

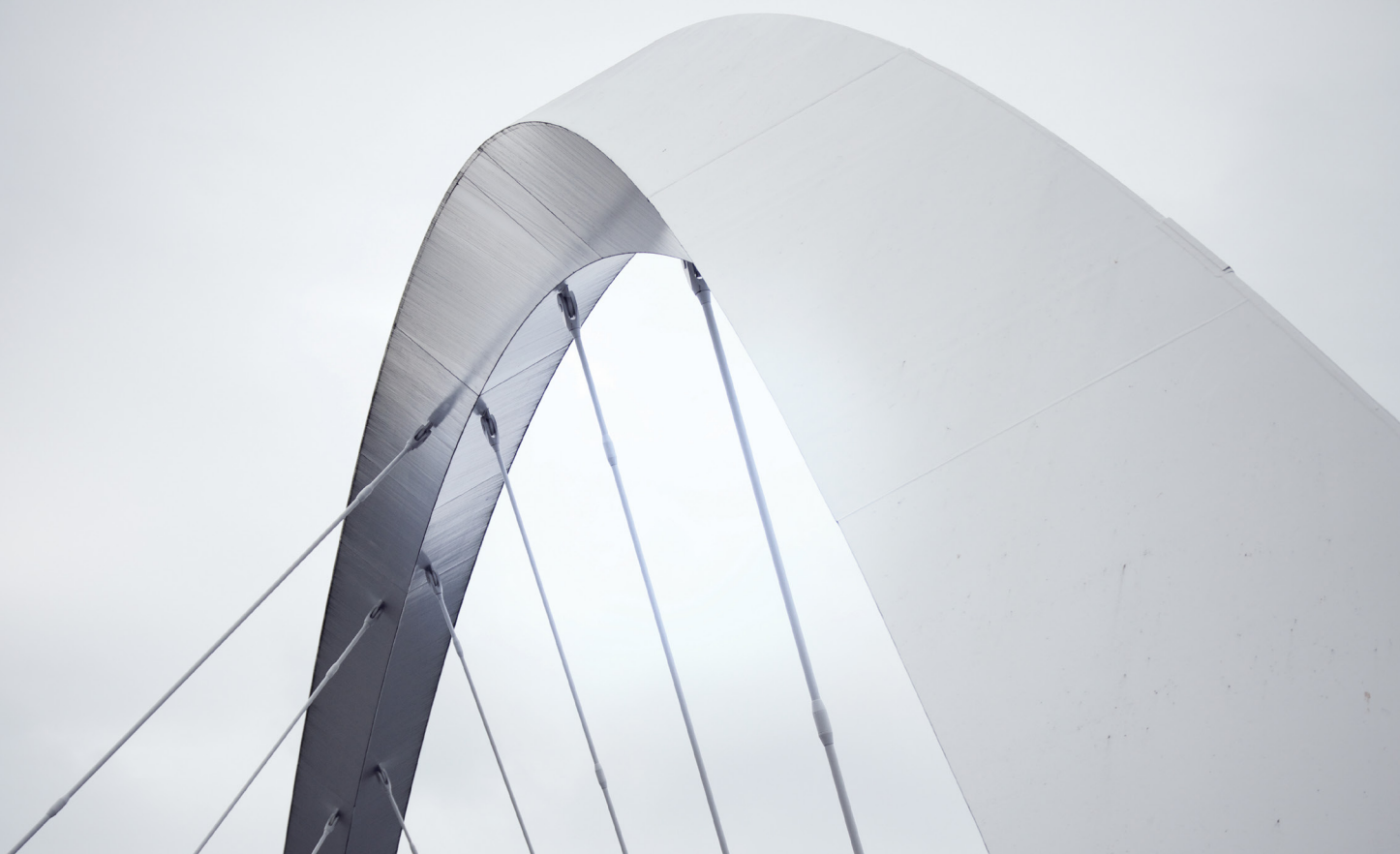
Carbon costing and control through activity-based emissions accounting: Insights from a UK container port case study in carbon costing



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Introduction

Regulatory, investor and customer expectations now require businesses to measure and reduce emissions with the same rigour applied to financial costs. In the United Kingdom, for example, the Streamlined Energy and Carbon Reporting (SECR) framework requires large companies to publish energy use and greenhouse gas data, while ports and logistics firms, responsible for roughly three per cent of global greenhouse gas emissions (Misra et al. 2017), face additional scrutiny specific to their sector. Net-zero commitments, such as the Port of London Authority's Thames Net Zero Coalition, illustrate the growing momentum. As part of this natural evolution, the decarbonisation agenda at seaports has expanded beyond vessel exhausts to include terminal activities such as crane power, reefer cooling, diesel yard equipment and refrigerant losses.

