Supplier, industry, ecosystem

How to identify, quantify, and abate your supply chain emissions

Introduction

Upstream Scope 3, or supply chain, emissions are typically the largest component of most companies' carbon inventories, on average accounting for 71% of total emissions; for companies in the top quartile, the average is 93% (see *Easy as 1, 2, 3*).[1] Consequently, companies with net-zero ambitions must somehow cut a significant source of emissions, over which they have no direct control, by at least 90%.[2] That is proving no small feat, and for many companies, supply chain emissions have become the bête noire of their net-zero strategy.

Three generic approaches are taking shape. The go-to is *supplier engagement*, a term of art that captures a wide range of activities but can be as passive as encouraging and supporting suppliers' adoption of their own net-zero commitments or as active as co-investing with suppliers in abatement technologies.[3] In addition, some organizations are supporting decarbonization through *industry collaboration*; for example, the automotive sector is pursuing standardization and inter-operability for electric vehicle charging infrastructure for both consumer and commercial markets.[4] Finally, *ecosystem activation* expands the remit of collective action further still: The First Movers Coalition, an initiative operating under the auspices of the World Economic Forum, seeks to aggregate the purchasing power of organizations of all types to support the decarbonization of targeted "hard-to-abate" (HTA) commodities, including cement, steel, aluminum, and others.

But when and how should each approach be used to address which sources of supply chain emissions? Companies of any complexity are often faced with a carbon inventory comprising inputs from thousands—even tens of thousands—of suppliers. Executives charged with making progress toward demanding net-zero goals soon find themselves asking, "What is the best way to decarbonize office supplies? Or legal services? Or international couriers?" The strategy triptych of supplier engagement, industry collaboration, and ecosystem activation might as well be *cleek, mashie, and niblick* for all it means to those charged with making real choices.

Consequently, just as even the best golfers appreciate a good caddy to advise on when to use which club (cleek off the tee, mashie in the fairway, niblick out of a bunker), many companies might benefit from a rigorous, credible way to determine which of these tools, singly or in combination, are best used for which sources of supply chain emissions.

Thanks to how carbon inventories are often created, many companies have an answer at their fingertips; all that's missing is direction on how to use it. Specifically, companies that use spend-based emission factors to estimate their carbon footprint are implicitly relying on the same data and assumptions required to identify and quantify the entirety of their supply chain emissions and, by extension, to gain valuable insight into how best to achieve the desired emissions reductions.

This report explains how companies can leverage the United States Environmental Protection Agency's Environmentally Extended Input-Output tables to build an integrated, comprehensive net-zero strategy—one that applies the right kind and level of effort to each source of supply chain emissions.[5] Better still, the resulting insights can be combined with well-understood, effective, and innovative (a rare combination!) carbon market instruments to support net-zero. Best of all, this approach can set not only a single company on the path to net-zero but also the entire global economy.

1 Averages based on CDP disclosures. Scope 3, or value chain, emissions comprise "upstream" and "downstream" emissions. Your suppliers' Scope 1 emissions are your upstream Scope 3, or supply chain emissions, while downstream captures emissions related to the use and disposal for your products and services. Companies can choose which elements of Scope 3 they disclose.

2 Perhaps the most widely adopted standard is set by Science Based Targets initiative (SBTi), which defines "net-zero" as achieving a 50% reduction in absolute emissions for all three Scopes, compared to a base year, by 2035, and a 90% reduction by 2050. That is, if absolute emissions in, say, 2019, were 10 tonnes (Scope 1), 5 tonnes (Scope 2) and 100 tonnes (Scope 3), then by 2035 this company would need to have emissions of 5, 2.5, and 50 tonnes, and 1, 0.5, and 10 tonnes by 2050—regardless of the company's economic growth. That is, merely efficiency improvements (i.e., reductions in the tonnes of emissions per dollar of output) are not sufficient; there must be a 90% reduction in absolute emissions. Unless otherwise specified, "net-zero" refers to an SBTi-compliant goal.

3 SBTi-compliant net-zero requires that at least one-half of one's suppliers, accounting for at least two-thirds of one's supply chain emissions, have committed to an SBTi net-zero target.

4 See, for example, "Roadmap of standards and codes for electric vehicles at scale," from the American National Standards Institute (June 2023).

5 Wesley W. Ingwersen et al., "The US environmentally extended input-output model v2.0," *Scientific Data* 9, no. 194 (May 3, 2022). Unless otherwise cited, all carbon inventory estimates, in quantity and structure, presented in this report are derived from an analysis of these tables. This approach does not address downstream Scope 3 nor all categories of upstream Scope 3. Estimates of percentages of totals should be interpreted accordingly.

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Easy as 1, 2, 3

Greenhouse Gas (GHG) Protocol has developed, manages, and promulgates perhaps the best-known carbon reporting framework and standards.

Scope 1 emissions arise from the operation of assets over which a company has "operational control" and can arise from either combustion or industrial process reactions. For example, a trucking company might lease or own trucks, but either way, it controls the use of those trucks, and when they combust diesel fuel, the resulting emissions are deemed Scope 1 for the trucking company. Similarly, a concrete manufacturer generates process-driven Scope 1 emissions when limestone is converted to lime in order to create clinker, which is in turn an input into the production of concrete. For the companies purchasing the trucking services or the concrete, these Scope 1 emissions are deemed supply chain Scope 3 emissions.

However, it is not only the upstream Scope 1 that is passed along. Our trucking company needs trucks, after all, and manufacturing those trucks generated Scope 1 emissions upstream from the trucking company: mining iron ore, processing the ore into pure iron, smelting the iron into steel, and so on. All those emissions were passed along, becoming the trucking company's Scope 3, which in turn adds to the Scope 3 emissions of the customers of the trucking company.

But wait, there's more. Downstream Scope 3 captures the emissions arising from the use and disposal of a company's production. Our truck manufacturer and the processor of diesel fuel, for example, might choose to report the trucking company's Scope 1 emissions as its downstream Scope 3. Downstream reporting is not yet widespread and can create considerable complexity in reporting, analysis, and mitigation strategies. We will focus exclusively on upstream Scope 3 in this report; any references to downstream Scope 3 will be explicitly called out.

Scope 2 emissions are a special case of Scope 3, arising from the production of purchased energy, which comprises electricity, heating, and cooling. When the energy producer burns fossil fuels, these Scope 1 emissions are passed along to the energy consumer, which then reports them as its Scope 2.

Table 1: Pass the emissions

	Extractive	Processing	Manufacturing	Services
Scope 1	5	10	15	3
Scope 2	3	5	10	5
Scope 3 (upstream)	10	18	33	58
Total inventory	18	33	58	64

Source: Deloitte analysis

Cleek, mashie, and niblick

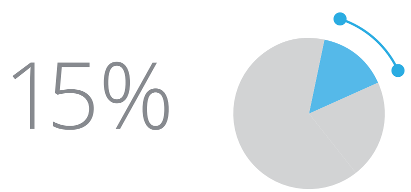
A good golf shot begins with using the right club for the lie of the ball. Similarly, each of the three generic strategies is likely to be most effective in particular circumstances. Specifically, how best to manage a given source of emissions is a function of *visibility, materiality,* and *influence*. Each of the three strategies is most appropriate for a unique set of values along these three dimensions, and each is typically most appropriate for a very different percentage of total supply chain emissions.

Consider each in turn.

Supplier engagement

When to use		
Visibility	**Materiality**	**Influence**
▲ High	▲ High	▲ High

Percentage of supply chain emissions



Source: Deloitte analysis

Supplier engagement is the most intuitive of the three strategies and can be highly effective. For example, a retailer might deal directly with a trucking company for logistics services. The Scope 1 emissions from trucking services that become the retailer's supply chain Scope 3 emissions arise almost entirely from the combustion of diesel fuel in the trucks. Reducing those emissions might be accomplished through an integrated, three-pronged approach of reducing carbon intensity through route and load factor optimization, shifting from trucks to trains, or electrifying vehicles (see *Cut, switch, abate*).

This can sound appealing, but consider what this sort of supplier engagement requires. First, a company must have the necessary *visibility* to know that a given source is contributing abatable Scope 1 emissions to its Scope 3 inventory. This condition is met in the trucking services example, but for many inputs, finding any significant measure of suppliers' Scope 1 emissions can be difficult. For example, most companies purchase legal services, but law firms have few Scope 1 emissions: Supply chain emissions account for more than 90% of the carbon inventory of legal services, so engaging with a law firm is unlikely to offer the same benefits accruing to engagement with a trucking services provider. In other words, supply chain emissions from trucking services are highly visible; those from legal services, far less so.

Second, although it is increasingly common for the cost savings from decarbonization to more than pay back the required investment, often much of the value of decarbonization is the decarbonization itself.[6] Consequently, a simple metric such as "dollars per tonne abated" can feature prominently when determining with which suppliers to engage and how. This implies that, in addition to visibility, the *materiality* of the emissions source can feature prominently when developing a Scope 3 reduction strategy. Larger sources can be subject to economies of scale, reducing the cost per tonne abated, sometimes significantly. And since supplier engagement is likely to be among the more resource-intensive abatement strategies, the more material the source of Scope 3 emissions, the more suitable supplier engagement is likely to be.

Third and finally, effective engagement will turn at least in part on the degree of *influence* a company has with the relevant supplier. If a company devotes a large portion of its spend to a given input, or if that spend is a significant portion of a supplier's revenue, a company is likelier to be able to have at least some impact on a supplier's willingness and ability to invest in carbon abatement.

Since supplier engagement is likely a primary abatement strategy for, on average, 15% of total supply chain emissions, it is more than a little unfortunate that in many organizations the supply chain abatement strategy begins and ends here. An understanding of when and why to turn to the remaining two options provides the foundation for a more nearly comprehensive strategy.

6 Benefits arise not only from reduced energy expenditures but also from tax and other incentives.

Cut, switch, abate

This simple, three-part framework can be a useful way to begin organizing what invariably becomes a complex undertaking. The three reduction strategies described here can be used singly or in combination to reduce the carbon footprint associated with any particular input.

Cut: Reducing your consumption of any input will, presumably, reduce the production of that input and the emissions associated with that production. Do you have a large Scope 3 footprint from air travel? One option is to fly less and forego the interactions that travel would have made possible.

