these strategies align, refiners can optimize throughput, improve performance, and steer decarbonization efforts with greater precision and flexibility. In addition, they can effectively anticipate and respond to ESG expectations. This integrated approach helps accelerate operational resilience while Bringing Decarbonization to Life. The next step involves translating these aligned strategies into a credible, site-specific roadmap.

Building a Credible Roadmap

A credible decarbonization roadmap doesn't just check regulatory boxes – it charts a path to meaningful change. It starts by establishing a refinery-wide baseline that quantifies Scope 1, 2, and 3 emissions. It then uses integrated lifecycle modeling and supplier engagement to fuel visibility and decision-making. From there, refiners can identify and rank high-impact opportunities, especially around product use (Category 11) that is often over 75% of lifecycle emissions. Targeting these emissions means preventing fossil molecules from being combusted and trimming carbon at the source.

Fortunately, lifecycle tools like IP3EM, GREET, supported by the BT Index, can help refiners fill data gaps and test the impact of biofuels, co-processing, and energy transition to enable asset-specific modeling.

Once the baseline is established, refiners can shift to modeling Scope 1, 2, and 3 reduction initiatives. Integrating these initiatives into the roadmap catalyzes high-impact emissions reduction actions. These initiatives may include alternate feedstock strategies, SAF, renewable diesel, biodiesel, ethanol blending, biogas, and more that impact a refinery's lifecycle emissions profile, as shown in Table 2.

Replacing natural gas with biogenic alternatives such as biomethane can significantly reduce Scope 1 and Scope 3 emissions. As part of the natural carbon cycle, biogas is considered carbon-neutral when sustainably sourced to deliver both operational and lifecycle benefits.

Table 3 illustrates this impact, comparing refinery emissions for natural gas and biomethane across all scopes.

As shown, biomethane reduces total emissions by over 90% compared to natural gas—primarily by eliminating Scope 1 emissions and lowering upstream intensity. When refineries calculate Scope 1, 2, and 3 emissions accurately, the benefits of the decarbonization initiatives become visible, measurable, and bankable.

#	Initiative	Present Case	New case/ replacement	Impact on Scope 1	Impact on Scope 2	Impact on Scope 3
1	Biogas use	Natural gas	Replaced by biogas	Reduction in emissions, biogenic $Co_{2,}$ treated as neutral	No impact	Reduction in upstream emissions, as biogas supply chain has lower GHG footprint than natural gas
2	Ethanol/ Biodiesel /Renewable Diesel/SAF	Conventional gasoline/ Diesel/Jet fuel	Replace with low-carbon alternative fuels	No impact	Minimal to no impact	Reduction in upstream and downstream emissions, downstream biogenic CO_2 treated as neutral
3	Renewable electricity	Conventional electricity	Replaced with renewable electricity	Reduction, no emissions	Significant reduction (renewable sources have negligible emissions)	Reduction in upstream emissions from power generation
4	Co-processing bio-feed/ recycled feedstock	Conventional gasoline/ Diesel/Jet fuel	Replaced with alternative feedstocks (bio-based or recycled)	Reduction due to lower emissions from bio-content or re-cycled materials	No impact	Reduction in upstream emissions (bio/recycled feedstocks) and down-stream largely biogen-ic CO_2 treated as neutral

Table 2. Example of refinery emissions impacted by different decarbonization initiatives

Proving It Works: A 50% Reduction Case Study

A recent study involved a refinery that aimed to reduce its lifecycle emissions (Scopes 1, 2, and 3) by 15% in the short term and 50% over 12 years. Using a refinery-wide IP3EM model, the team evaluated multiple decarbonization technologies based on:

- Mass, carbon, and heat balances model IP3EM in Petro-SIM software.
- Scope 3 emissions modeling via GREET, BT Index, and Research.
- Market and legislative conditions influencing renewable feed adoption.

Key results included:

- Short-term, low-CapEx strategies that reduced lifecycle emissions by 3%.

Particulars	Scope 1	Scope 2	Scope 3 - upstream	Scope 3 - downstream	Total emissions
Natural gas	2.75 (combustion + fugitive)	~0.03, depending on the Cl of the compressor's electricity	Methane leakage and processing emissions: 0.36 (0.05 supplier Scope 1 + 0.03 supplier Scope 2 + 0.308 methane leakage)	~0	~3.09
Bio methane	0 (biogenic)	~0.03, depending on the Cl of electricity for the compressor	Methane leakage and feedstock emissions: 0.19 (0.02 + 0.03 + 0.14)	~0	0.22

Table 3. Comparison of emissions from natural gas and biomethane use in refinery operations (tCO_2e per tonne of fuel)

- Long-term pathways—such as bio-feedstock integration and unit retrofitting—showed a significant potential reduction.
- Deeper reductions requiring significant CapEx and a full reconfiguration of feedstock and product flows and quality.

This case underscores how data-driven modeling, scenario evaluation, and integrated emissions planning help refiners set achievable strategies.

Harnessing Scope 3 for Strategic Advantage

Scope 3 emissions should not be seen as a compliance burden—they are a strategic opportunity. Across the globe, mandates such as bio- and e-fuel blending requirements are gaining traction, while high premiums for renewable fuels in markets like the EU create strong commercial pull. Together, policy, pricing signals, and improved decision-making through modeling capabilities are accelerating investment in Scope 3 reduction initiatives.

For refiners ready to act, getting ahead of Scope 3 emissions reduction doesn't just reduce risk—it delivers a resilience dividend with bottom-line returns. Taming these emissions is now essential to maintaining access to capital, meeting stakeholders' expectations, and delivering competitive, low-carbon products.

Key Takeaways

- Scope 3 emissions typically represent the majority of a refinery's lifecycle footprint, especially in product use. Targeting these emissions ignites the greatest potential for impact.
- ESG mandates and investor pressure are fueling demand for full-value-chain emissions visibility.
- Accurate Scope 3 modeling requires integrated tools that trace, simulate, and harness operational, feedstock, and lifecycle data.
- Effective decarbonization roadmaps should prioritize high-impact initiatives, balance modeling detail, and align with business realities.
- Refineries that command Scope 3 strategies can contain risk, ignite progress, and unleash both compliance value and competitive advantage.

Tools like KBC's IP3EM provide the clarity and granularity needed to integrate emissions reduction into core business strategy. In doing so, they empower refiners to go beyond reporting—transforming Scope 3 from a source of risk into a driver of resilience and innovation. Refiners who treat Scope 3 as a bridge – not a burden - will lead the next chapter in emissions reduction while Bringing Decarbonization to Life®.

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