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Reliable CO2 Numbers: Data Quality, Provenance and Uncertainty in Procurement Decisions

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ABSTRACT

Procurement decisions increasingly depend on the carbon footprint reported for purchased goods and services, yet the numbers that reach buyers vary widely in how they were produced. This review examined how the quality, provenance and uncertainty of emissions data shape the reliability of the carbon figures used in sourcing decisions across manufacturing and automotive supply chains. Recent open-access studies and the corporate greenhouse gas accounting standards were synthesised to trace where carbon data come from, how their quality can be judged, and how uncertainty arises and spreads. The evidence showed that supply-chain emissions dominate most corporate footprints while resting on the weakest data, since firms often replace measured supplier values with industry averages and spend-based estimates. Five recurring data-quality deficits were identified: unclear boundaries, limited verification, incomplete coverage, weak interoperability, and the use of generic instead of specific data. Uncertainty was found to enter through input parameters, methodological scenarios and the calculation models themselves, so a single value can hide a wide plausible range. Sharing primary data between trading partners, supported by digital platforms and clear governance, raised reliability, although adoption stayed uneven. The review concluded that procurement teams should treat a carbon figure as a claim with a known pedigree rather than a fixed fact, and should weight supplier comparisons by data quality. Implications for buyers, suppliers and standard setters were set out.

Keywords: carbon data quality, scope 3 emissions, data provenance, uncertainty, sustainable procurement, supplier selection, greenhouse gas accounting

INTRODUCTION

Most of a company's climate impact lies beyond its own gates. For the majority of firms the emissions embedded in purchased goods and services, the part of the inventory labelled Scope 3, form the largest share of the carbon footprint, frequently between three quarters and nine tenths of the total.[1][2] Procurement therefore sits at the centre of corporate decarbonisation, because the choice of a supplier or a material fixes much of the emissions a finished product will carry. A recent systematic review of sustainable supply-chain management confirmed that Scope 3 emissions dominate corporate greenhouse gas totals while remaining underrepresented in both research

and reporting, with most studies still focused on estimating these emissions rather than reducing them.[2]

Acting on these emissions depends on numbers that buyers can trust, and here lies the difficulty. A carbon figure attached to a component is not measured the way a price or a mass is measured. It is the output of an accounting exercise built on chosen system boundaries, input data of mixed origin, emission factors and modelling assumptions. When that figure is poorly documented or carries a wide margin of error, a sourcing decision that ranks suppliers by carbon performance can reward whoever reports the more flattering estimate rather than whoever causes less harm. Research on construction procurement has tied slow decarbonisation directly to data-quality deficits, among them diverging boundaries, weak verification and fragmented interoperability.[3] Smaller suppliers frequently cannot quantify their own supply-chain emissions without outside support, which widens the distance between the reported value and the real one.[4]

The stakes have risen as disclosure has become mandatory. Tightening corporate sustainability reporting now obliges firms to publish annual emission figures that auditors, investors and customers will examine, which turns a once-voluntary estimate into a number with legal and commercial weight.[4] Buyers increasingly pass this obligation down the chain, asking suppliers for product-level carbon data as a condition of doing business. The pressure is useful, yet it also creates an incentive to report something rather than to report accurately, a tension that runs through the rest of this review.[2]

This review asks a focused question. How do the quality, provenance and uncertainty of emissions data affect the reliability of the carbon numbers that enter procurement decisions, and what can buyers reasonably do in response? The synthesis draws on open-access studies published between 2023 and 2026, set against the corporate value chain and product greenhouse gas accounting standards that define the underlying methods.[5][6] Manufacturing and the automotive value chain provide the main setting, since both combine many supplier tiers with strong regulatory and customer pressure on emissions disclosure. The aim is not to propose another accounting method, but to clarify where carbon numbers originate, how their trustworthiness can be judged, and how procurement should treat them.

SOURCES AND PROVENANCE OF EMISSIONS DATA

The reliability of a carbon figure starts with where its data come from. The corporate value chain standard separates primary data, collected from specific activities inside a company's value chain, from secondary data, which is not activity-specific and includes industry averages drawn from databases, government statistics and trade associations, together with spend-based and proxy figures.[5] Primary data describe the actual supplier and process, so they capture real differences between vendors. Secondary data fill the many gaps where primary data are missing, but they smooth over exactly the supplier-to-supplier variation that a procurement comparison is meant to detect. The standard frames the choice as a hierarchy,

asking companies to prefer supplier-specific data for the activities that matter most and to fall back on secondary data only where direct collection is impractical.[5]