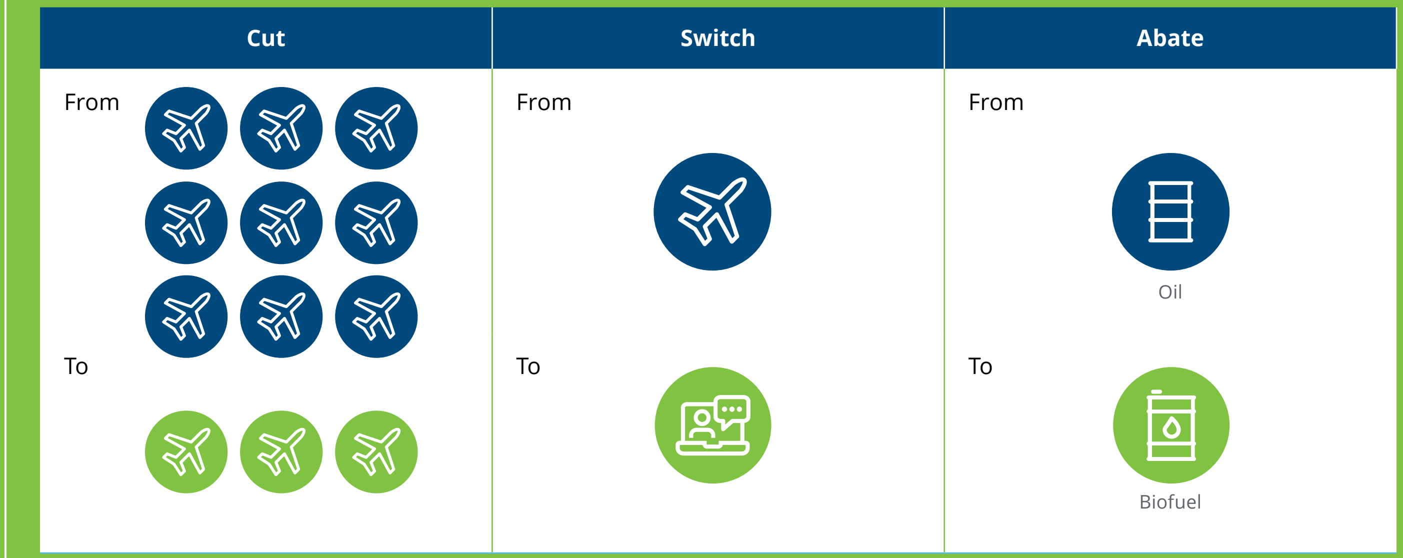
Switch: Rather than entirely forgo interactions enabled by physical travel, invest in remote meeting capabilities. A decade ago, this implied expensive video-conferencing infrastructure; today, it might mean adapting or defining protocols for personal interactions to accommodate the requirements of video calls enabled by software platforms. Changing behavior can imply some measure of compromise, as the lower-carbon alternative might suffer from some combination of lower quality or higher cost.

Abate: It is often possible to materially reduce the carbon intensity of an input. So, for example, where some measure of air travel remains necessary, one might invest in lower-carbon fuels through an intermediary such as the Sustainable Aviation Buyers Alliance (SABA), which can dramatically reduce the Scope 1 emissions arising from flight.

It is important not to fall into the trap of confusing "efficiency" with "abatement." For example, a trucking company might increase its load factors or streamline its route structure in ways that reduce carbon emissions per ton-mile. Such initiatives are often financially beneficial since they typically reduce waste as well as carbon emissions. However, increasing the efficiency of a necessarily carbon-reliant system is very rarely a viable strategy for achieving net-zero. Consequently, companies will typically find that absolute emissions grow as the company grows, regardless of how efficient it becomes. In other words, anything that burns fossil fuels is unlikely to achieve a 90% reduction in absolute emissions.

Even so, efficiency can be a useful step toward meaningful reductions by enabling a subsequent cut, switch, or abate strategy. For example, a more efficient routing structure and higher load factors can cut the consumption of trucking services required to the point that switching to an electric fleet becomes feasible. This, in turn, can have implications on the required abatement efforts: Adopting EVs at scale will increase the upstream reliance on mining inputs, which remain carbon intensive, implying a need to support the adoption of low-carbon mining technologies and processes.

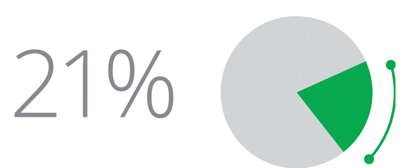
Figure 1: Cut, switch, abate



Source: Deloitte analysis

Industry collaboration

When to use		
Visibility	**Materiality**	**Influence**
▲ High	▲ High	▼ Low
▲ High	▼ Low	▲ High
▲ High	▼ Low	▼ Low
▼ Low	▲ High	▲ High
Percentage of supply chain emissions		



Source: Deloitte analysis

Regardless of the level of visibility, when materiality or influence is low, supplier engagement often just doesn't pay.

For example, in food processing, many producers of end products consume relatively small quantities of common inputs, such as some flavor additives. The emissions are visible, but cost savings from emissions reduction might be minimal, and materiality is low, making direct engagement potentially prohibitively expensive per tonne abated. In these cases, customers can work collectively to establish new industry standards for lower carbon production of these inputs. By coordinating their efforts, they can increase the efficiency of their interventions.

Alternatively, some inputs might be significant to the customer, while to the supplier, any one customer's requirements are trivial. In such cases, industry-level collective action can aggregate customers' influence, increasing the effectiveness of their efforts.[7]

In both cases, participants largely forego the opportunity for short-term competitive advantage based on unique access to a lower carbon version of a specific input, since, very likely, many customers and suppliers are party to the new norms. However, it sets up the participants to compete more effectively for fully compliant net-zero status, since it allows participants to cost-effectively address some of the long-tail drivers of their Scope 3 footprint, which frees them to concentrate their differentiated efforts where they are likelier to have more impact.

In addition, most companies typically work within a variety of operating constraints that can make it difficult for some companies to pursue promising avenues of decarbonization, regardless of the visibility or materiality of the sources.

For example, in pharmaceuticals, Food and Drug Administration approvals for some products can stipulate product and production parameters, for example, inactive ingredients, heat sources, transportation methods, packaging materials, and so on. Making changes along any of these or other dimensions can be involved, making demonstrating the equivalence, safety, and efficacy of new lower-carbon alternatives potentially time consuming and expensive.

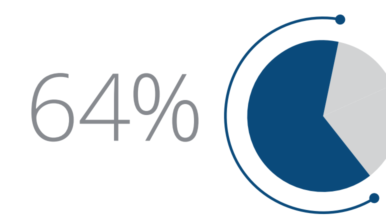
In such instances, coordinated industry effort demonstrates a collective commitment of meaningful emissions reduction. This might well advance efficient collaboration between industry and relevant governing bodies to review standards, regulation, or legislation in ways that might advance good-faith decarbonization efforts. After all, few industry practices were developed and adopted with decarbonization in mind. Introducing the requirements of decarbonization into the conversation might advance the net-zero objective without unnecessarily increasing the cost of meeting appropriate safety and efficacy standards.

Finally, some high-carbon input commodities are sold into market-clearing mechanisms—for example, metals exchanges—which can reduce visibility into what would otherwise be garden-variety and relatively transparent supplier interactions. In these cases, industry-level efforts can maintain the benefits of aggregated markets while restoring the lost visibility into upstream Scope 1 emissions through, say, commodity-specific accreditations and chains of custody. This would allow, for instance, direct customers of some mining commodities to prefer buying from low-carbon producers while operating within the existing market structure. Such efforts, however, are likely to be expensive and require close managerial attention, suggesting that they will be attractive only when materiality and influence are high.

[7] In any collaboration among corporate entities, it is critical to be fully aware of and compliant with all applicable legal and ethical constraints and not to engage in any anti-competitive behavior.

Ecosystem activation

When to use		
Visibility	Materiality	Influence
▼ Low	▲ High	▼ Low
▼ Low	▼ Low	▲ High
▼ Low	▼ Low	▼ Low
Percentage of supply chain emissions		



Source: Deloitte analysis

Part of what makes supplier engagement and industry collaboration challenging is that effective interventions must typically be highly bespoke, tailored to the nature and breadth of participants' shared interests and needs and the nature of the inputs being decarbonized. For such solutions to work, typically two or all three dimensions must register "high."

Unfortunately, for most companies, most of the far-upstream Scope 1 emissions that constitute the bulk of their supply chain footprint are "low" on at least two dimensions. With no direct commercial transaction at stake, any meaningful level of influence is vanishingly unlikely. And, although collectively these upstream Scope 1 emissions are are a significant portion of the overall carbon inventory, individually none of them matters much, and so materiality is low—if it can be estimated all. In these circumstances, neither supplier engagement nor industry collaboration is likely to be either effective or efficient.

Enter *ecosystem activation*, the third of the three generic strategies, which lies still further along the implicit continuum of fewer shared interests among a larger and broader set of participants. Where supplier engagement involves as few as two parties exploring a wide range of common goals, and industry collaboration mobilizes a greater number of players with fewer but significant shared interests and constraints, ecosystem activation marshals a larger and more diverse population around a narrower and more focused objective. As a result, it tends to require a more standardized solution with far less Scope for customization.

Perhaps the most visible and effective form of net-zero ecosystem activation is the increasingly widespread support for renewable electricity generation. Generating electricity by burning fossil fuels is among the largest sources of carbon emissions in the United States and globally.[8] Reaching collective net-zero depends critically on the economy's ability to transition completely and quickly to zero-carbon sources of electricity.

Electricity from solar energy is an increasingly viable alternative. The first commercially viable silicon solar cell was launched by Bell Labs in 1954, and the cost per watt has dropped from more than $100 in 1976 to less than one cent in 2019.[9] In the United States, zero-carbon generation technologies now supply more than one-fifth of total demand—more than is supplied by coal or nuclear.

Which abatement strategy is likely most effective for electricity? Grid-based distribution blends power from all sources. There is no "tracking the electrons," so companies cannot know precisely how their electricity was generated. Worse, many utilities source power from a dynamic and changing set of suppliers in order to meet peak demand, even importing power across state and national borders. Consequently, visibility into the upstream Scope 1 emissions from electricity purchases is low.

Materiality, however, tends to be high: Scope 2 is, on average, 12% of total corporate emissions. Yet since most companies account for only a small percentage of a utility's revenue, influence is typically low.

With a "low/high/low" profile, electricity seems best suited for an ecosystem activation response. And that is precisely how it has been addressed by many companies seeking to eliminate their Scope 2 emissions.

Central to Scope 2 decarbonization has been separating the physical electricity (the commodity) from the carbon footprint

[8] According to the EPA, electricity generation accounts for 25% of US greenhouse gas (GHG) emissions. Transportation accounts for 28% but is a far more aggregated category and includes car, rail, air, and sea transportation and many different types of vehicles within it. At the level of similarly homogenous categories, it seems reasonable to tag electricity as the single largest source.

[9] See Wikipedia, including sources; e.g., "Renewables were the world's cheapest source of energy 2020, new report shows," World Economic Forum, July 5, 2021.

associated with generating that electricity (the commodity's environmental attributes). Renewable Energy Certificates (RECs) verify that the source of a given quantity of electricity has been appropriately generated. Virtual power purchase agreements (VPPAs) are complementary instruments that allow companies to pay only the premium required for specific providers to generate renewable electricity, even if the electricity the purchaser actually consumes does not come from that specific provider.[10] These financial instruments allow companies to take environmental credit for the purchase of electricity generated from renewable sources for the quantity of electricity they consume, even if they don't actually consume the zero-emissions electricity. In other words, companies can claim net-zero Scope 2 status based on what they *buy* and not what they *use*.