Most ports have responded with engineering modernisations and external disclosures aligned with the GHG Protocol or ISO 14064. While these measures create transparency, their integration into cost systems, budgets or pricing models is less clear. This has left management accounting teams in a state of uncertainty, as indicated by interviews with our case company. Although environmental management accounting tools are available, they tend to focus more on long-term strategic planning than on routine operational control. As a result, financial systems that guide margins and performance make only limited use of environmental data.

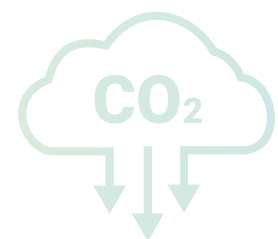
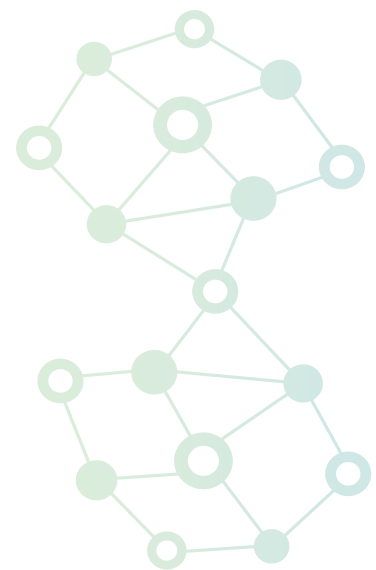
This study addresses that gap by presenting a management accounting approach that treats carbon as a measurable and controllable cost. Using detailed operational data from DP World Southampton, a UK container terminal in 2023 (that is, the case company), we apply Activity-Based Costing (ABC) principles to trace emissions back to the operational activities that generate them. The analysis focuses on three major sources of emissions: electricity, fuel and refrigerants. These inputs were selected because they account for the vast majority of Scope 1 and Scope 2 emissions at terminals (*note that many ports now compile annual greenhouse gas (GHG) inventories following the GHG Protocol Corporate Standard 7 (Port of Vancouver USA, 2023), which defines Scope 1, 2, and 3 emissions (i.e., direct on-site fuel use, purchased electricity, and indirect supply chain emissions)*). Electricity powers cranes, lighting and refrigerated containers; fuel is consumed by yard equipment such as straddle carriers; and refrigerants, although used in smaller quantities, carry a disproportionately high carbon impact due to their chemical properties.

Our work translates these emissions into financial terms by calculating the cost per kilogram of carbon dioxide equivalent (kgCO_{2e}), the standard unit for aggregating the impact of different greenhouse gases (GHG). This enables direct comparison of the financial and environmental performance of options such as diesel versus HVO (Hydrotreated Vegetable Oil), a renewable fuel with significantly lower emissions that is increasingly used as a substitute for conventional diesel. The same analysis supports variance analysis, allowing management accountants to compare actual emissions against expected levels just as they would for labour or material costs, and to carry out breakeven calculations for investment planning and operational decision-making.

This analysis is not just a technical report. It shows how emissions can be treated as real costs within a working costing system. It shows management accountants how emissions add to costs and affect budgets, prices and investment choices. **By bringing carbon into regular financial tools, accountants can show how emissions affect profit margins and performance targets.** It also makes it possible to assign a cost to carbon that was previously ignored. This is increasingly important as supply chain partners like Maersk and IKEA now ask for carbon data per shipment to meet their own reporting needs (Maersk, 2021). Using an internal carbon value helps ports estimate the cost of their emissions early, so they are ready for rules like the European Union Emissions Trading System (EU ETS) and other future carbon charges.