How a figure is calculated matters as much as its source. A study of data-centre equipment compared life-cycle assessment estimates against the average-data and spend-based methods that companies commonly apply, and found the conventional approaches insufficient for indirect emissions, since spend-based values mainly track expenditure rather than physical reality.[7] The same limitation appears across sectors. When a buyer multiplies a purchase price by an average

emission factor, two suppliers with identical prices receive identical footprints, regardless of how cleanly each one actually produces. A comparison built on such averages can even rank a genuinely cleaner supplier below a dirtier one whose sector happens to carry a lower default factor. Supply-chain studies state the consequence plainly, noting that current Scope 3 estimates rest largely on industry averages and approximations, which blunts their value for steering decarbonisation.[1]

Even physically based calculations inherit the quality of their emission factors. An assessment of publicly available electricity emission factors showed that figures for the same kilowatt-hour differ depending on the source, the system boundary and the reference year, so the choice of factor visibly shifts the result.[8] Provenance, the documented trail from a measured activity to a reported number, is therefore as important as the number itself. Work on carbon accounting across organisational boundaries argues that digital tools can record and share this trail between trading partners, yet most current practice still keeps carbon data inside a single organisation, which leaves the supplier-side origin of many figures opaque and hard to audit.[9]

In real inventories the two kinds of data are mixed rather than chosen once. The accounting standards expect companies to combine measured primary data for the activities that matter most with secondary data for the long tail of smaller inputs, and then to record which is which.[5] This hybrid picture is sensible, but it places a weight on documentation, because a footprint that blends a metered value, an industry average and a spend-based estimate is only as transparent as the record that says so. A buyer who cannot see this mix cannot tell a well-measured figure from a mostly estimated one.[7]

ASSESSING DATA QUALITY

Because data of such mixed origin must be compared, the accounting standards offer a structured way to grade it. The product standard defines five data-quality indicators: technological, geographical and temporal representativeness, completeness, and reliability.[6] These indicators turn a vague sense that one figure is better than another into criteria a buyer can apply. Does the value reflect the actual technology and region, is it recent, does it cover all relevant flows, and was it gathered and checked in a dependable way? The standard ranks primary data above secondary on this scale and asks companies to document the assessment rather than leave it implicit. Applied to sourcing, the indicators let a buyer score competing quotations, so that a footprint built on a supplier's metered energy outranks one inferred from a spend category, even when the second carries more decimal places. Temporal representativeness deserves particular attention in fast-changing sectors, since an emission factor that was accurate five years ago can misstate a grid or a process that has shifted since, a risk underlined by the spread found among current electricity factors.[8]

In practice the same weaknesses recur. The construction-procurement review sorted these weaknesses into four kinds: boundaries that diverge between firms, sparse independent checking, gaps in coverage, and data formats that will not work together, and it showed that such deficits, rather than any lack of ambition, hold back procurement-driven decarbonisation.[3] A case study of a German production site reached a similar conclusion from the supplier side, reporting that an organisation with a real manufacturing line still struggled to assemble accurate Scope 3 figures across its purchases and leaned on external providers to do so.[4] Independent verification would raise confidence, yet it stays patchy, and the figures of smaller suppliers are rarely audited at all.

Reliability also has a behavioural side that the indicators do not capture. An analysis of customer pressure on suppliers separated substantive accountability from symbolic compliance, where a supplier discloses carbon data to satisfy a customer without improving the underlying measurement.[10] A figure can therefore satisfy a reporting requirement and still be a poor guide to real performance. For a buyer this means that the presence of a number says little on its own, and that the questions worth asking are how the number was produced, whether it was checked, and whether the supplier can show its working.

UNCERTAINTY IN CARBON FOOTPRINTS

Uncertainty is not a flaw to be removed but a property to be understood. The corporate value chain standard divides it into three kinds. Parameter uncertainty concerns whether an input value, such as an activity figure or an emission factor, truly represents the activity it stands for. Scenario uncertainty stems from methodological choices, for example how emissions are allocated between co-products or how a product's use and disposal are assumed to unfold. Model uncertainty arises because any model simplifies reality and so introduces error of its own.[5] The three overlap, and together they mean that a single reported value is better read as the centre of a plausible range than as an exact quantity.

The standard does not leave companies to ignore this. It recommends that they characterise these uncertainties, and quantify them where practical, for instance by testing how sensitive a result is to its main assumptions before relying on it.[5] Such testing rarely reaches procurement, where a footprint usually arrives as a single clean figure with no stated range. If each value arrived tagged with its data-quality level, or even a plain confidence rating, a buyer would see not just the number but how firmly it is known.