By separating the environmental attributes (i.e., zero carbon) of the electricity from the commodity itself, RECs and VPPAs have "activated the ecosystem" of generators and (virtual) consumers of zero-carbon electricity. As more companies enter the market, the demand for renewable electricity increases, further driving down cost and prices in a virtuous cycle.[11]

It is, in concept, a short hop from VPPAs to a virtual purchase agreement for *any* commodity: a VC(commodity)PA. For example, the Sustainable Aviation Buyers' Alliance has created contracting mechanisms that allow companies to fund the purchase and use of Sustainable Aviation Fuel (SAF) and is developing SAF certificates (SAFc) that are eligible for recognition by the appropriate standards bodies.[12] In principle, companies with Scope 3 emissions attributable to their airline suppliers' Scope 1 emissions will be able to purchase SAFc instruments and retire them against their declared Scope 3 inventory. Like VPPAs, the viability of the SAFc instrument depends on companies being able to both *determine that* they consume air travel *and* to estimate the Scope 1 emissions arising from that travel. And, although more involved than looking at a monthly electricity bill, these estimates are not difficult to generate.[13]

VPPAs and SAFc's are specific instances of an "indirect inset" (see *Inset vs. offset*). That is, where an "inset" is the decarbonization of inputs you buy and consume directly, an indirect inset decarbonizes inputs you use but don't buy. And if we can create indirect insets that allow companies to virtually purchase zero-carbon electricity and, soon, bio-based jet fuel, why not virtually purchase zero-carbon iron ore in order to eliminate the Scope 3 emissions from that problematic laptop computer?

The key to the success of VPPAs is each purchaser's ability to know, first, that it consumes electricity at all and, second, how much electricity it consumes. Of course, electricity use is ubiquitous—we all know we use it almost all the time, but it is worth making this requirement explicit even so. And thanks to its monthly electric bill, a company knows precisely how much clean electricity to purchase to remain zero carbon for Scope 2. So, although the visibility of electricity is low at the electron level, its economic visibility is high.

For essentially every other input commodity, however, these two conditions are not met. Although it's a safe assumption that, say, a consulting firm uses *something* that requires, say, iron ore or copper as an input—a laptop computer, for example—do you really *know*? Worse, determining the quantity used seems essentially impossible. Without knowing what is consumed and how much of it, it is impossible to create the relevant VCPA.

Many companies are therefore in more than a bit of a conundrum: Almost two-thirds of their supply chain emissions are some combination of too hard to find, too expensive to abate, or too far removed to meaningfully influence. Put somewhat glibly, these emissions are swept into the category of "hard problem, solve later."

Although framed as rational prioritization, it is more accurately characterized as procrastination with potentially devastating consequences. The deep supply chain footprint for many companies includes precisely the HTA commodities—for example, agricultural inputs (e.g., grain, soy, etc.), building materials (e.g., steel, concrete, etc.), and zero emissions energy and feedstock sources (e.g., metals, minerals, hydrogen, etc.)—that must be largely decarbonized with the next 20 years if the world is to reach a meaningful net-zero footprint. That means starting now, for the requisite innovation and cost reduction will not happen by magic. Explicit and significant demand signals in the form of volume guarantees and price supports from downstream users of these commodities are essential to action at the necessary speed and scale (see *Demand better*).

[10] The specifics of the REC and VPPA markets can be complex, and a more fulsome explanation is beyond the Scope of this paper. See here and here for more.

[11] See, for example, this recent Deloitte report.

[12] See SABA's homepage.

[13] Companies for which air travel is a material contributor to Scope 3 emissions typically spend enough on air travel to manage it fairly closely. They tend to be able to generate good estimates of the number and types of flights taken. Per-passenger fuel burden factors are readily available, and the resulting estimate of the quantify of fuel burned is sufficient to accurately inform Scope 3 reduction efforts.

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Inset vs. offset

An "offset" is typically the removal or avoidance of carbon emissions via a mechanism that is unrelated to the processes that generated the emission being addressed. For example, a trucking company that generates carbon emissions by burning diesel fuel might remove carbon from the atmosphere through forestry-based removal offsets or prevent the emission of carbon from coal-fired electricity generation by paying for the installation and maintenance of solar panels that would not otherwise be deployed, thereby creating an avoidance offset. In both cases, the trucking company pays for these activities and acquires the rights to the removed or avoided carbon.

What constitutes a credible offset and how to account for them is evolving. The more demanding and widely adopted standards acknowledge the benefits that responsible offsetting can create but tend not to recognize offsets as a mechanism for reducing a company's reported carbon footprint.

An "inset" is typically generated by decarbonizing activities that would otherwise have generated additional emissions within a company's supply chain. For example, a retailer that uses trucking services could subsidize its logistics provider to deploy electric vehicles on relevant routes. If the electric fleet is used exclusively on the routes subsidized by the retailer, then the trucking would report forward the relevant Scope 1 emissions (zero) to the retailer, which would then realize a lower Scope 3 inventory.

An "indirect" inset is an emerging instrument that allows a company to fund the decarbonization of a commodity that it uses, in the quantity it uses it, and to claim the decarbonization benefit via a lower Scope 3 inventory even if the funding company does not consume that specific commodity. For example, a company might determine that its activity generates demand for 100 tons of copper. It could then fund the decarbonized production of 100 tons of copper anywhere in the world, which would then be sold into global commodity markets. The funding company would claim a lower Scope 3 footprint, even though the decarbonized copper would have no traceable relationship to the funder's consumption of products with copper content.

Demand better

Corporate decarbonization efforts are subject to a second paradox: They succeed only if they fail. That is, some companies—perhaps most—are leading the charge for voluntary decarbonization to create competitive differentiation. But if only a few companies achieve net-zero, then the planetary-level catastrophes that await us will have made the "success" of any individual company utterly pointless. But if collective success requires that every company achieve net-zero, differentiation based on net-zero is nonsense.

Perhaps somewhat obviously, the answer lies in timing: Can a company reach credible net-zero far enough in advance of enough other companies that it can reap the benefits of net-zero leadership?

The solutions described here make this possible. By supporting the decarbonization of upstream hard-to-abate commodities and claiming the credit against declared Scope 3 emissions, leading companies can catalyze the deployment of technologically viable low-carbon production technologies and processes. As these new approaches race down their learning curves, the supporting companies will achieve their own net-zero status years ahead of most of other companies.

Better still, learning curve-based cost reductions allow low-carbon approaches to achieve scale-driven cost reduction, at which point market forces will drive the widespread deployment required for industry-wide and, ultimately, planetary net-zero status—all within the relevant time horizon.

Consequently, leading companies that focus their decarbonization support using the methods described here will reap two benefits: earlier net zero status and a legitimate claim to having enabled global net-zero.

Why the alley is dark

The level and allocation of resources to each source of emissions (Scopes 1, 2, or 3) and each generic Scope 3 abatement strategy (supplier, industry, ecosystem) rarely deliberately reflects the relative magnitude of each emissions source. Instead, decarbonizing Scope 1—emissions from controlled assets—can, understandably, hog the limelight: There is often a visceral and commendable compulsion to "clean up your own mess." Scope 2—emissions from purchased energy, typically electricity—can require less effort, thanks to the effectiveness of RECs and VPPAs as abatement mechanisms, although it can command a healthy share of financial resources. And when it comes to supply chain emissions, supplier engagement is often the beginning and end of the conversation.

Yet Scopes 1 and 2 are typically less than 30% of most companies' emissions, while supply chain emissions addressable through supplier engagement contribute another 15%. Add it all up, and many companies' current practices tend to devote almost 100% of effort to much less than half of their total carbon footprint.

The unfortunate implication is that most companies' net-zero strategies tend to resemble searching for your lost car keys under the streetlamp where the light is brightest ... and not in the dark alley where you dropped them.

The alley where the other 85% of supply chain emissions (and, on average, more than half of total emissions) lurk is so dark thanks to two compounding features of modern supply chains: *dynamism* and *complexity*. Singly and in combination, these characteristics severely limit a company's visibility and influence into the sources of supply chain emissions; and, lacking insight into any given source's materiality, it is uncommonly difficult to allocate resources efficiently.

One solution is to address the visibility and influence factors directly through sophisticated supply chain analysis. Where companies are willing and able to devote the necessary resources, it is not unreasonable to expect even significant progress. Certainly at least some organizations are likely to find at least some, and perhaps much, of the upstream Scope 1 that is driving their supply chain Scope 3.

Even so, improving supply chain visibility is intrinsically and unavoidably limited in ways that will leave significant upstream emissions forever out of sight, for two reasons.

Dynamism

Well-managed supply chains are constantly balancing what is often a trade-off among the benefits accruing from stable, long-term supplier relationships, and changing suppliers to better match evolving customer requirements with supplier capabilities. Consequently, few organizations have the liberty of committing irrevocably to one supplier in the pursuit of a single objective, viz., carbon reduction.

That puts suppliers in a bit of a fix: A customer with a carbon reduction mandate might well be one of only a few customers that values, and is willing to pay for, a materially lower carbon footprint. Since changes to inputs and production processes can have an impact on the quality or regulatory compliance of production, should carbon-oriented customers have a change of heart, a supplier might have trouble finding new customers for its newly decarbonized outputs. As a result, fewer suppliers will be willing to make the necessary investments in decarbonization.

Even if you're willing to make meaningful purchase commitments, this applies only to your first-tier suppliers. Beyond that, your suppliers define the rest of your supply chain, and they'll make the choices that make sense to them. Should you want to "go around" your first tier, you might be able to support upstream decarbonization, but any changes in the supply chain mean that the benefits you create will redound to others. After all, if you procure machined steel products and invest in the manufacture of "green" rolled steel, you see a Scope 3 reduction only if your provider of the machined good continues to source from the green steel manufacturer you are supporting.

To see this more clearly, consider the supply chain emissions attached to a management consulting firm's purchase of a computer—that is, the accumulated Scope 1 emissions from every stage of value added that created it. Working upstream, this includes the jet fuel to air freight the device from the manufacturer to the consulting firm's IT department, the diesel fuel to truck the chips from the chip maker to the manufacturer, the natural gas to shape raw steel into the chip maker's lithography machine, the coal to smelt raw iron ore into sheet steel for the lithography machine, and the diesel fuel to extract the raw iron ore.[14]

The consulting firm likely has a direct commercial relationship with the assembler of the computer and perhaps the air freight company, so that is where its influence is greatest. Beyond that, the stability of the upstream supply chain is forever at the mercy of every other link in the chain. Yet investment in decarbonizing, say, iron ore mining can require years-long commitments, and the consulting firm's far-removed downstream demand for iron ore is unlikely to account for much of those distant suppliers' immediate revenue. That puts the consulting firm's decarbonization strategy low on the iron ore mine's list of priorities.

This would be less of a concern if one could count on suppliers to engage with their suppliers all the way up the chain. For most companies, however, hitting net-zero is mostly about Scope 3, and relying on "cascading commitments" is to leave success almost entirely in the hands of others—most of which can't be directly or even meaningfully influenced. Relying on a daisy-chain of net-zero targets would essentially ensure that a company would reach net-zero only when the last of its extended supply chain does. That's the strategy of a laggard, not a leader.