Although developed for a port setting, our work is readily transferable to any sector where emissions arise from resource use. A manufacturing plant can link machine run time electricity to kilograms of per finished part. A logistics operator can attach warehouse energy use to kilograms of CO₂ per order shipped. Hotels can measure energy and water use per guest night, and airlines can report fuel use per route as kilograms of CO₂ per seat kilometre. By mapping inputs to activities and applying the same principles as ours, management accountants gain detailed, decision-ready carbon insights.

If carbon can be costed, it can be managed. Treating emissions as a cost centre gives accountants a way to reflect environmental impact in everyday decisions, helping firms take responsibility for their own pollution and that of their partners across the supply chain. It supports better transparency, planning and accountability, rather than treating ESG as just a reporting requirement.



Research objectives and methodology

This research was conducted using operational and financial data from DP World Southampton, a UK container terminal, for the 2023 calendar year.

The study applied Activity Based Costing (ABC) principles to map emissions data from electricity, fuel, and refrigerants to the activities that generate them, such as crane operations, reefer storage, and yard vehicle movement. The aim was to translate emissions into financial terms, such as the cost per kilogram of carbon dioxide equivalent (kgCO₂e), and to integrate this into management accounting tools, including variance analysis, marginal costing, and break-even analysis.

The analysis did not rely on modelling or forecasting but instead worked with actual recorded inputs (e.g., kWh, litres of fuel, kg of refrigerants) and applied published emissions factors (e.g. from BEIS 2022, i.e., the Department for Business, Energy and Industrial Strategy in the United Kingdom) and cost data to calculate both environmental and financial impact. This approach enabled the construction of a costed emissions breakdown that management accountants can use for budgeting, operational decision-making, and pricing strategy.

Research objectives

This study focused on the following objectives.

Objective 1:

To study how businesses keep track of their pollution levels and how these fit into their everyday accounting practices.

Addressed through the use of Activity Based Costing, variance analysis, and break-even analysis to integrate emissions from electricity, fuel, and refrigerants into routine cost accounting.

Objective 2:

To examine how companies weigh environmental trade-offs and how this connects to spending plans.

Demonstrated through comparison of diesel and HVO using cost per kilogram of CO₂ equivalent, enabling marginal costing and investment appraisal.

Objective 3:

To assess how businesses respond to climate rules and how this shapes cost decisions.

Our analysis is aligned with the principles of SECR (i.e., The UK Streamlined Energy and carbon Reporting) and the GHG Protocol. It establishes a foundation for internal carbon costing and emissions attribution, supporting cost allocation and preparing firms for regulatory mechanisms such as the EU Emissions Trading System (EU ETS).

Objective 4:

To explore how firms include climate risks and benefits in future financial planning.

Supported by internal carbon pricing, variance tracking, and costing analysis that link environmental performance to budgeting and investment decisions.

This practice-oriented, data-driven methodology ensures that the findings are applicable not just to ports, but also to other sectors seeking to embed environmental accountability into management accounts.

Main findings and their implications for practice

Activity-Based Costing (ABC) assigns costs to outputs based on the resources and activities they consume.

We extend this logic to environmental costs, including carbon emissions, starting from the premise that activities drive emissions just as they drive costs. By identifying carbon-intensive activities, management accountants can target improvements or investments that deliver emission reductions per pound spent.

Our case company is DP World Southampton, the UK's second-largest deep-sea container terminal, located in Southampton on the south coast of England, and is wholly operated by DP World. In recent years, the terminal has handled close to 2 million TEU per annum. Its operations encompass full seaside and landside logistics, unloading containers from vessels and loading them onto trucks and trains, and vice versa, serving as a critical hub in the UK supply chain. We analysed its 2023 operational data. The first step was to agree on a common unit for costing. Because the terminal's two core activities are (i) loading and unloading containers from vessels and (ii) transferring containers to or from trucks and trains, the natural denominator is the 20-foot equivalent unit, or TEU, which represents one standard container. Both activity streams can therefore be costed on a per TEU basis.