The practical consequences are clearest in product carbon footprints along deep supply chains. The electricity-factor study illustrates parameter uncertainty directly, since the spread between equally legitimate factors can move a footprint by a noticeable margin.[8] Scenario and model uncertainty surface in the automotive value chain, where a discussion paper documented how unharmonised rules for calculating product carbon footprints produce figures that are not comparable between suppliers, and proposed harmonisation as the remedy.[11] Independent life-cycle work on passenger cars reinforced the point, showing that the result depends heavily on methodological choices and on the factors chosen for electricity and materials.[12] Where these choices stay undocumented, a buyer cannot tell whether a lower reported footprint reflects a cleaner supplier or a more generous method.

IMPROVING THE RELIABILITY OF CARBON DATA

Several routes can raise the reliability of carbon numbers, and most run through the supply relationship itself. Sharing primary data between trading partners replaces industry averages with vendor-specific measurements, which sharpens Scope 3 estimates and rewards genuine reductions.[1] Recent work frames this as a problem of crossing organisational boundaries, and shows that automated, platform-based exchange of carbon data can preserve provenance while lowering the effort each firm has to spend on collection and reconciliation.[9] Digital methods reach further. A comparative study across agri-food, textile and port-logistics cases reported that artificial-intelligence tools improved transparency and helped firms avoid emissions before they occurred, rather than only accounting for them afterwards.[13]

Tools work only on top of common rules. The automotive discussion paper showed that without harmonised product-footprint rules supplier figures cannot be compared, so shared methods and interoperable data

formats are a precondition for fair carbon-based sourcing rather than an optional extra.[11] The construction review reported the same barrier, where fragmented formats blocked the reuse of supplier figures across systems, and argued that governance mechanisms and digital technologies have to be designed together inside procurement workflows for reliability to improve.[3] Clear ownership of carbon data, with defined responsibility for collecting, checking and updating it, turns these tools and rules into a routine rather than a one-off project, and keeps the provenance trail intact as data move between firms.[9]

External pressure can set the process in motion. Corporate reporting under tightening European rules has moved firms from slow progress toward faster supplier engagement, although disclosure programmes report that many companies still lag the pace their own targets demand.[14] The behavioural evidence adds a caution that bears repeating. Pressure can produce disclosure without substance, so a buyer should reward suppliers who can demonstrate how their figures were produced and verified, not simply those who return a completed form.[10]

DISCUSSION

Read together, these strands point to one practical conclusion. A carbon number should be treated as a claim with a pedigree, not as a settled fact. The most reliable figures come from primary, activity-specific data, with consistent boundaries, recent and regionally appropriate emission factors, and a documented assessment of quality and uncertainty. The corporate accounting standard frames reliable accounting around relevance, accuracy, completeness, consistency and transparency, principles a procurement function can borrow when it judges supplier data.[15] The least reliable figures rest on spend-based averages with undocumented assumptions, and these are unfortunately the most common where primary data are scarce.[1][7] For procurement this means that two supplier footprints are rarely comparable at face value. A buyer who ranks vendors on carbon performance should weight the comparison by data quality, prefer suppliers who provide verifiable primary data, and treat a precise-looking number from an unknown method with caution. A workable rule asks not for perfect data but for data good enough for the decision at hand, with the required quality rising as the value and the carbon intensity of the purchase grow.

The same logic carries implications beyond the buyer. For suppliers, the lesson is that investment in primary measurement, even for a few material-intensive processes, now earns a commercial return, because customers increasingly reward data that can be verified rather than estimated.[1][4] For standard setters and platform operators, the priority is harmonisation and interoperability, so that a product footprint calculated by one firm can be read, checked and reused by the next without manual rework.[11][9] Without that shared infrastructure, even high-quality primary data lose value as they cross each organisational boundary.[3]

Several limits temper these conclusions. Much of the recent evidence consists of literature reviews and sector case studies rather than large-scale measurement, so the prevalence of each data-quality deficit is described more often than quantified.[2][3][4] The reliance on openly available sources in this review also leaves out parts of the standards literature that sit behind paywalls, which may tilt the picture toward the construction, data-centre and automotive cases that happen to be openly published. Findings from one sector do not transfer automatically to another, and the governance arrangements that suit a large manufacturer may exceed what a small supplier can sustain. These gaps mark out where targeted, quantitative work on carbon-data reliability in procurement would help most.

CONCLUSION

Carbon numbers now influence which suppliers win business, yet their reliability varies far more than their appearance suggests. This review found that supply-chain emissions dominate corporate footprints while resting on the weakest data, that quality can be judged through the representativeness, completeness and reliability of the underlying figures, and that uncertainty enters through parameters, scenarios and models alike. It also found that sharing primary data, supported by digital platforms and clear governance, offers the most credible route to better numbers, provided that disclosure reflects real measurement rather than symbolic compliance. Procurement teams that ask where a figure came from, how it was calculated and how well it is known will make sounder decisions than those that read the headline value alone. Reliable carbon numbers are less a matter of more decimal places than of documented provenance and honest uncertainty.

Declaration by Authors

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