[14] It's even worse, actually. This illustration captures only the accumulated "intermediate use" of inputs. Production processes typically rely on various forms of fixed capital, both tangible (metal presses, trucks, etc.) and intangible (capitalized R&D). The production of these fixed assets generates emissions. The "fully loaded" carbon burden of goods for final consumption should include a share of those emissions. The GHG Protocol reporting standards do not call for the allocation of emissions arising from the imputed consumption of fixed capital to production; instead, the total carbon from additions to fixed capital is added to the company's total company inventory in the year the fixed capital is added. However, when fixed assets are leased, fixed capital is allocated on an annual basis, since the lease payments are used to generate the carbon estimate using spend-based emission factors. For large companies with significant fixed assets, annual capital costs likely reflect depreciation, effectively turning a "stock" into a "flow."

Complexity

In our consulting-and-laptop example, the highly simplified supply chain hardly does justice to the true complexity involved. Consequently, it is at least ambitious—if not heroic or hubristic—to believe that any company could reliably, accurately, and consistently identify and quantify enough upstream Scope 1 for enough of its inputs to make a material and lasting difference to its Scope 3 footprint (see *The limits of supply chain transparency*).

Worse, even if sophisticated financial systems can help identify suppliers several tiers upstream, for those suppliers' reductions to show up in lower Scope 3 emissions, a company must demonstrate that the *very same production* (with the now-lowered footprint) is an input to its products or services. Since suppliers sell into complex markets and often to many different customers, tracking specific outputs across several supply chain tiers can be even more difficult than finding the upstream supplier in the first place. In other words, it's one thing to follow the money upstream to your suppliers, but it's another to follow the molecules back downstream.[15]

Either way—money or molecules—the number of interactions that define the modern supply chain quickly become overwhelming. Imagine a company with three tier 1 suppliers. There are three "pair-wise" interactions between the company and its first tier. Suppose each tier 1 supplier has three suppliers; that's nine pair-wise interactions between tier 1 and tier 2 and 12 pair-wise interactions between the company and its first two tiers of suppliers.

Now imagine a more realistic scenario: a company with hundreds or even thousands of tier 1 suppliers, with each tier 1 supplier dealing with thousands of its own suppliers.[16] For example, the carbon inventory for the US-based production of management consulting services is 92% supply chain Scope 3. Those emissions are generated from the use of 298 tier 1 input commodities, e.g., real estate, air travel, and so on. Each of those tier 1 inputs draws on its own "recipe" of anywhere from fewer than 100 to more than 300 input commodities. This generates more than 68,000 pair-wise connections between the first and second tiers, more than 16 million between the second and third tiers, and more than four and half billion between the third and fourth tiers—and that's at the *commodity level*; since each commodity is typically provided by multiple suppliers, the number of *supplier-level* connections is, literally, inestimable (see *Economy, industry, commodity, establishment*).

To avoid this complexity, many companies rank suppliers by their contributions to supply chain emissions and focus their engagement efforts on those at the top of the list. And if supply chain emissions were a classic "Pareto problem"—where, say, 20% of suppliers generated 80% of emissions—such an approach might work. However, supply chain emissions is a "long-tail problem": Few input commodities account for even double-digit percentages of the total.[17] For example, to capture 90%, most US-based production would have to address at least 30 different input commodities (see figure 2, on page 14).[18] With multiple suppliers for each commodity, there is no escaping the crushing complexity of seeking net-zero through direct supplier engagement.[19]

It is not simply the number of companies one must engage with that creates complexity. The diversity of the engagement required is similarly challenging. Consider first a more typical co-investment initiative—say, cost reduction. Here, suppliers and customers are often able to reach mutually beneficial terms, in large part because both parties have relevant experience and good visibility into expected outcomes, and the benefits are more likely to be transferable to other suppliers or customers.

15 Standard setters, e.g., the GHG Protocol, are relaxing these constraints to incorporate concepts such as the "supply shed" to allow companies to claim credit for decarbonizing upstream inputs even if they cannot track that decarbonized production exactly. This is precisely the sort of adaptation that will be required to solve the "Scope 3 paradox," as is explored at length in the balance of this report.

16 For example, Walmart is reported to have more than 100,000 suppliers, and Proctor & Gamble more than 75,000.

17 The "scare quotes" connote that "Pareto" and "Long Tail" are used colloquially. A Pareto distribution can have a long tail, and more commonly Pareto distributions are contrasted fat-tail distributions. But Scope 3 emissions do not have a particularly "fat" tail. The claim here is that success in decarbonizing Scope 3 emissions means managing a large number of small contributors to the Scope 3 inventory.

18 Achieving SBT-compliant net-zero requires a 90% reduction in absolute Scope 3 emissions. One could hope to achieve this goal by identifying "only" (!) 90% of one's Scope 3 inventory ... and then decarbonizing it by 100%. More likely, however, is the need to identify very nearly 100% of the total Scope 3 inventory and then decarbonize enough of it by 90%+ to achieve the necessary 90% overall emissions reduction.

19 The Bureau of Economic Analysis tables work with economy-wide, commodity-level averages. Consequently, each output commodity will have an input "recipe" that captures the averages for all the "establishments" (a term of art in the development of the IO tables) that produce a given commodity. This means that if one establishment is unique in its use of a given input, it will show up as a (very low) average requirement for that input. That is why, in figure 1, the upper limit for the number of commodities required to capture 100% of Scope 3 emissions is so high. Working with the number of inputs required to capture 90% of Scope 3 seems more reasonable, and any inflation in the number of input commodities introduced by averaging input requirements across all establishments is almost certainly overshadowed by the fact that few companies procure each input from only one vendor.

The limits of supply chain transparency

Not surprisingly, the challenge of managing Scope 3 emissions typically involves—and might even become the responsibility of—the procurement function; after all, estimating a Scope 3 inventory typically requires knowing what a company buys and for how much. If the procurement folks don't know those answers, who will?

Most well-run companies are likely to have reliable and accurate tier 1 supplier data. But following a complex supply chain to any material depth can easily confound even the most sophisticated procurement professional. As pandemic-related supply disruptions revealed, hiccups in the unlikeliest of places ripple through global supply chains in unexpected ways, giving the lie to the idea that most companies know where even the closets are, never mind the skeletons therein.

Certainly, it is possible that renewed emphasis on upstream transparency might create a qualitative breakthrough in data completeness and the accuracy required to measure—rather than merely estimate—a company's total requirements for any given commodity. The purchasing discipline has had significant financial incentives to improve upstream visibility for decades, yet complete and accurate data continues to elude even the best practitioners of that dark art. It seems largely a declaration of faith that somehow the quest for net-zero will reveal a solution that the profit motive has yet to inspire.

Economy, industry, commodity, establishment

As part of its data-gathering activities, the US Bureau of Economic Analysis (BEA) surveys tens of millions of the nation's commercial establishments. An establishment is a physical location for a business entity (i.e., a commercial concern, regardless of legal form, e.g., a corporation, partnership, sole proprietorship, etc.). Each establishment's production (subject to materiality) is allocated to one of 411 commodities, each of which has a namesake industry. Each establishment is allocated to an industry based on the commodity it produces the most of.

For example, a professional services firm's New York office is an establishment. That establishment might produce $100 of the "management consulting" commodity and $50 of the "tax preparation" commodity. That production would be added to the totals for each of those commodities produced by the economy as a whole. However, the establishment would be added to the "management consulting" industry, and as a result, the management consulting industry would make an incremental $100 of the management consulting commodity and $50 of the tax preparation commodity. That's why each commodity can be made by more than one industry, and each industry tends to make more than one commodity.

Using these production data, the BEA creates the industry-by-commodity "make" table: the total production of each of the 411 commodities by each of the 411 industries.

In addition, the BEA collects data on establishment purchases, which are used to create the commodity-by-industry "use" table: the identity and quantity of each commodity consumed by each industry.

The "make" and "use" tables are combined to create a "commodity-by-commodity" direct requirements input-output table for the US economy—that is, how much of each commodity is required as an input to produce $1 of output of any given commodity. For example, on average, the production of $1 of management consulting services requires 0.8 cents of legal services, whereas the production of $1 of tax preparation services requires 1.1 cents of legal services.

These tables are updated every five years and are released approximately six years in arrears. This report is based on the 2012 IO tables. The 2017 tables are scheduled to be released in the fall of 2023.

Contrast this with co-investment in emissions reduction efforts. It can take years to source and deploy new equipment and make the production adaptations necessary to materially lower carbon emissions. Furthermore, carbon reduction technologies and processes are often relatively new, and so the cost, timelines, and results can be especially uncertain. That makes each attempt at meaningful engagement a major investment for both parties.

Putting the two together—the scale and the nature of the engagement needed—and the likelihood of effective action would seem to be low.

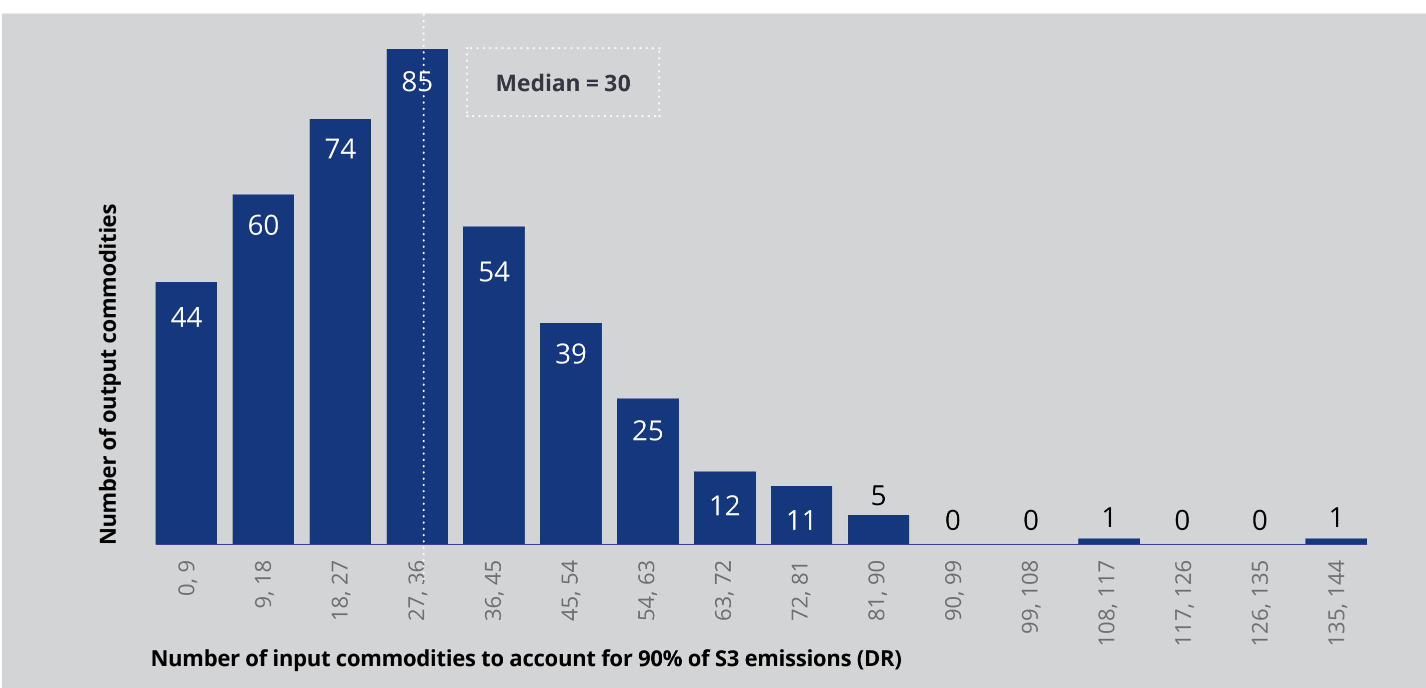
Worst of all, due to the underlying structure of the economy, finding nearly 100% of upstream Scope 3 is not merely a practical impossibility, it is a *literal* impossibility—at least as long as our thinking is limited to the dominant paradigm of a "linear" supply chain.