Next, we identified the operating costs that drive emissions. We limited the scope to revenue expenditure and excluded capital items; the limitations of that choice are discussed later in the report. The four cost categories examined were electricity, fuel (diesel and Hydrotreated Vegetable Oil, HVO), water, and refrigerants. Each category has a clear physical measure: kilowatt hours for electricity, litres for fuel, cubic metres for water, and kilograms of gas for refrigerants. For 2023, the port recorded both the quantities used and the amounts spent in each category.

To express environmental impact, we converted these quantities to kilograms of carbon dioxide equivalent, abbreviated kgCO_{2e}. This metric combines different greenhouse gases into a single figure, allowing like-for-like comparison across resources. The conversion used the emission factors listed in Table 1 below.

Table 1:

Emission conversion factors used for resource inputs

Resource	Emission factor (kgCO _{2e} per unit)	Source
Electricity, grid mix	0.207070 per kWh	BEIS 2022
Electricity, renewable	0.000000 per kWh (assumed)	Internal assumption
Diesel	2.705530 per litre	BEIS 2022
HVO	0.035580 per litre	BEIS 2022
Water	0.000344 per litre	Industry average
Refrigerants	Already recorded in kgCO _{2e}	BEIS 2022

In the remainder of the analysis, the reported figures have been adjusted for confidentiality, while ensuring the findings still reflect the company's real operations.

Emissions were estimated for each input by multiplying total consumption by its respective factor. These emissions were then summed and normalised by the port's annual throughput (measured in TEUs), producing an average emission value per TEU for 2023 as shown in Table 2.

Table 2:

Emissions calculation by resource input

Resource	Total Consumption (assumed)	Unit	Emission Factor (kg CO ₂ e per unit)	Emissions (kg CO ₂ e)
Electricity (Grey*)	8,000,000	kWh	0.20707	1,656,560
Electricity (Green*)	8,000,000	kWh	0.00000	0
Diesel	0	Litres	2.70553	0
HVO	6,100,000	Litres	0.03558	217,038
Water	14,000,000	Litres	0.000344	4,816
Refrigerants	400,000	kg CO ₂ e	1.00000	400,000
Business Travel	150,000	kg CO ₂ e	1.00000	150,000
Total Emissions				2,428,414
TEU (Annual Volume)	2,000,000			
Emissions per TEU				1.21 kg CO ₂ e per TEU

*Grey electricity refers to grid-supplied power generated from fossil fuels and other non-renewable sources, while green electricity is produced from renewable sources such as wind, solar, or hydro, and is considered to have zero associated carbon emissions.

Our case company replaced diesel with HVO in 2023, and sourced half of its electricity from renewable sources.

The advantages are obvious and shown in Table 3.

Table 3:

Comparative emissions under alternative fuel and electricity scenarios

Scenario	Total emissions (kg CO ₂ e)	Emissions per TEU (kg CO ₂ e)
2023 actual (100% HVO, 50% green electricity)	2.4 million	1.21
2022 baseline (100% diesel; 50% green electricity)	18.7 million	9.36
Worst case scenario: 100% Diesel; 100% grey electricity	20.4 million	10.19

In 2023, the case company implemented one key operational change that significantly reduced its carbon emissions: a full transition from diesel to Hydrotreated Vegetable Oil (HVO), a low-emission alternative fuel. Given that diesel combustion is a major source of Scope 1 emissions in port operations, this shift alone resulted in a substantial decrease in overall emissions. In addition, the company sourced 50 per cent of its electricity from renewable (green) energy contracts, thereby halving the emissions typically associated with electricity consumption. When modelled against a baseline scenario using only diesel and grey electricity, these measures collectively led to an estimated 88 per cent reduction in total emissions (see Table 3). The emission intensity for 2023 was calculated at 1.21 kg CO₂e per twenty-foot equivalent unit (TEU), significantly lower than the 15 kg CO₂e per TEU reported in recent literature (Budiyanto et al., 2024).

This difference is largely attributable to the use of HVO and 50 percent green electricity at the case company.