Consider the iron ore mine, the putative "first link" in the example of the laptop value chain. A full-Scope decarbonization of iron ore production would have to account for the inputs to the mine, including dump trucks, management consulting services ... and, yes, laptops—each of which has its own Scope 3 burden that would need to be traced back to its underlying Scope 1 emissions, some of which will come from the mine where it all started, but also from the consulting firm trying to decarbonize. You might even find that more than one major vendor in your supply chain is also a significant customer, which makes you a significant contributor to your own Scope 3 inventory! In other words, no product or service is the output of a linear value chain, but is instead both output and input in an infinite recursion.

This rather inconvenient truth shows up in the fact that, just as a given company's carbon inventory is mostly Scope 3, so, too, are its suppliers' inventories dominated by Scope 3, as are their suppliers' and their suppliers' and so on, *ad infinitum*. Consequently, just as you feel compelled to turn to your suppliers to reduce their emissions to reduce your Scope 3, they do the same in their turn, and for the same reason: Just as a company doesn't control most of its emissions, its suppliers don't control most of theirs.

For example, management consulting's supply chain emissions inventory is led by real estate (15%), air transport (6%), ground transport (5%), and truck transport (5%)—31% of total Scope 3 emissions with just four commodities. That might seem a good start.

Figure 2: The long tail of Scope 3



Source: US Environmental Protection Agency (EPA) Environmentally Extended Input-Output (EEIO) tables; Deloitte analysis

Supplier, industry, ecosystem: How to identify, quantify, and abate your supply chain emissions

Unfortunately, real estate is only 16% Scope 1. Air, ground, and truck transport have 74%, 37%, and 79% Scope 1 emissions, respectively, which is more promising. But together, the Scope 1 component of these inputs' Scope 3 contribution—that is, the emissions that these suppliers can control directly—amounts to barely more than 12% of management consulting's total Scope 3 inventory. There's still 88% to go, and each additional commodity adds an ever-smaller increment to the total inventory.

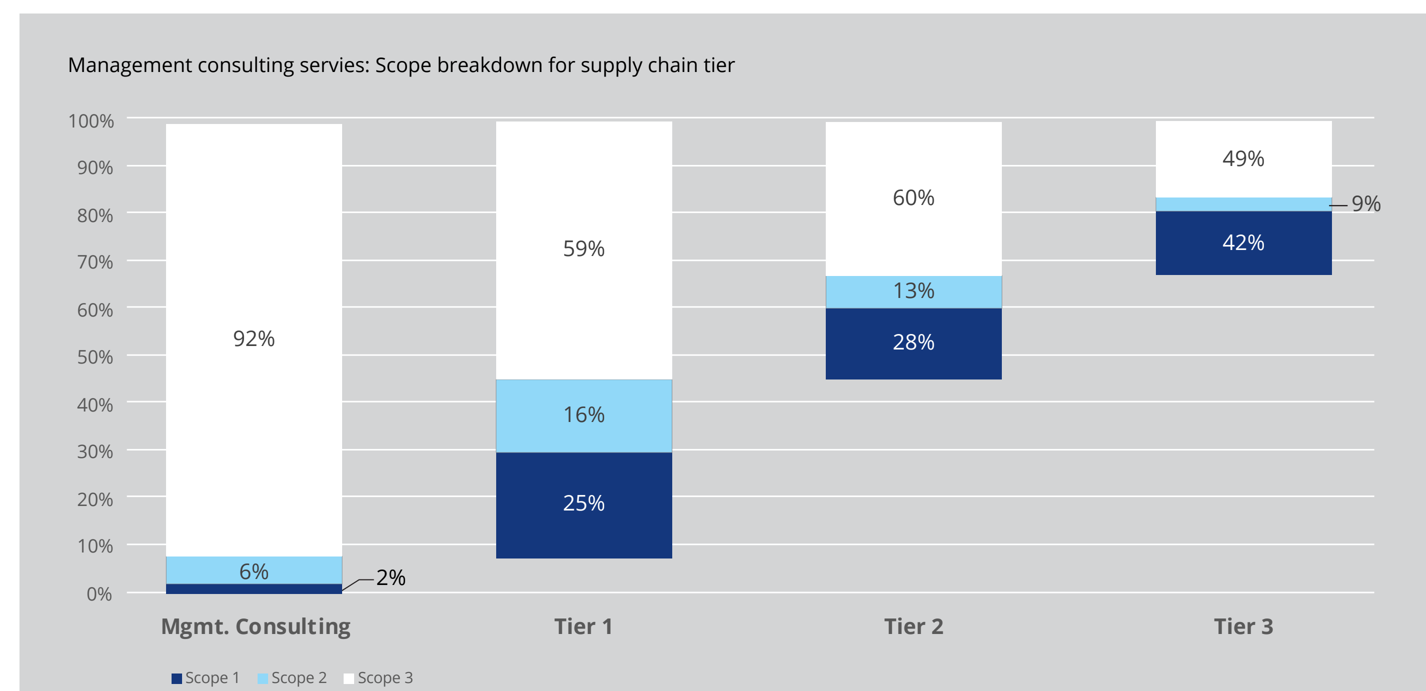
***Figure 3 shows** management consulting's recursive carbon inventory. Tier 1 captures management consulting's own Scope 1 and Scope 2 emissions; the Scope 3 emissions are its tier 1 suppliers' emissions. Tier 2 captures the Scope 1 and Scope 2 emissions from its tier 1 suppliers, while the tier 1 suppliers' Scope 3 emissions are management consulting's tier 2 supply chain emissions. And so on.*

Add it all up, and the *entire* tier 1 supply chain of management consulting's 298 input commodities is only 28% Scope 1. Therefore, if the stereotypical management consulting firm were to eliminate 100% of its own Scope 1 emissions and were able to convince *all* of its direct suppliers to eliminate 100% of their Scope 1 emissions, its total carbon footprint would fall by less than 28%.

Since we can estimate each commodity's Scope-based carbon inventory, we can repeat these calculations for all the tier 1 inputs to management consulting to estimate the aggregate inventory for the tier 1 supply chain (see figure 2). The first tier, all-in, is 25% Scope 1, 16% Scope 2 ... and 59% Scope 3. The only emissions addressable at each tier are Scope 1 (and, at the margin, Scope 2). So we repeat these estimates to get a sense of how far up the supply chain we have to go to find the upstream Scope 1 that, eventually, becomes management consulting's Scope 3.

These figures are indicative of the overall US economy: On average, the tier 1 supply chain is 60% Scope 3, while tiers 2 and 3 are 54% and 51% Scope 3, respectively. Consequently, we are left with a Zeno-like paradox: No matter how far back into the supply chain we reach, we can *never* find *100%* of supply chain emissions because even the most sophisticated supply chain management models are flummoxed by infinity.

Figure 3: The structure of Scope-based emissions for management consulting's deep supply chain



Source: EPA EEIO tables; Deloitte analysis

Double trouble

It is worth reinforcing that the only "real" emissions are Scope 1—that is, when combustion, industrial processes, or land use changes (e.g., deforestation) release GHGs into the atmosphere. And all Scope 1 emissions are Scope 1 emissions only once and are attributed to the entity with the requisite level of control over those emissions. If all Scope 1 emissions were reported, adding them up would yield actual anthropogenic GHG emissions.

Scope-based carbon accounting accumulates Scope 1 emissions along a value chain, and each stage of the value chain is held responsible for the emissions accumulated to its stage in the chain. However, when Scope 1 emissions are passed along, they are reported as Scope 3 emissions by the "receiving" organization. This is sometimes referred to, frequently disparagingly, as "double counting," although it goes far beyond that: Scope 3 emissions are passed along as well, which means that the original underlying Scope 1 emissions are counted as many times as they are passed along in a value chain.

This accounting method serves two complementary objectives. First, it gives each company visibility into how its demand choices drive upstream emissions. For many services companies, this insight is essential to changing their demand patterns to support a net-zero ambition. For example, a consulting company might have very low Scope 1 emissions, leading it to believe that there is little it can do to affect climate change. However, some consulting companies fly a lot, and the airlines' Scope 1 emissions are passed along to become the consulting company's Scope 3 emissions. This gives the consulting company an incentive to manage its air travel choices.

Second, "cumulative counting" facilitates collaboration along a value chain. For example, assume stage 1 of a four-stage value chain has significant, hard-to-abate Scope 1 emissions. If each stage were responsible for all and only its own Scope 1 emissions, the ability of stage 1 to reduce its Scope 1 would depend on its ability to pass along the cost to its direct customers in stage 2, and so on along the entire chain. In complex supply chains, it can be very difficult for "upstream" Scope 1-intensive emitters to have the confidence necessary to invest in abatement technologies.

However, just as each ton of Scope 1 emissions increases the Scope 3 emissions of all participants in that value chain by one ton, a one-ton reduction decreases everyone's collective Scope 3 emissions by one ton. Consequently, every stage captures its share of the full benefit of any Scope 1 reduction anywhere in the value chain. Since everyone benefits, making the case for everyone to contribute to reducing others' Scope 1 emissions is much easier. For example, the consulting company might collaborate with other travel-intensive service companies to subsidize airlines' use of lower-carbon biofuels—something the airlines might well support but be unable to adopt if their only choice were to pass along the full cost to all their customers, many of whom might have a different willingness or ability to pay.

Supplier, industry, ecosystem: How to identify, quantify, and abate your supply chain emissions

Cataloging carbon

There is a way out, one long hidden in plain sight and already used as the foundation of most companies' carbon inventory estimates, viz., spend-based emission factors (EFs), typically provided by third parties, including government agencies, which estimate the quantity and nature of the carbon generated by the production of a given commodity. There are typically two parts to a spend-based EF: direct impact, which is equivalent to Scope 1 emissions, and indirect impact, which captures Scopes 2 and 3. In the United States, for example, legal services have a direct impact of 0.0005 kg of carbon dioxide equivalent (CO_2e) per dollar and an indirect impact of 0.0795 kg CO_2e/$, for a total impact of 0.08 kg CO_2e/$. A company that spends $100,000 on legal services would add eight tonnes of CO_2e to its Scope 3 inventory.

The indirect impact component of the emission factor is calculated by estimating the total upstream input requirements for the production of every input to the provision of a given output and multiplying each of the direct impacts associated with those inputs. That is, by estimating how much copper, plastics, trucking services, and so on is required for each $1 of legal services and adding up the Scope 1 emissions associated with those inputs, we get the supply chain, or indirect, impact factor for legal services.

Consequently, companies using spend-based EFs to estimate their carbon inventory can recast their emissions estimates in terms of the commodity inputs and associated Scope 1 emissions that eventually roll up to become their Scope 3 inventory. This allows our management consulting company to estimate the dollar value of, say, mining inputs, construction materials, agricultural products, and so on, that it requires to produce management consulting services as well as any other commodity it might produce (e.g., tax preparation services), even if that company didn't actually *purchase* any of those inputs.

For example, it is possible to estimate that, although a management consulting firm with revenues of $25 billion buys, directly and on average, less than $500,000 of construction materials, which is 0.01% of the firm's direct spend, which implies a low level of influence with upstream suppliers.[20] Yet the consulting firm is responsible, indirectly, by virtue of its purchases of other goods and services with a more significant direct connection to these commodities, almost $60 million in construction materials. That spend translates into a Scope 3 liability of more than 50,000 tonnes of CO_2e, or 2.5% of the average consulting firm's total Scope 3 inventory, implying a high level of significance; yet almost 98% of this lies beyond the tier 1 supply chain, suggesting a low level of visibility. Taken together—low visibility, low influence, high materiality—construction materials would appear to be a candidate for "ecosystem activation." And, thanks to the very data that allows this input to be characterized in this way, it is now possible to lay the foundation for the VCPAs required.

Here's how it works.

[20] Preferably, one would assess the materiality of the consulting firm's spend with specific suppliers of construction materials, but these data tend to be closely guarded, making industry-level averages unrepresentative and potentially misleading. The IO tables allow us to assess average-level spend by purchasers, and so here influence is estimated based on the percentage of total purchaser spend—the inference being that, when a company spends a lot (in relative terms) on something, it cares a lot, and this is a sufficiently useful proxy for influence with suppliers.

The matrix

The US Bureau of Economic Analysis (BEA) compiles detailed data on the US economy to construct input-output (IO) tables, categorizing all US-based production into one of 411 commodities, and calculates the average input of each commodity required to produce every other commodity.

Consider a highly condensed model of the US economy in which each commodity is allocated to one of Extractive, Processing, Manufacturing, and Services. The IO tables, then, provide average input requirements, e.g., producing $1 of Services (e.g., management consulting, legal) requires, in direct purchases, $0.01 of Extractive (e.g., mining, oil & gas), $0.02 of Processing (e.g., iron ore smelting), $0.06 of Manufacturing (e.g., computer hardware), and $0.30 of Services (see table 2).[21] These *direct requirements* (DR) coefficients capture what each commodity producer purchases *directly*—that is, from its tier 1 suppliers—to produce its output.

The DR matrix (technically, the A matrix) has two salient, salutary, and related features. First, every commodity is both input and output, so we can abandon the linear "value chain" mental model. Instead, we can quantify the extent to which everything relies on everything else. Second, although the DR matrix captures explicitly only the "first-order" nature of input relationships, it allows us to infer all subsequent tiers of required inputs.

For example, Services has a direct requirement of $0.30 of Services. That $0.30 needed to be created so that it could serve as an input into the incremental $1 of Services we are accounting for. In other words, the first-order requirements of $0.30 of Services is the second-order requirements of the initial $1 of Services we are analyzing. This second-order direct requirement is 0.30 ($0.01) of Extractive, 0.30($0.02) of Processing, 0.03($0.06) of Manufacturing, and 0.30($0.30) = $0.09 of Services. Similarly, *that* $0.09 of Services had to be produced—the third-order requirement for Services—which triggers another round of multiplications ... and similarly for all the other inputs to Services.

Wassily Leontief, a Russian-Soviet-American economist, won the 1973 Bank of Sweden Prize in Economic Sciences for his theoretical development and practical application of a solution to this infinite recursion. The resulting *total requirements* (TR) coefficients, also known as the L matrix, are an algebra-based, finite solution to an infinite recursion. In this example, Services has a DR of 0.30 for Services and TR of 0.48 (see table 3).[22]

Table 2: The direct requirements coefficients for the US economy (condensed)

DR coeficients				
	Extractive	**Processing**	**Manufacturing**	**Services**
Extractive	0.15	0.03	0.18	0.01
Processing	0.03	0.19	0.07	0.02
Manufacturing	0.10	0.11	0.27	0.06
Services	0.20	0.22	0.15	0.30

Table 3: The total requirements coefficients for the US economy (condensed)

TR coeficients (Leonteif of DR, -1 on diagonals)				
	Extractive	**Processing**	**Manufacturing**	**Services**
Extractive	0.23	0.11	0.33	0.05
Processing	0.07	0.26	0.14	0.04
Manufacturing	0.21	0.24	0.47	0.13
Services	0.41	0.47	0.45	0.48

Source: US Bureau of Economic Analysis; Deloitte analysis

21 This captures the *revenue* accruing to each producing establishment. That is, the $1 of Services produced is $1 of revenue to the producer of the Services commodity, and the dollar values of the inputs are similarly in revenue to the providers of those inputs.

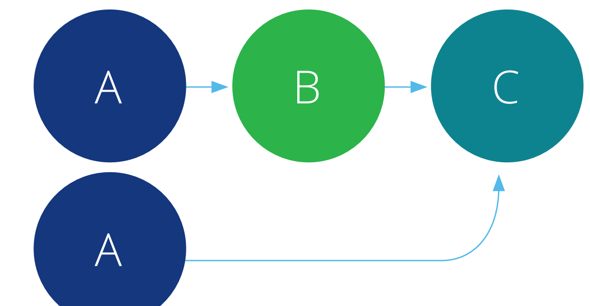
22 In the traditional formulation, the TR tables include the $1 of output that is being accounted for. In table 7, this has been removed.

Thanks to the TR matrix, an organization can now estimate its total requirements for every input to its production. In this case, a Services business with $10.5 million in revenue has a total requirement, in expectation, of $525,000 in Extractive, $420,000 in Processing, $1.365 million in Manufacturing, and $5.04 million in Services.

These figures capture the total quantity of all inputs required to produce $10.5 million in Services. For example, it captures what Services (e.g., a consultancy) spends on Manufacturing (e.g., computers) but also captures, in Services' total requirements for Extractive, Manufacturing's need for Extractive inputs (e.g., a computer's need for nickel) to provide the Manufacturing outputs that Services purchases (e.g., the consultancy's implied use of nickel that arises from its purchase of a computer with nickel content).

Inferring the total requirements in this way "double" (actually, "multiple") counts the use of each input (see figure 4). For example, in a three-stage supply chain, two units of commodity A are produced; one unit is a direct input to commodity B, and the other unit is a direct input to commodity C. But commodity B is an input to commodity C. In this case, commodity B has a DR for A of 1, while commodity C has a DR for B of 1, a DR for A of 1, and TR for A of 2. The sum of the DRs for A is the total production of A, but the sum of the TRs for A exceeds A's production. In this way, the TR coefficients accumulate requirements for given inputs in the same way Scope 3 accumulates emissions.

Figure 4: The accumulation of total requirements in a simple value chain



Source: Deloitte analysis

***Figure 4 shows** how total requirements accumulate. A is an input to B, and B has a direct requirement of one unit of A, and a total requirement of one unit of A. C purchases one unit of A. C purchases one unit of A, so has a direct requirement for A of one unit. But, thanks to its need for one unit of B, C has a total requirement for A of two units. Adding the direct requirements of B and C for A yields the actual production of A (two units). The sum of B's and C's total requirements for A, however, is three units—one unit more than was actually produced.*

The results can be somewhat counterintuitive and hence quite revealing. Note that Services has a DR for Extractive of $0.01 per dollar, which seems reasonable: One doesn't expect law firms to be buying much in the way of raw iron ore. But the TR for Extractive is five times that amount—$0.05 per dollar—reflecting the reliance of Services on Manufacturing and Processing inputs that *do* have material DR coefficients for Extractive inputs.[23]

23 To really get into the weeds: The DR coefficients are averages for the US economy. Each output commodity has a "long tail" of input commodities for which it has very low average direct requirements. This very likely reflects the heterogeneity of the inputs requirements for each output commodity. That is, most management consulting firms require a certain set of core inputs in some material quantity—say, computer hardware, legal service, air travel, and so on; even if the actual amount required varies across firms, they all need these inputs to some meaningful degree. Other inputs, however, reflect differentiation across management consulting firms. Some might purchase raw iron ore ... because they specialize in assays or other insights that depend on acquiring inputs that are unique to their business. They might even acquire large quantities of these inputs—but, on average, this would be reflected as a low average direct requirement for a particular input. It is for that reason that this report focuses on the "90%" number: to reduce the risk of overstating the average level of complexity at the DR level. Fascinatingly, however, at the TR level, the degree of variance across output commodities is dramatically lower; there is no analogous "long tail" in the distribution of TR averages. This reflects the fact that output commodities' total requirements converge, and whatever the immediate (DR) inputs might be, eventually everyone needs some of everything.

Deep impact

The US Environmental Protection Agency (EPA) compiles direct impact (DI) emission factors for a variety of pollutants generated by the production of the same commodities cataloged in the BEA IO tables. Among the pollutants measured are a variety of greenhouse gases (GHGs). Methods for compiling such estimates include, for example, inventorying the quantity of specific fossil fuels consumed in the production of each commodity and multiplying by the known emissions arising from the combustion of that quantity of fuel. Data on the emissions inventory for all GHGs are synthesized into a single DI factor expressed as a carbon dioxide equivalent (CO_2e). Practically speaking, the DI factor for a commodity is an industry-level estimate of the Scope 1 emissions associated with the production of $1 of that commodity (see table 4).[24]

A producer of Services can scale the EPA's DI factor for Services to its revenue to generate a rough estimate of its own Scope 1 footprint. This can serve as a useful benchmark when taking on the challenge of developing a more precise and accurate estimate using a "bottom up" approach that might be built on purchase data for fossil fuels, GHGs emitted due to production processes, and so on.

In addition, and potentially far more usefully, a company can use EPA impact factors to estimate its Scope 3 inventory. Typically, and in keeping with guidance from GHG Protocol, companies compile data on their purchases and then multiply that figure by the appropriate spend-based emission factor. It would not, however, be sufficient to multiply merely by the DI factor for legal services (0.06 kg/$); this would capture only the Scope 1 emissions associated with *that* purchase, not the total of all the Scope 1 emissions that went into the provision of those legal services. In other words, we need the Scope 1 emissions from legal services *plus* the Scope 1 emissions from all of the inputs to legal services for the *infinite sum* of the matrix of *all inputs* to legal services.

The TR coefficients provide exactly that—the total requirements for the provision of any commodity. And so the EPA multiplies the TR coefficient for each of the inputs to services by the DI factor for that input. Sum across all the inputs to legal services, and voila: the *Total Impact* (TI) factor for services (see table 5). Now a company buying $500,000 of services multiplies by a TI factor of 0.14 kg/$—and so services are estimated to contribute 70,000 kg to the company's Scope 3 inventory. The company need not try to chase down its "true" upstream value chain—the TI factors provide a useful proxy.