To preserve space, the individual costs of each emission generating resource for 2023 (namely electricity (grey and green), diesel, HVO, water, refrigerants, and business travel) are not itemised. However, their combined expenditure is estimated at £20 million. This figure was used to calculate the average cost per kilogram of carbon dioxide equivalent (kgCO_{2e}), using the following formula:

$$\text{Cost per kgCO}_2\text{e} = \text{Total cost of emission-related resources} / \text{Total emissions in kgCO}_2\text{e}$$

Applying this to the case company's data:

$$\text{£20,000,000} / \text{2,428,414 kgCO}_2\text{e} = \text{£8.24 per kgCO}_2\text{e}$$

Table 4 shows how emissions and cost per kilogram of CO₂ equivalent (kgCO_{2e}) vary under three scenarios. In 2023, the company fully switched to HVO fuel and sourced half of its electricity from green, zero-emission sources. As a result, total emissions dropped to 2.4 million kgCO_{2e} and emissions per container (TEU) fell to just 1.21 kgCO_{2e}. However, the cost per kgCO_{2e} rose significantly to £8.24.

Table 4:

Carbon emissions and marginal cost per kilogram of CO_{2e} under alternative operational scenarios

Scenario	Total emissions (kg CO _{2e})	Emissions per TEU (kg CO _{2e})	Cost per kgCO _{2e} = Total cost of emission-related resources / Total emissions in kgCO _{2e}
2023 actual (100% HVO, 50% green electricity)	2.4 million	1.21	£20,000,000 / 2,428,414 kgCO _{2e} = £8.24 per kgCO _{2e}
2022 baseline (100% diesel; 50% green electricity)	18.7 million	9.36	£20,000,000 / 18,715,709 kgCO _{2e} = £1.07 per kgCO _{2e}
Worst case scenario: 100% Diesel; 100% grey electricity	20.4 million	10.19	£20,000,000 / 20,371,669 kgCO _{2e} = £0.98 per kgCO _{2e}

This might appear counter-intuitive, i.e., why would cleaner operations lead to a higher carbon cost? The reason lies in the denominator of the calculation. While the company continued to spend £20 million on resources like fuel, electricity and refrigerants, its total carbon output fell dramatically. Because the emissions decreased, each kilogram of carbon is now associated with a greater share of that cost. In other words, the business is spending the same amount to run its operations but generating much less pollution.

Compare this to the 2022 baseline scenario in Table 4, where the company used diesel but still had 50% green electricity. Emissions were much higher (18.7 million kgCO_{2e}) and so the cost per kgCO_{2e} was only £1.07. In the worst-case scenario, using diesel and 100% grey

electricity, emissions were even higher at 20.4 million kgCO_{2e}, driving the cost per kgCO_{2e} down to just £0.98.

For management accountants, the key insight is that a higher cost per kgCO_{2e} is a positive signal in this context. It means the company is achieving lower emissions for the same level of operational costs. It reflects better environmental performance, not financial inefficiency. Clean operations naturally shift the cost-emissions ratio upwards, because fewer emissions are being generated overall.

We refer to the cost of £8.24 per kgCO_{2e} as a carbon-efficiency price tag, and a higher value reflects cleaner operations, signals lower emissions, and helps justify green investment.

To help management accountants evaluate the financial implications of emissions, we introduce another key figure. We researched the average cost of cleaning or offsetting 1 kg of CO₂e across other industries, drawing on sources such as the UK Green Building Council (ukgbc.org). Their 2023 report estimates this value between £0.15 and £0.25 per kg CO₂e, depending on the offset quality and approach. Based on this, and supported by wider industry research, we adopt £0.18 per kg CO₂e as a realistic benchmark for carbon neutrality in port operations. This means that to offset its 2023 emissions of 2.4 million kg CO₂e, the case company would need to budget approximately £433,000.

At first glance, it may seem more cost-effective for the company to pay £0.18 per kilogram of CO₂e to offset emissions, given that each kilogram of CO₂e emitted at the port is associated with £8.24 in combined resource costs from electricity, diesel, HVO, and refrigerants. However, there are several reasons why this view is misleading.

First, carbon offsetting does not eliminate the source of emissions (Cullenward et al., 2023). Paying £0.18 per kilogram simply compensates for emissions after they occur; it does not reduce the company's actual carbon footprint or reliance on fossil fuels. In contrast, switching to HVO prevents emissions at source.