Table 4: The DI and TI factors for services (condensed)—in kg/$ of production (at producers' prices)

Legal services	TR coefficient	DI factor (Scope 1)	TI factor (Scope 3)
Extractive	0.05	1.80	0.09
Processing	0.04	0.16	0.01
Manufacturing	0.13	0.12	0.02
Services	0.48	0.06	0.03
		TOTAL	**0.14**

Source: EPA EEIO tables; Deloitte analysis

24 Ingwersen et al., "The US environmentally extended input-output model v2.0."

Supplier, industry, ecosystem: How to identify, quantify, and abate your supply chain emissions

Table 5: Abatement strategy categorization for inputs to management consulting

Primary abatement strategy	Commodity	% of 53
Supplier engagement	Real estate and rental and leasing	4.6%
	Category total	**4.6%**
Industry collaboration	Transportation and warehousing	20.3%
	Manufacturing	3.2%
	Government	1.2%
	Finance and insurance	0.5%
	Category total	**25.2%**
Ecosystem activation	Utilities	28.9%
	Manufacturing	12.8%
	Mining, quarrying, and oil and gas extraction	8.8%
	Administrative and support and waste management and remediation services	4.4%
	Agriculture, forestry, fishing and hunting	2.6%
	Transportation and warehousing	1.8%
	Construction	1.0%
	Category total	**60.3%**
	TOTAL	**90.2%**

Source: EPA EEIO tables; Deloitte analysis

Total recall

Whether the sources are the BEA's IO tables and the EPA's emission factors or some other credible provider, the underlying method for creating TI factors is the same: An IO table provides the TR coefficients, and the DI factors are the estimates of Scope 1 emissions associated with those inputs. The product of those two terms, i.e., TR x DI, is the input's TI factor, which is an estimate of the full-Scope impact of a given input.[25] In other words, the TI factors for each commodity operate at the level of economy-wide, commodity-level averages.

Thanks to TI factors, companies can estimate their Scope 3 inventories using data on just the first tier of their supply chains—and good thing, given the complexity of modern supply chains. The procurement function compiles information on what has been purchased from whom, inputs are allocated to underlying commodities, and spend-based TI factors are used to translate that spend into imputed Scope 3 emissions.

But, as described above, when it comes to reaching "through" the supply chain to find the upstream Scope 1 emissions so that the resulting Scope 3 emissions can be materially *reduced*, many companies find themselves essentially handcuffed. In other words, TI factors tell them *what* their emissions are but not *where* they are.

An answer lies in the very same information that generated the TI factors.

Recall: To the extent a company uses TI factors to estimate its suppliers' emissions, it is assuming that its suppliers' carbon inventories are appropriately captured by economy-wide, commodity-level averages. But TI factors are the sum of the products of the TR and DI parameters for all the inputs to your suppliers. Consequently, as a mathematical identity, a company's Scope 3 inventory is the same whether it is calculated using DR coefficients and TI factors or TR coefficients and DI factors (see equation 1):

Equation 1: The equivalence of DRxTI and TRxDI

$$\sum_{i=1}^{n} DR_i \times TI_i = \sum_{i=1}^{n} TR_i \times DI_i$$

Source: Deloitte analysis

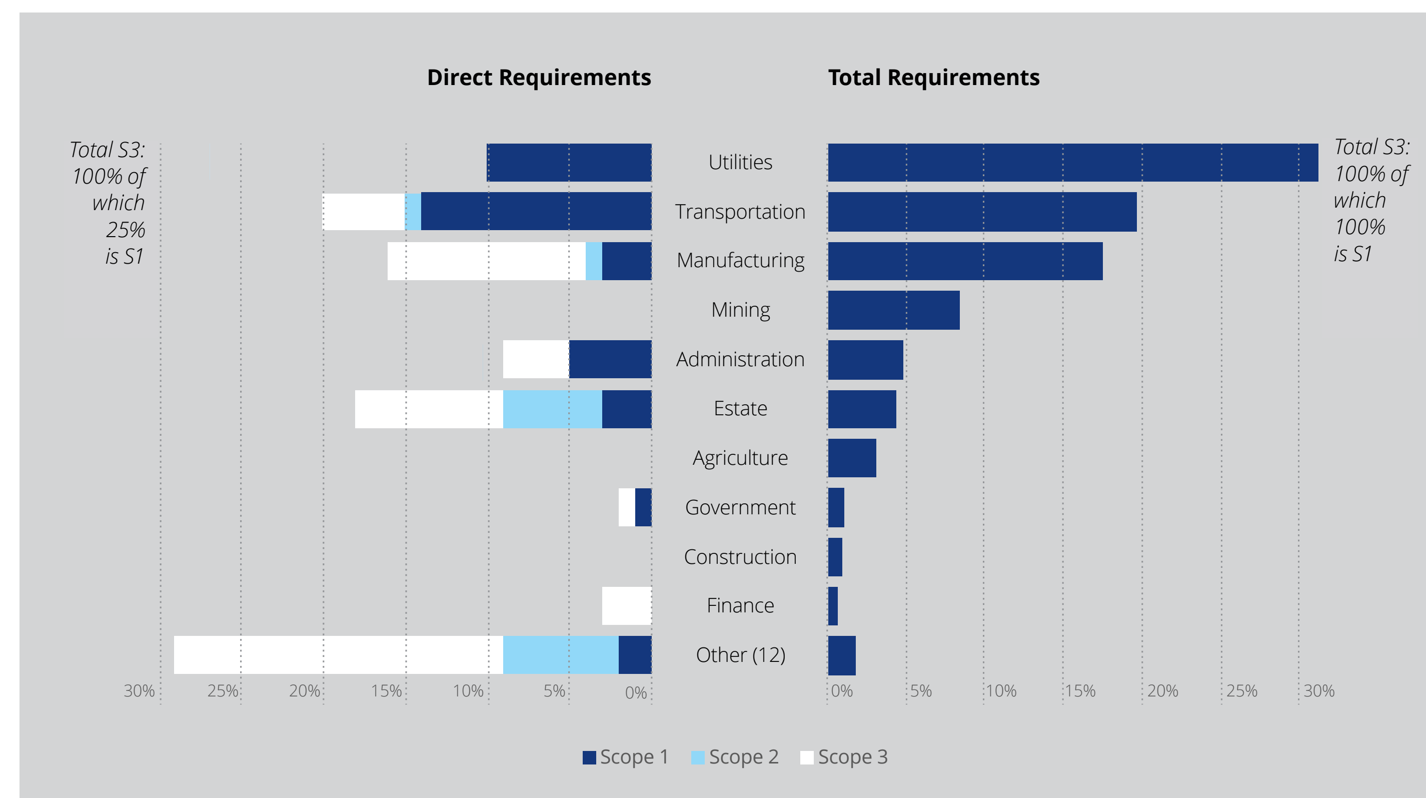
[25] Justin Kitzes, "An introduction to environmentally-extended input-output analysis," Resources 2, no. 4 (2013): pp. 489–503.

What's *different* between the two approaches is that, where the DR-based estimate leaves us chasing our Scope 3 tail, a TR-based estimate reveals, in a single step, where all the upstream Scope 1 emissions are generated. To repeat, this change in perspective yields precisely the same estimate of the quantity of Scope 3 emissions, but allocates upstream Scope 3 to the still-further-upstream Scope 1 that must be abated.

For management consulting, for example, a DR-based inventory implies that Restaurants and Accommodations, and Professional Services are significant drivers of Scope 3 emissions, implying that supplier engagement with eating establishments and hotels, and everything from law firms to marketing services to financial institutions should be a key component of a Scope 3 management strategy (see figure 5). However, all these input commodities are 90%+ Scope 3, sending us spiraling into an infinite recursion.

On a TR basis, we see instead that construction materials, waste management, agriculture, and plastics—none of which is significant under a DR lens—are now major drivers of scope 3 emissions, thanks to prime drivers. This makes some intuitive sense: Hotels have high Scope 3 emissions thanks to their reliance on building construction, and restaurants depend on agricultural inputs. These upstream Scope 1 emissions can be very difficult to find, but a TR-based inventory reveals them at a stroke. And better still, the *only* emissions to be managed in each case are each input's Scope 1, that is, the very emissions that upstream suppliers have direct control over.

Figure 5: A DR vs. TR Scope 3 inventory for management consulting



Source: EPA EEIO tables; Deloitte analysis

A light in the alley

We can now apply this analytical method to demonstrate in full what was merely sketched in rough outline above, viz., identifying and characterizing the sources of upstream Scope 1 emissions by visibility, influence, and materiality.

Figure 6 expresses management consulting's carbon inventory in terms of TR coefficients and DI factors. The *size* of each *bubble* (as distinct from the blue rings) reveals the *materiality* of each source of Scope 3 emissions. For example, Truck Transportation and Air Transportation are both quite large, at 7% of total Scope 3 each, whereas the bubble for Legal Services is a relative pin prick. Any source that accounts for at least 2% of total Scope 3 is deemed to have "high" materiality.

The *size* of the *blue ring* that is concentric with each bubble is estimates the direct spend on that commodity—a measure of expected *influence*. The ring for Rail Service is quite small, for example, compared with the ring for Accounting Services. The focal company is said to have "high" influence with any commodity that accounts for at least 2% of total direct spend.

Finally, the position of each bubble reveals the *visibility* of each source of Scope 3. The diagonal line is the point at which equal shares of that commodity's total emissions come from the first tier of the supply chain and all other supply chain tiers combined. Sources that lie above the line are characterized as "high."

This lens reveals that, when addressing 90% of Scope 3 emissions, Supplier Engagement is likely of relatively little use (4.6% of total Scope 3); Industry Collaboration is materially more significant (25.2%), and most important of all is Ecosystem Activation (60.3%)—numbers that aren't all that different from economy level averages of 15%, 21%, and 64%.

A first-order analysis of a company's Scope 3 inventory provides the identification, quantification, and characterization of the sources of upstream Scope 1 that comprise a company's Scope 3 burden.[26] In some cases, the analysis confirms what one might readily intuit: For a management consulting firm, it likely comes as no surprise that air travel is a major contributor of Scope 3 emissions and that much of those emissions arise from the direct purchases of air travel services.

Other insights will be less intuitive: Few consulting firms are likely to believe that construction materials are significant drivers of Scope 3 since, in expectation, consulting firms buy almost none of the relevant commodities. Yet it turns out that supporting the production of, say, "green cement" might account for as much as 2.5% of total Scope 3. Grain is low on all three dimensions—perhaps no surprise there—but this analysis reveals that, at just over 1.5% of total Scope 3, it is nevertheless important to build a strategy for abating these far-upstream Scope 1 emissions if true net-zero is the goal.

A second-order analysis generates a hypothesized primary abatement strategy for each commodity. Where are the scarce resources available for active supplier engagement likely to yield the greatest impact? Perhaps just as important, which commodities will require a multi-pronged approach? For example, trucking is a commodity with significant direct purchases but with even *higher* indirect sources. Consequently, supplier-, industry-, and ecosystem-level interventions might be needed to some degree.

Further layers of analysis are possible. For example, finer-grained characterizations of each commodity's profile *within* each strategic category might point toward different approaches to each generic strategy. For example, industry collaboration might have a different complexion when applied to commodities, where influence is high, versus those for which influence is low.