Second, overreliance on offsetting can weaken the company's ESG credibility (S&P Global, 2021), particularly with clients such as IKEA and Maersk, who expect verifiable low-carbon operations as part of their own Scope 3 reporting.

Third, the £8.24 per kilogram is not the marginal cost of

Table 5:

Carbon emissions and offset cost comparison

Scenario	Total emissions (kg CO ₂ e)	Cost incurred per kgCO ₂ e	Cost of capture per kgCO ₂ e @ £0.18
2023 actual (100% HVO, 50% green electricity)	2428414	£8.24	£433,077
2022 baseline (100% diesel; 50% green electricity)	18715109	£1.07	£3,337,606
Worst case scenario: 100% Diesel; 100% grey electricity	20371669	£0.98	£3,633,033
Diesel; 100% grey electricity			

carbon reduction or decarbonisation. It represents the total resource cost (for electricity, fuel, refrigerants, etc.) divided by total emissions. Many of these costs would be incurred regardless of emissions reduction efforts. The more relevant question is the incremental cost of using HVO over diesel. If diesel costs £1.10 per litre and HVO costs £1.40, the marginal cost of carbon reduction is the £0.30 difference; not the full £8.24 per kilogram.

Fourth, operational decarbonisation offers long-term benefits beyond cost (Boston Consulting Group, 2023), including improved energy security, supply chain resilience, and compliance with evolving regulations such as the EU ETS and the UK's Carbon Border Adjustment Mechanism (CBAM). **Fifth**, offsetting costs often exclude capital expenditure (CapEx) associated with internal decarbonisation infrastructure (such as installing carbon capture systems, or upgrading to renewable energy) as well as ongoing maintenance costs.

Finally, as Table 5 illustrates, although the cost per kilogram of CO₂e appears highest in 2023, the actual amount of carbon to offset is far smaller. At the assumed offset price of £0.18 per kgCO₂e, the cost of offsetting 2023 emissions would be approximately £433,000. In contrast, the cost of offsetting the 2022 baseline scenario, with much higher emissions, would exceed £3.3 million. The worst-case scenario would cost even more, at over £3.6 million. In other words, lower emissions mean lower total offset liabilities, even if the cost per unit of carbon appears higher.

Break-even analysis

When conducting break-even analysis, management accountants should focus not on the total average cost of emissions (£8.24 per kgCO₂e), but on the marginal cost of abatement, i.e., the additional cost incurred to reduce one unit of carbon dioxide equivalent through operational changes.

For instance, if diesel costs £1.10 per litre and Hydrotreated Vegetable Oil (HVO) costs £1.40 per litre, the marginal cost of switching is £0.30 per litre. Given that diesel emits approximately 2.7 kgCO₂e per litre, the cost of reducing one kilogram of CO₂e by switching to HVO is roughly £0.11 (£0.30/(2.70553 – 0.03558)), which we refer to as the Marginal Abatement Cost (MAC). This figure is lower than the estimated external offset price of £0.18 per kgCO₂e, based on industry benchmarks and our estimate. Therefore, from a break-even perspective, using HVO is not only environmentally preferable but also more cost-effective than relying on offsets. This underscores why the higher average cost figure (£8.24) should not deter investment in low-carbon operations as it reflects total resource use, not the marginal cost of reducing emissions.

Management accountants can evaluate any operational switch using the marginal abatement cost (MAC) formula as follows:

$$\text{MAC} = \frac{\text{Unit Cost}_{\text{new}} - \text{Unit Cost}_{\text{old}}}{\text{Emission Factor}_{\text{old}} - \text{Emission Factor}_{\text{new}}}$$

If MAC < offset price (£0.11 < £0.18),
internal abatement is cheaper than buying offsets.

ABC analysis

This analysis links emissions directly to the specific activities that generate them, allowing carbon to be assigned to individual operations rather than treated as a general overhead. Using ABC principles, we grouped emissions by activity to help management accountants identify where carbon is being produced and where reduction efforts would have the most operational and financial impact.