***How to read the chart:** Each input commodity is represented by two concentric circles. The white rings represent each commodity's share of total direct spend on that commodity. The solid bubbles capture each commodity's share of Scope 3 emissions as determined using TR (total requirements) coefficients. When a paired ring and bubble are different sizes, the share of spend and share of emissions are disproportionate.*

The vertical axis captures the percentage points of a commodity's contribution to Scope 3 via its Scope 1 emissions arising from the quantity of production that goes to direct purchases of that commodity. The horizontal axis captures the percentage points attributable to the consumption of that commodity in tiers 2 through "infinity"; call these "indirect" purchases. Bubbles that lie on the 45-degree line have equal percentages of the total contributed by direct and indirect purchases.

The colors of the bubbles indicate which abatement strategy is likely to be "primary" based on the categorization scheme described in Table 2. Visibility is "high" when the bubble lies on or above the 50% diagonal line, and Influence and Materiality are each "high" when the commodity's share of direct spend or total Scope 3 is equal to or greater than 2% of the relevant total.

As with any estimation method, it is important to assess whether the level of accuracy is relevant to the task. (See What's good for the goose ...)

[26] To repeat, this is not a different way of quantifying supply chain emissions; it is a different way of understanding the original upstream Scope 1 sources.

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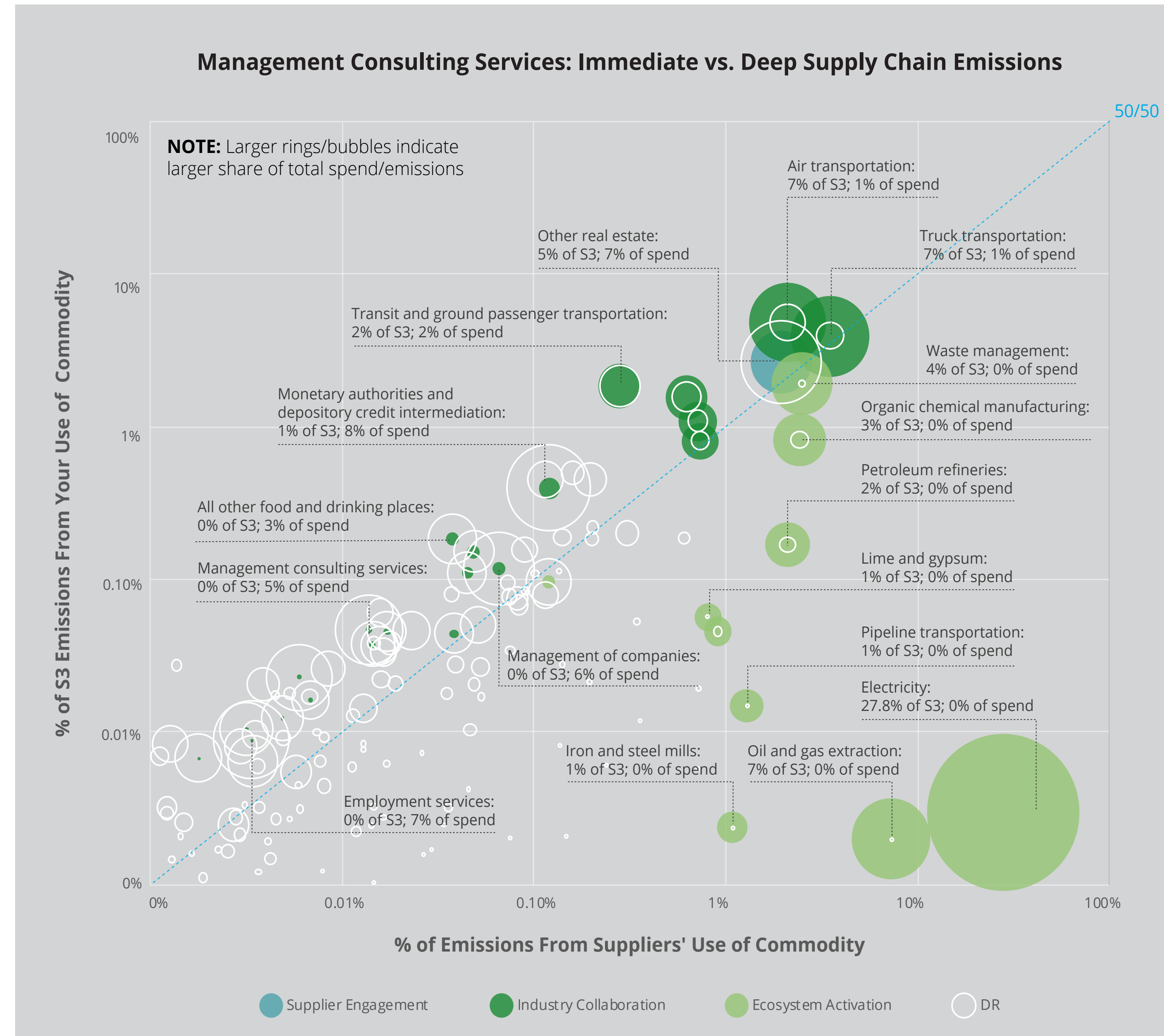
Figure 6: A TR-based lens on the drivers of Scope 3 emissions



Source: EPA EEIO tables; Deloitte analysis

What's good for the goose ...

Creating a Scope 3 inventory can be laborious, time consuming, and expensive. Companies often begin by compiling detailed spending records. Then the purchased goods must be mapped to commodities for which spend-based TI (emissions) factors are available. For example, a purchase invoice might identify "Transcontinental Transport" as a vendor with whom $1.7 million was spent. Additional effort is required to determine how much of that sum to allocate to any or all of Ground, Trucking, Air, Sea, or Rail transport commodities, for each has a very different TI factor. These data are then summed across all inputs from all suppliers to generate a Scope 3 inventory. Call this a "consumption-based" Scope 3 estimate because it is driven by a focal company's consumption of specific inputs in specific quantities.

One could, alternatively, build a "production-based" Scope 3 estimate. Rather than compile procurement data, one could specify the products or services produced, map those to commodity codes for which emissions factors are available, and then generate a Scope 3 inventory using the same IO tables and emission factors that inform consumption-based estimates.

Few companies build consumption-based estimates; anecdotal evidence suggests that most believe production-based inventories to be more accurate. After all, just as no family has the average of 1.9 children, few companies are likely to have a supply chain that is identical to the average for the entire economy.

Certainly, consumption-based estimates can feel more accurate, but they are subject to a number of sources of error. Incomplete cost data and inaccurate cost allocation are always possibilities. And allocating purchased goods and services to the right commodity is frequently not straightforward; after all, vendor invoices are not created with the BEA's commodity definitions in mind. When dealing with thousands of such ascriptions, getting it right every time is a practical impossibility, and the differences matter: Seemingly similar commodities can have emission factors that differ by an order of magnitude.

Also, keep in mind that the TI factors applied to your carefully collected spend data are themselves based on the assumption that your suppliers have total requirements that are captured by the same high-level averages you don't want to apply to your production. That is, a consumption-based estimate avoids only one layer of high-level averaging.

Unfortunately, we have no way of knowing which approach is more accurate because we do not have primary data that actually measures all the upstream Scope 1 associated with the production of any given commodity; all we have are different ways of estimating. And in that case, the question becomes less "Which one is right?" and more "Which one is useful?"

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When perfect is the enemy of progress

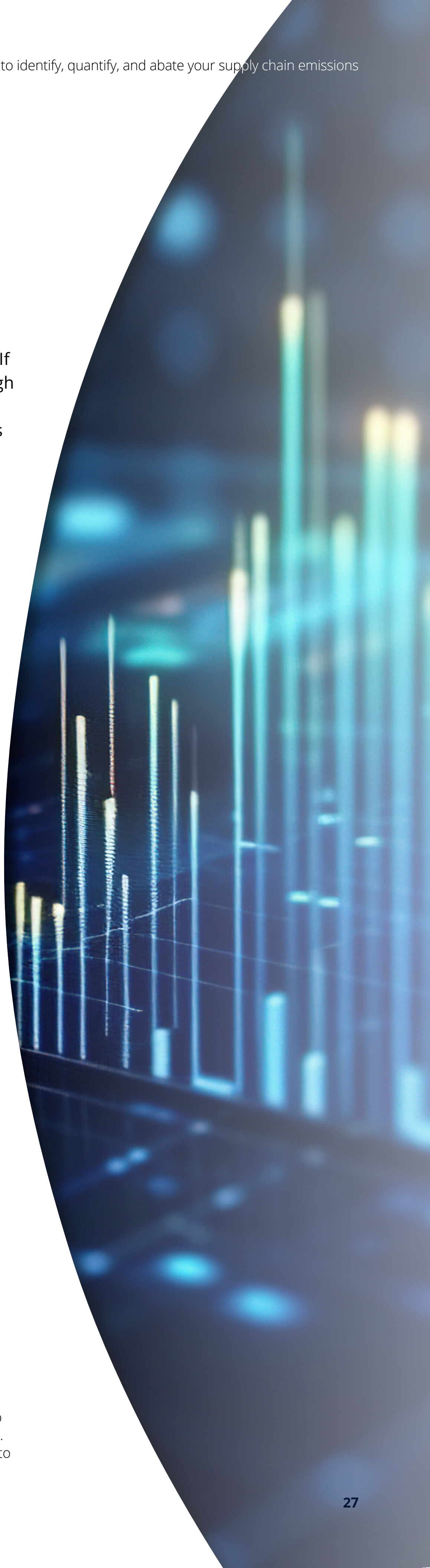
This analysis is not a dispositive test that definitively prescribes a specific course of action. If nothing else, the cut-off points for visibility, materiality, and influence are arbitrary (although not groundless). One might wish to see 60% or 70% of emissions lying in the first tier of the supply chain before declaring the upstream emissions "visible" or see 5% of total emissions as a more appropriate boundary for "material."

In addition, there is the question of accuracy: Does this approach capture a company's *actual* emissions?

On this score, it is useful to recall that the analysis here draws only on the same inputs and assumptions that are used to generate spend-based emission factors. Expressing a company's supply chain emissions in terms of total requirements for upstream commodities is *analytically prior* to the generation of the emission factors many companies use. Consequently, this approach is, necessarily, precisely as accurate as an inventory generated using those factors.[27]

Whatever the limitations of this or any other approach might be, never lose sight of the ultimate objective: decarbonization of the global economy, which is, ultimately, a collective effort. The measurement methods we use are accurate enough if they enable and reward the right actions and outcomes. Given the complexity of the measurement challenge, the pursuit of precision and accuracy might easily undermine accomplishing the far more important and urgent primary task.

In that spirit, the approach described here is likely most useful as a jumping-off point—a "light in the alley" that allows us to begin looking for the keys that we so desperately need, not where the light is brightest but where there is at least a chance that we might find them.



[27] An important qualification: The method described here will be analytical equivalent only if the IO tables used to generate the total commodity requirements are the same as those used to generate the emission factors used. In the examples described here, a company would need to use only emission factors from the EPA EEIO tables to estimate its carbon inventory.

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