We began by treating the port's annual carbon footprint as a cost pool to be allocated to specific activities and cost objects, such as per container unit (TEU). In 2023, the terminal emitted approximately 2,428 tonnes of CO₂ in its operations. To keep the explanation focused, we summarise the key findings rather than detailing each step of the calculations.

Straddle carrier operations accounted for about 50 percent of total emissions. These involved transporting containers within the yard and are highly fuel intensive. Quay crane lifts came next, accounting for 20 percent of emissions, as they operate utilising electricity. Reefer container storage followed at 15 percent, with energy used to keep refrigerated containers running. The remaining 15 percent came from other terminal activities, such as buildings, yard lighting, and maintenance vehicles.

By applying earlier steps, we can also calculate emissions per container (i.e., TEU) for each activity. Adding energy cost data to the analysis enables the estimation of cost per kg of CO₂. The benefit of applying this carbon-focused ABC approach is that it improves pricing, product mix decisions, operational planning, and accountability. For example, if certain types of containers require additional yard movements or consume more energy, resulting in higher emissions, the port can revise its pricing to reflect the associated carbon cost or explore operational efficiencies to reduce the environmental impact. Management accountants can also focus on the main sources of carbon cost. In this case, yard operations are the primary contributor. Finally, this approach supports the development of a carbon return on investment (ROI) measure when evaluating projects that aim to reduce emissions.

Budgeting and variance analysis

To support environmental performance evaluation, we applied standard variance analysis techniques to carbon emissions. This allows changes in emissions to be decomposed into meaningful categories, clarifying whether increases result from higher activity levels, inefficient resource use, changes in energy sourcing, or external factors like updated emissions conversion rates.

Volume variance measures the change in total emissions due to differences between actual and expected activity levels. In our case, this would reflect changes in the number of TEUs (i.e., containers) processed. Suppose the budget assumed 1.8 million TEUs for the year, but the terminal processed 2 million. If the budgeted emission rate was 1.21 kgCO₂e per TEU, then:

Expected emissions

$$= 1.8 \text{ million} \times 1.21 = 2,178,000 \text{ kgCO}_2\text{e}$$

Actual emissions

$$= 2 \text{ million} \times 1.21 = 2,420,000 \text{ kgCO}_2\text{e}$$

Volume variance

$$= 2,420,000 - 2,178,000 = 242,000 \text{ kgCO}_2\text{e}$$

Thus, emissions increased due to higher volume.

Efficiency (or Usage) variance examines whether more or less of a resource was used per TEU than expected. Let us assume the budgeted fuel use was 3 litres of HVO per TEU, but actual usage increased to 3.5 litres. Given that the emission factor for HVO is 0.03558 kgCO₂e per litre:

Expected emissions per TEU

$$= 3 \times 0.03558 = 0.1067 \text{ kgCO}_2\text{e}$$

Actual emissions per TEU

$$= 3.5 \times 0.03558 = 0.1245 \text{ kgCO}_2\text{e}$$

Variance per TEU

$$= 0.1245 - 0.1067 = 0.0178 \text{ kgCO}_2\text{e}$$

Total variance

$$= 0.0178 \times 2,000,000 \text{ TEUs} = 35,600 \text{ kgCO}_2\text{e}$$

This increase indicates inefficient use of fuel per container, which raised emissions.

Rate (or Price) variance captures changes in the cost of carbon mitigation per unit of emission. Suppose the budgeted cost of abatement was £0.20 per kgCO₂e, but the actual cost rose to £0.25:

Variance

$$= (0.25 - 0.20) \times 2,428,414 \text{ kgCO}_2\text{e} = \text{£}121,421$$

This shows that emissions became more expensive to mitigate, raising overall operational costs.

Offset efficiency variance refers to a change in the type or quality of carbon offset used. For example, the company may have budgeted to use offsets costing £0.15 per kgCO₂e but ended up spending £0.25 per kgCO₂e:

Variance

$$= (0.25 - 0.15) \times 2,428,414 = \text{£}242,841$$

This additional cost reflects a higher-than-expected price for offsets.

Mix variance results from a shift in the energy mix used. Suppose the budget assumed 75 percent green and 25 percent grey electricity, but actual use was evenly split at 50 percent each. The extra 25 percent grey electricity amounts to:

Additional grey electricity

$$= 25\% \text{ of } 16,000,000 \text{ kWh} = 4,000,000 \text{ kWh}$$

Extra emissions

$$= 4,000,000 \times 0.20707 = 828,280 \text{ kgCO}_2\text{e}$$

This suggests that greater reliance on grey electricity increased the company's emissions relative to plan.

Emission factor variance considers changes in official emission factors over time. Suppose the published emission factor for grey electricity increased from 0.20707 to 0.28000 kgCO₂e per kilowatt hour:

Variance

$$= (0.28000 - 0.20707) \times 8,000,000 \text{ kWh} = 583,440 \text{ kgCO}_2\text{e}$$

In this case, emissions rose not because of any operational changes, but because the national electricity grid became more carbon intensive. This type of variance may arise because carbon accounting metrics are still evolving and subject to change (Financial Times, 2025). As these metrics improve, guidance on emission factors is revised to be more accurate.

Conclusions

This study illustrates how Activity-Based Costing (ABC) principles can be adapted to environmental management by treating carbon emissions as a traceable cost. Instead of viewing emissions as a general overhead, they are linked to the specific operational activities that generate them. This enables management accountants to identify carbon-intensive processes and to target those areas for efficiency improvements and investment.

A key insight is that the headline figure representing the cost of emitting carbon, calculated by dividing total resource expenditure by total emissions, may appear high. However, this figure should not discourage operational decarbonisation. When viewed from the correct perspective (i.e., that of marginal abatement cost), the additional expense incurred by switching to cleaner alternatives such as low-emission fuels is often well below the market cost of offsetting emissions externally. This suggests that internal reduction strategies can be both environmentally effective and economically justifiable.

The port operator analysed achieved significant emissions reductions through two changes: a strategic transition to low-carbon fuel and the benefit of sourcing part of its electricity from renewable sources via its lessor. While only the fuel switch was a deliberate internal decision, both factors contributed to a lower emissions intensity without compromising operational throughput. Although the average cost per unit of carbon appeared to rise, this reflected a sharp reduction in total emissions rather than inefficiency. In practical terms, this resulted in a significantly lower volume of emissions requiring offsetting, which is an increasingly important outcome as both regulators and stakeholders place greater emphasis on actual emissions reductions rather than reliance on offset mechanisms (Wall Street Journal, 2024). Therefore, despite a higher cost per kilogram, the overall burden of carbon compliance is reduced.

This research also demonstrated the value of break-even analysis in assessing environmental decisions. By comparing the marginal cost of reducing emissions through cleaner inputs, such as switching from diesel to HVO, with the estimated cost of offsetting the same emissions externally, we found that internal abatement was more cost-effective. This suggests that lowering emissions at source is financially beneficial.

By applying standard variance analysis techniques to emissions data, this study also demonstrates how management accountants can decompose changes in carbon output into meaningful categories. These include changes due to operational volume, resource efficiency, energy mix, or revisions to emission factors. Such tools can now be used to track environmental performance.

In conclusion, integrating carbon metrics into costing and decision-making frameworks equips management accountants with a practical and forward-looking approach to sustainability. By focusing on marginal costs, tracing emissions to activities, and applying variance analysis, they are better equipped to guide their organisations towards low-carbon and sustainable operations.

Study limitations

This study has a few limitations that should be considered when interpreting the results. First, the analysis only includes emissions from sources that are directly measured and costed by the port operator, such as electricity, fuels, refrigerants, water, and staff travel. It does not cover emissions from trucks, trains, or ships that move containers to and from the port. These are typically classified as Scope 3 emissions and are likely to be substantial. Second, the study does not include the cost of capital investments, such as replacing old equipment with newer, more energy-efficient machines. Third, emissions from contractors working at the port or from ongoing construction projects were not captured, even though these activities are common and carbon-intensive. Fourth, the data set represents a single year; effects of economic cycles, operational disruptions, or policy changes are therefore not assessed. These limitations present opportunities for future research, including extending the analysis across the full supply chain, incorporating capital expenditure, conducting multi-year evaluations, and undertaking comparative benchmarking with peer terminals.

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Further reading

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